Miami University
Department of Mechanical Engineering Technology
ENT 498 Senior Design

Multi-Purpose Motorcycle Trailer (MPMT)

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Miami University Regionals Middletown Campus

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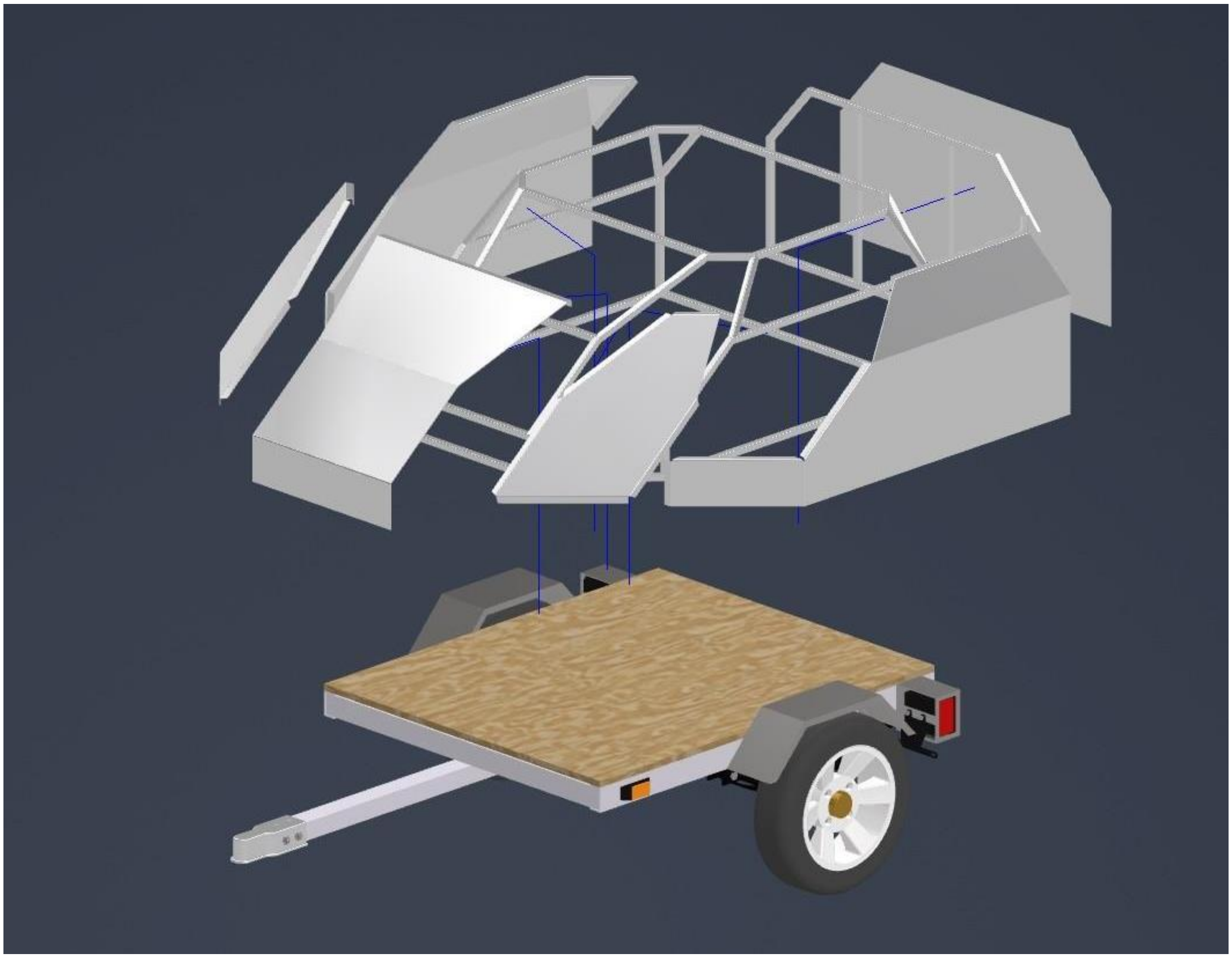
Date:
05/10/2021

Multi-Purpose Motorcycle Trailer

3D Rendering



Statement of Purpose

The purpose of the project is to design and modify a trailer to be pulled by a motorcycle that will allow the user to bring up to two dogs with them. The trailer will also be able to be used as a dry storage space for their motorcycle gear or a short camping trip. The trailer can also be converted back to a flatbed trailer that can be pulled with a truck or an SUV for various purposes. A strong aerodynamic design is the intent to keep the trailer stable from the wind, so riders and pets will have a safe ride.

The market for motorcycle trailers is a small market. However, for the true enthusiast or long-distance tourer, they really enjoy the idea of having a trailer that they can take with them to hold all of their luggage and gear. There are certain motorcycle specific trailers that are available for purchase, but they tend to be fairly expensive. Also, a new common trend is that people are now taking their pets along with them when they ride their motorcycles. Most of the time they do this by having their animals ride in a backpack or in a sidecar if their motorcycle is able to have one. However, those animals have to be smaller to fit in a backpack or in a sidecar. Therefore, we want to design a multi-purpose trailer that can carry animals and also be converted back to being a simple flatbed trailer for multiple other uses.

Since one of our group members has a need for this kind of trailer for his motorcycle. We want to treat this project as a real-life experience. We are looking at this as though a customer has reached out to us to customize their needs for this product. Therefore, the problem is: "He has 2 dogs (one weighs about 18 lbs. and the other weighs about 50 lb.). He and his wife enjoy riding motorcycles with their dogs. However, they can only take the smaller dog with them. This trailer will make it possible for them to take both dogs along with their motorcycle rides." We came up with the idea of having a trailer that could fit two dogs for the motorcycle and can also be used for other applications.

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Scope and Methodology

The scope of this project is for us to develop a trailer that can be safely pulled behind a motorcycle and that will have the ability to safely transport two dogs, cargo, or be able to be converted back into a flat-bed configuration for multiple uses. In order to achieve this, we: conducted extensive research in regard to laws and regulations for the State of Ohio, developed a step-by-step plan for the project as well as a Gantt Chart for the project's timeline, designed the pet enclosure, performed a finite element analysis (FEA), performed a computational fluid dynamics (CFD) analysis, conducted wind tunnel testing of a 3D printed model, and assembled the trailer and pet enclosure. The duration of the project is from 8/17/2020 to 4/23/2021. Below is our step-by-step plan for the project and within the appendices our project Gantt Chart can be found.

Project Step-By-Step Plan:

1. Gather group members and discuss various project ideas.
2. Decide on a project and also develop a name for the project.
3. Refine the scope for the project and begin performing research on standards, availability of parts/materials, premade items that can be purchased, current market, etc.
4. Create a document for recording the various costs of the materials and items that will need to be purchased for the project in order to develop the required budget.
5. Select a base trailer that can be used for the project and begin drafting rough 3D models that can be used for development of the design.
6. Finish initial research and begin drafting the project proposal for the project. This includes this step-by-step plan, development of a Gantt chart/project timeline, etc.
7. Continue design/research for the project and start developing various 3D models, plans for manufacturing, tools and resources needed, etc.
8. Decide/source a motorcycle hitch that is compatible for the motorcycle that will be used for the project. Also, find a wiring harness that can be used to add a trailer plug in to the motorcycle so that it can work with the trailer.
9. Perform a finite element analysis of the cage design (FEA) that is planned to be created and also compare some material options for the design.

10. Determine where will assemble the design as well as where we can outsource the necessary welding of the cage design. Outsourcing the welding is crucial that way it is done professionally and by a certified welder.
11. Begin collecting various quotes for the cost of having the cage fabricated and decide on a shop that will be able to do the work required effectively/timely.
12. Develop a document for requesting funding for the project based upon the estimated budget. This document will need to be revised and reviewed to ensure it is accurate for the project. Once revision is completed, submit the request for funding.
13. Continue testing the design and begin looking into options for a drag study of the trailer model. Also, make changes if needed based upon results from the FEA.
14. Begin drafting the final report and PowerPoint that must be created for the first duration of the project. Both the final report and PowerPoint will be reviewed, revised, and edited to ensure it accurately portrays the work we have done.
15. Order the necessary components for the project and have the welder begin fabricating the cage design once funding is approved.
16. Once the base trailer is obtained, assemble the trailer, and complete the necessary setup/wiring so that the licensing can be completed so that the trailer is legal and able to be transported on roadways. This includes installing decking onto the trailer.
17. Begin working on a computational fluid dynamics (CFD) analysis for the trailer model with the cage design within Ansys Fluent. A simplified trailer model will be used for this analysis. Later on, a wind tunnel analysis will also be conducted to compare the CFD results.
18. Once the motorcycle hitch and wiring harness is obtained install them on the motorcycle so that it is ready for testing.
19. When the welder finishes the fabrication of the cage design, begin developing a plan for the paneling process. This will be conducted within the Miami University Middletown's engineering lab by project team members.
20. Once the trailer and the completed cage design is at Miami University Middletown as well as the aluminum sheet metal that is going to be used for the paneling begin developing templates out of poster boards that way we can shape and model the panels in an efficient and effective manner.

21. During the assembly process for the paneling a 3D model will be printed and the plan for the wind tunnel analysis will be developed. Certain materials resources will need to be acquired as the wind tunnel is not currently functioning. This analysis process will be ongoing with the assembly process and its goal is to gain an insight into the air flow path lines of our design. These resources will be obtained by the engineering department at Miami University.
22. Once the templates are completed, they will then be traced onto the aluminum sheet metal which will then be cutout using metal shears. The panels will then be formed by using a metal brake, shaping hammers, and dead blow hammers. The edges for the panels will also be filed down and proper safety equipment will be used throughout this process.
23. Once all of the panels are completed, they will then be attached by sheet metal screws so that they can be removed if they ever need to be replaced. The door on the back of the trailer will be attached by a piano hinge and also be supported by metal cables.
24. Once the panels and the door are installed rivnut inserts will be installed so that a lid can be created for the top section. The lid will be made from excess materials that are available for use within the engineering lab.
25. Once the lid is installed and can be removed the inside of the trailer will be sealed with caulking to prevent water from being able to get inside. Once this is cured the finished design will then be bolted down onto the trailer to ensure that it is secure and stable.
26. Once the design construction is completed the trailer will be transported to Miami University Hamilton as testing with the motorcycle will be conducted in the large parking lots on campus property. This process will be documented by video recordings.
27. After testing is completed, the design will then be sent out for bodywork/painting as the bare aluminum is very reflective which is problematic for road use.
28. Future testing will be conducted once the paint work is completed.
29. The final poster, presentation, and report will be the primary focus during and after the testing process. Once these documents and the video for the presentation is reviewed/revised the project will then be officially completed.

Laws and Regulations

Based on the research performed, we have found there are a few laws and regulations in Ohio that are associated with this project, especially when it comes to trailers for motorcycles. These laws mostly apply for larger size trailers. These laws are:

- Brakes are required if the trailer has an empty weight of over 2,000 lbs.
- The original owner of any trailer weighing 4,000 lbs. or less and used exclusively for non-commercial purposes shall, upon application for initial registration, obtain and present such evidence of the trailer's weight as the registrar may require. Total length: 65 feet; trailer length: 40 feet; width: 102 inches; height: 13 feet 6 inches.
- When 1 vehicle is towing another vehicle, the drawbar or other connection may not exceed 15 feet from 1 vehicle to the other.
- When the connection consists only of a chain, rope, or cable, there shall be displayed upon such connection a white flag or cloth not less than 12 inches square.
- In addition to a drawbar or other connection, each trailer and each semitrailer which is not connected to a commercial tractor by means of a 5th wheel shall be coupled with stay chains or cables to the vehicle by which it is being drawn.
- Every trailer or semitrailer shall be equipped with a coupling device, which shall be so designed and constructed that the trailer will follow substantially in the path of the vehicle drawing it, without whipping or swerving from side to side.
- 55 mph is the maximum speed for any vehicle or vehicle combination that weighs over 8,000 lbs.

A Non-Commercial Trailer needs to meet these requirements to be registered:

- Maximum weight is less than 10,000 lbs.
- Title is not issued on trailers that weigh less than 4,000 lbs.
- Trailers must carry, either as part of the tail lamps or separately, 2 red reflectors.
- Trailers must be equipped with at least 1 red tail lamp visible from 500 feet to the rear and a white light to illuminate the license plate and render it visible from at least 50 feet from the rear.
- Trailers must be equipped with at least 2 brake lights and turn signal lights, visible from 500 feet to the rear.

- Trailer should have safety chains. Safety chains prevent the trailer from separation if the hitch connection fails.
- Ohio driver license or state ID
- Proof of weight: Official Weight Slip (form BMV 5721), or Manufacturer's Certificate of Origin (MCO) / Statement of Origin (MSO), or if using previous owner's Ohio registration, complete a notarized Affidavit of Original Weight (form BMV 5728) available at any local deputy registrar license agency.

There are some general rules of thumb that are associated with a pull-behind motorcycle trailer:

- Pull-behind trailers should only be designed for motorcycles with an engine size of 1000cc or more.
- Only pull a trailer that weighs less than half of your total weight (vehicle + riders + gear).
- The actual weight of the trailer must be lower than the curb weight of the motorbike. Also, the trailer's unladen weight must be clearly specified on the trailer. Curb Weight is the total weight of the vehicle without any passenger or load attached.
- Gross Vehicle Weight Rating (GVWR) – Curb Weight = Total Capacity of Motorcycle
- The distance between the rear of the bike and the trailer must not exceed 8 feet.

Also, from our research, we found that Ohio did not have any laws that prohibit dogs in trailers. Most state laws that address the issue make it illegal to transport a dog on a public road in the back of an open bed vehicle. It appears that only six states (CA, CT, ME, MA, NH, and RI) have such laws related to pets in open vehicles or trailers:

- Maine prohibits transporting a dog in an open vehicle like a pick-up truck or convertible in a manner that does not protect the dog.
- Connecticut prohibits dogs in the back of pickups unless the dog is caged and secured.
- New Hampshire adds a requirement that the vehicle's side extend to a height of at least 46 inches vertically. In addition to that, the dog must be cross-tethered, and protected in a secured container, cage, or other form of protection from jumping or falling out.
- California's law is nearly identical in its requirements to New Hampshire. That state's law also has exceptions for the transportation of livestock, the transport of a dog in a rural area to and from a livestock auction, and the transport of a dog for purposes associated with ranching or farming.

- Massachusetts extends its law to all animals instead of just dogs in the back of a motor vehicle in a space intended for a load on the vehicle on a public way unless such space is enclosed or has side and tail racks to a height of at least 46 inches extending vertically from the floor, the animal is cross tethered to the vehicle, the animal is protected by a secured container or cage or the animal is otherwise protected in a manner which will prevent the animal from being thrown or from falling or jumping from the vehicle.
- Rhode Island required animals are placed in the enclosed motor vehicle and safely restrained by a harness manufactured for the purpose of restraining animals.

We designed this trailer to be used in Ohio and under the restrictions of Ohio laws. However, we also considered some of the laws about pets in trailers from other states such as having restraints and cages, so that the pets will be safe and feel safe when riding in our trailer. Overall, we set out to design a trailer that is stable, tracks straight and pulls smoothly behind the motorcycle and gives the rider a piece of mind as well that it is safe.

Project Design and Development

During our research, all of the trailers that were found were either bulky and not aerodynamic, or they were mainly fiberglass bodies, that would not provide protection in case of a car accident. To address this, we decided to design a skeletal cage/frame to act as protection for the animals. When we began designing the MPMT, we started by picking out a base trailer. We wanted to make sure that the trailer was rather small so that it would be easier to safely be pulled behind a motorcycle. We found two versions of the same ‘Ironton’ trailer that we believed would meet our needs, one steel and one aluminum. The trailers have a 40” by 48” deck.

We considered building our own trailer so it could be narrower, but the costs would have risen significantly. From what we could find, there were not any trailer axles shorter than the one on the selected Ironton trailers. Because of this, we would have had to purchase an axle-less suspension system. The axle-less system on its own, without wheels, had the same cost of the entire Ironton trailer including the wheels.

Once we knew which trailer we wanted to use, we used Autodesk Inventor to design an inventor assembly model of the trailer that we wanted to use. Once we obtained the trailer, an exact model was made to help with designing the cage, this model is shown in Figure 1.

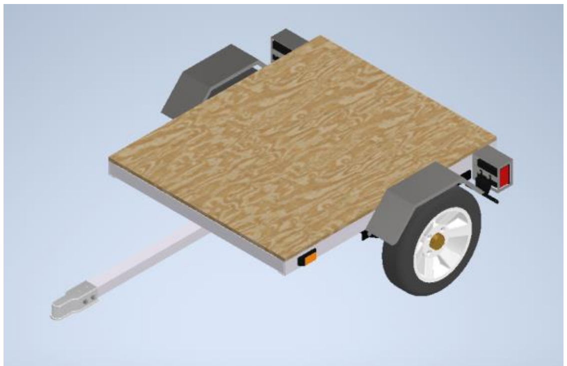


Figure 1: Trailer model

During the design period, we decided to use 3/4” square aluminum tubing. We decided to use square tubing because it is hollow which will help with the weight restrictions to make pulling a trailer behind the motorcycle safe. Square tubing also provides a better welding surface than round tube would. The first design that we drafted was very rudimentary. Since we had already decided on a trailer, we knew what the deck size of the trailer was going to be. We used the 40” x 48” deck size as a footprint for designing a rough idea of what the cage would need to look like as shown in Figure 2.

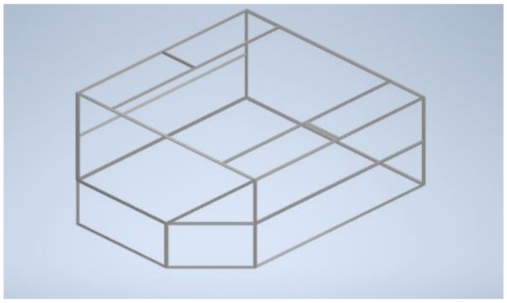


Figure 2: Initial cage design

As seen in Figure 3, the second design was much more visually appealing, as well as aerodynamic. An aerodynamic design is important because we want to limit the effect the trailer has on the motorcycle while in operation.

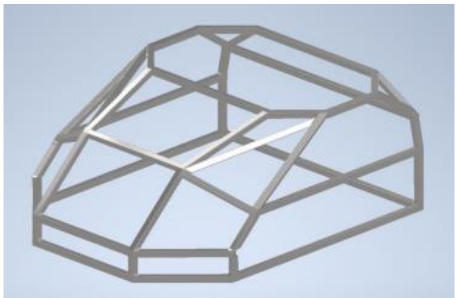


Figure 3: 2nd Version of the cage design

This design would be difficult to construct so we created a simpler cage assembly design as seen in Figure 4. This would consist of a three-tier design. Each tier has simple angles. These tiers would be assembled independently, then all of the more difficult angles would become easier to assemble.

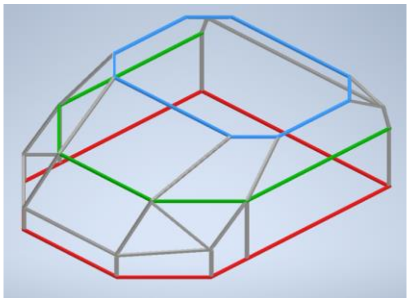


Figure 4: 3rd Version of the cage design

The design was further simplified, as seen in Figure 5, and some un-necessary supports were removed. This design is the current/final design that was used. It still utilizes the three-tier design to make the assembly process easier.

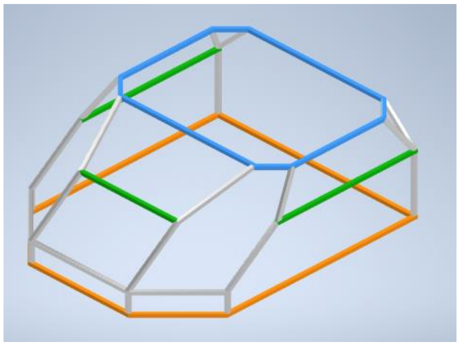


Figure 5: Final version of the cage design

Once the cage frame design was set, 20-gauge aluminum panels were added to the frame as shown in Figure 6. Some additional support bars were also added to support the panels properly.

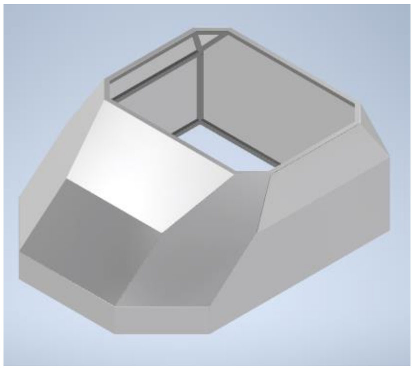


Figure 6: Final version with aluminum plating

Since one of the pets that is going to be pulled in the trailer weighs around 50 lbs., we designed a tailgate that will open in the rear of the trailer making it possible for the dogs to jump onto the trailer themselves, so they do not have to be picked up and placed through the opening on top. As shown in Figure 7.

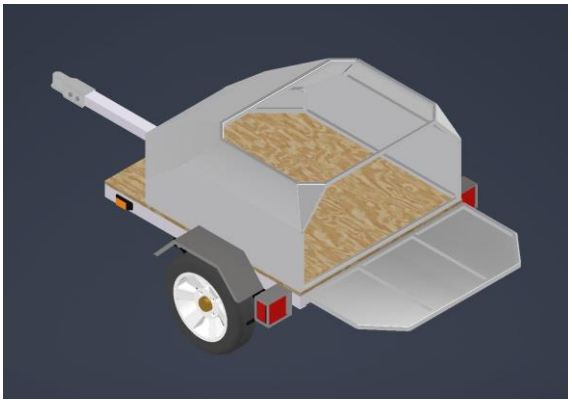


Figure 7: Tailgate design

The deck of the trailer needs to be padded as pets will be hauled on it. A mat was made that can then be removed when the pet enclosure is not on the trailer. Padding was also added around the opening on the top of the pet enclosure. Although we hope to not get in an accident, if we were to, the padding would help to protect the pets from the hard metal cage. While riding in the trailer, the pets will also experience changes in momentum when the motorcycle accelerates, as well as brakes. During these moments, the padding would also be beneficial.

For the trailer to be multi-purpose we created a lid to go over the opening on top to create dry storage. The trailer uses a 1 ⅞" ball hitch so it can be pulled by any vehicle that has a matching ball hitch. The entire pet enclosure is able to be easily removed by one person so that the trailer can be used with just the flat deck, making it super helpful if a pickup truck is not available when something needs moved.

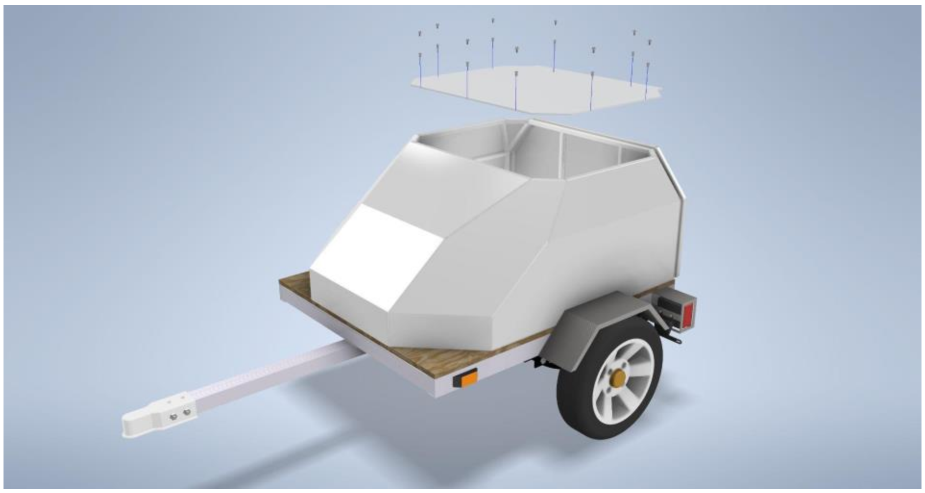
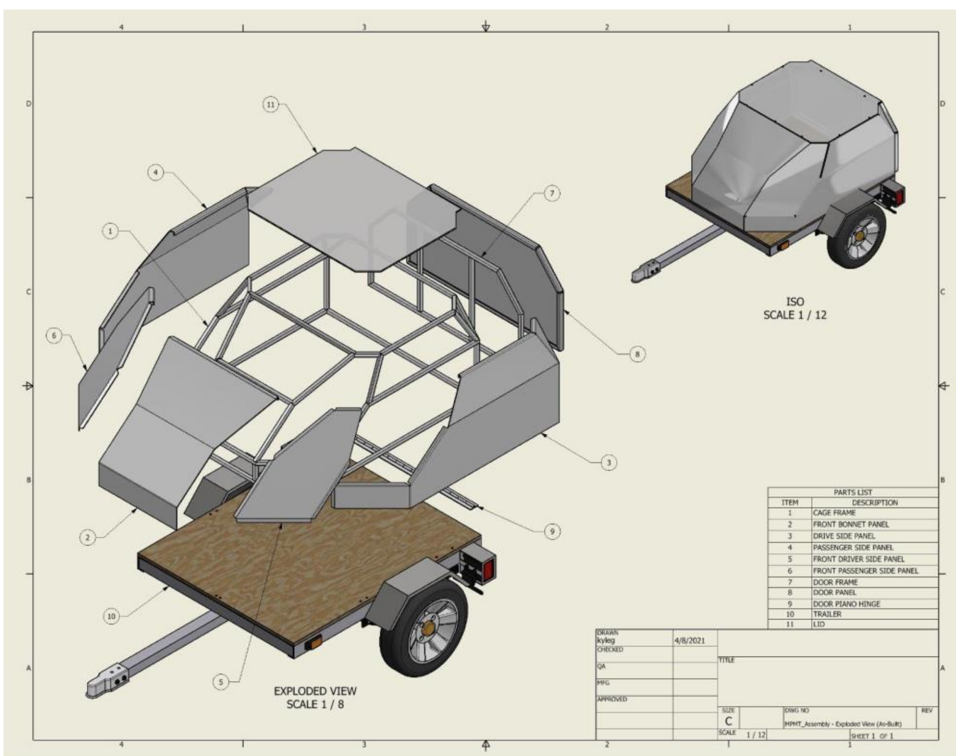


Figure 8: Lid design



PARTS LIST	
ITEM	DESCRIPTION
1	CAGE FRAME
2	FRONT BONNET PANEL
3	DRIVE SIDE PANEL
4	PASSENGER SIDE PANEL
5	FRONT DRIVER SIDE PANEL
6	FRONT PASSENGER SIDE PANEL
7	DOOR FRAME
8	DOOR PANEL
9	DOOR PIANO HINGE
10	TRAILER
11	LID

Figure 9: Exploded view of the trailer and parts list

Project Budget

We applied for funding through the Armin Fleck Grant and were approved for $4000. Our original design would have left us with an $816 dollar deficit. This was partly due to the fact that the original design would have used ⅛ inch aluminum plates that would be welded to the frame costing $1660. To reduce cost, we decided to use a 20-gauge aluminum sheet to cover the exterior of the cage, and do the metal working ourselves. The aluminum sheet only cost $215 and miscellaneous hardware was only $139.10. This allowed us to come in under budget as seen in our budget shown in Figure 10.

Material	Supplier	Units	Cost per ($)	Quantity	Total ($)
Welding and Materials	https://www.cgwelds.com/		1,750.00	1	1,750.00
Aluminum Sheeting	https://www.cgwelds.com/		215.00	1	215.00
40"x48" Ironton Aluminum Trailer	Northerntool.com		399.00	1	399.00
Motorcycle Hitch	ebay.com		370.32	1	370.32
Trailer Decking	Lowes	3/4"x4'x8'	47.00	1	47.00
Pool Noodle	Bass Pro Shop		2.99	2	5.98
Piano Hinge	McMaster.com		27.33	1	27.33
Weather Strip	Amazon.com		11.98	2	23.96
Trailer Wire Adapter	amazon.com	1"x1/4"x10'	34.95	1	34.95
Miscilanious hardware	Lowes		139.10	1	139.10
Door Latches	Amazon.com		11.99	1	11.99
Weather Seal	MM seals		17.50	1	17.50
Paint (estimated)	Shane Syx		350.00	1	350.00
				Total	3,392.13

Figure 10: Project budget

Assembly Process

Trailer & Wire Harness Assembly

We purchased a 40x48 inch pre-built aluminum trailer kit from Northern Tool Equipment and assembled it. The trailer kit came with reflectors, running lights, license plate light, signal lights, brake lights and wiring harness. The wire harness for the lights were soldered and heat shrink wrapped. The lights were tested to make sure they worked properly. A 40x48x¾ inch thick weather resistance sheet of plywood was bolted on top of the trailer to use as the trailer's deck.

Figure 11: Assembly of the trailer

Motorcycle Hitch & Wire Harness Assembly

The motorcycle we used to pull the trailer is a Yamaha V-Star 1100, therefore we required to purchase a ball hitch that is specifically designed for the motorcycle. The hitch was installed to the frame of the motorcycle, leveled, and properly tested. The ball hitch provided the motorcycle with a good amount of lean angle when turning. A standalone wiring harness kit was connected to the motorcycle to use the trailer lights during normal operation. The wiring harness was soldered to the motorcycle, heat shrink wrapped, and electrical tape was used for cable management. All lights were tested with the trailer to make sure they worked properly.

Figure 12: Motorcycle hitch

Cage Frame Assembly

The cage frame fabrication was outsourced to CG Welds for welding using ¾ inch square aluminum tubing. Additional ¾ inch aluminum flat bars were added to the side of the cage to provide more support to the aluminum panels. Four 1.5x0.5 inch square tabs were welded to the bottom of the cage for securely bolting the cage to the deck of the trailer. The case was then sanded to smooth out the welds, so the panels can be properly installed.

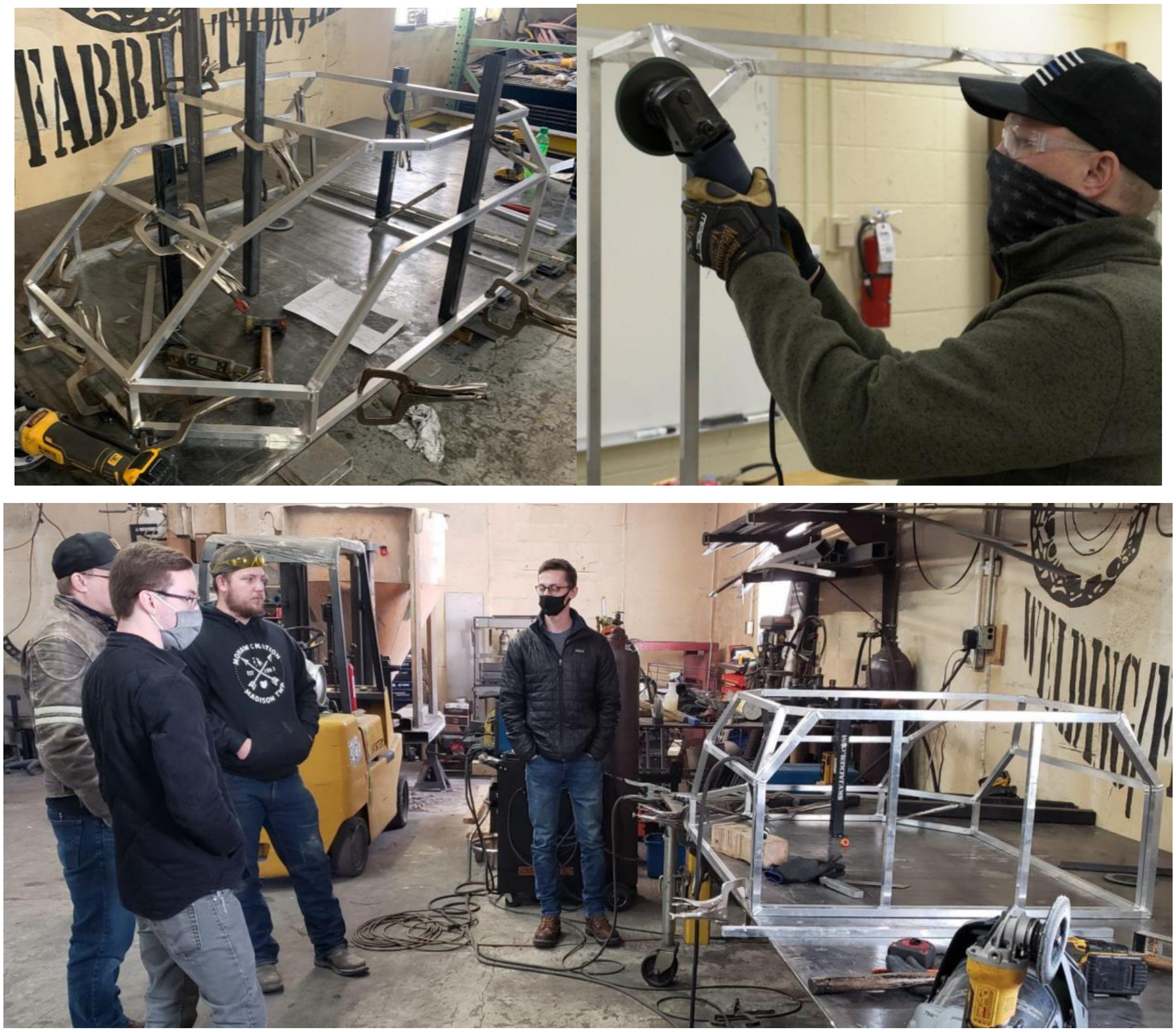


Figure 13: Assembly of the cage frame

Panel Assembly

This was our very first time working with sheet metal, therefore we had to make sure that we knew exactly what we needed to do by creating templates for the panels. The first attempt to make the panel templates was using cardboard to form around the frame. This was a total failure because the cardboard was very flexible, but we did learn a lot during this process. The next and final attempt of making the panel templates was using poster board instead of cardboard. This gave us a more accurate fit and closer dimensioning for the panels.

The templates were then traced onto the 20-gauge aluminum sheet so they could be cut out. Electrical sheet metal shears & aviation snips were used to cut the aluminum panels. We first had to rough cut each individual panel using the electrical shears to make it easier to maneuver the individual pieces. We then used the aviation snips to cut the panels more accurately.

The panels were then formed using a metal brake, shaping hammers, and rubber dead blow hammers. We had just enough sheet metal to make one of each piece that was needed, so we had to practice using scrap sheet metal pieces before working on the master pieces. First, we had to bend all the longer bends needed using the metal brake, then slowly form the panel to the frame using rubber dead blow hammers. We used dead blow hammers because we did not want to dent the panels. After all panels were formed, we then used stainless steel sheet metal screws to secure the panels to the cage frame.

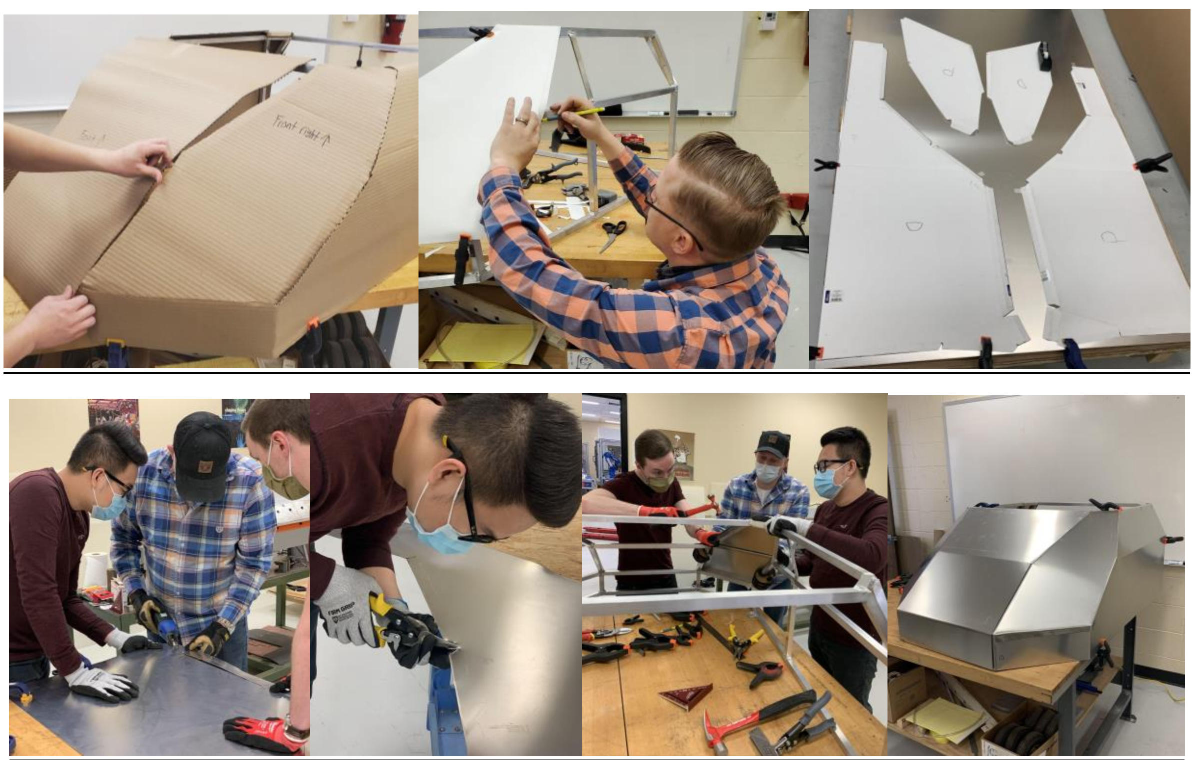


Figure 14: Assembly of the panels

Lid & Door Assembly

The lid was made out of a piece of ¼ inch thick polycarbonate sheet. It was securely bolted to the top of the cage using rivnuts for when the trailer will be used for dry storage. An angle grinder was used to put a chamfer on the lid to remove sharp edges.

The door frame was also welded by CG Welds using ¾ inch square aluminum tubing. The outer door panel was installed with a 20-gauge aluminum sheet using self-tapping screws. The inner door panel was riveted with ⅛ inch thick polycarbonate sheet and rubber padding was glued on top to provide better traction for the dogs when they jump onto the tailgate. The door was attached to the cage frame using a heavy-duty aluminum piano hinge and the hinge was riveted to the cage frame. Two 1/16-inch stainless steel wire cables were attached on both sides using bolts to hold the door as a tailgate.

Figure 15: Assembly of the door

Weather Sealing & Padding Protection

Quarter inch thick rubber strips were used to seal the gap between the door and the cage. An additional seal was added as well to ensure a watertight seal between the door, lid, and the cage. All weather resistance silicon was used to seal up any gap between the panel from the inside of the trailer and reduce panel vibration during use. A ¾ inch thick, soft, rubber foam mat was used on the top of the trailer deck to have some cushion for the dogs. Thick foam pipe insulation was used to wrap around the top frame to give the protection for the dog's head and neck. The dogs will be securely attached with a leash and harness that will be secured to the base of the trailer; therefore, the dogs will not be able to jump out of the trailer while it is moving.

Figure 16: Assembly of the sealing and padding protection

Expected Findings and Engineering Analysis

The expected findings for this project include the following: strengths and weaknesses of our cage design, drag/lift coefficients and forces of the trailer/design, air flow paths and turbulence regions of the trailer/design, maneuverability of the trailer/design while being pulled behind the motorcycle, how the trailer/design reacts under acceleration and deceleration while being pulled behind the motorcycle, ease of use and functionality, etc. In order to find the answers to what we expected to find with our project we performed a finite element analysis (FEA), a computational fluid dynamics (CFD) analysis, wind tunnel testing and analysis of a 3D printed model, and real-world testing using the assembled/completed design. In the following sections the results from these types of tests and analysis will be discussed.

Finite Element Analysis

The finite element analysis (FEA) that was conducted for this project included a few different simulations. The main focus of these simulations was for us to gain a better understanding of the strengths and weaknesses of the cage design as a whole. These simulations were done using Ansys 2020 R2 Static Structural. The cage design that was used for the finite element analysis was the final version of the design and is also the design that was assembled/fabricated. For more detailed information please refer to Appendix F as it contains two Ansys reports for the finite element analysis. One of these reports is for a 1000 lbf (side impact) simulation, while the other is a pressure loading simulation (0 psi to 100000 psi) acting on the outside of the design and is increased with time to measure changes in deformation due to pressure. Within the following Figures (18-21) these conditions/results from these simulations can be seen, however as mentioned previously, please refer to Appendix F for more information.

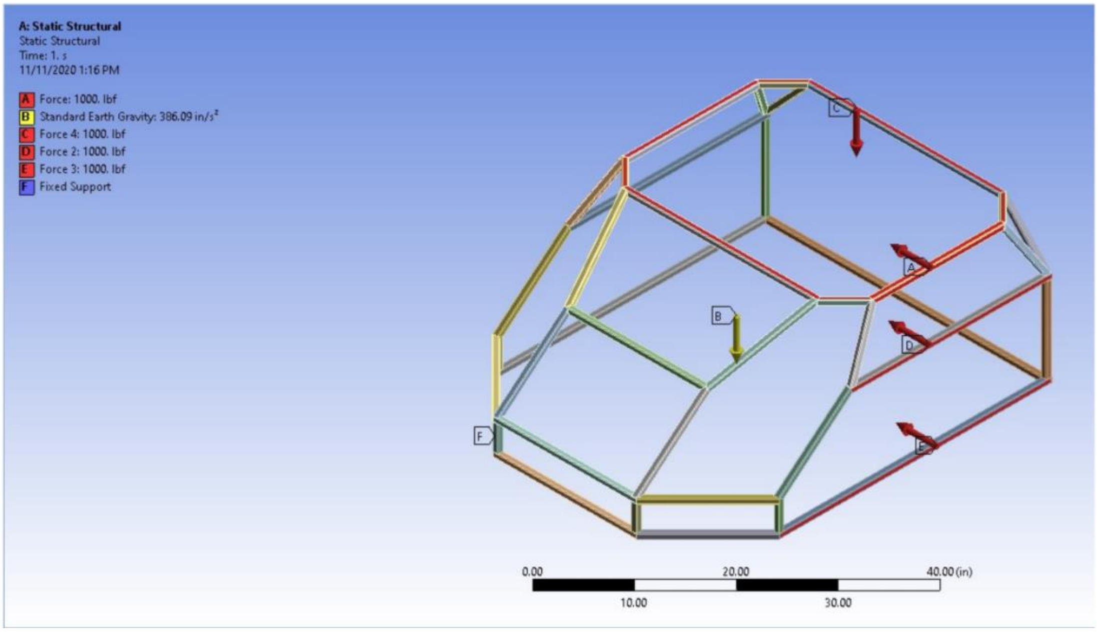


Figure 18: Test conditions for 1000 lbf side impact

As seen in Figure 19 below, after a side impact of 1000 lbf, the largest amount of deformation is only 5 inches.

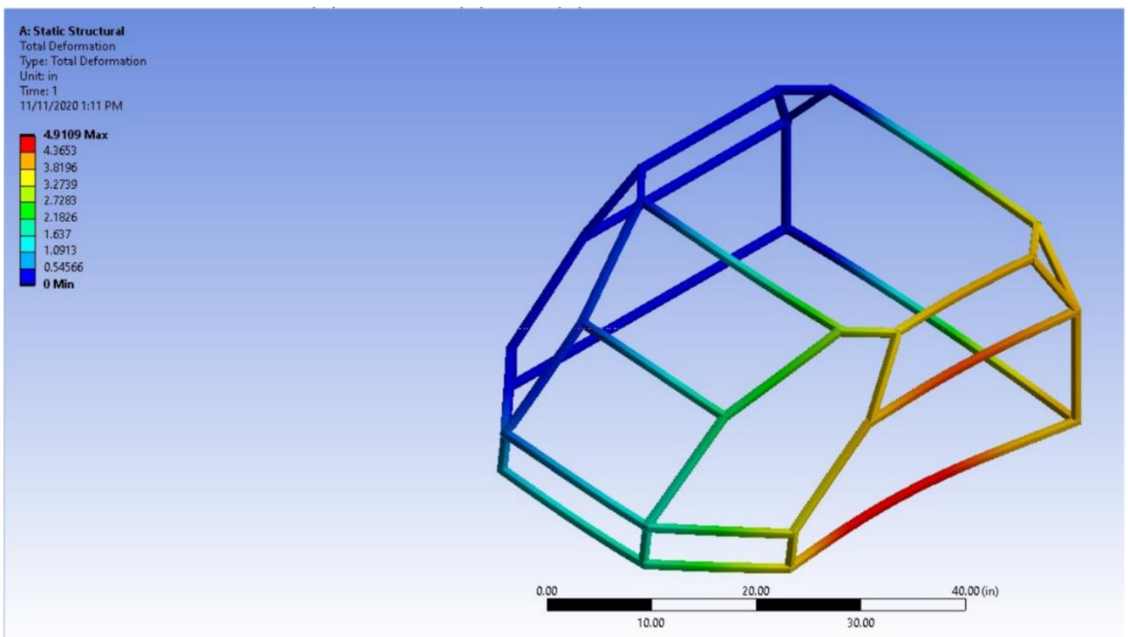


Figure 19: Total deformation from 1000 lbf side impact

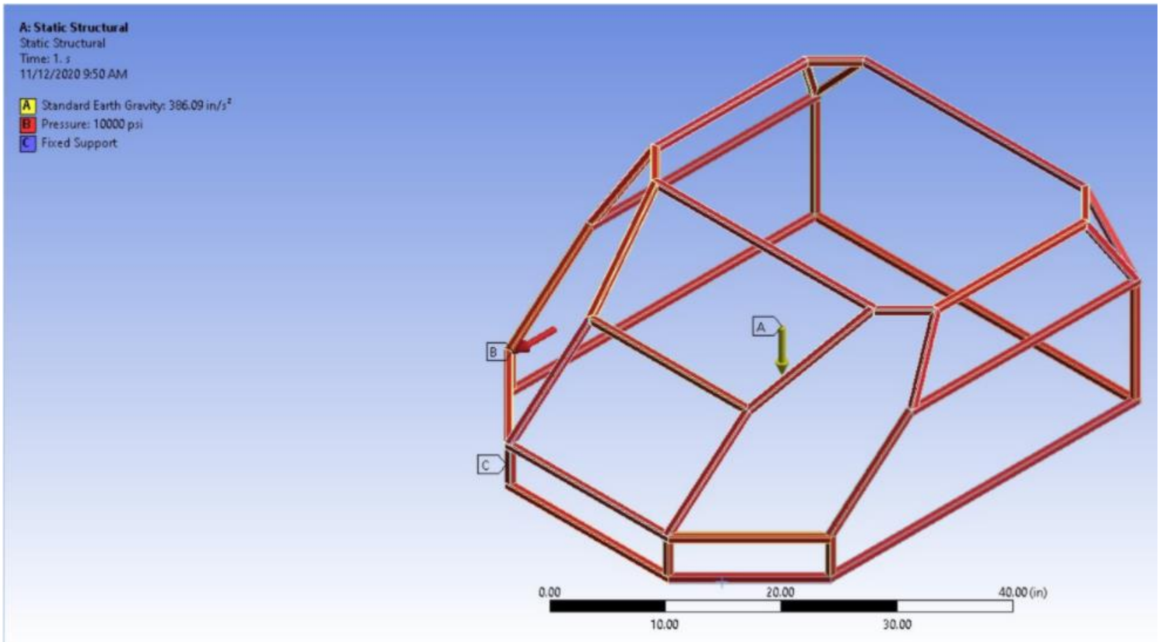


Figure 20: Initial conditions increasing pressure to 100,000 psi

As seen in Figure 21, the largest amount of deformation after 100,000 psi of pressure is applied is only .013926 inches.

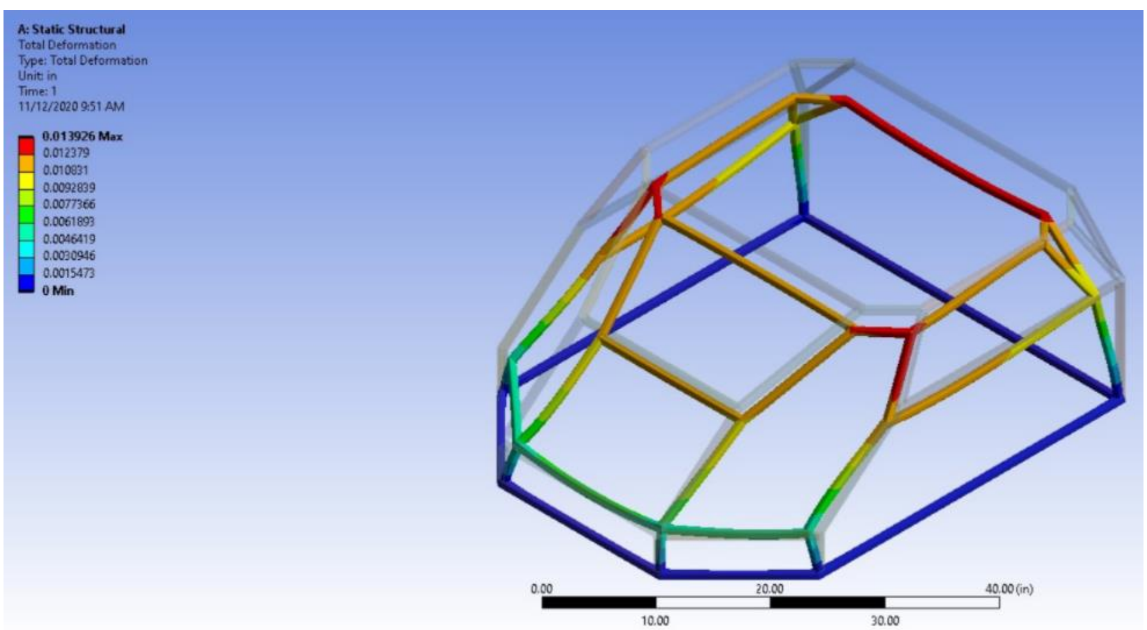


Figure 21: Total deformation after increasing pressure to 100,000 psi

Computational Fluid Dynamics Analysis

The computational fluid dynamics (CFD) analysis that was conducted for this project was based around using a simplified model of our design that we prepared/refined for simulation. This analysis was conducted using Ansys 2020 R2 Fluent/Fluent meshing. The main goal of this analysis was to gain a better understanding of the drag/lift coefficients, drag/lift forces, and fluid flow characteristics of the design. The simulations were modeled around a symmetrical analysis of the geometry and this was done in order to reduce the total computational time since many simulations were performed. In the following paragraphs the geometry and initial modeling will be discussed, the mesh development/refinement within Fluent meshing, the conditions and physics models that were used, and finally the overall results from the simulations.

As mentioned previously a simplified model was used for the simulations. This model was created using Autodesk Inventor and then prepared/refined for the CFD simulations using Ansys Space Claim. These refinements included repairing the geometry, removing unnecessary features, creating a large enclosure for the fluid flow path, splitting the model so that it is symmetrical, creating name selections for mesh refinement/boundary conditions, creation of bodies of influence around the model for mesh refinement, etc. Once these refinements were completed the geometry was then transferred into Fluent meshing. The simplified model prior to refinement and then the model used for the simulations after being refined are as shown in Figure 22.

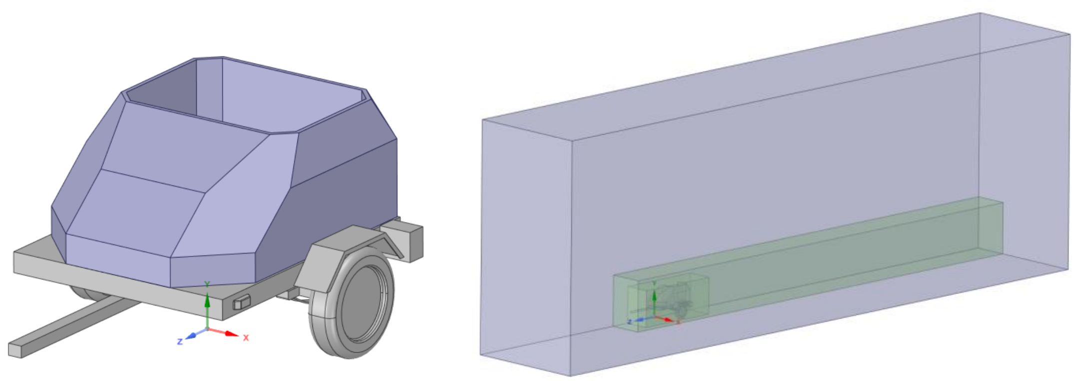


Figure 22: Simplified trailer model

Within fluent meshing the refined geometry model (Shown on the right side in *Figure 22*) was used for all of the simulations that were conducted. The initial mesh that was used consisted of sizing controls that were placed on the various name selections that were created for refining the mesh. The type of mesh that was used for the simulations was a poly-hexcore mesh. The reason this mesh type was chosen was because it is one of the more efficient forms of meshing that is available within Ansys and it was suitable for analysis that was being conducted. Two versions of the mesh were created as well and the reason this was done was to compare and contrast the original mesh against a very refined mesh in order to see if any dramatic changes occurred. The original mesh consisted of 2,607,967 nodes and the very refined mesh consisted of 13,304,816.

The result of this comparison was that original mesh compared to the very refined version only had a variance of around ± 1 for the measured values such as the drag force and drag coefficient. However, the computation time for the very refined version took nearly three times as long as the original mesh and because of this the original mesh was then used for the extended simulation cases and is the mesh that the results shown later on are responsible for. Below is a side view comparison of the original mesh as shown in Figure 23 and the very refined version as shown in Figure 24.

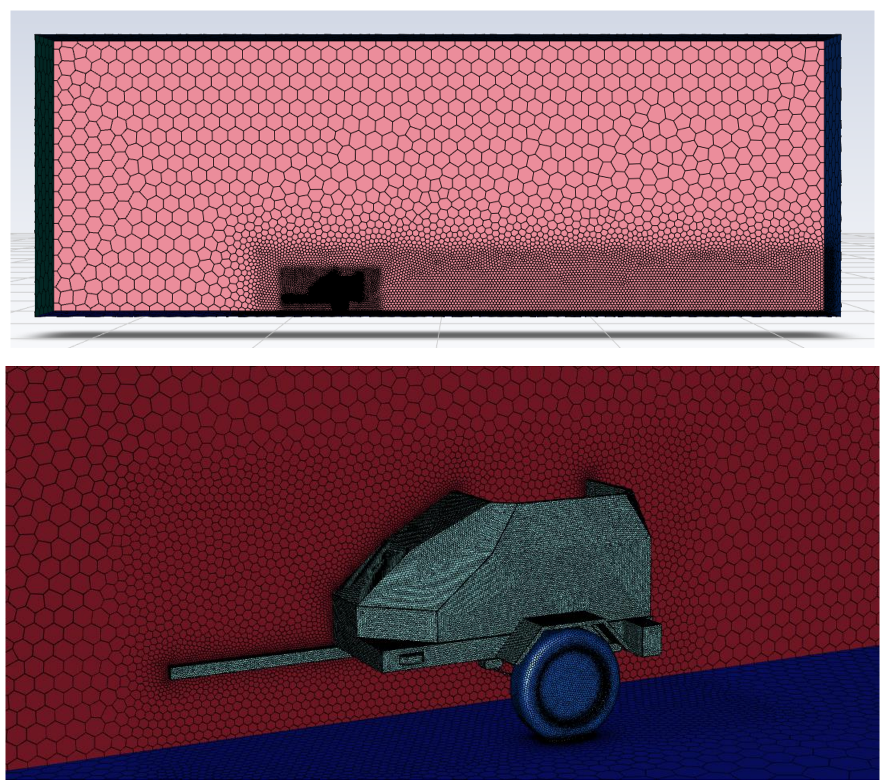


Figure 23: Original mesh

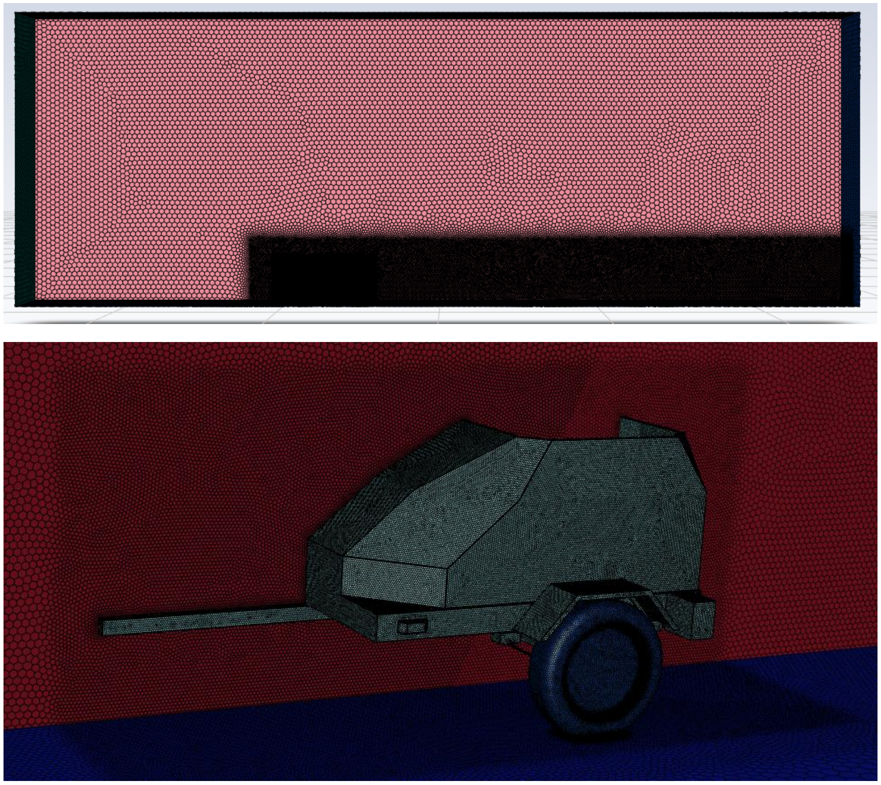


Figure 24: Refined mesh

Once the meshing was completed the simulations were then set up and ran to collect data for the drag/lift coefficients and forces. Two physics models were used and compared against each other these models are as follows: $k - \omega$ GECKO and $k - \varepsilon$ with enhanced wall treatments as well as realization enabled. Both of these models are included within Ansys Fluent and both cases were run at the same number of iterations and timesteps for each as well. The number of iterations used is 500 at a timestep of 0.01. The fluid used in these simulations is air as the purpose of the CFD analysis was to gain an understanding of how the design would react in operation.

With this in mind the simulations for both cases had the following inlet velocities: $45\ mph\ (20.11\ m/s)$, $35\ mph\ (15.65\ m/s)$, $25\ mph\ (11.18\ m/s)$, $15\ mph\ (6.71\ m/s)$, $10\ mph\ (4.47\ m/s)$, and $5\ mph\ (2.24\ m/s)$. The reason for this various amount of velocities is because these are the typical speeds that the trailer will be traveling at when being pulled behind the motorcycle. Within the solver setup this velocity is also attributed to the wall boundaries to simulate them as being moving walls except for the wheel on the trailer model which follows a rotational moving wall condition. The reason for this is so that we can have the model essentially be stationary while the boundaries around it are moving at the operation speeds allowing us to model the airflow over the model.

Once the simulations were completed, their results for the drag/lift coefficients and drag/lift forces were documented into an excel spreadsheet. These results can be viewed in Figures 25 and 26. From these results we can see that the total drag increases as we increase the inlet velocity and decreases when we lower the inlet velocity. The total drag/lift force also follows the same pattern as well as the lift coefficient. In Figure 27, the graph shown shows the drag coefficient compared against the speed (inlet velocity) in meters per second for the $k - \omega$ GECKO model.

$k - \omega$ GECKO Model Results								
Speed (Mph)	Speed (Km/h)	Speed (m/s)	Drag Coefficient	Lift Coefficient	Drag Force (N)	Lift Force (N)	Drag Force (lbf)	Lift Force (lbf)
45	72.42	20.11	0.2463	0.0438	61.05	10.85	13.73	2.44
35	56.33	15.65	0.1460	0.0290	36.18	7.20	8.13	1.62
25	40.23	11.18	0.0773	0.0069	19.16	1.72	4.31	0.39
15	24.14	6.71	0.0287	0.0041	7.11	1.01	1.60	0.23
10	16.09	4.47	0.0131	0.0006	3.24	0.15	0.73	0.03
5	8.05	2.24	0.0032	0.0001	0.78	0.03	0.18	0.01

Figure 25

$k - \varepsilon$ with Enhanced Wall Treatments and Realization Model Results								
Speed (Mph)	Speed (Km/h)	Speed (m/s)	Drag Coefficient	Lift Coefficient	Drag Force (N)	Lift Force (N)	Drag Force (lbf)	Lift Force (lbf)
45	72.42	20.11	0.2376	0.0447	58.89	11.08	13.24	2.49
35	56.33	15.65	0.1434	0.0258	35.54	6.39	7.99	1.44
25	40.23	11.18	0.0748	0.0129	18.53	3.19	4.17	0.72
15	24.14	6.71	0.0272	0.0055	6.74	1.36	1.52	0.31
10	16.09	4.47	0.0121	0.0025	2.99	0.61	0.67	0.14
5	8.05	2.24	0.0031	0.0005	0.76	0.12	0.17	0.03

Figure 26

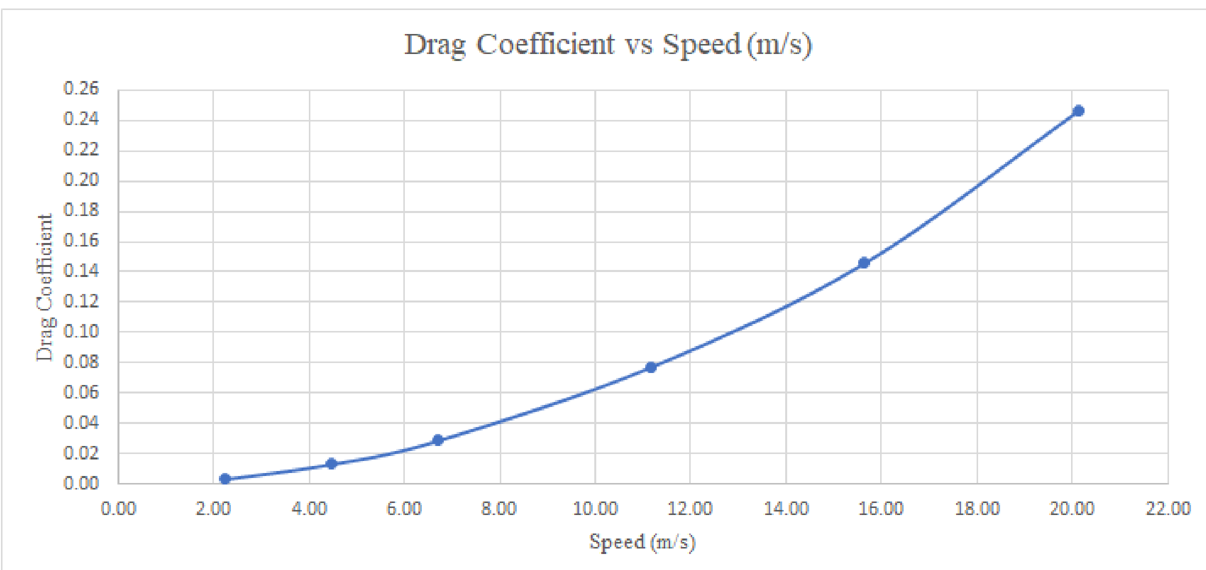


Figure 27: Drag coefficient plot from $k - \omega$ GECKO model

Overall, from the CFD analysis we were able to gain an insight into the aerodynamics of our design. In the future further research may be conducted to address the Y+ values for the wall boundaries and also to compare more of the turbulence models within Ansys Fluent. Also, there are future plans for developing a removable windshield for the design and because of this a future CFD analysis is planned that way we can compare the characteristics of the design with and without a windshield. Additionally, within the appendices in Appendix C, some additional information/images/plots from two of the simulations in Ansys Fluent can be seen.

Wind Tunnel Testing

The CFD results were verified by conducting tests in a subsonic wind tunnel. A model of the trailer with the pet enclosure was 3D printed at 1/12th scale for this testing. The 3D printed model was created using the same file that was used in the CFD simulations. The blockage ratio of the scaled model in the wind tunnel was calculated to be 6.42%.

$$Blockage\ Ratio = \frac{Max\ Frontal\ Area\ of\ the\ Model}{Cross\ Section\ Area\ of\ the\ Wind\ Tunnel} = \frac{9.247\ in^2}{144\ in^2} = 6.42\%$$

The wind tunnel we used needed some work done before it would become operational because the smoke machine did not produce enough smoke to get clean streamlines. With assistance from Dr. Dinc, research was done, and a replacement smoke machine was ordered. Once the replacement smoke machine arrived, we had to modify the delivery system used with the previous smoke machine so that it would work with the new one. To do this, we used various plumbing supplies purchased from Lowes.

Once we began testing utilizing the wind tunnel, we saw that we needed to modify the smoke inlet pipe. During the first test, we noticed that the smoke streams would only appear on the top half of the 3D printed model. To fix this, we added new holes to the bottom of the inlet pipe to create streams that would hit lower on the model. After more testing, we noticed that the smoke streams were thicker than we wanted. Because of this, we rotated the inlet pipe, closed off the larger holes, and put in smaller holes.

The wind tunnel testing gave us a better understanding of the aerodynamics in comparison to the CFD simulations. Testing was conducted using speeds of 15 MPH, 25 MPH, 35 MPH, and 45 MPH. These speeds match the speeds used for the CFD simulations so that they could be directly compared. In Figure 28 we can see a high turbulence directly behind the trailer. In Figure 29 we have an image from one of the CFD results that was collected and here we can also see high turbulence behind the trailer as well. As expected, the turbulence behind the trailer became more intense as the air flow speed increased.

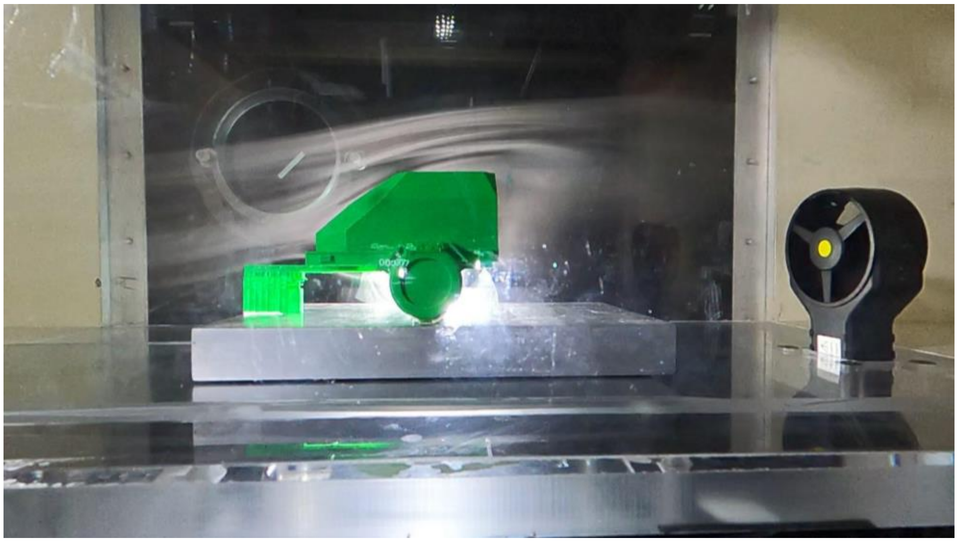


Figure 28: Wind tunnel testing

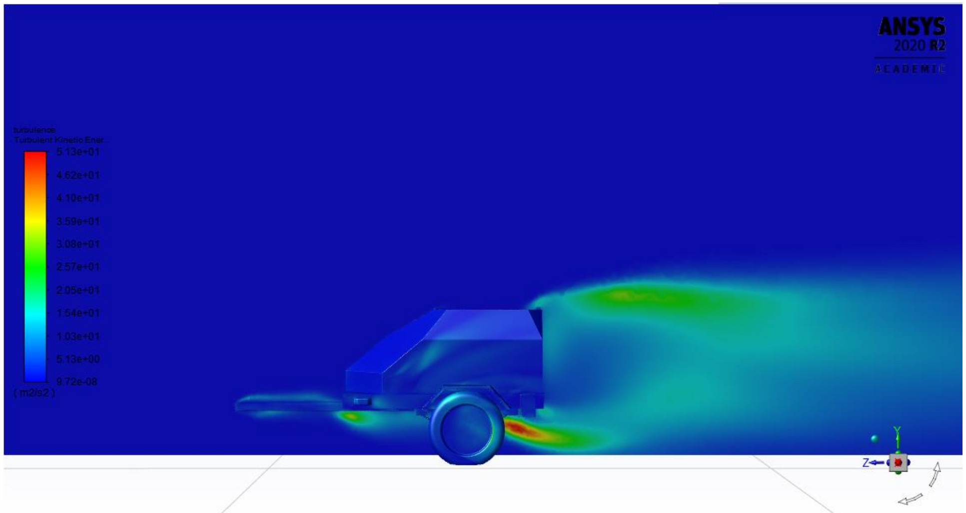


Figure 29: Ansys fluent turbulence result

Execution Testing

The first time the trailer was attached to the motorcycle, it was just the trailer without the pet enclosure. We wanted to ensure safety by starting with just the trailer, then the trailer with the enclosure, then the trailer with the enclosure and weights to simulate the pets, and finally have the pets in the enclosure being pulled behind the motorcycle.

Due to safety concerns, the trailer was only to be pulled behind the motorcycle while on Miami University property. The first time the trailer was attached to the motorcycle was on Miami University's Middletown campus. This was just a quick test to ensure that the trailer lights worked and to see if there were any major problems that could be noticed. While pulling the trailer with the motorcycle, there was no difference in maneuverability, acceleration, or breaking. The only difference noticed is that the trailer is much wider than the motorcycle. This could become a potential problem in some situations.

Typically, while riding a motorcycle, the rider will keep the wheels of the motorcycle in the same path that the tires from a car would be. This is because most of the oil and other substances that make the road slick is typically in the center of the lane. Because of the width of the trailer, the motorcycle will not be able to ride in its normal position. This new position for the motorcycle is closer to the center of the lane to ensure that the entire trailer stays fully in the intended lane of travel.

Because of the size of the parking lots on the different Miami Regionals campuses, the trailer was moved to the Hamilton Campus to have more space to test the trailer. One of the concerns for the trailer was whether or not the ball hitch would limit the ability of the motorcycle to lean enough to make some turns. To test this, one of the tests performed was to lean the motorcycle as much as possible safely to see if the ball hitch would limit the lean angle. During testing, we were able to determine that the ball hitch did not reduce/limit the lean angle, in either direction, because the footpads had scraped against the pavement on multiple occasions.

After we were comfortable with pulling the trailer with the enclosure and weights to simulate pets, we began testing with the dogs in the trailer. To prepare the dogs for testing, they were trained to jump onto the tailgate of the trailer and sit in position so that leashes that are secured to the deck of the trailer could be attached to their harness. This training took place over the course of a few weeks to get the dogs acclimated to the trailer before any testing would take place with the dogs.

When the dogs were first pulled in the trailer, they were visibly unsure. We started pulling the trailer with the dogs at a very slow pace to allow the dogs to get used to the trailer in motion. We would slowly increase the speed, being sure to keep an eye on the dogs to ensure that they were not trying to jump out of the trailer. Eventually, they dogs became less nervous and began to enjoy the wind, and the smells of the field as we drove by.

Because of safety restrictions we were unable to do road testing. Going forward, testing will be performed on the road first without the dogs, and then with the dogs once we know that the trailer is safe on the road.

Figure 29: Finished product

Conclusion

In conclusion, this project was a success, and we were able to achieve our intended goals. By applying the skills and knowledge that we have learned at our time at Miami University this is what led to the success of our project. As a team, we collaborated and used our skills and strengths to address various design problems and questions. We also applied and developed new skills within this project and pushed ourselves to achieve the best results that we could. The challenges we faced, and lessons learned along the way from this project are truly invaluable and will allow us to continue and grow as engineers and individuals.

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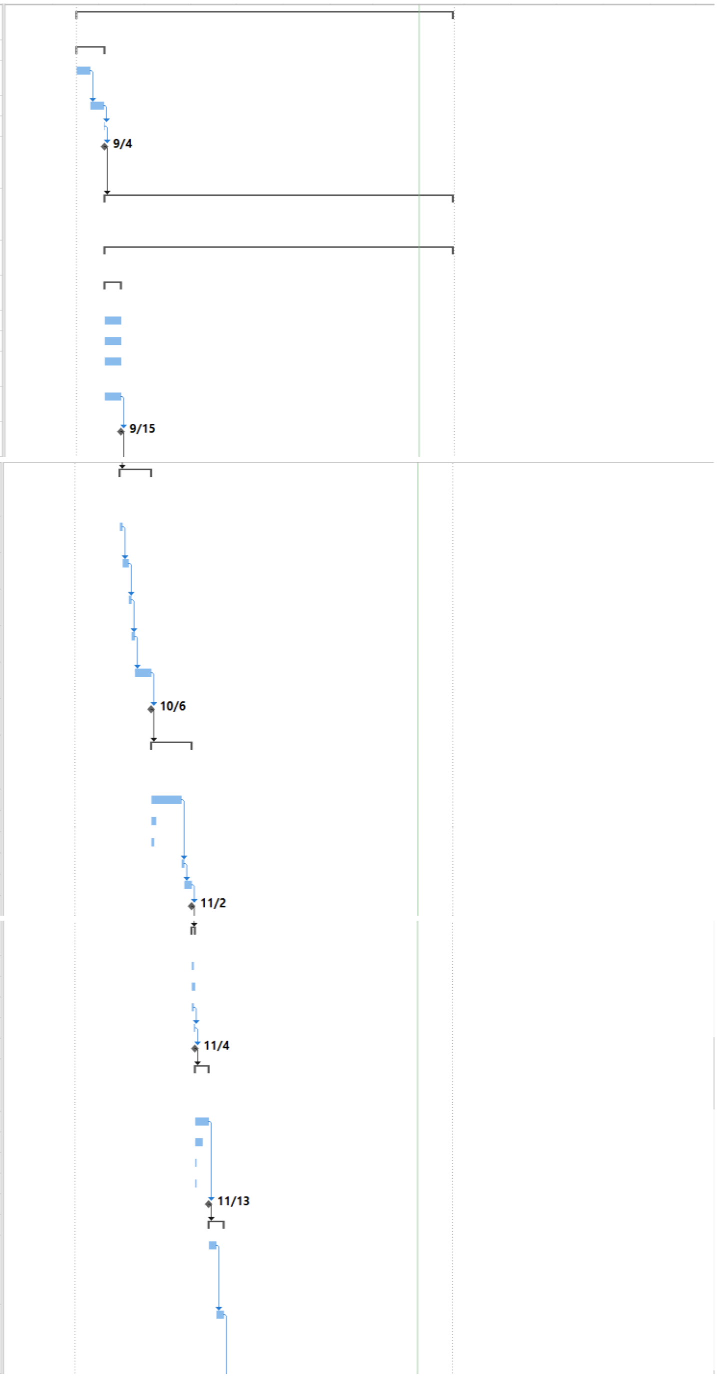
Appendices

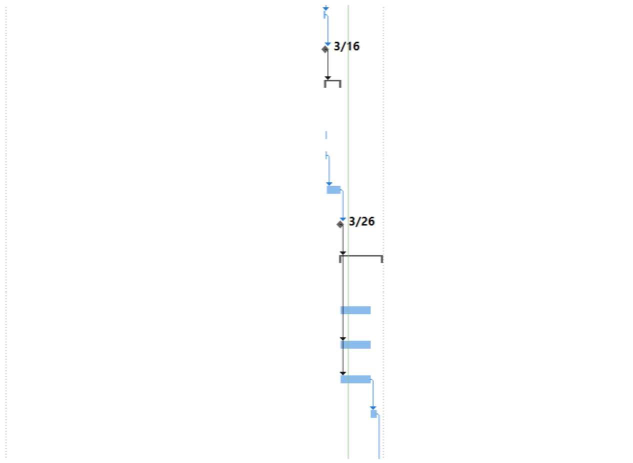
Appendix A: Project Gantt Chart (Microsoft Projects)

Task Name	Duration	Start	Finish	Predecessors
ENT497/498 Senior Design Project	**179.25 days**	**8/17/20**	**4/23/21**	
Assemble Project Teams	**14.25 days**	**8/17/20**	**9/4/20**	
Gather group members and discuss project	7 days	8/17/20	8/25/20	
Decide on a project and	7 days	8/26/20	9/3/20	3
Discuss and decide on a	2 hrs	9/4/20	9/4/20	4
Finish assembly of project team and project name	0 days	9/4/20	9/4/20	5
Multi-Purpose Motorcycle Trailer (MPMT)	**165 days**	**9/4/20**	**4/23/21**	**6**
Project Stage 1 (ENT497)	**165 days**	**9/4/20**	**4/23/21**	
Research Project Requirements	**7 days**	**9/4/20**	**9/15/20**	
Perform research c	7 days	9/4/20	9/15/20	
Determine what pa	7 days	9/4/20	9/15/20	
Select a base trailer that will be	7 days	9/4/20	9/15/20	
Begin recording and documenting	7 days	9/4/20	9/15/20	
Finish Initial Research	0 days	9/15/20	9/15/20	13
Begin Drafting and Working on Project Proposal	**15 days**	**9/15/20**	**10/6/20**	**14**
Fill out the project proposal and state	2 days	9/15/20	9/17/20	
Add in details for the ustification for	2 days	9/17/20	9/21/20	16
Develop a step by step plan for the	2 days	9/21/20	9/23/20	17
Develop a gantt chart for the	2 days	9/23/20	9/25/20	18
Continue working on the project	7 days	9/25/20	10/6/20	19
Submit the project proposal	0 days	10/6/20	10/6/20	20
Design/Research and Development Part 1	**19 days**	**10/6/20**	**11/2/20**	**21**
Discuss and begin c	14 days	10/6/20	10/26/20	
Perform more reas	3 days	10/6/20	10/9/20	
Determine the too	2 days	10/6/20	10/8/20	
Begin performing a	2 days	10/26/20	10/28/20	23
Compare materials	3 days	10/28/20	11/2/20	26
Finish R&D Part 1	0 days	11/2/20	11/2/20	27
Request Funding for the Project	**2 days**	**11/2/20**	**11/4/20**	**28**
Review and revise	1 day	11/2/20	11/3/20	
Have the request f	2 days	11/2/20	11/4/20	
Make adjustments	1 day	11/2/20	11/3/20	
Review and revise	1 day	11/3/20	11/4/20	32
Submit the request	0 days	11/4/20	11/4/20	33
Design/Research and Development Part 2	**7 days**	**11/4/20**	**11/13/20**	**34**
Continue testing th	7 days	11/4/20	11/13/20	
Make changes to t	3 days	11/4/20	11/9/20	
If funding is approv	1 day	11/4/20	11/5/20	
Determine where v	1 day	11/4/20	11/5/20	
Finish R&D Part 2	0 days	11/13/20	11/13/20	36
Final Project	**6 days**	**11/13/20**	**11/23/20**	**40**
Begin drafting final report and powerpoint for ENT497	3 days	11/13/20	11/18/20	
Revise and review the final report as well as powerpoint	3 days	11/18/20	11/23/20	42

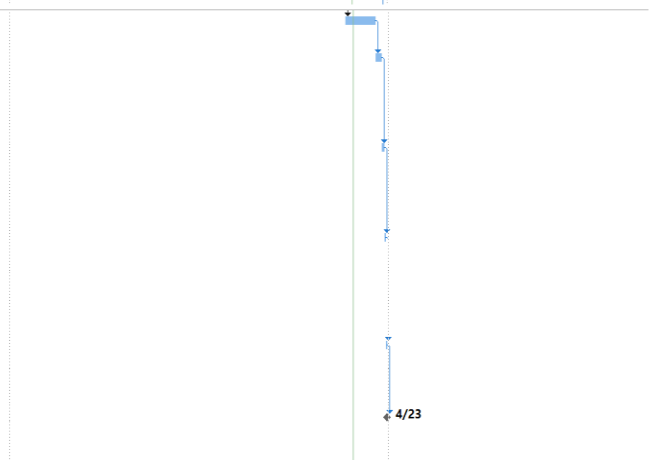


Task Name	Duration	Start	Finish	Predecessors
Finalize and submit final report	0 days	11/23/20	11/23/20	43
Project Stage 2 (ENT498)	**109 days**	**11/23/20**	**4/23/21**	**44**
Design Review and	**43 days**	**11/23/20**	**1/21/21**	
Review/finalize the cage design so that it can be	21 days	11/23/20	12/22/20	
Assemble the trailer so that it can be	3 days	12/22/20	12/25/20	47
Send the revised cage design to the welder so	21 days	12/22/20	1/20/21	47
Install the wood decking onto the trailer	1 day	12/25/20	12/28/20	48
Submit the revised quote	1 day	1/20/21	1/21/21	49
Finish Design Review	0 days	1/21/21	1/21/21	51
Drag analysis and CFD Research Part 1	**20 days**	**1/21/21**	**2/18/21**	**52**
Revise and edit the trailer model so that it	1 day	2/10/21	2/11/21	54
With the revised model, cleanup the geometry	5 days	2/11/21	2/18/21	55
Continue CFD research and	0 days	2/18/21	2/18/21	56
Trailer Wiring/Testing and Resource Collection	**2 days**	**2/18/21**	**2/22/21**	**57**
Order the wiring harness for the	1 day	2/18/21	2/19/21	
Meet as a group and install the	1 day	2/19/21	2/22/21	59
Order the aluminum	1 day	2/19/21	2/22/21	59
Look into potential	1 day	2/19/21	2/22/21	59
Drag analysis and CFD Research Part 2	**14 days**	**2/22/21**	**3/12/21**	**62**
Continue CFD research and	7 days	2/22/21	3/3/21	
Finish and finalize atleast	7 days	2/22/21	3/3/21	
3D print the trailer model so	7 days	2/22/21	3/3/21	
Once the materials needed for	7 days	3/3/21	3/12/21	64
Continue CFD and	0 days	2/22/21	2/22/21	
Paneling and Installation of the Cage Design and Motorcycle Hitch	**16 days**	**2/22/21**	**3/16/21**	**62**
Once the cage design is	1 day	2/22/21	2/23/21	
Begin installing the paneling for	14 days	2/23/21	3/15/21	70
Once the motorcycle hitch is available	2 days	2/22/21	2/24/21	
Add in the foam base insert to the cage design as well as the foam barriers on the inside of the cage	1 day	3/15/21	3/16/21	71

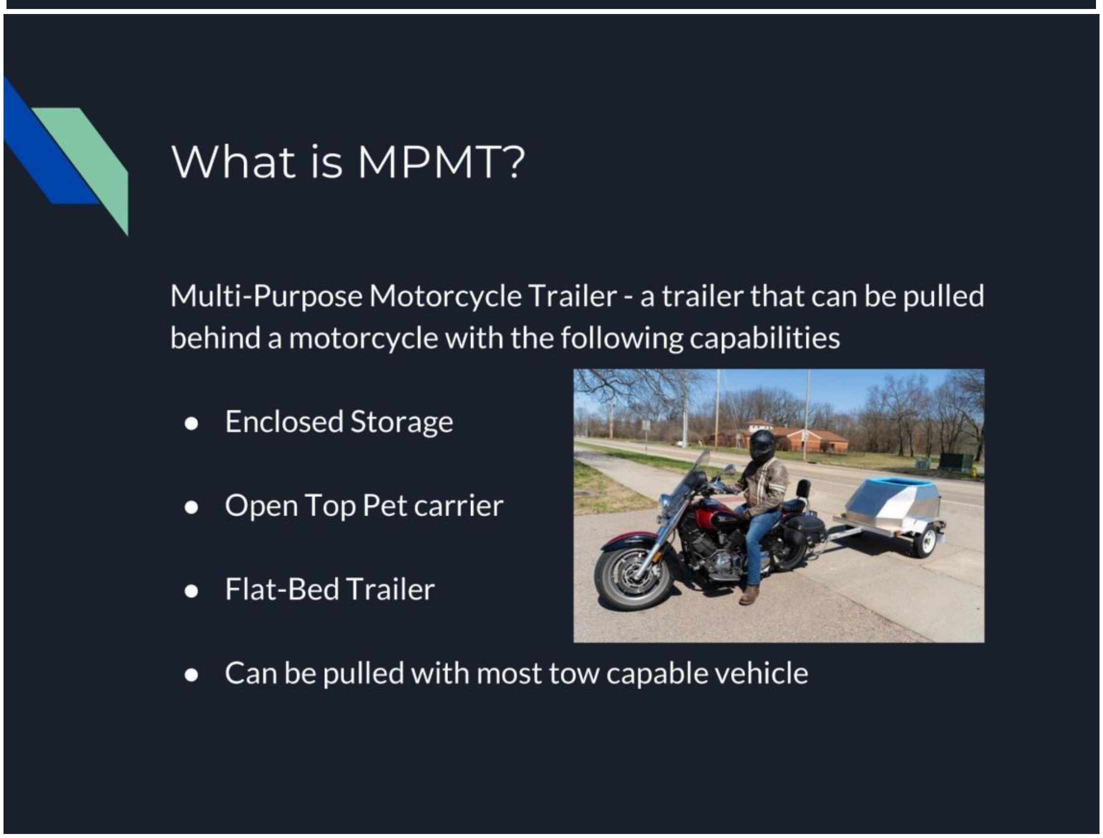
	Perform an electrical/lightin	1 day	3/15/21	3/16/21	71
	Finish the paneling and	0 days	3/16/21	3/16/21	74
	Trailer and Motorcycle Testing	**8 days**	**3/16/21**	**3/26/21**	**75**
	Perform a stabili	1 day	3/16/21	3/17/21	
	Relocate the trailer to the	1 day	3/16/21	3/17/21	
	Perform live testing and	7 days	3/17/21	3/26/21	78
	Finish and review the test	0 days	3/26/21	3/26/21	79
	Final Report and Video Preperation	**20 days**	**3/26/21**	**4/23/21**	**80**
	Begin editting and adding in	14 days	3/26/21	4/15/21	
	Continue working on the	14 days	3/26/21	4/15/21	80
	Begin working on the project	14 days	3/26/21	4/15/21	80
	Review and finalize the final report draft and	2 days	4/15/21	4/19/21	84



	Begin working on the project	14 days	3/26/21	4/15/21	80
	Review and finalize the final report draft and have it sent to be reviewed	2 days	4/15/21	4/19/21	84
	Revise and edit the final report and continue working on the project video	2 days	4/19/21	4/21/21	85
	Have the final report and video reviewed and make changes if needed	1 day	4/21/21	4/22/21	86
	Finalize the report/video and submit them	1 day	4/22/21	4/23/21	87
	Project is now completed	0 days	4/23/21	4/23/21	88



Appendix B: Project Presentation



Why did we design it?

- One of our team member has a need/desire for this project
- It is not a common/readily available product
- Designed for special uses and was a challenging design in general
- New/Ongoing trend in the motorcycle community

Requirements & Laws

- Only pull a trailer with a motorcycle with an engine size of 1,000cc or more
- The weight of the trailer must be lower than half the curb weight of the motorbike.
- The distance between the rear of the bike and the trailer must not exceed 8 feet.
- Maximum speed is 45 mph (manufacturer's statement)
- Design specifically to Ohio's Laws requirements.
- There are no laws associated with hauling pets in trailers.
- Brakes are not required for trailer under 2,000 lbs (law)

Requirements & Laws

Requirements to be registered by Ohio State Law:

- Operable Tail Lights visible from 500 feet to the rear
- License plate lights
- Safety chains
- Brake lights
- 2 red reflectors
- Turn signal lights
- Ohio Driver license or state ID
- Proof of weights of the trailer (must less than 10,000 lbs)

Project Timeline

GANTT CHART

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		ENT497/498 Senior Design Project	179.25 days	8/17/20	4/23/21	
2		Assemble Project Teams	14.25 days	8/17/20	9/4/20	
7		Multi-Purpose Motorcycle Trailer (MPMT)	165 days	9/4/20	4/23/21	6
8		Project Stage 1 (ENT497)	165 days	9/4/20	4/23/21	
9		Research Project Requirements	7 days	9/4/20	9/15/20	
15		Begin Drafting and Working on Project Proposal	15 days	9/15/20	10/6/20	14
22		Design/Research and Development Part 1	19 days	10/6/20	11/2/20	21
29		Request Funding for the Project	2 days	11/2/20	11/4/20	28
35		Design/Research and Development Part 2	7 days	11/4/20	11/13/20	34
41		Final Project	6 days	11/13/20	11/23/20	40
45		Project Stage 2 (ENT498)	109 days	11/23/20	4/23/21	44
46		Design Review and	43 days	11/23/20	1/21/21	

Project Timeline Continued

GANTT CHART

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
53		Drag analysis and CFD Research Part 1	20 days	1/21/21	2/18/21	52
58		Trailer Wiring/Testing and Resource Collection	2 days	2/18/21	2/22/21	57
63		Drag analysis and CFD Research Part 2	14 days	2/22/21	3/12/21	62
69		Paneling and Installation of the Cage Design and Motorcycle Hitch	16 days	2/22/21	3/16/21	62
76		Trailer and Motorcycle Testing	8 days	3/16/21	3/26/21	75
81		Final Report and Video Preperation	20 days	3/26/21	4/23/21	80

Budget

- Fleck Grant Approved for $4,000
- $816 Deficit With Original Design
- Exterior Panels Cost $1,660
- 20 Gauge (0.032”) Aluminum Sheet $215

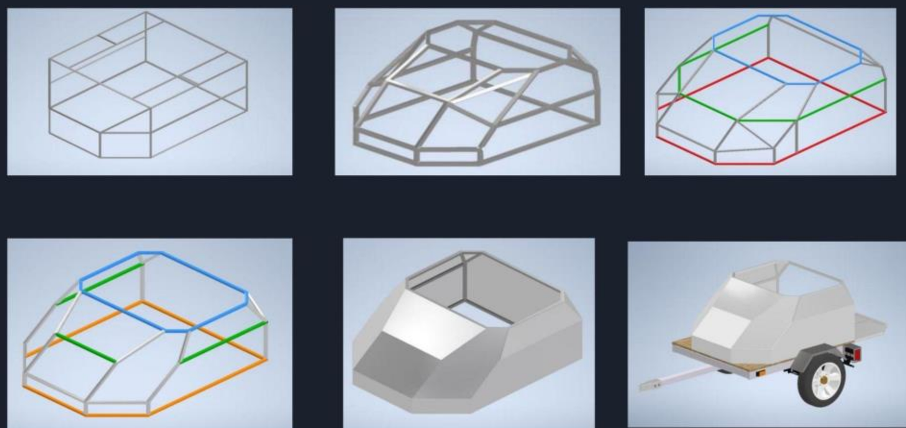
Budget

Material	Supplier	Units	Cost per ($)	Quantity	Total ($)
Welding and Materials	https://www.cgwelds.com/		1,750.00	1	1,750.00
Aluminum Sheeting	https://www.cgwelds.com/		215.00	1	215.00
40"x48" Ironton Aluminum Trailer	Northerntool.com		399.00	1	399.00
Motorcycle Hitch	ebay.com		370.32	1	370.32
Trailer Decking	Lowes	3/4"x4'x8'	47.00	1	47.00
Pool Noodle	Bass Pro Shop		2.99	2	5.98
Piano Hinge	McMaster.com		27.33	1	27.33
Weather Strip	Amazon.com		11.98	2	23.96
Trailer Wire Adapter	amazon.com	1"x1/4"x10'	34.95	1	34.95
Miscilanious hardware	Lowes		139.10	1	139.10
Door Latches	Amazon.com		11.99	1	11.99
Weather Seal	MM seals		17.50	1	17.50
Paint (estimated)	Shane Syx		350.00	1	350.00
				Total	3,392.13

Design

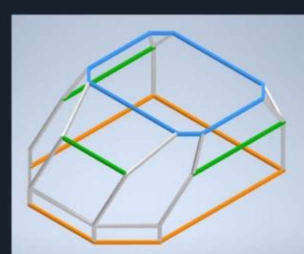
- We designed a scale trailer model that was modeled to be a replica of the actual trailer within Autodesk Inventor.
- The structural cage was designed using Autodesk Inventors Cage Design Feature.
- The aluminum panels were designed within Autodesk Inventor as well using the Sheet Metal Design Feature.

Design



Design

- The design has a skeletal cage
- ¾” Aluminum Square Tubing
- 20 Gauge Aluminum Sheeting
- Cage can be easily attached and removabled from the trailer
- Lid was designed for dry storage
- Tailgate is designed to allow safe/sturdy loading of the animals



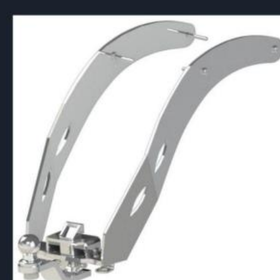
Design

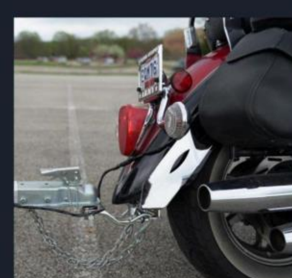
This video was made using Autodesk Inventor 2021

Assembly Process

Motorcycle Hitch and Wire Harness:

- The ball hitch is designed for a Yamaha V-Star 1100 motorcycle.
- The hitch was installed to the frame of the motorcycle.
- A standalone wiring harness kit was connected to the motorcycle to use the trailer lights during normal operation.





Assembly Process

Trailer assembly and wiring the trailer lights:

- A pre-built 40" x 48" aluminum trailer kit.
- Wiring harness for the trailer lighting was installed by us.
- 40" x 48" x ¾" thick weather resistance plywood was bolted on top of the trailer to use as the trailer base.

Assembly Process

Cage Frame:

- Cage fabrication was outsourced to CG Welds for welding using ¾" square aluminum tubing.
- Additional ¾" aluminum flat bars were added to the cage to provide more support to the aluminum panels.
- Four 1.5" tabs were added on the bottom of the cage for bolting the cage to the trailer.

Assembly Process

Panels:

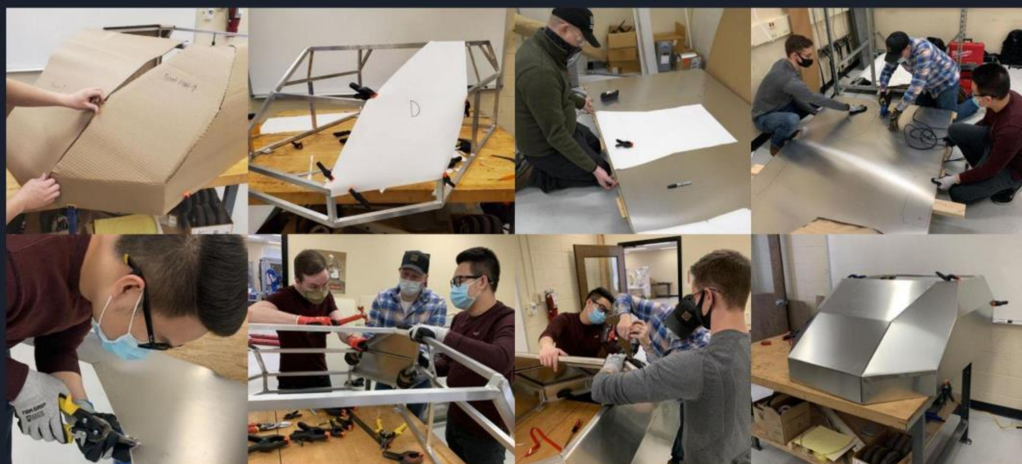
- First attempt of making the panels template was done with cardboard.
- Final attempt was done using poster boards to make the panel templates.
- The templates were then traced on the 20 gauge aluminum sheet for cutting.

Assembly Process

Panels:

- Electrical sheet metal shears & aviation snips were used to cut the aluminum panels.
- The panels were then formed using a metal brake, shaping hammers, and rubber dead blow hammers.
- Stainless steel sheet metal screws were used to secure the panels to the cage.

Assembly Process (Panels)



Assembly Process

Lid:

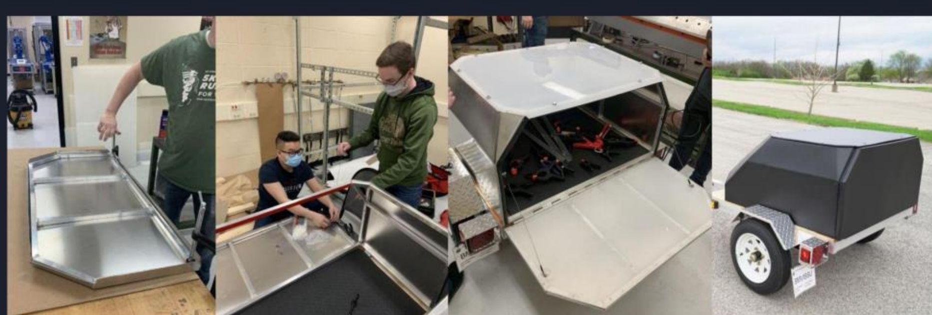
- The lid was made out of ¼” thick polycarbonate sheet.
- It was securely bolted to the top of the cage via rivnuts when used for dry storage.

Assembly Process

Door:

- The door frame was welded by CG Welds using ¾” square aluminum tubing.
- Inner door panel was riveted with ⅛” thick polycarbonate sheet and rubber padding was glued on top to provide better traction on the surface.
- Door was attached to the cage frame using a heavy-duty aluminum piano hinge and 1/16” stainless steel wire cables.
- Two latches were used to secure the door.

Assembly Process (Lid & Door)



Assembly Process

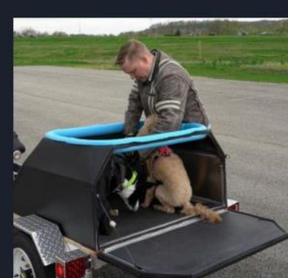
The Weather Sealing:

- ¼" thick rubber strips were used to seal up the gap between the door and the cage.
- All weather resistance silicon was used to seal up any gap between the panel from the inside of the trailer.

Assembly Process

The Padding & Protection:

- ¾" thick, soft rubber foam mat was used on the top of the base to have some cushion protection for the dogs.
- Thick foam pipe insulation was used to wrap around the top frame to give the protection on the dog's head and neck.
- The dogs will be securely attached with a leash that will be secured to the base of the trailer.



Assembly Process (Sealing & Protection)




Assembly Process

The Paint Finish:

- Outsourcing to Shane Syx to paint.
- Getting rid of the shiny panel surfaces is required to safely pull the trailer on the road and have a more finished look.

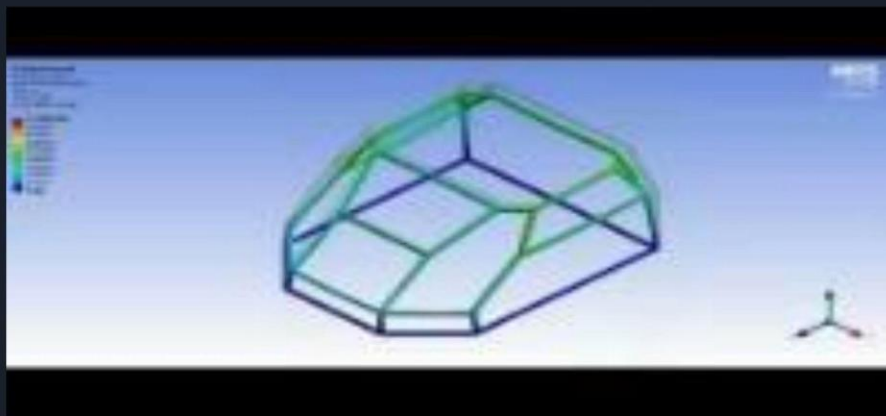

Analysis

- We have conducted a finite element analysis (FEA), a computational fluid dynamics analysis (CFD), and a wind tunnel analysis to gain a better understanding of the aerodynamics, drag/lift coefficients, drag/lift forces, and strengths/weaknesses of our design.
- Ansys 2020 R2 was used for both the FEA and CFD Analysis.
- The wind tunnel that was used is the one located at Miami University Middletown Campus.

Finite Element Analysis (FEA)

- The FEA included a comparison between static loading and increasing pressure acting on the entire cage structure.
- Within the FEA our primary focus was on the cage design and testing its strengths and weaknesses through simulations.
- The static loading focused on having 10000 lbf acting on individual components throughout the cage design.
- The increasing pressure simulation had increasing pressure acting on the outside of the cage design that was increased with time.

FEA Ansys Simulation (Increasing Pressure)



This video was made using Ansys 2020 R2

Computational Fluid Dynamics (CFD)

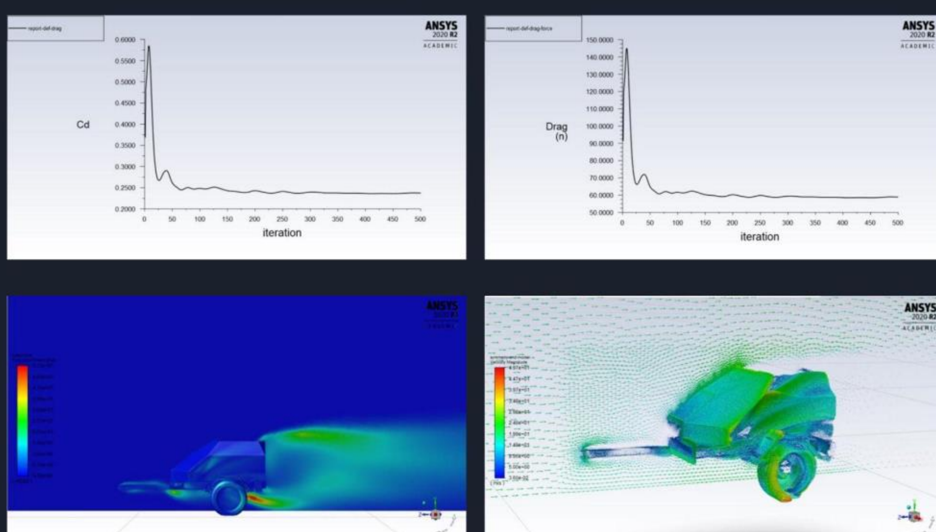
- The CFD analysis for this project was a symmetrical analysis of a simplified trailer model. The reason a symmetrical analysis was done was to reduce the total computational time.
- Two physics models were used for comparison purposes to validate the results as well as check for any discrepancies between them.
- Multiple simulations were done and addressed various speeds in which the design will experience while in operation.

Computational Fluid Dynamics (CFD) Results

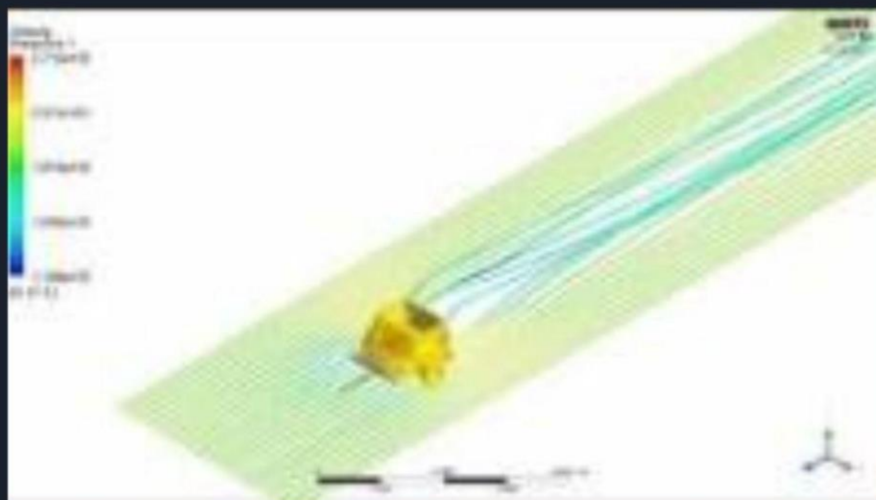
K-Omega GECKO Model Results							
Speed (Mph)	Speed (Km/h)	Drag Coefficient	Lift Coefficient	Drag Force (N)	Lift Force (N)	Drag Force (lbf)	Lift Force (lbf)
45	72.4205	0.2463	0.0438	61.0536	10.8464	13.7254	2.4384
35	56.3270	0.1460	0.0290	36.1847	7.1970	8.1346	1.6179
25	40.2336	0.0773	0.0069	19.1647	1.7159	4.3084	0.3858
15	24.1402	0.0287	0.0041	7.1107	1.0056	1.5986	0.2261
10	16.0934	0.0131	0.0006	3.2422	0.1454	0.7289	0.0327
5	8.0467	0.0032	0.0001	0.7848	0.0288	0.1764	0.0065

K-Epsilon with Enhanced Wall Treatments Model Results							
Speed (Mph)	Speed (Km/h)	Drag Coefficient	Lift Coefficient	Drag Force (N)	Lift Force (N)	Drag Force (lbf)	Lift Force (lbf)
45	72.4205	0.2376	0.0447	58.8911	11.0808	13.2392	2.4911
35	56.3270	0.1434	0.0258	35.5357	6.3925	7.9888	1.4371
25	40.2336	0.0748	0.0129	18.5339	3.1927	4.1666	0.7178
15	24.1402	0.0272	0.0055	6.7402	1.3585	1.5153	0.3054
10	16.0934	0.0121	0.0025	2.9925	0.6087	0.6727	0.1368
5	8.0467	0.0031	0.0005	0.7576	0.1201	0.1703	0.0270

Computational Fluid Dynamics (CFD) Results 45-MPH K-Epsilon



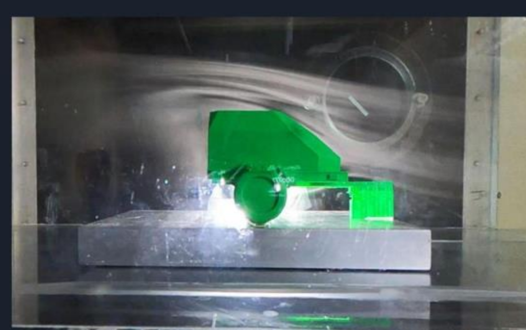
CFD Ansys Simulation (45-MPH K-Epsilon)



This video was made using Ansys 2020 R2

Wind Tunnel Results

- The wind tunnel testing was done using a 3D printed model of the MPMT at 1/12th scale.
- The testing gave us a better understanding of the aerodynamics in comparison to the CFD simulations.
- Various speeds were tested to match the simulations done in Ansys.
    - 15 MPH
    - 25 MPH
    - 35 MPH
    - 45 MPH
    - 50 MPH



Wind Tunnel Results

Testing

- Maneuverability Test
- Braking Test
- Stability Test
- Reaction Under Speed and Loading
- Pets Reaction Test

- Tongue Weight 8.3 lbs (Goal under 40 lbs)

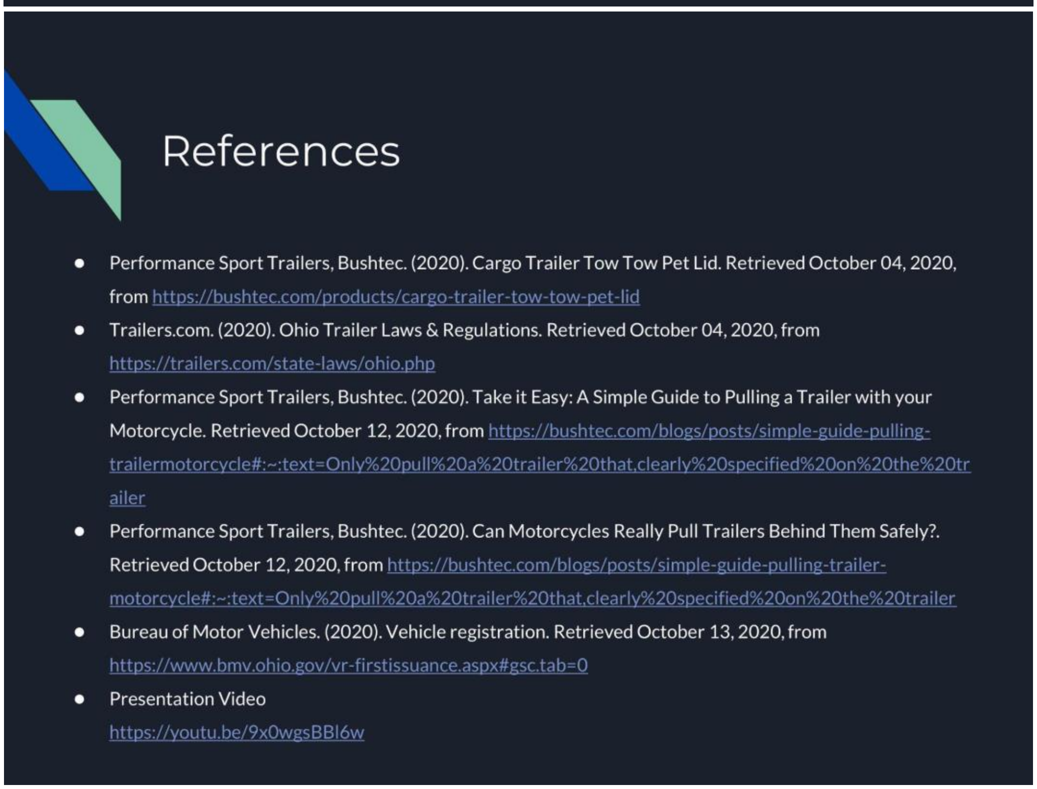
- Total Weight is 263 lbs (Goal under 402.5 lbs)

Testing

Pet training and reaction test

Outcomes of the Project

- A functional/safe design.
- The trailer is registered and safe for road use and follows Ohio's state laws.
- The finished product is safe to be used behind a motorcycle and other tow capable vehicles.

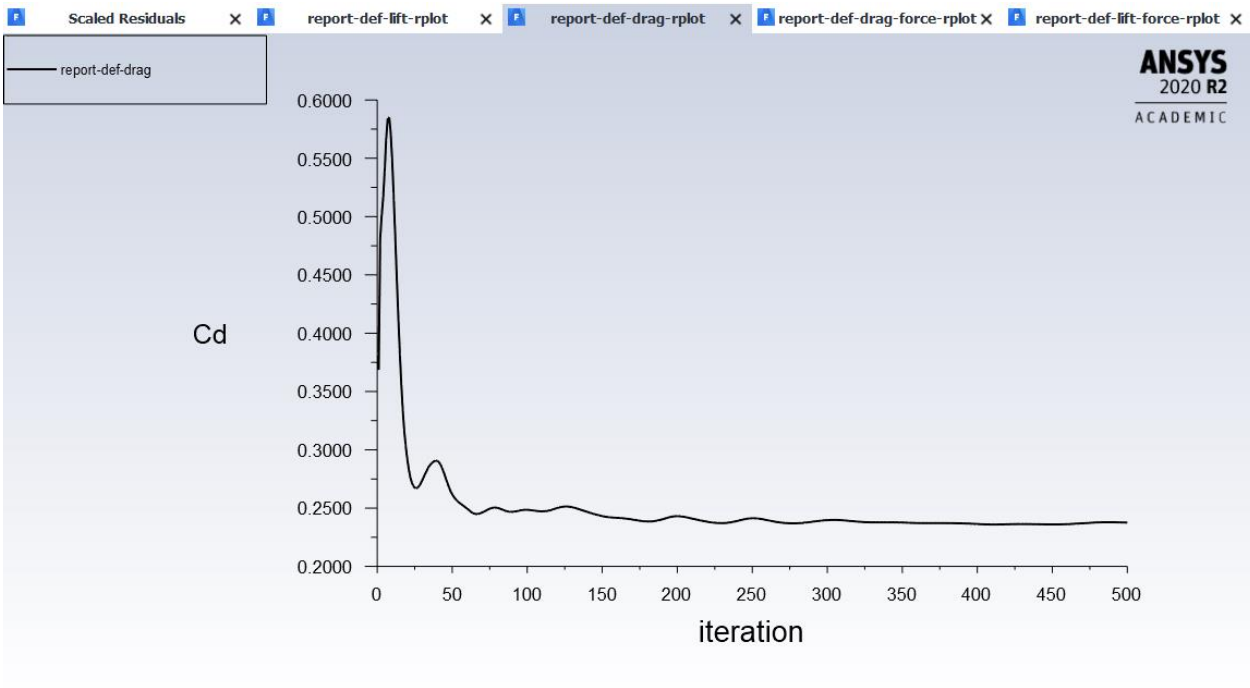


Presentation Video Link: https://youtu.be/9x0wgsBBl6w

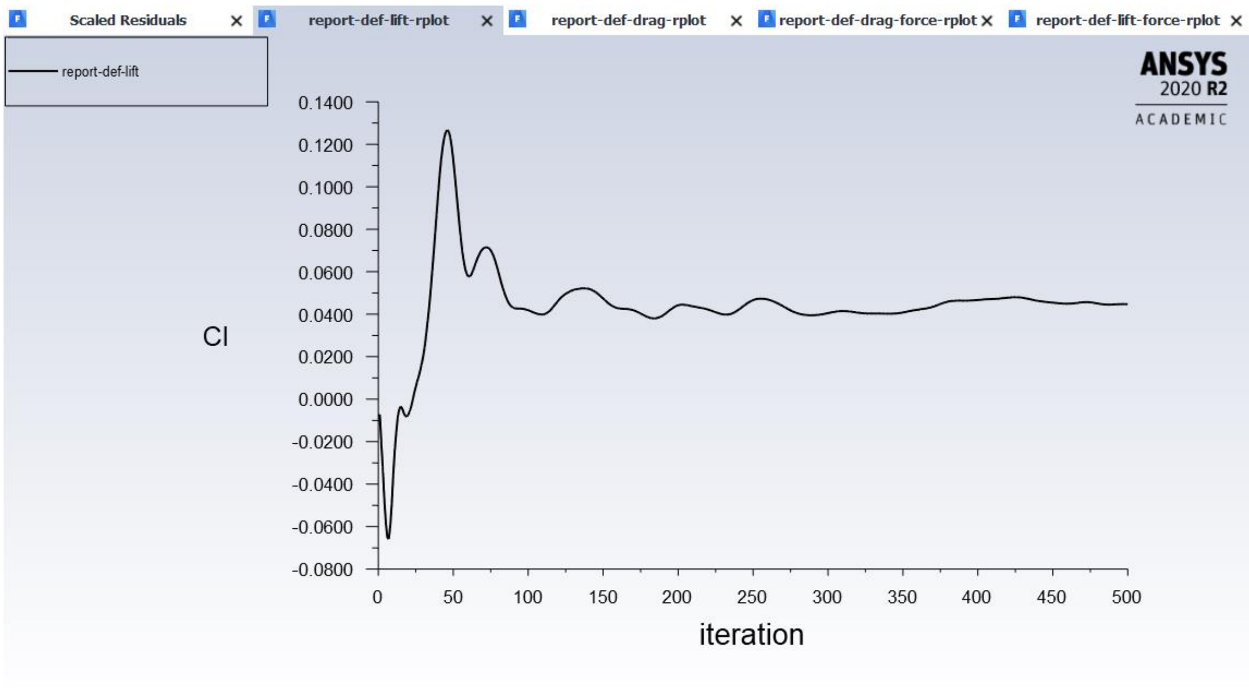
Appendix C: Additional CFD Images/Information

Additional information from the 45 MPH (K-Epsilon Model) from Ansys Fluent:

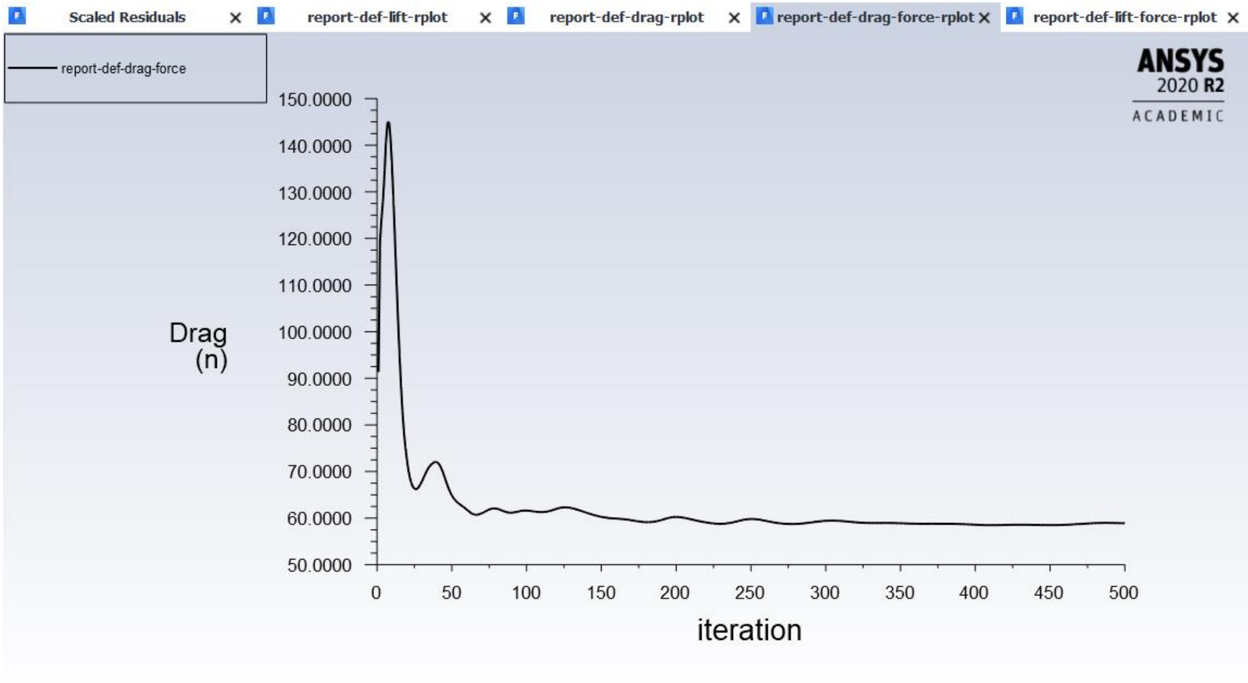
Drag Coefficient Plot



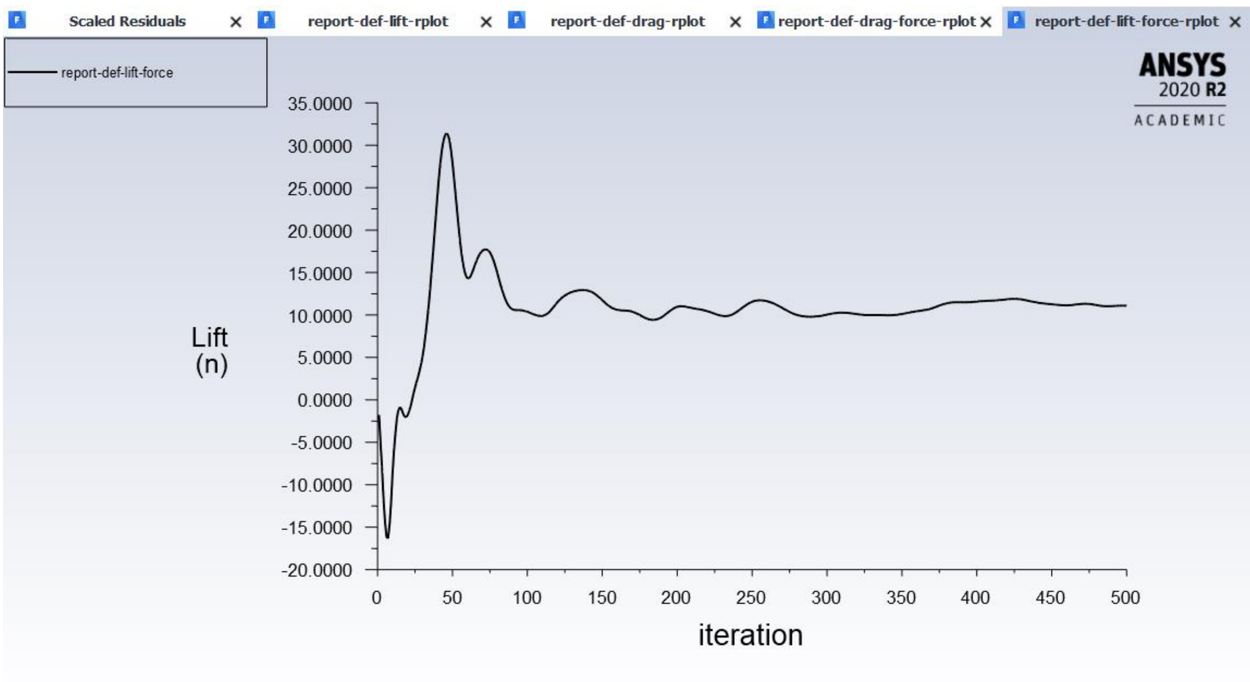
Lift Coefficient Plot



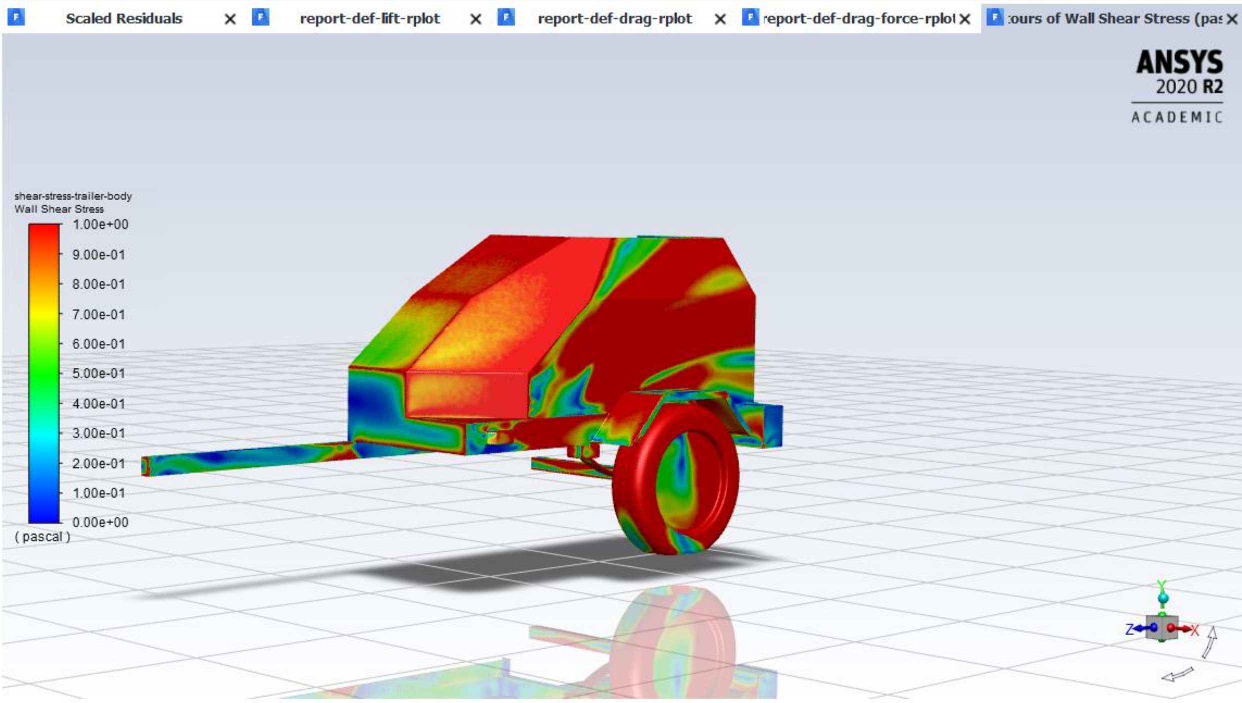
Drag Force Plot



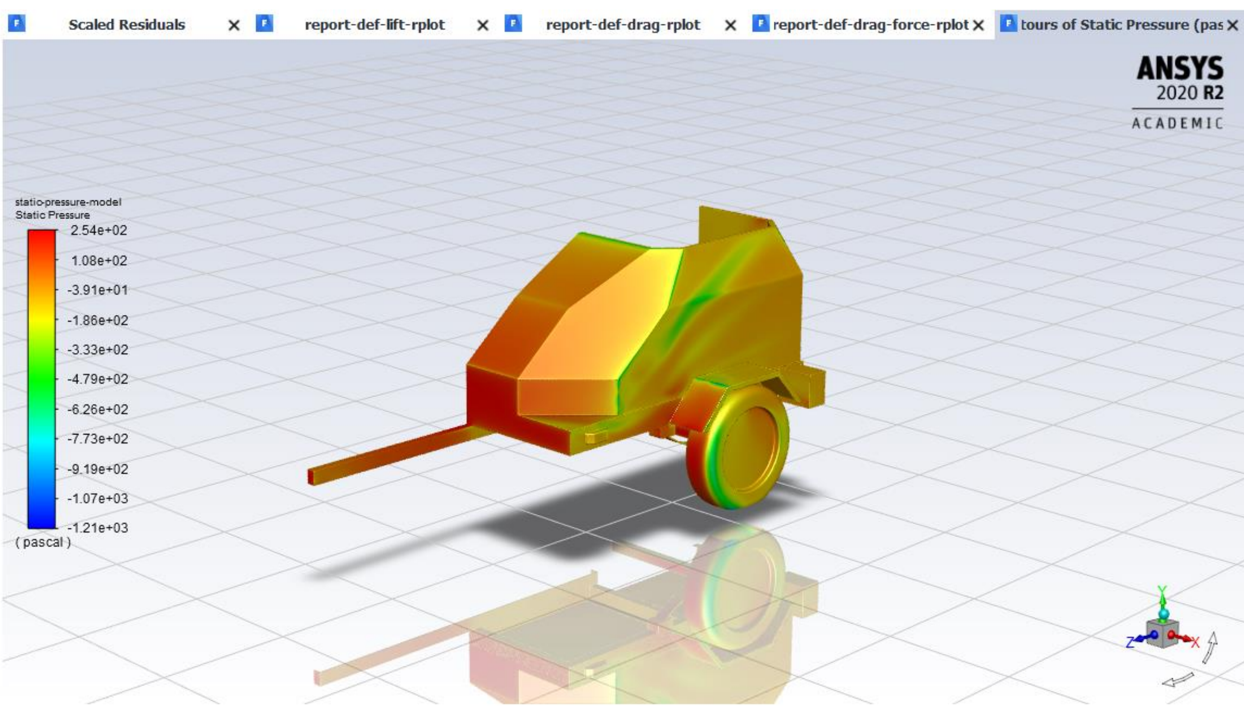
Lift Force Plot



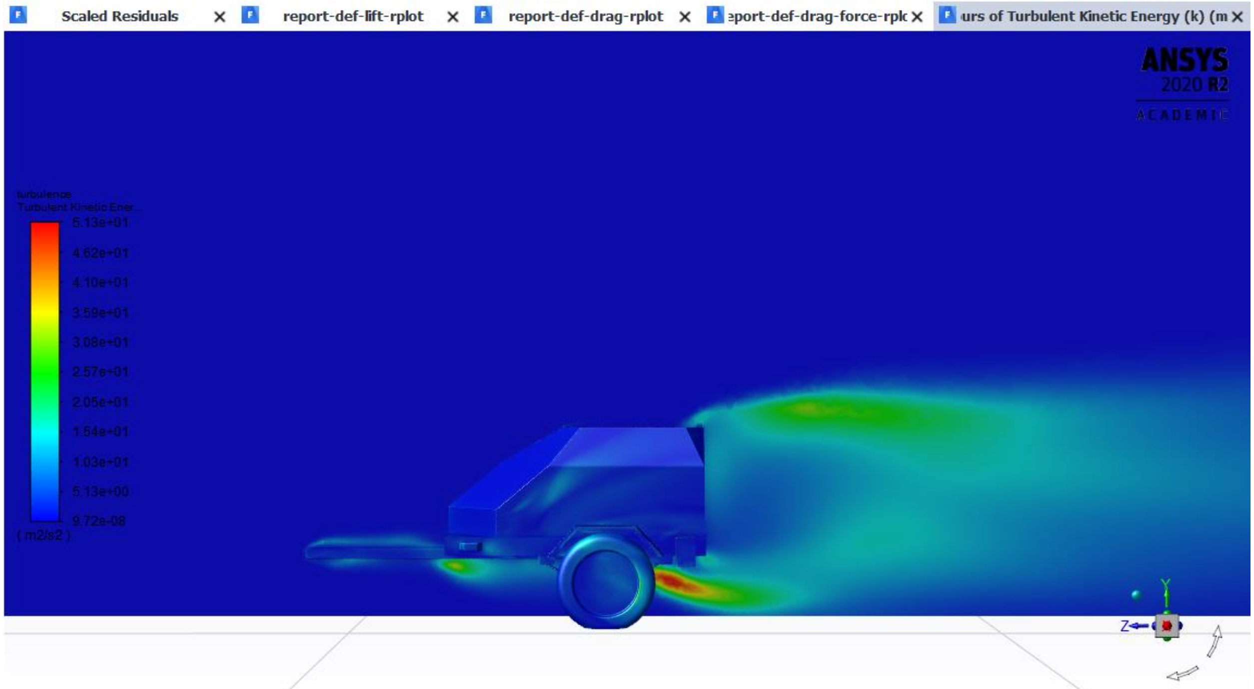
Shear Stress



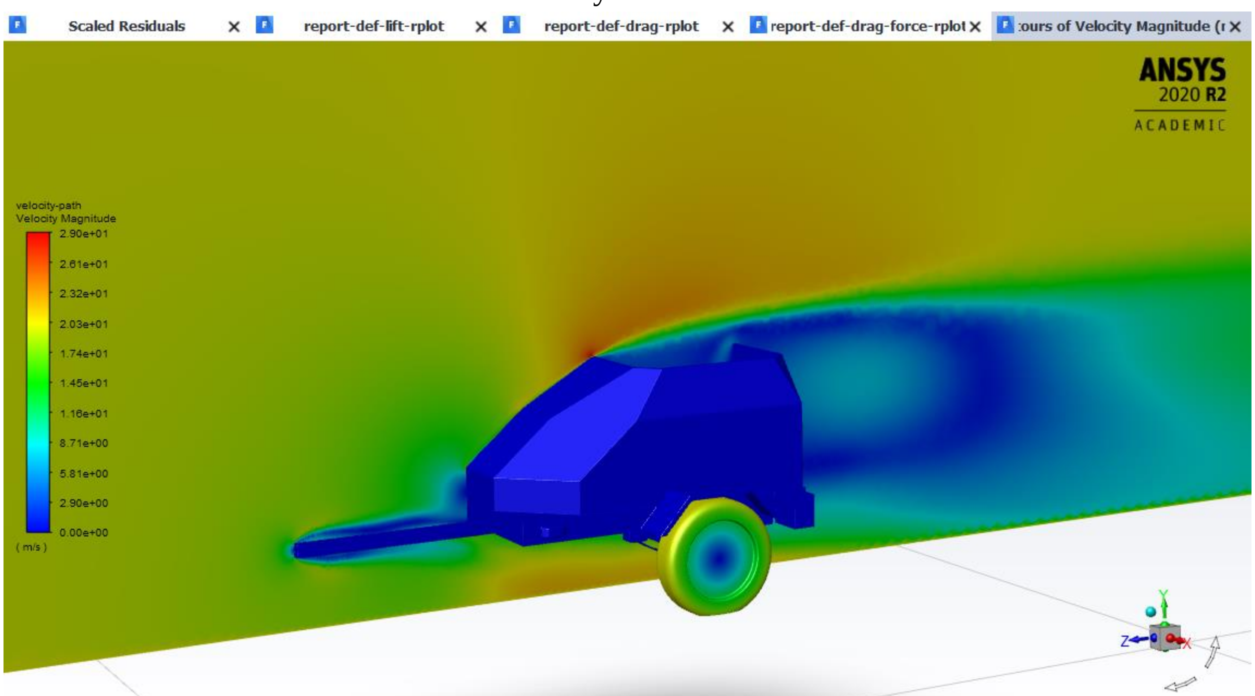
Static Pressure



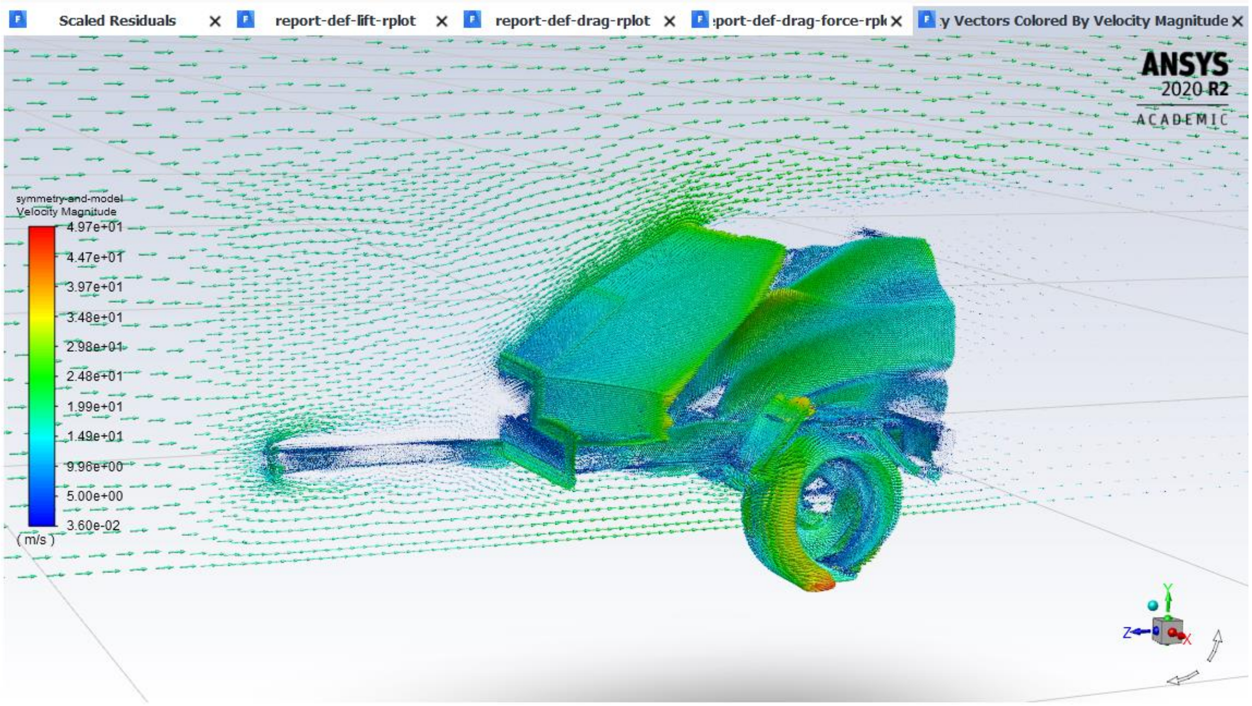
Turbulence



Velocity Streamline

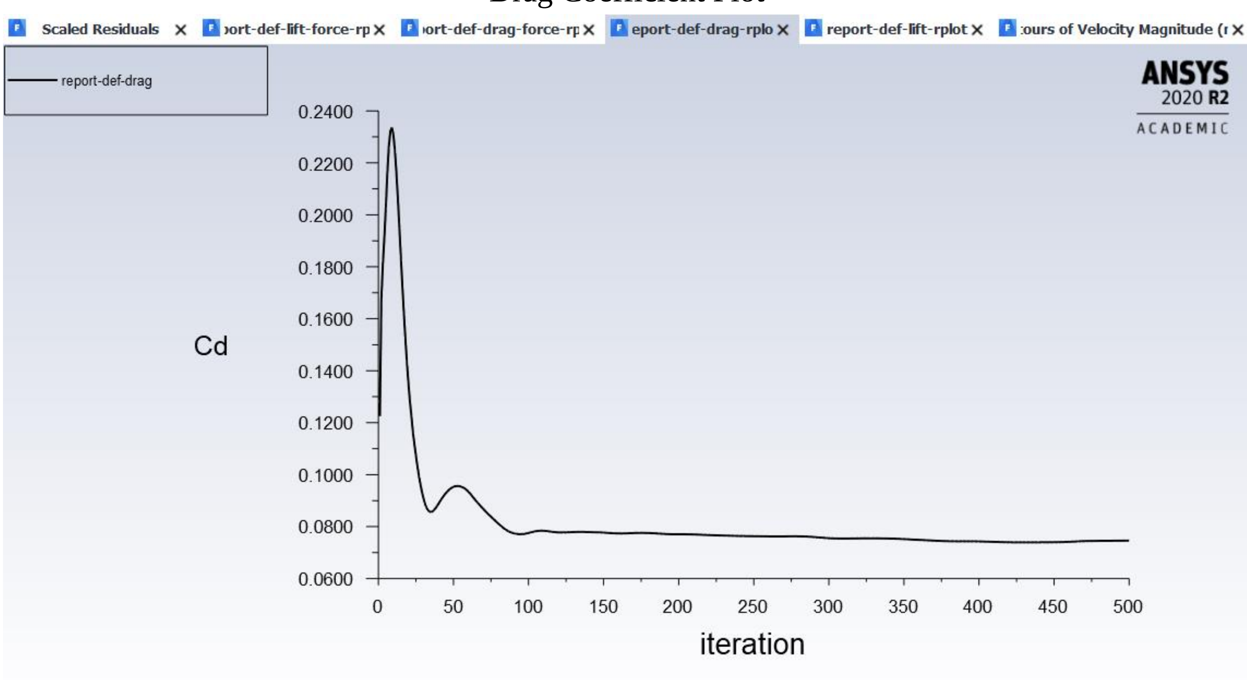


Velocity Vector Streamline

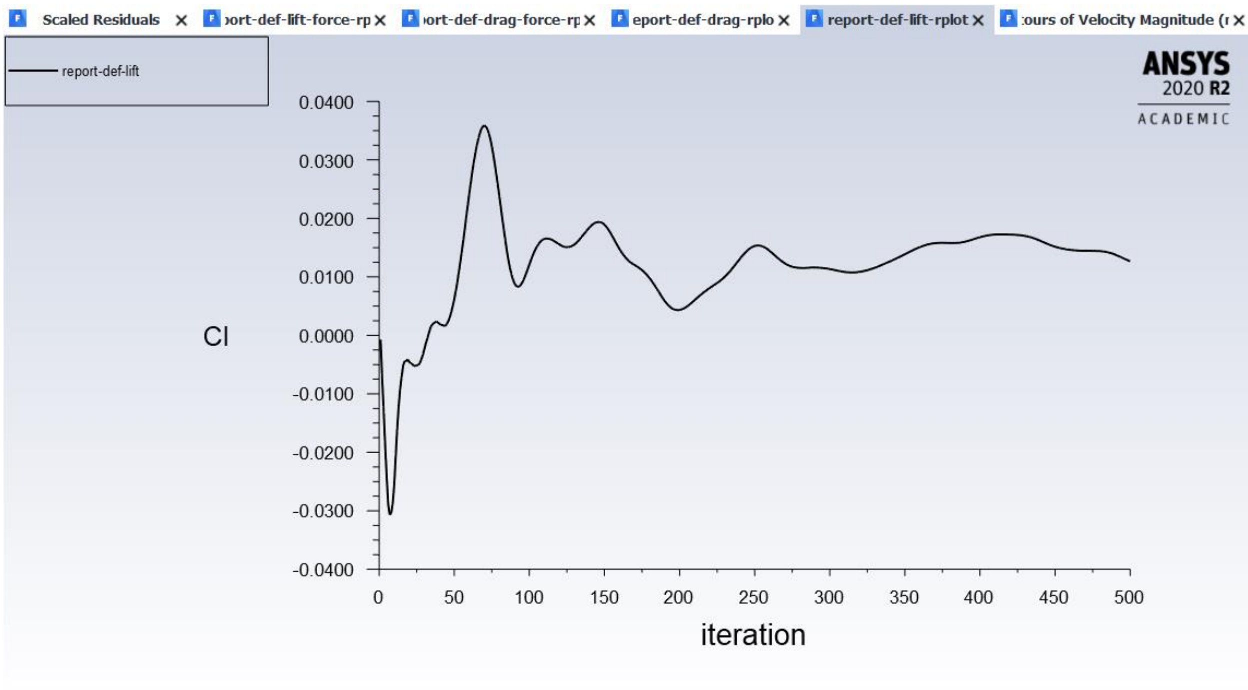


Additional information from the 25 MPH (K-Epsilon Model) from Ansys Fluent:

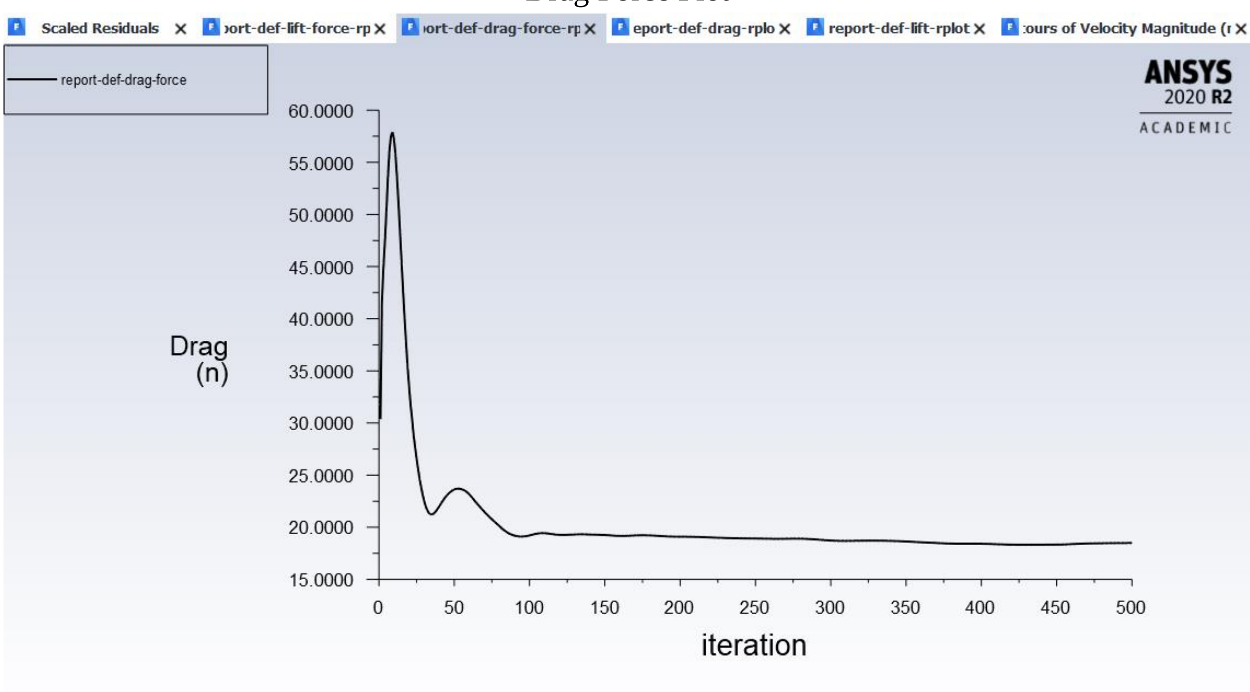
Drag Coefficient Plot



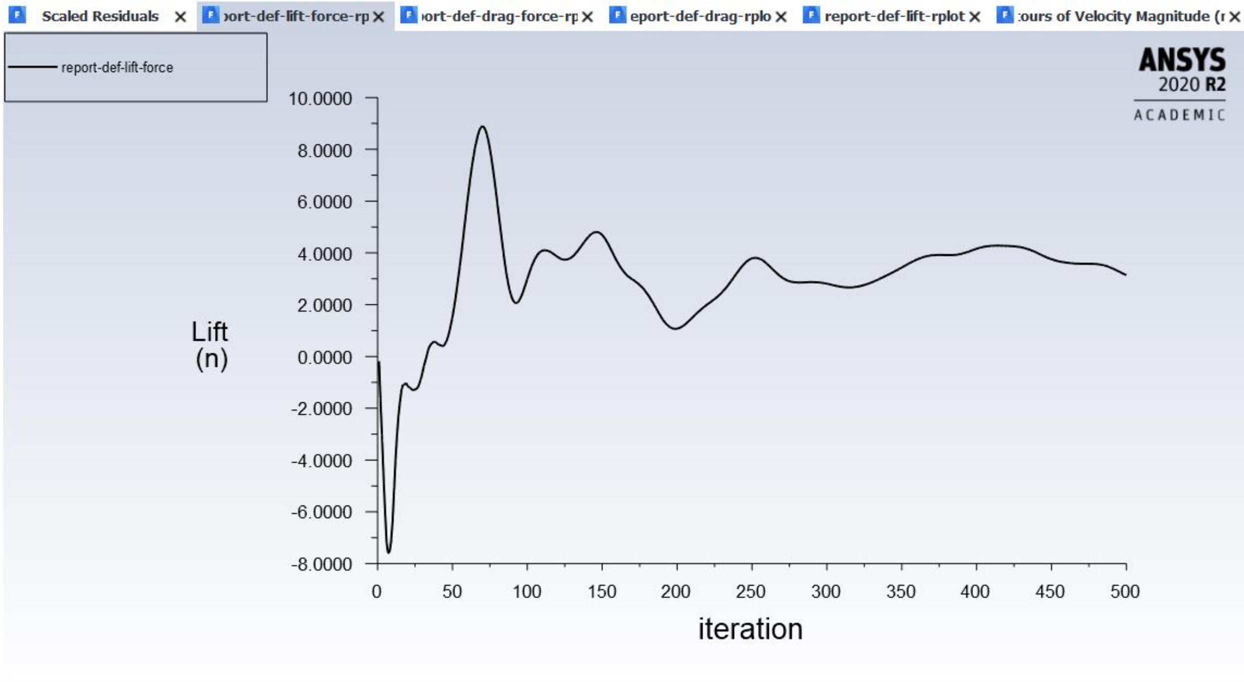
Lift Coefficient Plot



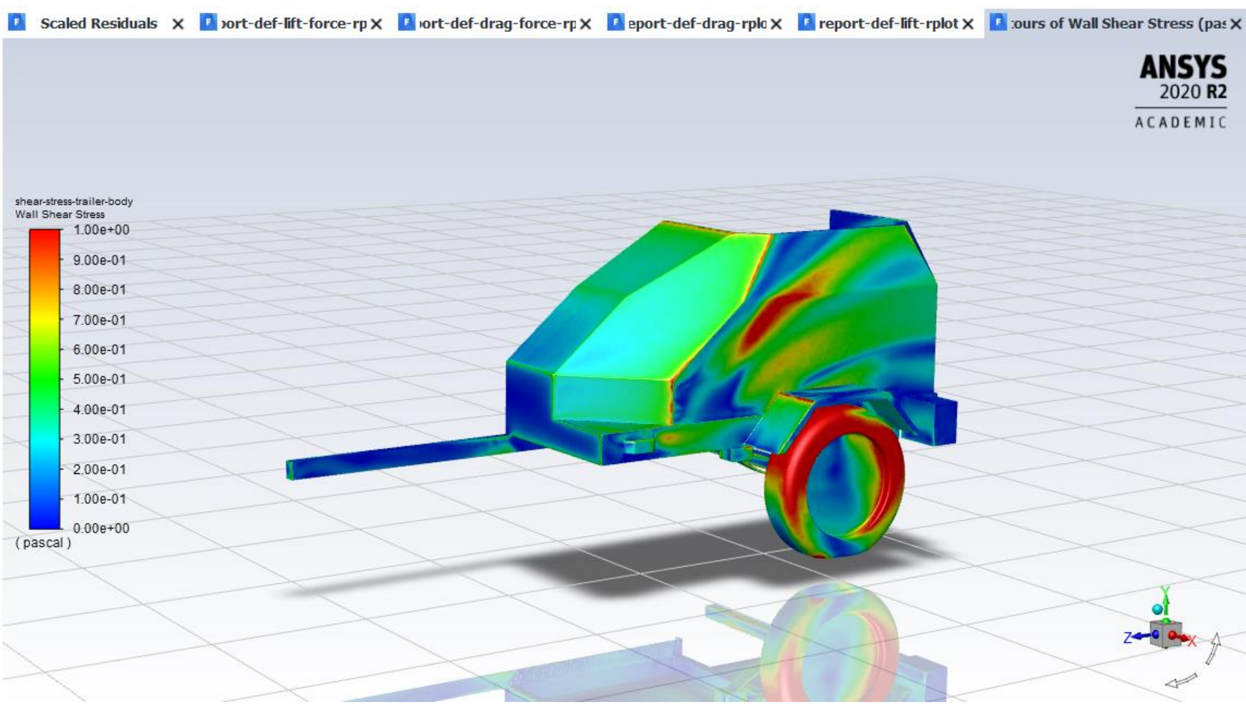
Drag Force Plot



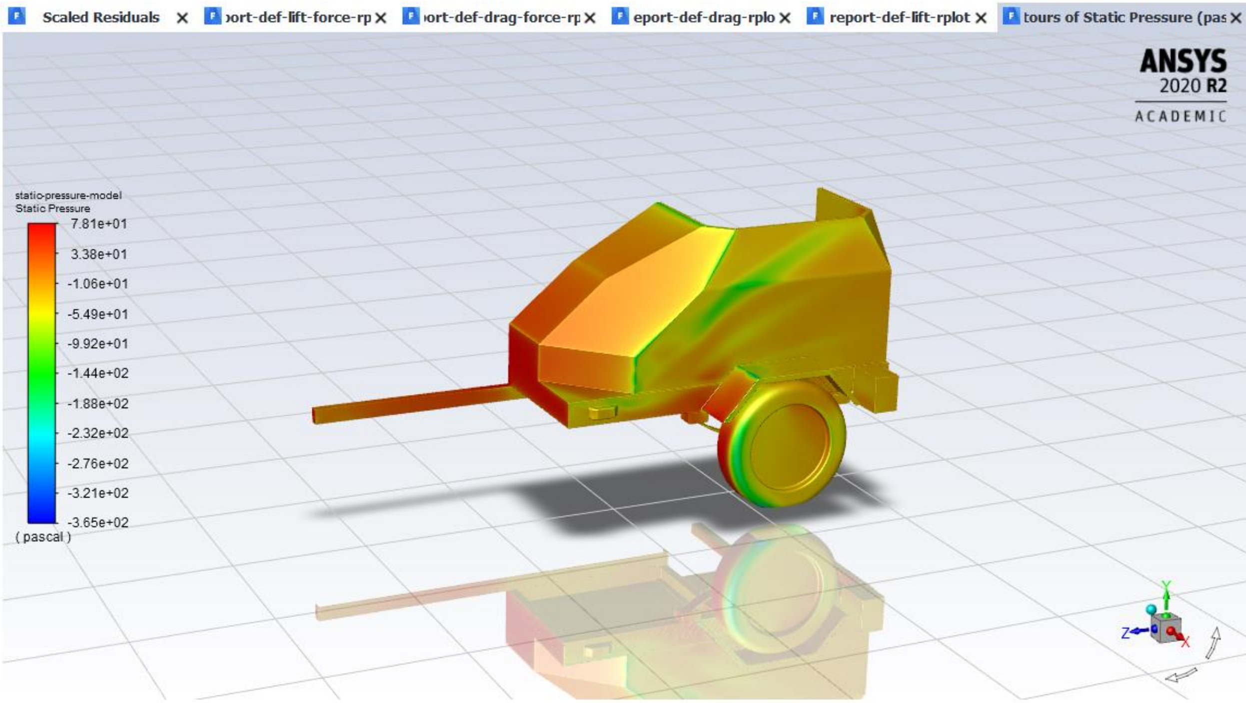
Lift Force Plot



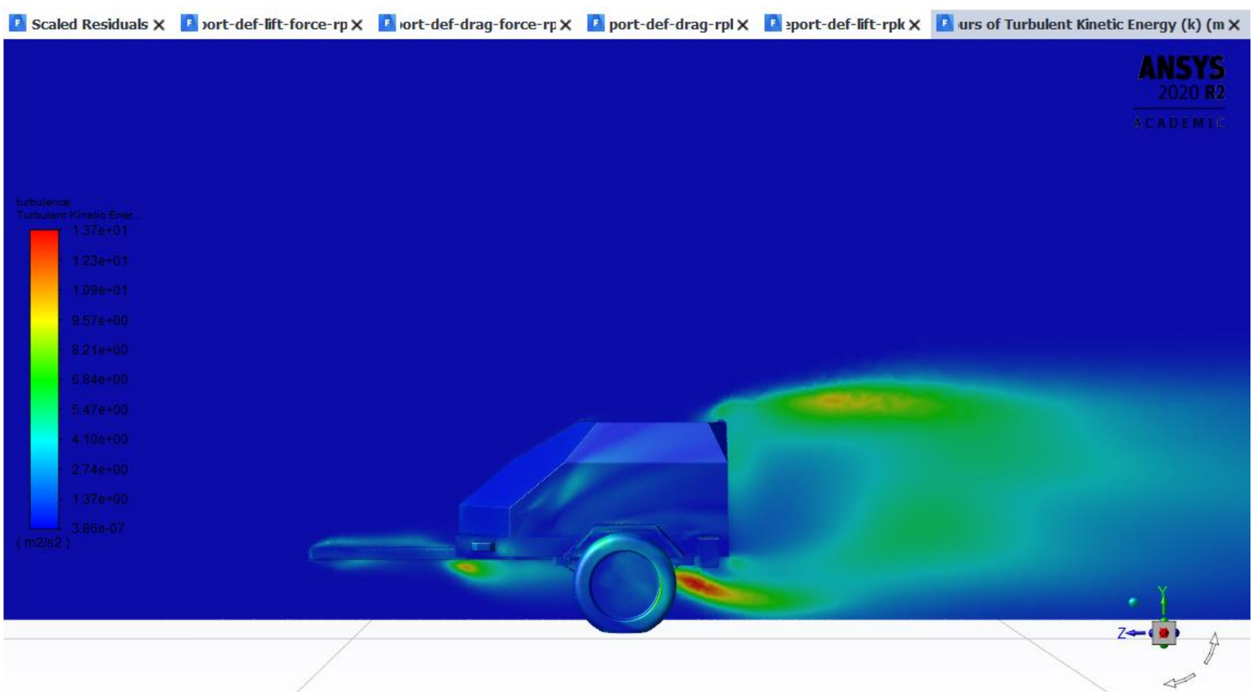
Shear Stress



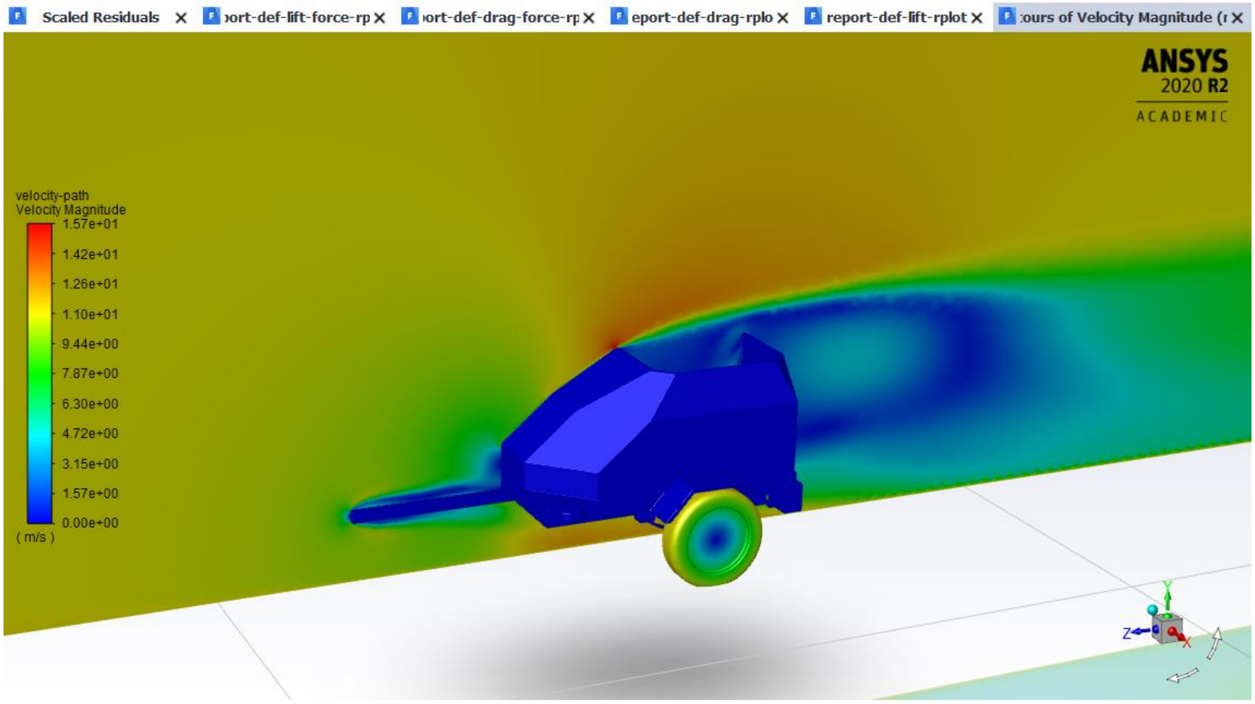
Static Pressure



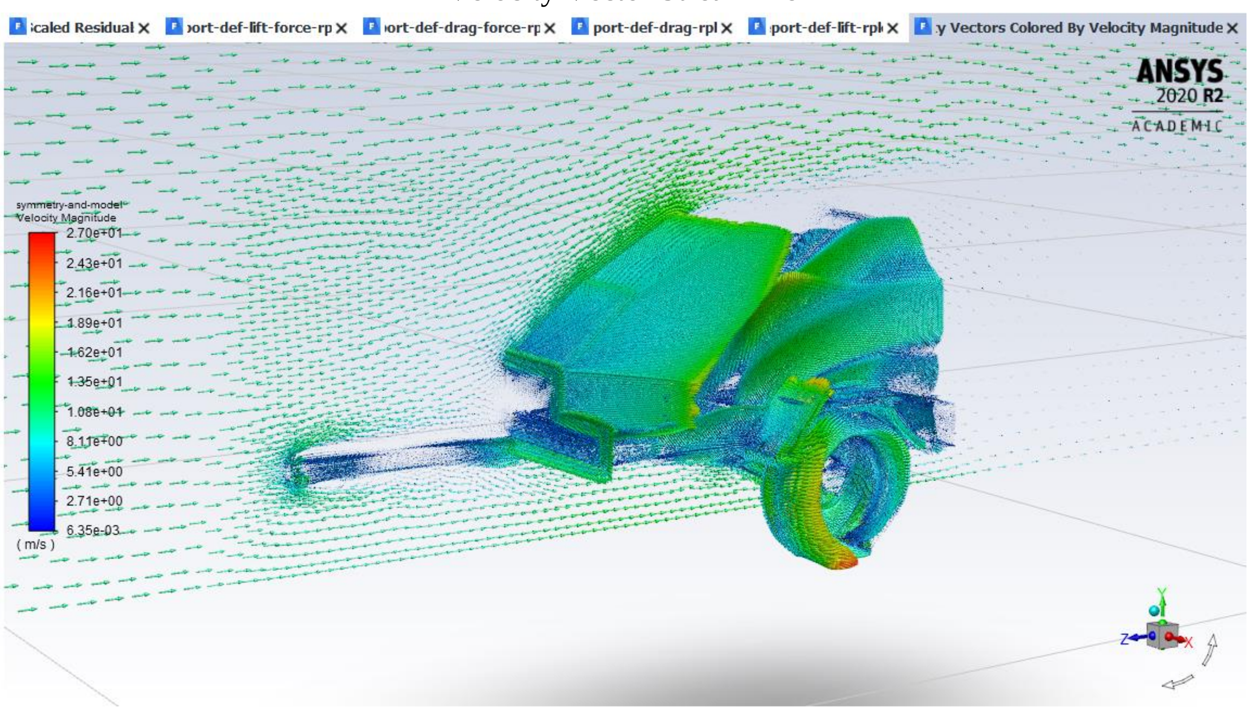
Turbulence



Velocity Streamline



Velocity Vector Streamline



Appendix D: Individual Reflective Essays

Logan Street

Professor Gary Drigel

ENT498 – Senior Design

10 May 2021

Individual Reflective Essay

Throughout ENT498 I have enjoyed the experience and personally feel that this course is one of the most important and rewarding courses that I have had the opportunity to attend and be involved with. Despite the fact that the normality of this course was greatly impacted by the Covid-19 pandemic and this resulted in the course structure to be drastically different then what it would normally be. In the start of senior design that was a concern that I had at the very beginning of the project. However, due to the fact that the team I was involved with was both dependable and active with communicating the concerns due to the pandemic were quickly subdued. When we started ENT498 we continued on with our original plan from ENT497, but we did have to adjust since we gained another team member at this stage in the project. This turned out to be excellent because it allowed us to carry out additional forms of analysis that we wanted to do but were not able to do within our original team of three members.

In terms of communication, I feel that myself as well as my team did a good job with communicating and working with each other. Whenever, an issue came about or if anyone had any questions or concerns we were able to address them quickly and professionally. We mainly communicated through weekly meetings as well as a cellphone group chat. During our weekly meetings we would discuss in detail any results, data, concerns, plans, and more. In my opinion I think that communication is one of the most important aspects of any project and for myself I believe that ENT498 helped me a lot with discussing and presenting any new information or research that I had collected. Moving on I would like to discuss the design process and general skills/knowledge that myself and my team utilized during this project.

For my team, our project was the Multi-Purpose Motorcycle Trailer (MPMT). This project was unique due to the fact that we were going to make something that is uncommon and not readily available. Due to this we had to overcome many challenges and obstacles one of which was that we needed to make sure that design followed Ohio’s laws and regulations. William Dao conducted research around the laws and regulations that we needed to follow and once he concluded his research we began designing in accordance with Ohio's laws. Within the design and development for the project my main contributions involve the following: design/drafting a trailer model in Autodesk Inventor, developing/maintaining the project schedule/Gantt chart, keeping the meeting journals up to date, performing finite element analysis simulations of the designs, performing computational fluid dynamic simulations, etc. I was not the only person to do some of these tasks, everyone drafted/designed using Autodesk Inventor and we made various components and designs for components. For example, Kyle Guggenheim drafted the panels for the project design in Autodesk Inventor using the sheet metal function and William Dao designed the tailgate/door in Autodesk Inventor as well.

In terms of the general skills/knowledge that I utilized in this course I found myself very grateful for the courses that I had taken in the past while at Miami University. In order to solve some of the various problems I encountered I applied the information that I learned from my past courses. Some of these courses are as follows: ENT316 Project Management, ENT235 Computer-Aided Design, ENT272 Strength of Materials, ENT355 Introduction to Finite Element Analysis, ENT301 Dynamics, and more. All of these courses and the knowledge that I gained from them helped me to solve and overcome the problems that myself and my team encountered. For example, I was responsible for the development/creation of our project Gantt chart and general timeline. In order to do this, I had to apply the knowledge that I gained from ENT316 and utilize Microsoft Projects to develop the Gantt chart. Moving on however I will next discuss some of the various things/skills that I learned on my own as well as my overall performance during this project.

Within this project I had to learn a lot on my own and because of that it only made the project more enjoyable as well as rewarding. For starters I was familiar with Ansys Fluent as well as Computational Fluid Dynamics (CFD), but I had never done a 3D flow simulation at the scale of what we wanted to do within our project. In order to overcome this, I spent a lot of time my time working within the Ansys software and also studying and researching various aspects of properly performing a 3D flow analysis in Ansys Fluent. I had previous experience with Ansys Fluent when I was involved in academic research that required me to use the software. However, for that research I was only using 2D flow analysis rather than 3D. I am glad that we decided to implement this form of analysis into our project because I enjoyed learning about it and also feel that it has allowed me to improve my analytical skills within Ansys. Also, during this project my team and I implemented and utilized new functions within Autodesk Inventor that we had not previously used before. This includes the frame design function as well as the sheet metal function. Having the opportunity to use these functions and simply learn about them was quite rewarding and a key factor within our project. Tony Hester utilized the frame design function and he drafted and designed the cage structure that we actually had fabricated and used for the project.

In terms of my performance in general throughout ENT498 I feel that I have done a good job and have been a helpful team member. I feel the same way towards my team members, and I feel that we have come to be an effective team. One aspect that I feel I have improved upon during ENT498 is my drafting as well as simulation skills. I was proficient in drafting as well as running analytical simulations, but I definitely felt that I still had room to improve and even now I still feel that I can continue to improve and develop these skills. However, this project has been a great learning experience for myself and has allowed me to apply these skills and to develop them further. One thing I have come to find out is that I really enjoy performing various forms of analysis and from this project it has inspired me to continue developing these skills.

In conclusion I am grateful for the opportunity to be involved in this project during ENT498 and I am proud of myself as well as my team members. I feel that our project was a success because we were able to utilize the skills that we have developed while attending Miami University and I hope that they continue to have students participate in senior design projects. Despite everything that is going on in the world I found the experience to be quite enjoyable and rewarding. As with anything you get what you make of it and I feel that myself and my team members put forth a lot of effort into this project and by doing so we have all grown as engineers. However, this is only the beginning as we continue into our professional careers I feel that as we reflect back on this project while taking on future projects we will be able to apply the same optimism and passion that we did within this project.

Tony Hester

Professor Gary Drigel

ENT498 – Senior Design

10 May 2021

MPMT Individual Reflective Essay

I have thoroughly enjoyed my time in ENT-497 and ENT-498. I have learned a great amount of what it takes to work as a team to achieve a goal from just a concept to a functioning product. There were times during the senior design when I did not know if we would have anything to show at the end of the school year. From insanely expensive quotes from welders to licensing issues that kept the trailer off the road or thinking we could not confirm our Computational Fluid Dynamics analysis results using the wind tunnel, we had our share of troubles. Despite all the obstacles that we had to face we were able to finish our senior year with a project we can say we were proud to work on.

One of the largest contributing factors to us being able to complete our senior design project was our ability to communicate with each other. Even though the whole world was essentially shut down due to Covid-19, as team members, we were able to maintain constant contact with one another. We would meet as a group at least two times a week using WebEx and would text message each other in a group text on almost a daily basis. Not only did we stay in constant contact with each other we also kept in contact with Gary Drigel and Dr. Dinc outside of the Thursday evening class times. On multiple occasions we would encounter problems such as a delay in receiving needed supplies that had been ordered. We were able to communicate with each other to set up a plan to keep the team on track despite these obstacles. One of the largest delays was receiving the Hitch. What I expected to be delivered shortly after it was ordered in December, wasn't delivered until February 23rd.

My group was able to work as a team throughout both semesters. Even though an additional member was added at the beginning of spring semester, it did not affect the group dynamic or have a negative impact on our performance. Because of the additional members, we were able to complete more than we originally thought we could have. With the addition of a new team member, we were able to take on the task of replacing the smoke machine on the wind tunnel in the engineering lab on the Middletown campus. In doing so, this allowed us to be able to verify our Computational Fluid Dynamics analysis. This also allowed all four of us to get experience operating the wind tunnel and we learned quite a bit about wind tunnels in the process. Another example of how effective our teamwork was the end result of the project. With none of the team members having any real experience in metalworking, with the four of us working together, we were able to wrap the trailer in 20 GA aluminum sheets without any known defects.

For our senior design project, we were able to pull from multiple different classes that we have taken as students at Miami. We spent a lot of time using Autodesk Inventor which was originally introduced to me in ENT-235. Using the knowledge gained from that class, we were able to use and figure out more features inside Autodesk Inventor that were not taught in class like the sheet metal feature and the frame design feature. We used Ansys software that was taught to us during ENT-355 to perform Finite Element Analysis, and with the help from Dr. Dinc, we were able to use Ansys Fluent to perform Computational Fluid Dynamics. There was also a lot that was used from Project Management, ENT-316, to complete the project.

I liked that unless they were asked, the professors gave us the freedom to design, assemble, and test our project as we saw fit. One thing that I was told while attending the police academy that applies to my time as a student entering the world of engineering, is just because we went through the training, that does not mean we know what it's like to be an engineer (I was told similar, but it was about being a police officer). We have gone through classes teaching us formulas and computer programs. We are told how to apply them, but that is it. During our senior design project, we had to choose what formulas to use, what programs to use, and determine if the direction we wanted to go in, would be supported by the math and science that we were taught.

One of the greatest lessons I think that I have learned from this senior design project is that not everyone is as enthusiastic as I am about the project I am doing. I do not mean that my group members were not enthusiastic, they were amazing. I am referring to vendors or contractors that I contacted to have work done or to have materials sourced. I was surprised at how difficult it was to get information that was required to make it possible for the contractor to get paid. Just to get a simple invoice to have the tax removed so that the Fleck grant could be used to pay for work took a week. I had to text message or email someone multiple times just to be able to give them money. Even having someone begin work on the trailer took longer than expected too. In early December I emailed a contractor the inventor file of what we wanted done. In the email I asked them to open the file to make sure they were able to access it, and if they could, I asked for them to email me letting me know that they needed a different file type submitted. After a month I contacted them asking how everything was going and was told that they were never able to open the file. I was then able to convert the files into the correct file type, but there was a month of progress that was postponed. I have learned that following up if you have not heard back is more of a necessity than originally thought.

Engineering is using science and math to solve problems. This project has given us the opportunity to prove that we can use the science and math we have learned in class to solve a problem in the real world. I have learned more throughout this experience than I have learned any other single class. I believe that having a senior design project will make the transition from student to engineer smoother than having not had a project to learn from.

William Dao

Professor Gary Drigel

ENT 498 – Senior Design Project

10 May 2021

Individual Reflective Essay

In all my years of schools, I have found Senior Design to be the most challenging but exciting experience of my entire education journey. Senior Design allowed students to use what they had learned throughout their school years and applied it into making a real product. Beside the skills and materials that students had learned in class, they also have to use skills and knowledge that they had developed outside from the classroom. Senior Design allows students to improve their people skills and prepares students to get ready for the real-world working environment.

In the beginning of Senior Design, I was very concerned about the lack of in-person learning and interaction. It is difficult for us engineering students to work and communicate with team members and professors in Senior Design projects. Thanks to Miami University, professors and the Mechanical Engineering Technology department made online learning work successfully during this Covid-19 pandemic time, especially for senior design. Also, thanks to Tony Hester and Logan Street and Kyle Guggenheim for being very well team players. As a group, we did a fantastic job with communicating during the project. We are constantly using emails, text messages, google docs, google sheets and WebEx as communication tools to work together on this senior project. We constantly use text messages to update any new information as well as short discussions before we can get together for a meeting.

Senior design allows us engineering students to apply what we have learned in previous classes into real working experiences. I realize that all classes that I have taken in the past were to be greatly helpful in senior design projects especially Computer-Aided Design, Mechanics, Strength of Materials, Project Management, Finite Element Analysis and more. For example, Project Management was a very helpful course for this senior design project as we need to make a Gantt chart to make sure we can stay on track with the project as well as manage the whole project properly. Computer-Aided Design and Finite Element Analysis are extremely important to this project as we need to design the trailer and perform FEA and CFD analysis.

Our senior design project was a product that is not commonly done which will have a lot of challenges that we had to overcome. In the beginning, we have to do lots of research about the laws and requirements that are associated with the project. Then each team member tries to come up with design ideas and we would compare them to see which one will be the best. We end up using Tony's design because of how aerodynamic and the trailer having an esthetic look. I think the hard part of this project is to stay under or within our budget. Our first model of the trailer frame was overly designed because we want it to be strong. The original plan was outsourcing the trailer frame and panels assembly. However, after reviewing the cost of the materials and labors, we were way over the budget. We then have to simplify our design, as well as installing the metal panels ourselves to stay under budget.

Everyone was very good about staying on top of the project, making sure that every problem can be solved within the time limit. However, there are a few problems that we unexpectedly ran into that were beyond our control such as the delay in shipment of the motorcycle hitch, and the trailer licensing with the University which led to the trailer cannot be tested on the road. At the second semester of Senior Design, an additional team member was introduced to our group, and we did have a little bit of scope creep. We were required to add more works into our Senior Design project such as printing a 3D model and have it tested in the wind tunnels. We had to spend a lot of time modifying/fixing the wind tunnels so it could give us the best results of the test. At the beginning, we were concerned about not being able to have everything finished by the end of the semester. However, we were working very hard to fit everything in schedule and manage to finish the project in time. We were all glad that an additional team member was introduced because that would allow us to add more testing to our design that we were not able to fit in our schedule.

Senior design has given me the opportunity to improve my ability to work as a team. Beside applying what we have learned in the past, we have learned a lot during the Senior Design process. I have majorly improved in researching as well as designing. We all learned new features in Autodesk Inventor, for example, the frame design and sheet metal design were something that we found, and we have not learned about it in class. We all improved our people skills and learned how to stay well communicated as a team, as well as budgeting and time management. Senior design helped us learn how to solve a problem quickly and efficiently. We also have to use skills and knowledge that we had developed outside from the classroom such as metal working, installing motorcycle parts, fixing the wind tunnel, ordering materials, working with vendors/manufactures to outsource certain jobs that required specific skills and tools that we were not able to access.

In conclusion, Senior Design is a very exciting and well-planned project for us engineering students, to apply what we have learned to a real-world project. This project allows us to review and refresh our education as well as learning more new materials and developing new skills that are going to help us in the future. Senior Design also allows us to improve our people skills and the ability to work as a team, as well as be more responsible with our work. Overall, I hope that the Senior Design program will continue to improve and provide engineering students the best experiences as well as prepare them to get ready for the real-world environments.

Kyle Guggenheim

Professor Gary Drigel

ENT 498 – Senior Design

10 May 2021

Individual Reflective Essay

This last semester at Miami has truly been an experience. Starting ENT 498 with a new group was a huge change in pace. This meant completely learning and becoming familiar with a totally new project than what I had been working on during the previous semester in ENT 497. I was very excited to start working with Logan, Tony, and William and I am grateful that they were able to accept me into their project with ease. They made working in a group easy in large part because of how active they were in communicating with each other. I think we all shared a similar opinion in that we all believed communication was the most important thing in getting this project not only completed but completed with a high level of detail.

My group utilized various different methods for communicating throughout the project. One of the main reason's communication was so import for this project was that the COVID-19 pandemic was still in effect. This meant that face-to-face meetings were minimized to only occur when absolutely necessary like when we had to physically build the trailer and the cage for the trailer. Most of our communication occurred during video conferences through WebEx which occurred at least once a week but sometimes two to three times a week. These video calls are where we did a vast majority of our project planning and coordinating. We would also use that time to get into more detail about our data and results we had. Another form of communication that we utilized was texting through a group chat on our cell phones. This method allowed us to formulate plans quickly and easily for meeting times or just to quickly give each other minor updates on our individual tasks we assign to each other.

Everyone in my group for this Senior Design Project was capable of working together in a group setting. My team made use of a shared Google Drive because it is a cloud storage service that allowed us to easily keep all of our project files in a common location. This also allowed us to work on complex tasks simultaneously so that no project time was left unused. Throughout the second half of this project most of my responsibilities leading the wind tunnel testing, creating an as-built 3D model using Autodesk Inventor. Some other tasks I worked on in coordination with my team were taking pictures during the process of building the cage for the trailer, filming the motorcycle testing, and editing videos that were going to be used in our presentation.

Working on this Senior Design Project required the use of a variety of skills and knowledge bases. A lot of the problems I faced were problems that are addressed in most of the engineering classes I took throughout my time at Miami University. Some of the classes that had a direct link to this project are ENT 235 Computer Aided Design, ENT 355 Introduction to Finite Element Analysis, ENT 316 Project Management, ENT 301 Dynamics, and ENT 272 Strength of Materials. These courses gave me the tools I needed to be able to be able to tackle the problems and tasks that were put in front of me throughout this project.

As far as skills go, I still had to learn a variety of new things in order to complete some tasks. One of the best examples I can give has to do with working with metal. Working with metal is something I have never personally experienced myself. Thankfully, my team members had all worked with metal before. They were able to teach me and guide me through the process of working with aluminum sheet metal while putting together the cage for the trailer. Our teams' ability to not only teach each other but to also learn from each other gave us the ability to work simultaneously so that we could maximize our workload as efficiently and effectively as possible.

Joining this senior design group halfway through the project timeline meant that myself and my teammates had to get over some hurdles that other groups did not. As for myself I think I was able to quickly adjust to the way this group was working, and I was able to learn the project in a relatively quick manner. I think my proficiency in working with Autodesk Inventor came to great use for documenting the trailer and cage that was build and being able to adjust the original 3D model to represent more closely what we had in the real world. I was also able to contribute a variety of images and videos that were used for the project's presentation and report.

Overall, I am very happy with my opportunity to be a part of this Senior Design Project. I feel very lucky to have been able to work with such fine and well-rounded fellow student engineers as well as some very experienced advisors like Gary Drigel and Dr. Murat Dinc. The enthusiasm my teammates had for this project is something I rarely see in school projects and it made for an enjoyable and rewarding project experience. Because of this I think our project ended up being a great success and I am very excited to see what the future will bring us as engineers.

Appendix E: Team Meeting Journals

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 08/22/2020
Meeting Location: Webex Meeting

Topics Discussed

This meeting was about discussing and talking about ideas for our project.

One idea that we discussed in detail was designing a multi-purpose trailer for a motorcycle

We are thinking about going with this project however we need to discuss it with our advisor

Responsibilities/ Actions Taken

No immediate actions were taken at this time.

Continue brain storming and thinking of projects and design conflicts that may occur

Next Meeting Date: 08/27/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 08/27/2020
Meeting Location: Webex Meeting

Topics Discussed

We discussed our idea and components that we would like to purchase and build off of.

We also asked for feedback, both from the class and our advisor about our project.

We wanted to see if what we were thinking for our project was acceptable as well some plans and steps that we plan to do for the design process

Responsibilities/ Actions Taken

During our next meeting we are planning on starting our project proposal and discussing more components of the project in more detail. We are also going to start looking at the cost of building materials and various options.

Logan is going to setup the meeting for this upcoming Sunday 8/30/2020

Next Meeting Date: 08/30/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 08/30/2020
Meeting Location: Webex Meeting

Topics Discussed

We discussed various frame ideas and our goals for the upcoming week

We also discussed the types of metals for the structure of the frame and looked at the cost of the materials if we were going to build with them.

Responsibilities/ Actions Taken

Chose to use 1" x 1" box tubing for the framing

Everyone is going to draw and render their own frame in autodesk inventor and present it during our next weeks meeting

Continue working on the project proposal

Aquire microsoft projects and update autodesk inventor

Next Meeting Date: 09/03/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

MIAMI UNIVERSITY

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 09/03/2020
Meeting Location: Webex Meeting

Topics Discussed

We gave an update on our groups project/progress and stated the name of our project.

Currently we are still drafting our own cage designs and plan to discuss these drafts on Sunday 9/6/20

Responsibilities/ Actions Taken

Continue drafting our individual design ideas

Get microsoft projects

Continue working on the project proposal

Next Meeting Date: 09/06/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 09/06/2020
Meeting Location: Webex Meeting

Topics Discussed

Discussed frame ideas and potential concerns that may occur in the design

Current concerns are in the size of the trailer that we are considering to modify.

We currently believe that are previous frame option would not work for the project.

We have found a potential replacement idea however we are not certain if it would work for what we are trying to accomplish

Responsibilities/ Actions Taken

Continue working on the project proposal

Get microsoft projects and start drafting a gantt chart for the project

Try and use the frame design function within autodesk inventor to draft frame ideas

Next Meeting Date: 09/10/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 09/13/2020
Meeting Location: Webex Meeting

Topics Discussed

Update on quote and trailer information and its status (still waiting to hear back)

Proposal progress and topics on needed research as well as current standing and plan for the upcoming week

Cage ideas and potential changes and recommendations

Responsibilities/ Actions Taken

William is going to continue doing research and gather more information

Logan is going to start on the Gantt chart in microsoft projects

Tony is going to continue drafting up frame ideas and start learning the sheet metal function in inventor. He is also going to compare trailer heights in regard to the hitch placement on the motorcycle

Everyone is going to continue working on the proposal

Next Meeting Date: 09/17/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student:	**[ ]**

Meeting Date: 09/17/2020
Meeting Location: Webex Meeting

Topics Discussed

Frame design progress within autodesk inventor

The draft of the gantt and the current estimated timeline

Our overall progress within the project and current/upcoming plans and goals

Responsibilities/ Actions Taken

Continue working on the project proposal

Review the gantt chart (Document proposed changes/make changes in another copy)

Continue research around standards

Continue the frame development and design

Next Meeting Date: 09/20/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 09/20/2020
Meeting Location: Webex Meeting

Topics Discussed

We discussed the current 3D model progress and testing within inventor (Still having issues)

Discussed research that has been collected so far and reviewed some links to helpful resources and information

Responsibilities/ Actions Taken

Continue working on the project proposal and the 3D models

Create a table for the cost estimates and add it into the project proposal (Tony)

Continue working on the gantt chart (Logan)

Continue resarch on materials and ponder potential issues (William)

Continue working on the project proposal (Everyone)

Next Meeting Date: 09/24/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 09/24/2020
Meeting Location: Webex Meeting

Topics Discussed

Current standing of the project and goals for the next weekend

Gantt chart progress

Current research and project proposal progress

Concerns and current update about everyones current emotions around the project

Responsibilities/ Actions Taken

Continue research and development for the project

Continue working on the cost estimates and finalization of the costs for the project

Continue working on and finishing the project proposal

Send out the gantt chart to be reviewed by Drigel

Next Meeting Date: 09/27/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[No]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 09/27/2020
Meeting Location: Webex Meeting

Topics Discussed

Gantt Chart final version

Current cost estimates and project options/decisions

Project proposal progress

Frame design progress within Autodesk Inventor

Responsibilities/ Actions Taken

Continue working on the cost estimates and finalize the options for the project

Continue working on the project proposal and prepare it to be reviewed

Continue working on the frame design

Next Meeting Date: 10/01/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 10/01/2020
Meeting Location: Webex Meeting

Topics Discussed

Discussed trailer options and discussed the different manufacturing possibilities and the ability to outsource assemble work such as welding.

Discussed current proposal progress and looked at some of the frame design

Discussed the current cost estimates for the project and some new ideas

Discussed padding options for the inside of the trailer for comfort for the dogs

Responsibilities/ Actions Taken

Everyone is going to continue working on the project proposal

Finalize the rough version of the cost estimate for the project

Goal is to have the project proposal ready to be reiviewed sometime next week

Next Meeting Date: 10/04/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 10/04/2020
Meeting Location: Webex Meeting

Topics Discussed

Project Proposal and cost analysis were discussed in extensive detail

We also discussed current design ideas and solutions that we felt could improve the design

Current research and various topics/design information

Changed project title from Variable Motorcycle Trailer to Multipurpose Motorcycle Trailer
MPMT-1 (Multipurpose Motorcycle Trailer)

Responsibilities/ Actions Taken

Tony is going to continue on working on getting quotes for outsourcing welding he is also going to continue working on the cost analysis in case he gets this information back in time

William and Logan are going to continue refining and finalizing the project proposal and prepare it for submission on 10/15/2020

We are also going to send out are current draft of the project proposal to Drigel to be reviewed

Next Meeting Date: 10/08/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 10/08/2020
Meeting Location: Webex Meeting

Topics Discussed

Discussed different frame designs that we plan to perform testing on the designs

Discussed possible door and material options for the trailer/ideas

Discussed general ideas and concerns

Responsibilities/ Actions Taken

Begin drafting and remodeling of two different designs and prepare them for stress analysis (Logan and Tony are going to begin drafting the designs)

Research and look into the different types of paneling, hinges, and hydraulics for the trailer and door assembly (William)

Next Meeting Date: 10/11/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 10/11/2020
Meeting Location: Webex Meeting

Topics Discussed

Project proposal and revisions/added information

Current 3D models and sketches as well as cost information for the cost analysis (Materials and Welding)

Responsibilities/ Actions Taken

William sent another copy of our revised project proposal to Gary Drigel to be reviewed

William is going to continue performing research into the latches and hinges for the trailer to make a door for the animals

Tony and Logan are going to perform research into using Autodesk inventors frame analysis as well as the weldement functions to better improve the cage designs for testing.

Next Meeting Date: 10/15/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 10/15/2020
Meeting Location: Webex Meeting

Topics Discussed

Project proposal and current design plans and options

Current project progress

Trailer components design options and motorcycles wiring diagrams

Responsibilities/ Actions Taken

Continue working on research and design modeling

Continue on the project and reach out to more contacts and welders

Look into CFD options within Ansys for drag analysis and testing

Next Meeting Date: 10/22/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 10/22/2020
Meeting Location: Webex Meeting

Topics Discussed

Discussed current progress on the project

Discussed the trailer quote and which trailer design option we want to go with

Discussed the trailer design progress and the idea of adding in a door assembly

Discussed the material options and costs as well as motorcycle wiring harness

Responsibilities/ Actions Taken

Continue and get another quote for the cage welding including paneling

Reach out to Dr. Murat Dinc for help with the CFD analysis

Continue the frame analysis and testing for the design

Develop/design the mounting for the cage assembly to the trailer.

Decided on the trailer design we want to go with.

Next Meeting Date: 10/25/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 10/25/2020
Meeting Location: Webex Meeting

Topics Discussed

Discussed current progress on the project

Discussed trailer design concerns

Discussed the trailer door assembly

Discussued current quote progress

Responsibilities/ Actions Taken

Continue and get another quote for the cage welding including paneling

Continue the frame analysis and testing for the design

Develop/design the mounting for the cage assembly to the trailer.

Continue research for the door design

Next Meeting Date: 10/29/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

MIAMI UNIVERSITY

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 10/29/2020
Meeting Location: Webex Meeting

Topics Discussed

Gave an update on our current project progress

Discussed the current design and quote progress and needed research

Worked on the cost analysis for the grant/scholarship

Worked on refining the proposal for submission for the grant

Discussed upcoming group assignment

Responsibilities/ Actions Taken

Continue working on the project proposal for the grant

Start working on the upcoming group assignment

Perform more research and contnue working on the project

Next Meeting Date: 11/01/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student:	**[ ]**

Meeting Date: 11/01/2020
Meeting Location: Webex Meeting

Topics Discussed

We discussed the upcoming group assignment and selected our case

We discussed the current proposal grant progress and editted the document to properly show the intended project

Responsibilities/ Actions Taken

Continue working on refining the grant proposal

Finish/continue working on the ethics assignment

Continue working on the project

Next Meeting Date: 11/03/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student:	**[ ]**

Meeting Date: 11/03/2020
Meeting Location: Webex Meeting

Topics Discussed

Discussed and completed the ethics assignment

Discussed and refined the proposal grant document and cost information

Responsibilities/ Actions Taken

Tony is going to turn in the proposal grant to Drigel once the quote information is finalized

Continue working on the project as well as the individual assignment within the ethics assignment

Next Meeting Date: 11/04/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 11/08/2020
Meeting Location: Webex Meeting

Topics Discussed

Current project progress in regard to project timeline

Current needs and goals for the project and what needs to be done

Discussed ansys software and FEA trials that need to be done.

Optimal element size for meshing in ansys = 0.25

Responsibilities/ Actions Taken

Downloaded ansys discovery and ansys student 2020 R2

Logan is going to try and peroform FEA analysis within ansys

Logan is also going to experiment and test ansys discovery for CFD analysis

Tony is going to start on the paneling for cage design as well as the drawings for the structure

William is going to start on the presentation/report and work on the door design
He is also going to design/test in ansys as well if he has the times

Next Meeting Date: 11/08/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 11/08/2020
Meeting Location: Webex Meeting

Topics Discussed

Discovery update an overall impressions/progress/issues/etc

Door design update and progress as well as concerns (general discussion)

Upcoming presentation and what we needs to get done

3D Scanning Motorcycle Diecast

Responsibilities/ Actions Taken

Created a google slide presentation and the final report document. Begin working on both.

Continue door design and continue working with ANSYS

Plan/collect ideas and images for the presentation

Tony is going to look into getting a 3D scan of the motorcycle diecast

Next Meeting Date: 11/12/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 11/12/2020
Meeting Location: Webex Meeting

Topics Discussed

Current FEA progress and future simulations

Project presentation and overall plan

Current progress and concerns/suggestions

Responsibilities/ Actions Taken

Continue working and finishing the project presentation

Begin working on the final report

Continue working on the project

Next Meeting Date: 11/15/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 11/22/2020
Meeting Location: Webex Meeting

Topics Discussed

Discussed current order updates for the project (such as the trailer order)

Discussed the plan for the week and the tmeline in order to finish the final report

Responsibilities/ Actions Taken

Continue working and finishing/finalizing the final report

Begin working on our reflection reports

Continue working on the project

Next Meeting Date: 11/23/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[No]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 11/23/2020
Meeting Location: Webex Meeting

Topics Discussed

Continued working on the final report and finished the design as well as analysis sections

Discussed the plan for the week and the tmeline in order to finish the final report

Responsibilities/ Actions Taken

Continue working on our reflection reports

Continue working on the project

Next Meeting Date: 11/24/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[No]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 11/24/2020
Meeting Location: Webex Meeting

Topics Discussed

Finished the initial draft for the final report

Discussed the plan for the week and the tmeline in order to finish the final report

Responsibilities/ Actions Taken

Sent the draft to be reiviewed by William and then had him send it to Gary Drigel for review as well

Continue working on our reflection reports

Continue working on the project

Tony picked up the trailer and is going to assemble it on the upcoming weekend

Next Meeting Date: 11/30/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 11/30/2020
Meeting Location: Webex Meeting

Topics Discussed

Final project report current work and refinement

Trailer assembly completed. Discussed the current frame design and began refining the design so that we could later send the design off to the welder

Decided to go with plating the cage by using rivets rather then welding in order to reduce the total cost

Decided to use 3/4" plywood for the decking on the trailer

Responsibilities/ Actions Taken

Tony is going to contact the welder so that we can have the design begin assembly

We are going to send the final report out for review again prior to the submission date

Next Meeting Date: 12/01/2020 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student:	**[ ]**

Meeting Date: 12/01/2020
Meeting Location: Webex Meeting

Topics Discussed

Discussed current project status and finalized the final report for the fall semester

Discussed paneling options and decided to go with unpainted aluminum because the panels will be bended to shape

Responsibilities/ Actions Taken

Sent another copy of the final report out for review and upon review and revison if needed the final report will be submitted before or on 12/03/2020

Still waiting to hear from the welding shop. However Tony is planning to call them at some point tomorrow (12/02/2020)

Next Meeting Date: 12/06/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student:	**[ ]**

Meeting Date: 12/06/2020
Meeting Location: Webex Meeting

Topics Discussed

Discussed current project status and the welding situation as well as the expected delivery date/time

Talked amount the door assembly and the piano hinge we intend to use for the door assembly as well as the door assembly in general and on additions that may need added

Discussed the motorcycle hitch and are going to get it ordered for the motorcycle

Responsibilities/ Actions Taken

Continue working on the door assembly and finalize its design so that we can begin it's a addition into the project

Tony is going to order the motorcycle hitch so that we can aquire it in a reasonable amount of time and get the motorcycle prepped for pulling the trailer.

Next Meeting Date: 12/11/2020 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 12/11/2020
Meeting Location: Webex Meeting

Topics Discussed

Discussed current project status and the welding situation as well as the expected delivery date/time

Talked about the trailer hitch order progress and plan for the holiday/break

Discussed individual plans and upcoming conflicts with meetings

Discussed trailer titling progress for road use

Responsibilities/ Actions Taken

Continue working on the door assembly and finalize its design so that we can begin it's a addition into the project

Logan is going to revise the trailer model andmake it made available to everyone

Currently waiting on title information for the trailer

Next Meeting Date: 01/18/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[No]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 01/18/2021
Meeting Location: Webex Meeting

Topics Discussed

Discussed revised trailer and potential frame conflict issue

Discussed welding quote information and what needs to be done before we have the welder begin building the cage

Discussed trailer hitch conflict/progress

Responsibilities/ Actions Taken

Logan and Tony are going to verify that the revised trailer is correct and make sure that the plan for mounting of the cage is correct with the cage design that way we can have the welder begin working on the design

Next Meeting Date: 01/23/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[No]**
Student: Tony Hester	**[Yes]**
Student:	**[ ]**

Meeting Date: 01/23/2021
Meeting Location: Webex Meeting

Topics Discussed

Discussed welding progress/current status

Discussed trailer hitch information and any updates

Discussed 3D model status and want needs to be added

Responsibilities/ Actions Taken

Tony is going to fill out the request for funding and get in contact with the welder.

Logan is going to update and add to the 3D trailer model so that it includes the lights and wheel wells.

Next Meeting Date: 01/24/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 01/24/2021
Meeting Location: Webex Meeting

Topics Discussed

Discussed the trailer model and made a slight revision to the cage design to allow better bolt placements for the mounting of the trailer.

Discussed the title information and what we need to do as well as the trailer hitch information

Discussed what we need to get done for refining the 3D model further

Responsibilities/ Actions Taken

Tony is going to send the updated drawings and model to the welder

William is going to continue working and refining the door design

Logan is going to continue refining and editing the trailer model

Trailer wood top was installed

Next Meeting Date: 01/24/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 01/28/2021
Meeting Location: Webex Meeting

Topics Discussed

Current project standing and what still needs to be done and our current plan

Discussed the complications we ran into during the break and the issues we have ran into with delays with the welder and shipping of parts

Discussed potentially ordering another hitch due to current delays

Discussed the updated/refined 3D model

Responsibilities/ Actions Taken

Everyone is going to start on the CFD research within ANSYS

Tony is going to keep in direct contact with the welder and look for another motorcycle hitch due to the delays we are experiencing

Everyone is going to keep working on the project

Next Meeting Date: 01/31/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 01/31/2021
Meeting Location: Webex Meeting

Topics Discussed

Paneling optons and what is available/cost

Aquiring tools needed for paneling process

Current CFD progress

Motorcycle hitch status

Current welder status

Responsibilities/ Actions Taken

We are going to order the paneling for the project as well as the wiring harness for the motorcycle and the trailer.

Going to go with 1/4 inch aluminum rivets for mounting the panels

Continue working on the CFD analysis

Going to conduct more research on the motorcycle wiring harness before ordering
Got a copy of the motorcycle service manual for tonys motorcycle

Next Meeting Date: 02/04/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: **MPMT (Multi-Purpose Motorcycle Trailer)**

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 02/04/2021
Meeting Location: Webex Meeting

Topics Discussed

Current CFD progress, meshing error is now resolved. Moving on to setting up the solver in order to run the simulation and establish more parameters so that we can determine the drag coeffiecients as well as the force acting on trailer while moving at different speeds. Once the solver is setup the model will be run in three sets of simulations going from 25, 35, and 45 mph as these will be the common speeds that the trailer will experience.

Motorcycle Hitch Status - expected to ship on the 23 of February

We are going to get wiring harness ordered (Delayed because of research)

Responsibilities/ Actions Taken

We are going to get wiring harness ordered (Delayed because of research)

Tony is going to check in with the welder for an update on the cage progress

Tony is going to look into aluminum paneling for the project and then later submit an order

William submitting the form for the wiring harness

Tony is going to take the trailer to the middletown campus so that it can be stored

Logan is going to continue working on the CFD simulations for the drag coefficents

Next Meeting Date: 02/08/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 02/08/2021
Meeting Location: Webex Meeting

Topics Discussed

CFD progress and current status/issues

Door design progress

Trailer title progress/update

Welder status and current situation

Responsibilities/ Actions Taken

Logan is going to continue working on the CFD within ansys and continue to work towards finalizing the meshing so that the simulation cases can be started.

William is going to continue/finalize the door design

Tony is going to keep in contact with the welder and also in communication about the trailer title status.

Next Meeting Date: 02/11/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student:	[ ]

Meeting Date: 02/11/2021
Meeting Location: Webex Meeting

Topics Discussed

Cuurent CFD progress as well as trailer legality

Ordering the alumnium paneling

Current status of the wiring harness (Just ordered should arrive on Friday)

Motorcycle hitch status and welding progress/status.

Door design progress

Responsibilities/ Actions Taken

Going to order the aluminum paneling from the welder.

Going to plan a time to install the wiring harness for the motorcycle and run the wiring for the trailers lights.

Continue CFD analysis from drag coefficents

Continue door design development.

Next Meeting Date: 02/15/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: **MPMT (Multi-Purpose Motorcycle Trailer)**

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student:	**[ ]**

Meeting Date: 02/15/2021
Meeting Location: Webex Meeting

Topics Discussed

Current welders progress/status

Current CFD progress and status

Current wiring harness status for the motorcycle

Current door design progress

Responsibilities/ Actions Taken

Logan is going to continue working on the CFD

Tony is going to keep in contact with the welder as a group we are planning stop by the welding shop to see the current progress possibly on 02/20/21

William is going to keep working on the door design

Planning to start wiring the trailer lights for the trailer on 02/20/21 as well.

Next Meeting Date: 02/17/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 02/17/2021
Meeting Location: Webex Meeting

Topics Discussed

Addition of another group member (Kyle Guggenheim)

Project changes and what needs to be updated such as the gantt chart and project requirements

Current project status and current progress for the project and it's status

Responsibilities/ Actions Taken

Logan is going to start rearranging the gantt chart and continue CFD research

Kyle is going to review some of the current project materials so that he can be caught up on the design and project.

Tony is going to review the door design and get the model sent to the welder

Next Meeting Date: 02/18/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 02/18/2021
Meeting Location: Webex Meeting

Topics Discussed

Current gantt chart progress and revisions

Plan for 02/20/21 going to meet as a group at the miami middletown campus

Reviewing project needs and what needs to be ordered still

3D printing trailer model and

Taking images and recording group work

Responsibilities/ Actions Taken

Logan is going to continue working on CFD

Everyone is going to meet on campus on this upcoming Saturday to work on the trailer

Kyle is going to look into getting a trailer model 3D printed

William is going to review project resources and what is still needed

Next Meeting Date: 02/22/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 02/22/2021
Meeting Location: Webex Meeting

Topics Discussed

Current CFD results and progress

Hitch status, location of break on middletown, motorcycle storage location

Plan for working and assembling the motorcycle as well as the paneling for the cage

Everyones current schedule and days we can meet to work on the project

Current budget and what needs to be ordered

Responsibilities/ Actions Taken

Logan is going to continue working on CFD

Kyle is going to get the 3D print file sent to be printed

Everyone is going to meet at the campus on Thursday morning to start on the paneling

Tony is going to pick up the cage design and the sheet metal once it is available and deliver it to the middletown campus. He will also test the trailer lights

Next Meeting Date: 02/23/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[Yes]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student: Kyle Guggenheim	**[Yes]**

Meeting Date: 02/23/2021
Meeting Location: Webex Meeting

Topics Discussed

Fiberglass and paint option for enclosing/sealing the cage

Motorcycle hitch status and relocation of items in middletown lab

Current CFD progress

What materials need to be ordered/gather still

Door Design and materials

Responsibilities/ Actions Taken

Going to continue with the aluminum paneling instead of the fiberglass

William is going to get the remaining parts ordered

Kyle is going to send frank the 3D print form once the scaling of the model is complete

Tony is going to contact the welder for potential pickup as well as the painter to learn more about the fiberglass work for a backup option.

Next Meeting Date: 02/25/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: **MPMT (Multi-Purpose Motorcycle Trailer)**

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 02/25/2021
Meeting Location: Webex Meeting

Topics Discussed

Current project standing and current plan

Fog machine order for the wind tunnel and expected arrival time

Plan for the paneling and making refined templates

Ordering of wire for the trailer door

Responsibilities/ Actions Taken

Going to meet as a group to work on the motorcycle this upcoming Saturday

William is going to get the wire for the door ordered

Decided to use sheet metal screws instead of rivets to attach the panels

Tony is going to make refined templates out of poster board for the panels

Kyle sent the 3D model to be printed

Logan is going to send Dr. Dinc the current CFD results for review

Next Meeting Date: 02/27/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[No]

Meeting Date: 02/27/2021
Meeting Location: Webex Meeting

Topics Discussed

Met as a group and got the motorcycle hitch installed as well as the trailer wiring for the motorcycle to the trailer.

Got the motorcycle lights on the trailer tested and installed and also took the trailer for a test ride with the motorcycle at miami middletown

Responsibilities/ Actions Taken

Tony tested the trailer lights and used his motorcycle to test the trailer

Going to meet as a group on 03-042021 to continue working on the paneling for the cage

Overall, everyone as a group is planning on meeting within the next week to finish paneling so that we can move onto real-world testing.

Next Meeting Date: 03/04/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 03/04/2021
Meeting Location: Webex Meeting

Topics Discussed

Met as a group earlier today and worked on the wind tunnel as well as the cage paneling

The cage is now cleaned and prepped for the aluminum paneling to be mounted to it and the hardware/fasteners including the hinge have been obtained

Current CFD progress and final data collection for it

Plan for this upcoming Saturday 03/06/2021 is to meet as a group and finish/install the panels for the cage design

Responsibilities/ Actions Taken

Logan is going to finish the CFD analysis/study

Everyone is going to meet on 03/06/21 to install the panels for the cage and get it finalized so that we can move onto real-world testing

Kyle is going to send Dr. Dinc an update about the wind tunnel and current progress

Going to look into options for securing the trailer model/scale model so that it can be safely placed inside the wind tunnel

Next Meeting Date: 03/06/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student: Kyle Guggenheim	**[Yes]**

Meeting Date: 03/06/2021
Meeting Location: Webex Meeting

Topics Discussed

Met as a group at miami and got the main panels for the cage structure installed

Discussed waterproofing options and some of the finishing details that will need to be addressed

Going to meet as a group again on 03/11/2021 to work on the door and get it finalized

Responsibilities/ Actions Taken

Everyone is going to plan to meet at the school again on 03/11/2021

Overall, the main goal is to get the cage/door finalized and bolted onto the trailer so that we can begin testing at Miami Hamilton as soon as possible.

Next Meeting Date: 03/11/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 03/11/2021
Meeting Location: Webex Meeting

Topics Discussed

Met as a group and got the door finalized minus the closing latches and the seal

Tested the wind tunnel and made sure that it was working properly

Got the cage bolted to the trailer so that it can now be transferred to the hamilton campus

Got the lid installed onto the cage

Responsibilities/ Actions Taken

Ordered the seal and latches for the door and we are planning on installing them on 03/18/21

Overall, we are planning to begin the wind tunnel analysis soon and finish the main construction of the design so that we can move onto testing with the motorcycle.

Next Meeting Date: 03/18/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 03/18/2021
Meeting Location: Webex Meeting

Topics Discussed

Discussed current project standing amd our goal/plan for the upcoming weekend as we are planning to perform live testing this upcoming weekend.

Got the door sealed, latches installed, as well as the traction mat installed for the dogs

Got the lid sealed as well and trimmed/sanded so that it is smooth all around

Plan for the poster as well as the video for the project

Current wind tunnel results

Responsibilities/ Actions Taken

Everyone is going to meet at Miami Hamilton on 03/21/21 for live testing with the motorcycle

Tony is going to transport the trailer from Miami Middletown either on this upcoming Friday or this upcoming Saturday.

Everyone is going to start getting ideas for the poster as well as the video for the project

Next Meeting Date: 03/21/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 03/21/2021
Meeting Location: Webex Meeting

Topics Discussed

Met as a team and performed live testing with the trailer and the motorcycle.

Tests performed include the following:

Manuverabilty, braking, acceleration, and stability

We also collected footage using a gopro

Overall, testing was a success and the trailer worked exceptionally

Responsibilities/ Actions Taken

Kyle is going to review the footage and make a short film for the test results to be showcased as a claim for us to get permission for road testing

Logan is going to run some more CFD simulations for low speed and also start making videos for the CFD simulations

Tony is going to take the trailer home and finish the remaining installations of small parts/accessories

Everyone is going to meet on 03/25/2021 for continuing wind tunnel testing

Next Meeting Date: 03/25/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 03/25/2021
Meeting Location: Webex Meeting

Topics Discussed

Met as a group and continued wind tunnel testing as well and video coverage

Discussed the plan for the upcoming weekend as we are going to work on the report and poster as well as the powerpoint presentation

Overall, windtunnel analysis is now completed and we are now moving forward with focus on the report and other documents

Tony is going to meet with some different painters to get quotes

Responsibilities/ Actions Taken

Everyone is going to meet on 03/28/2021 to work on the poster, final report and the powerpoint presentation

Main focus now is shifting to focusing on the documents that are needed to be finished as well as getting the presentation video started

Kyle is going to review and edit the wind tunnel videos for the presentation

Next Meeting Date: 03/28/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student: Kyle Guggenheim	**[Yes]**

Meeting Date: 03/28/2021
Meeting Location: Webex Meeting

Topics Discussed

Final poster was edited/finalized and sent out for review

General outline of the video presentation was discussed and revised

Current design weight and calculations

Plans for the video presentation and the method for the video

Responsibilities/ Actions Taken

Logan sent a copy of the final poster to Gary Drigel for review

Tony is going to continue talking to painters and training the dogs to become more familiar with MPMT

Everyone is going to meet on Thursday 04/01/2021 to finalize and finish the video presentation so that we can get the video completed

Eveyone is also going to start writing and working on the final report

Next Meeting Date: 04/01/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 04/01/2021
Meeting Location: Webex Meeting

Topics Discussed

Final poster for the project revised and edited it

Continued working on the presentation for the video and decided on a day for when we will record and complete the presentation video

Continue working on the final report and get it ready for review

Responsibilities/ Actions Taken

Decided that we will record our video presentation on 04/08/2021

Going to meet as a team and continue working on the final report on 04/03/2021

Going to get the final poster and presentation reviewed

Next Meeting Date: 04/03/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 04/03/2021
Meeting Location: Webex Meeting

Topics Discussed

Current status with the painter and expected completion date

Project final presentation and edits that need to be done as well as additional images

Final report outline and plan

Process for citing our previous report so we can reuse some of our previous information

Responsibilities/ Actions Taken

Tony is going to keep in contact with the painter and plan for collecting the design once paint is finished

Planning to meet as a group on 04/08/2021 to continue working on the final report

Planning to do more testing and get more videos and images of the finished project once paint is finished

Next Meeting Date: 04/08/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student: Kyle Guggenheim	**[Yes]**

Meeting Date: 04/10/2021
Meeting Location: Webex Meeting

Topics Discussed

Met as a group and began working on the video presentation

Recorded various parts of the video presentation and selected which videos/images we were going to use

Finalized the overall presentation content expect for some of the images

Responsibilities/ Actions Taken

Everyone is going to meet on 04/12/2021 to get new videos and images with the finished trailer at Miami University Hamilton

Plan is to get a new group photo if everyone is available and also do some testing with the animals riding in the trailer for a brief amount of time

Next Meeting Date: 04/12/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 04/12/2021
Meeting Location: Webex Meeting

Topics Discussed

Met as a group and conducted some testing with the animals and the trailer

Got new photos of the finished/painted trailer with the animals

Got a new images for the poster/presentation/report

Responsibilities/ Actions Taken

Everyone is going to meet as a group on 04/15/2021 to finish the video presentation and the final poster

Tony when he has the time is going to collect the trailer from the Hamilton campus

Everyone is going to continue working on the final report as well

Next Meeting Date: 04/15/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 04/15/2021
Meeting Location: Webex Meeting

Topics Discussed

Submission of the final poster

Video presentation setup and what needs to be done still. Goal is to have the presentation completed by next Teusday so that it can be reviewed

Final report progress and what needs to be done still

Responsibilities/ Actions Taken

Everyone is going to meet on 04/18/2021 to finish and adjust the video presentation if changes need to be made

Everyone is going to continue working on the final report so that it can be sent out for review and then revised/editted based upon the feedback that we receive once the review is completed.

Tony is going to continue working on his 2-minute presentation for displaying our project

Next Meeting Date: 04/18/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 04/18/2021
Meeting Location: Webex Meeting

Topics Discussed

Met as a group and finalized the project presentation.

Planning to send the presentation out for review on 04/19/2021 as of current timeline

Final report progress as well as planned content and additional content within the appendices

Responsibilities/ Actions Taken

Everyone is going to meet on 04/22/2021 to continue working on the final report
we are also going to discuss the project presentation as well

Main focus now is on getting the final report finished so that we can have it reviewed

Tony is going to continue working on his 2-minute presentation for displaying our project

Next Meeting Date: 04/22/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[No]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student: Kyle Guggenheim	**[Yes]**

Meeting Date: 04/26/2021
Meeting Location: Webex Meeting

Topics Discussed

Final report progress and what needs to be done

Tony's progress on the 2-minute presentation

What files/documents need to be included into the final report

Reflective essays

Responsibilities/ Actions Taken

Tony is going to continue working on the 2-minute presentation

Logan is going to add some more of the CFD documents/images into the appendices

Everyone is going to start working on their reflective essays

Everyone is going to continue working on the final report

Next Meeting Date: 04/29/2021 **Location: Webex Meeting**

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	**[Yes]**
Student: Logan Street	**[Yes]**
Student: William Dao	**[Yes]**
Student: Tony Hester	**[Yes]**
Student: Kyle Guggenheim	**[Yes]**

Meeting Date: 04/29/2021
Meeting Location: Webex Meeting

Topics Discussed

Final report progress

Tony's 2-minute presentation for 04/30/2021

Individual reflective essays

What still needs to be done within the project

Responsibilities/ Actions Taken

A copy of the current final report is going to be sent out for review and feedback

Everyone is going to continue working on their individual reflective essays

Once feedback is received we are going to go through and revize and edit the report and have it sent out for review again.

Overall, primary focus is now on finishing the remaining/final details for the report and the project as a whole.

Next Meeting Date: 05/03/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[No]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 05/03/2021
Meeting Location: Webex Meeting

Topics Discussed

Final report progress

Status of the current review progress and if any updates have been received

Individual reflective essays

Responsibilities/ Actions Taken

Everyone is going to continue working on their individual reflective essays

Kyle is going to send a copy of the final report to the writing center for review

Everyone is going to wait for feedback and as soon as feedback is received we will make any of the changes that are necessary

Next Meeting Date: 05/06/2021 **Location: Webex Meeting**

MIAMI UNIVERSITY

Meeting Journal
Department of Engineering Technology
ENT 497/498 - Senior Design Project
Project Title: MPMT (Multi-Purpose Motorcycle Trailer)

	Present
Advisor: Gary Drigel	[Yes]
Student: Logan Street	[Yes]
Student: William Dao	[Yes]
Student: Tony Hester	[Yes]
Student: Kyle Guggenheim	[Yes]

Meeting Date: 05/06/2021
Meeting Location: Webex Meeting

Topics Discussed

Presentation review and reflection from the previous week

Final report and review progress towards the final version

Class conclusion and summary of the course/final comments

(This is the final meeeting journal entry)

Responsibilities/ Actions Taken

After we receive feedback we will go through and revise any changes that need to be made within our final report.

We will meet as a group and turn in the final report once revsions are finished

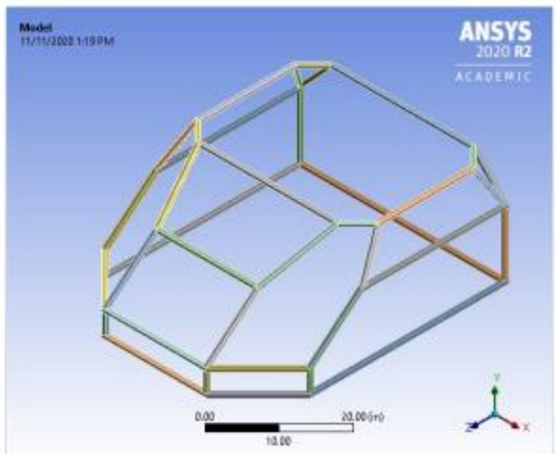
Next Meeting Date: N/A **Location: Webex Meeting**

Appendix F: Ansys FEA Simulations/Reports

1000 lbf (Side Impact) Static Structural Simulation

Project*

First Saved	Wednesday, November 11, 2020
Last Saved	Wednesday, November 11, 2020
Product Version	2020 R2
Save Project Before Solution	Yes
Save Project After Solution	Yes



Contents

Units

TABLE 1

Unit System	U.S. Customary (in, lbm, lbf, s, V, A) Degrees rad/s Fahrenheit
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Fahrenheit

Model (A4)

Geometry

TABLE 2
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\streetl3\Documents\ENT497 MPMT Project Files\MPMT Static Structural\MPMT Cage Skeleton Static Loading_files\dp0 \SYS\DM\SYS.scdoc
Type	SpaceClaim
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	40.097 in
Length Y	20.098 in
Length Z	47.796 in
Properties	
Volume	118.07 in³
Mass	11.815 lbm
Scale Factor Value	1.
Statistics	
Bodies	38
Active Bodies	38
Nodes	500660
Elements	242637
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	Yes
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D

Mixed Import Resolution	None
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3
Model (A4) > Geometry > Parts

Object Name	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 27.234\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 27.209\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.33849583 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 18.38036945 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.346\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.346_1 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 18.38\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.338\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 28\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 37.898\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 4.25\Solid1*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Aluminum Alloy										
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	27.234 in	27.209 in	4.3052 in	0.75 in	4.3102 in		0.75 in	4.3052 in	0.75 in		
Length Y	0.75 in										4.25 in
Length Z	0.75 in		4.3052 in	18.38 in	4.3102 in		18.38 in	4.3052 in	28. in	37.898 in	0.75 in
Properties											
Volume	5.7392 in^3	5.7075 in^3	1.0054 in^3	3.8575 in^3	1.0497 in^3		3.8575 in^3	1.0054 in^3	5.9395 in^3	7.9655 in^3	0.86868 in^3
Mass	0.57433 lbm	0.57116 lbm	0.10062 lbm	0.38603 lbm	0.10505 lbm		0.38603 lbm	0.10062 lbm	0.59439 lbm	0.79713 lbm	8.6931e-002 lbm
Centroid X	-5.5844e-002 in		15.231 in	16.967 in	15.152 in	-15.263 in	-17.078 in	-15.343 in	19.467 in	19.47 in	19.467 in
Centroid Y	20.028 in	20.029 in	20.043 in	20.03 in	20.033 in		20.03 in	20.043 in	13.334 in	0.77754 in	3.1921 in
Centroid Z	2.1339 in	-23.422 in	-21.592 in	-10.639 in	0.39472 in		-10.639 in	-21.592 in	-9.8835 in	-4.7384 in	13.735 in
Moment of Inertia Ip1	34.726 lbm·in^2	34.146 lbm·in^2	0.19763 lbm·in^2	10.557 lbm·in^2	0.22133 lbm·in^2	0.22158 lbm·in^2	10.558 lbm·in^2	0.19706 lbm·in^2	38.48 lbm·in^2	92.813 lbm·in^2	0.12729 lbm·in^2
Moment of Inertia Ip2	34.726 lbm·in^2	34.146 lbm·in^2	0.19706 lbm·in^2	10.558 lbm·in^2	0.22158 lbm·in^2	0.22133 lbm·in^2	10.557 lbm·in^2	0.19763 lbm·in^2	38.48 lbm·in^2	92.813 lbm·in^2	0.12731 lbm·in^2
Moment of Inertia Ip3	8.4162e-002 lbm·in^2	8.3672e-002 lbm·in^2	1.4679e-002 lbm·in^2	5.6534e-002 lbm·in^2	1.5358e-002 lbm·in^2		5.6534e-002 lbm·in^2	1.4679e-002 lbm·in^2	8.709e-002 lbm·in^2	0.11683 lbm·in^2	1.2712e-002 lbm·in^2
Statistics											
Nodes	22517	22391	4945	16220	5052	4994	16303	4952	23958	31561	4140
Elements	10982	10919	2362	7876	2402	2374	7902	2344	11750	15395	1955
Mesh Metric	None										
CAD Attributes											
PartTolerance:	0.00000001										
Color:143.143.175											

TABLE 4
Model (A4) > Geometry > Parts

Object Name	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 11.805\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.921\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_1 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 3.5\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.938\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.93787324 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 19.32772998 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 20\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 20_1\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_2 \Solid1*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Aluminum Alloy										
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.75 in		10.428 in		0.75 in			19.328 in	20. in		10.428 in
Length Y	11.805 in	8.8799 in	0.75 in		3.5 in	8.8908 in		0.75 in			
Length Z	0.75 in	10.38 in	10.428 in		0.75 in	10.393 in		0.75 in			10.428 in
Properties											
Volume	2.5165 in^3	2.6879 in^3	2.8708 in^3	2.9176 in^3	0.74608 in^3	2.6233 in^3		4.0421 in^3	4.1971 in^3		2.8708 in^3
Mass	0.25183 lbm	0.26899 lbm	0.28729 lbm	0.29198 lbm	7.4662e-002 lbm	0.26252 lbm		0.4045 lbm	0.42001 lbm		0.28729 lbm
Centroid X	19.467 in		14.557 in	14.631 in	9.5692 in	9.5719 in	-9.6836 in	-5.5844e-002 in			-14.669 in

Centroid Y	7.0552 in	9.2839 in	5.0275 in	0.77754 in	2.9025 in	9.3613 in	9.3613 in	13.334 in	0.77754 in	5.0275 in	5.0275 in
Centroid Z	-23.421 in	8.9005 in	18.867 in	18.789 in	23.625 in	18.71 in	18.71 in	13.726 in	23.628 in	23.628 in	18.867 in
Moment of Inertia Ip1	2.9411 lbm·in^2	3.5855 lbm·in^2	4.374 lbm·in^2	4.5811 lbm·in^2	8.1631e-002 lbm·in^2	3.3475 lbm·in^2	3.3475 lbm·in^2	12.148 lbm·in^2	13.598 lbm·in^2	13.598 lbm·in^2	4.374 lbm·in^2
Moment of Inertia Ip2	2.9411 lbm·in^2	3.5855 lbm·in^2	4.374 lbm·in^2	4.5811 lbm·in^2	8.1631e-002 lbm·in^2	3.3475 lbm·in^2	3.3475 lbm·in^2	12.149 lbm·in^2	13.598 lbm·in^2	13.598 lbm·in^2	4.374 lbm·in^2
Moment of Inertia Ip3	3.6891e-002 lbm·in^2	3.9412e-002 lbm·in^2	4.2084e-002 lbm·in^2	4.2781e-002 lbm·in^2	1.0937e-002 lbm·in^2	3.8391e-002 lbm·in^2	3.8391e-002 lbm·in^2	5.9267e-002 lbm·in^2	6.1546e-002 lbm·in^2	6.1546e-002 lbm·in^2	4.2084e-002 lbm·in^2
Statistics											
Nodes	10914	11198	12226	12016	3574	14087	14504	17403	17008	16996	12169
Elements	5281	5357	5901	5774	1674	6781	7010	8518	8200	8190	5884
Mesh Metric	None										
CAD Attributes											
PartTolerance:	0.00000001										
Color:143.143.175											

TABLE 5
Model (A4) > Geometry > Parts

Object Name	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_3 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 4.25_1\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 37.898_1 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 28_1\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 11.805_1 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 39.796\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 3.5_1\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.921_1 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.161\Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.161_1 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.10070407 \Solid1*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Aluminum Alloy										
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	10.428 in	0.75 in	0.75 in	0.75 in	0.75 in	39.796 in	0.75 in	0.75 in	6.815 in	6.815 in	3.3897 in
Length Y	0.75 in	4.25 in	0.75 in	0.75 in	11.805 in	0.75 in	3.5 in	8.8799 in	7.194 in	7.194 in	7.4579 in
Length Z	10.428 in	0.75 in	37.898 in	28. in	0.75 in	0.75 in	0.75 in	10.38 in	0.75 in	0.75 in	6.1336 in
Properties											
Volume	2.9176 in^3	0.86868 in^3	7.9655 in^3	5.9395 in^3	2.5165 in^3	8.3233 in^3	0.74808 in^3	2.6879 in^3	1.7305 in^3	1.7305 in^3	1.7685 in^3
Mass	0.29198 lbm	8.6931e-002 lbm	0.79713 lbm	0.59439 lbm	0.25183 lbm	0.83293 lbm	7.4862e-002 lbm	0.26899 lbm	0.17317 lbm	0.17317 lbm	0.17698 lbm
Centroid X	-14.743 in	-19.579 in	-19.582 in	-19.579 in	-19.579 in	-5.5844e-002 in	-9.6808 in	-19.579 in	16.337 in	-16.449 in	18.297 in
Centroid Y	0.77754 in	3.1921 in	0.77754 in	13.334 in	7.0552 in	0.77754 in	2.9025 in	9.2839 in	16.89 in	16.89 in	16.797 in
Centroid Z	18.789 in	13.735 in	-4.7384 in	-9.8635 in	-23.421 in	-23.425 in	23.625 in	8.9005 in	-23.436 in	-23.436 in	1.1057 in
Moment of Inertia Ip1	4.5811 lbm·in^2	0.12729 lbm·in^2	92.813 lbm·in^2	38.48 lbm·in^2	2.9411 lbm·in^2	105.91 lbm·in^2	8.1631e-002 lbm·in^2	3.5855 lbm·in^2	0.97859 lbm·in^2	0.97859 lbm·in^2	1.0355 lbm·in^2
Moment of Inertia Ip2	4.5811 lbm·in^2	0.12731 lbm·in^2	92.813 lbm·in^2	38.48 lbm·in^2	2.9411 lbm·in^2	105.91 lbm·in^2	8.1631e-002 lbm·in^2	3.5855 lbm·in^2	0.97956 lbm·in^2	0.97956 lbm·in^2	1.0358 lbm·in^2
Moment of Inertia Ip3	4.2781e-002 lbm·in^2	1.2712e-002 lbm·in^2	0.11683 lbm·in^2	8.709e-002 lbm·in^2	3.6891e-002 lbm·in^2	0.12207 lbm·in^2	1.0937e-002 lbm·in^2	3.9412e-002 lbm·in^2	2.5304e-002 lbm·in^2	2.5304e-002 lbm·in^2	2.5868e-002 lbm·in^2
Statistics											
Nodes	12021	4067	31878	23392	10914	33312	3574	11251	8230	8147	7982
Elements	5779	1903	15695	11439	5281	16287	1674	5431	3972	3910	3870
Mesh Metric	None										
CAD Attributes											
PartTolerance:	0.00000001										
Color:143.143.175											

TABLE 6
Model (A4) > Geometry > Parts

Object Name	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.10845212 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.108 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.10070407_1 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.91634287 \Solid1*	*ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.91634287_1 \Solid1*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Treatment	None				
Material					
Assignment	Aluminum Alloy				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	3.3326 in	3.3326 in	3.3897 in	4.3545 in	4.3545 in
Length Y	7.3052 in	7.3052 in	7.4579 in	7.4667 in	7.4667 in

Length Z	4.455 in		6.1336 in	12.183 in	
Properties					
Volume	1.5252 in³		1.7685 in³	2.8571 in³	
Mass	0.15263 lbm		0.17698 lbm	0.28591 lbm	
Centroid X	18.268 in	-18.38 in	-18.409 in	11.371 in	-11.483 in
Centroid Y	16.894 in		16.797 in	16.737 in	
Centroid Z	-21.494 in		1.1057 in	8.1123 in	
Moment of Inertia Ip1	0.67407 lbm·in²		1.0355 lbm·in²	4.3086 lbm·in²	
Moment of Inertia Ip2	0.67483 lbm·in²		1.0358 lbm·in²	4.3087 lbm·in²	
Moment of Inertia Ip3	2.2249e-002 lbm·in²		2.5868e-002 lbm·in²	4.1867e-002 lbm·in²	
Statistics					
Nodes	7077	7136	8158	12261	12132
Elements	3401	3418	3939	5945	5882
Mesh Metric	None				
CAD Attributes					
PartTolerance:	0.00000001				
Color:143.143.175					

TABLE 7
Model (A4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	2
Material Assignments	0

Coordinate Systems

TABLE 8
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. in
Origin Y	0. in
Origin Z	0. in
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Connections

TABLE 9
Model (A4) > Connections

Object Name	Connections
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes

TABLE 10
Model (A4) > Connections > Contacts

Object Name	*Contacts*
State	Fully Defined
Definition	
Connection Type	Contact
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Auto Detection	
Tolerance Type	Slider
Tolerance Slider	0.
Tolerance Value	0.16386 in
Use Range	No
Face/Face	Yes
Face-Face Angle Tolerance	75. °
Face Overlap Tolerance	Off
Cylindrical Faces	Include
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies
Statistics	
Connections	72
Active Connections	72

TABLE 11
Model (A4) > Connections > Contacts > Contact Regions

Object	*Contact*	*Contact*	*Contact*	*Contact Region 4*	*Contact*	*Contact*	*Contact*	*Contact*	*Contact*	*Contact*	*Contact*

Name	Region	Region 2	Region 3		Region 5	Region 6	Region 7	Region 8	Region 9	Region 10	Region 11
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	5 Faces	3 Faces							2 Faces		1 Face
Target	5 Faces	3 Faces	1 Face		3 Faces				2 Faces		1 Face
Contact Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 27.234\Solid1				ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 27.209 \Solid1				ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.33849583\Solid1		
Target Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.346\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.346_1 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.91634287 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.91634287_1 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.33849583 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.338\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.161\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.161_1 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 18.38036945 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.161\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.10845212 \Solid1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	0.16386 in										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 12
Model (A4) > Connections > Contacts > Contact Regions

Object Name	Contact Region 12	Contact Region 13	Contact Region 14	Contact Region 15	Contact Region 16	Contact Region 17	Contact Region 18	Contact Region 19	Contact Region 20	Contact Region 21	Contact Region 22
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face			2 Faces			1 Face			2 Faces	1 Face
Target	1 Face			2 Faces			1 Face			2 Faces	1 Face
Contact Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 18.38036945\Solid1			ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.346\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.346_1\Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 18.38\Solid1			ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.338 \Solid1	
Target Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.346\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.10070407 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.10845212 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.10070407 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 18.38\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.10070407_1 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 5.338\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.108\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.10070407_1 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.161_1 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.108\Solid1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	0.16386 in										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update	Program Controlled										

Stiffness	
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 13
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 23*	*Contact Region 24*	*Contact Region 25*	*Contact Region 26*	*Contact Region 27*	*Contact Region 28*	*Contact Region 29*	*Contact Region 30*	*Contact Region 31*	*Contact Region 32*	*Contact Region 33*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces	5 Faces	3 Faces					1 Face	3 Faces	5 Faces	3 Faces
Target	1 Face	5 Faces	1 Face						3 Faces	5 Faces	1 Face
Contact Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 28\Solid1					ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 37.898\Solid1				ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 4.25\Solid1	
Target Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 11.805\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.921\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.161\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.10070407 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.10645212 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 4.25\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 11.805\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_1 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 39.796\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.921\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998\Solid1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	0.16386 in										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 14
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 34*	*Contact Region 35*	*Contact Region 36*	*Contact Region 37*	*Contact Region 38*	*Contact Region 39*	*Contact Region 40*	*Contact Region 41*	*Contact Region 42*	*Contact Region 43*	*Contact Region 44*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face		3 Faces	4 Faces	3 Faces		5 Faces	1 Face		2 Faces	1 Face
Target	3 Faces		1 Face	2 Faces	3 Faces	1 Face	5 Faces	3 Faces		2 Faces	3 Faces
Contact Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 4.25\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 11.805\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998\Solid1			ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_1\Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 3.5 \Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.938\Solid1	
Target Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_1 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 39.796\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 3.5\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.938\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 20_1\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 3.5\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 20 \Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 20_1\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 19.52772998 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 20_1\Solid1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	0.16386 in										
Suppressed	No										

Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 15
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 45*	*Contact Region 46*	*Contact Region 47*	*Contact Region 48*	*Contact Region 49*	*Contact Region 50*	*Contact Region 51*	*Contact Region 52*	*Contact Region 53*	*Contact Region 54*	*Contact Region 55*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	5 Faces	2 Faces	1 Face		5 Faces	2 Faces		3 Faces			
Target	6 Faces	2 Faces	3 Faces		6 Faces	2 Faces		3 Faces	1 Face	3 Faces	1 Face
Contact Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.938\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.93787324 \Solid1				ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 19.32772998 \Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 20 \Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 20_1 \Solid1	
Target Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.91634287 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 19.32772998 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 20_1\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_2 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.91634287_1 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.91634287 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.91634287_1 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_3 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 3.5_1\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_2 \Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 3.5_1\Solid1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	0.16386 in										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 16
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 56*	*Contact Region 57*	*Contact Region 58*	*Contact Region 59*	*Contact Region 60*	*Contact Region 61*	*Contact Region 62*	*Contact Region 63*	*Contact Region 64*	*Contact Region 65*	*Contact Region 66*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	3 Faces		5 Faces	3 Faces	1 Face	3 Faces		1 Face	3 Faces	
Target	3 Faces	1 Face		5 Faces	1 Face	3 Faces		1 Face			3 Faces
Contact Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_2 \Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 13.998_3\Solid1			ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 4.25_1\Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 37.898_1 \Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 28_1\Solid1	
	ASTM A513 -	ASTM A513 -	ASTM A513 -	ASTM A513 -	ASTM A513 -	ASTM A513 -	ASTM A513 -	ASTM A513 -	ASTM A513 -	ASTM A513 -	ASTM A513 -

Target Bodies	3_2f_4 x 3_2f_4 x 83_2f_1000 - 4.25_1\Solid1	3_2f_4 x 3_2f_4 x 83_2f_1000 - 3.5_1\Solid1	3_2f_4 x 3_2f_4 x 83_2f_1000 - 4.25_1\Solid1	3_2f_4 x 3_2f_4 x 83_2f_1000 - 37.898_1 \Solid1	3_2f_4 x 3_2f_4 x 83_2f_1000 - 3.5_1\Solid1	3_2f_4 x 3_2f_4 x 83_2f_1000 - 37.898_1 \Solid1	3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.921_1 \Solid1	3_2f_4 x 3_2f_4 x 83_2f_1000 - 11.805_1 \Solid1	3_2f_4 x 3_2f_4 x 83_2f_1000 - 39.796\Solid1	3_2f_4 x 3_2f_4 x 83_2f_1000 - 11.805_1 \Solid1	3_2f_4 x 3_2f_4 x 83_2f_1000 - 12.921_1 \Solid1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	0.16386 in										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 17
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 67*	*Contact Region 68*	*Contact Region 69*	*Contact Region 70*	*Contact Region 71*	*Contact Region 72*
State	Fully Defined					
Scope						
Scoping Method	Geometry Selection					
Contact	3 Faces			1 Face	2 Faces	
Target	1 Face			3 Faces	2 Faces	
Contact Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 28_1\Solid1			ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 11.805_1\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.161\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.161_1\Solid1
Target Bodies	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.161_1\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.108\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 9.10070407_1\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 39.796\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.10845212\Solid1	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.108\Solid1
Protected	No					
Definition						
Type	Bonded					
Scope Mode	Automatic					
Behavior	Program Controlled					
Trim Contact	Program Controlled					
Trim Tolerance	0.16386 in					
Suppressed	No					
Advanced						
Formulation	Program Controlled					
Small Sliding	Program Controlled					
Detection Method	Program Controlled					
Penetration Tolerance	Program Controlled					
Elastic Slip Tolerance	Program Controlled					
Normal Stiffness	Program Controlled					
Update Stiffness	Program Controlled					
Pinball Region	Program Controlled					
Geometric Modification						
Contact Geometry Correction	None					
Target Geometry Correction	None					

Mesh

TABLE 18
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	0.25 in

Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	65.545 in
Average Surface Area	4.023 in²
Minimum Edge Length	1.431e-003 in
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	500660
Elements	242637

TABLE 19
Model (A4) > Mesh > Mesh Controls

Object Name	*Patch Conforming Method*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	38 Bodies
Definition	
Suppressed	No
Method	Tetrahedrons
Algorithm	Patch Conforming
Element Order	Use Global Setting

Named Selections

TABLE 20
Model (A4) > Named Selections > Named Selections

Object Name	*Bottom of Frame*	*Back Side (WALL)*	*Side of structure*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	6 Faces	1 Face	3 Faces
Definition			
Send to Solver	Yes		
Protected	Program Controlled		
Visible	Yes		
Program Controlled Inflation	Exclude		
Statistics			
Type	Manual		
Total Selection	6 Faces	1 Face	3 Faces
Surface Area	88.593 in²	20.874 in²	46.158 in²
Suppressed	0		
Used by Mesh Worksheet	No		

Static Structural (A5)

TABLE 21
Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	71.6 °F
Generate Input Only	No

TABLE 22
Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Off
Output Controls	
Stress	Yes
Surface Stress	No
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	C:\Users\streetl3\Documents\ENT497 MPMT Project Files\MPMT Static Structural\MPMT Cage Skeleton Static Loading_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	Bin

FIGURE 1
Model (A4) > Static Structural (A5) > Test Conditions

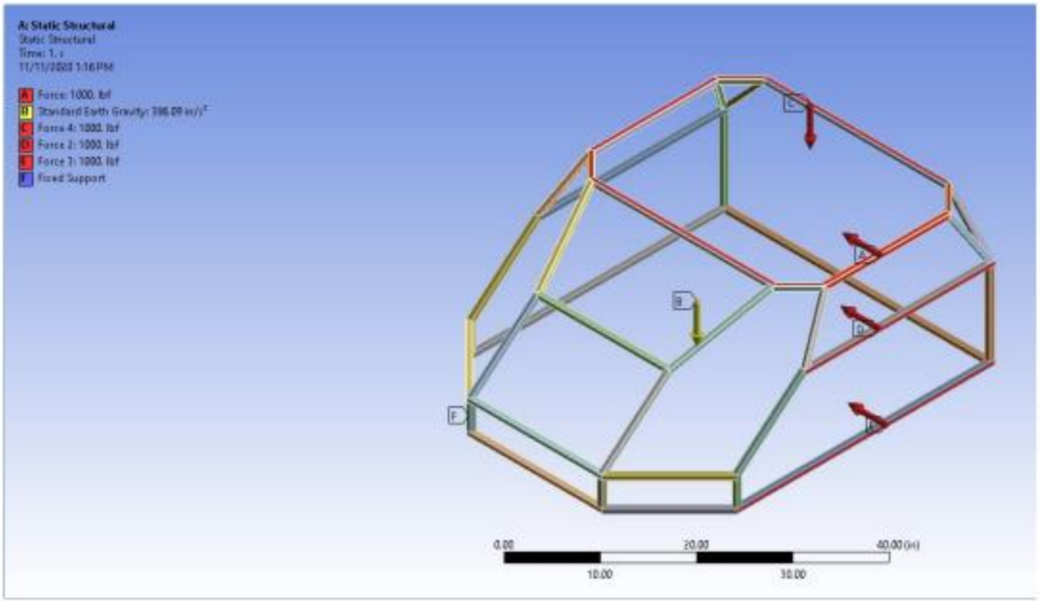


TABLE 23
Model (A4) > Static Structural (A5) > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
Coordinate System	Global Coordinate System
X Component	0. in/s² (ramped)
Y Component	-386.09 in/s² (ramped)
Z Component	0. in/s² (ramped)
Suppressed	No
Direction	-Y Direction

FIGURE 2
Model (A4) > Static Structural (A5) > Standard Earth Gravity

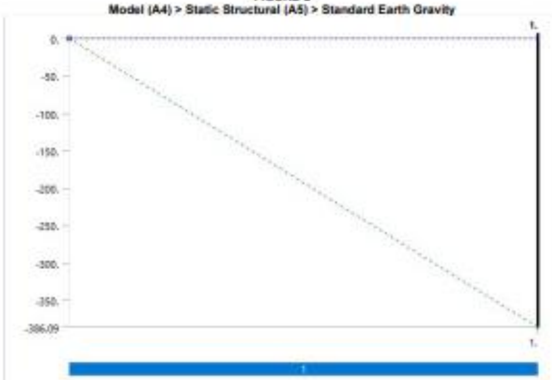


TABLE 24
Model (A4) > Static Structural (A5) > Loads

Object Name	*Force*	*Force 2*	*Force 3*	*Fixed Support*	*Force 4*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection			Named Selection	Geometry Selection
Geometry	1 Face				9 Faces
Named Selection				Bottom of Frame	
Definition					

Type	Force	Fixed Support	Force
Define By	Vector		Vector
Applied By	Surface Effect		Surface Effect
Magnitude	1000. lbf (ramped)		1000. lbf (ramped)
Direction	Defined		Defined
Suppressed		No	

FIGURE 3
Model (A4) > Static Structural (A5) > Force

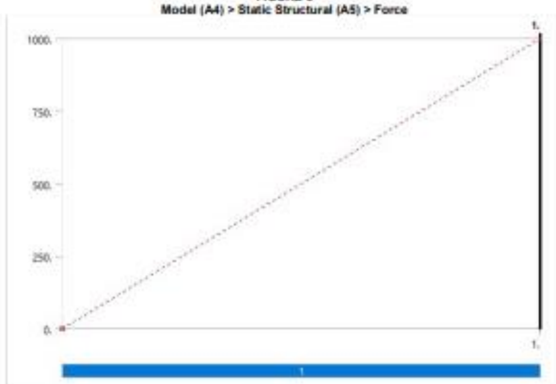


FIGURE 4
Model (A4) > Static Structural (A5) > Force 2

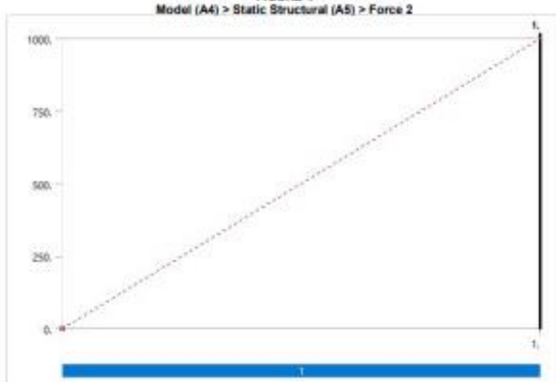


FIGURE 5
Model (A4) > Static Structural (A5) > Force 3

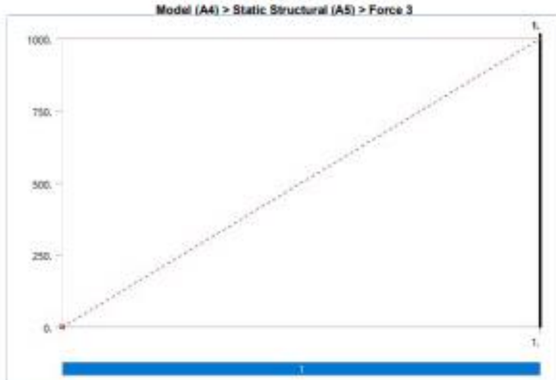
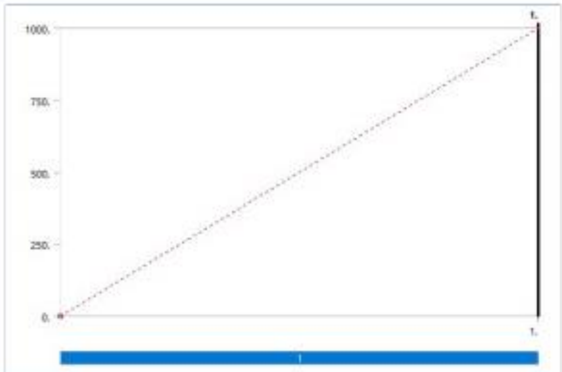


FIGURE 6
Model (A4) > Static Structural (A5) > Force 4



Solution (A6)

TABLE 25
Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	1 m 7 s
MAPDL Memory Used	6.5557 GB
MAPDL Result File Size	163.5 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 26
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 27
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Equivalent Elastic Strain*	*Equivalent Stress*	*Total Deformation*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Equivalent Elastic Strain	Equivalent (von-Mises) Stress	Total Deformation
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Integration Point Results			
Display Option	Averaged		
Average Across Bodies	No		
Results			
Minimum	2.1231e-009 in/in	9.554e-003 psi	0. in
Maximum	8.5962e-002 in/in	8.7017e+005 psi	2.2758 in
Average	1.6486e-003 in/in	15204 psi	0.75028 in
Minimum Occurs On	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 37.898_1\Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 37.898\Solid1
Maximum Occurs On	ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 8.10845212\Solid1		ASTM A513 - 3_2f_4 x 3_2f_4 x 83_2f_1000 - 18.38036945\Solid1
Information			
Time	1. s		
Load Step	1		
Substep	1		

Iteration Number	1

FIGURE 7
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain

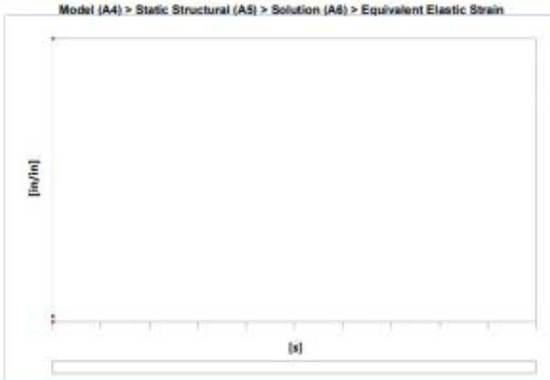


TABLE 28
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain

Time [s]	Minimum [in/in]	Maximum [in/in]	Average [in/in]
1.	2.1231e-009	8.5962e-002	1.6486e-003

FIGURE 8
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain > Strain 1000 lbf

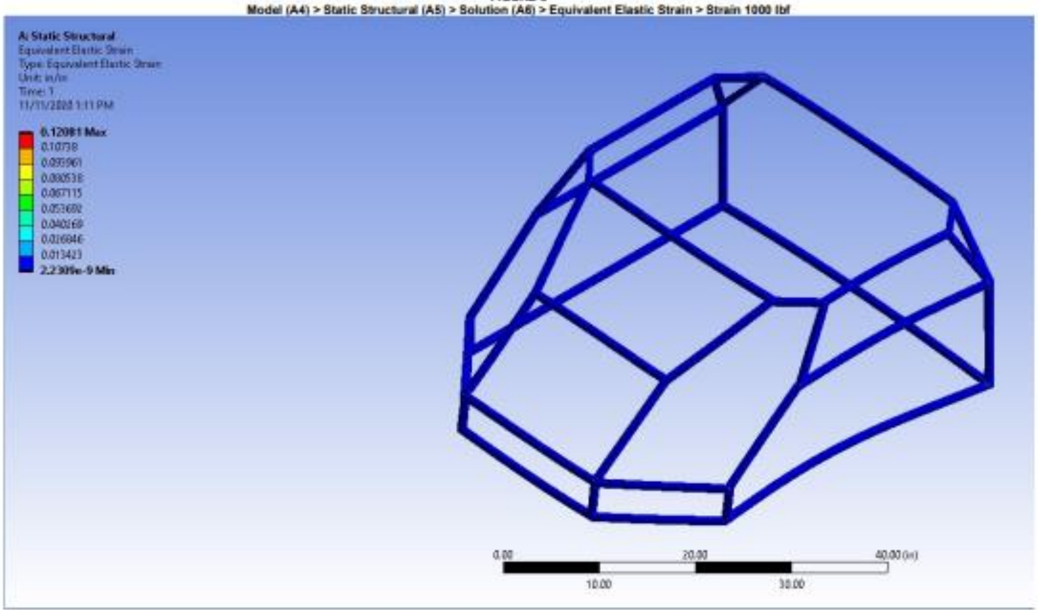


FIGURE 9
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

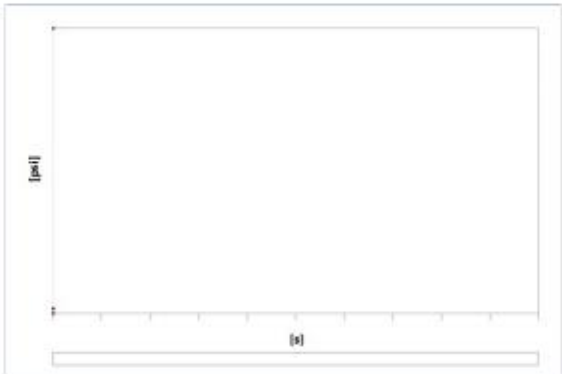


TABLE 29
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

Time [s]	Minimum [psi]	Maximum [psi]	Average [psi]
1.	9.554e-003	8.7017e+005	15204

FIGURE 10
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress > Stress 1000 lbf

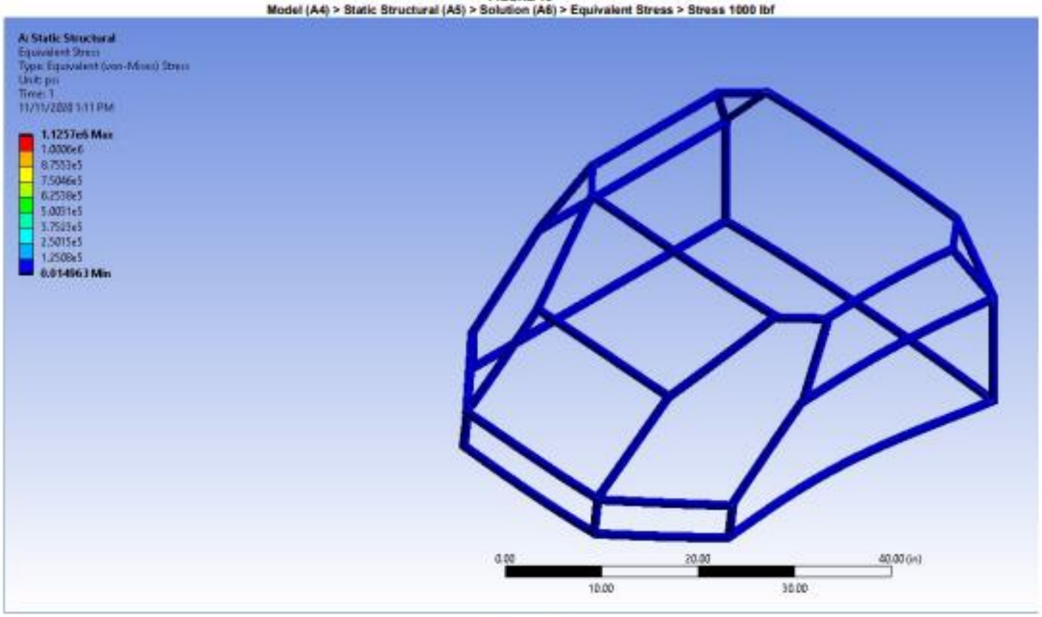


FIGURE 11
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

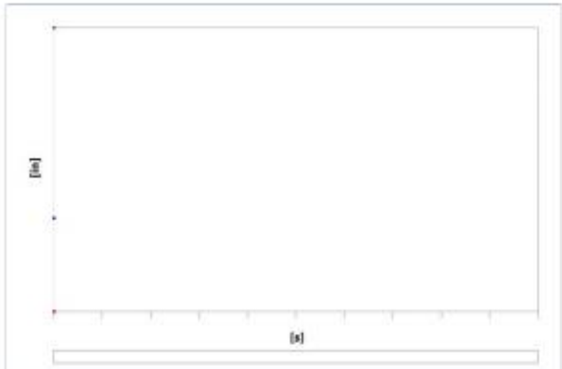
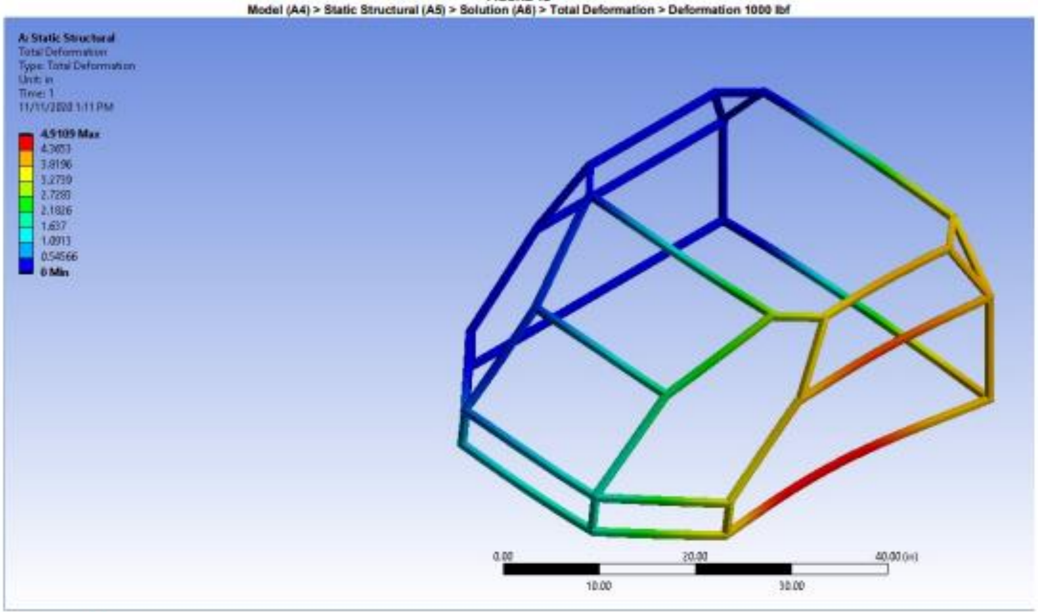


TABLE 30
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [in]	Maximum [in]	Average [in]
1.	0.	2.2758	0.75028

FIGURE 12
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation > Deformation 1000 lbf



Material Data

Aluminum Alloy

TABLE 31
Aluminum Alloy > Constants

Density	0.10007 lbm in^-3
Coefficient of Thermal Expansion	1.2778e-005 F^-1
Specific Heat	0.20899 BTU lbm^-1 F^-1

TABLE 32
Aluminum Alloy > Color

Red	Green	Blue
138	104	46

TABLE 33
Aluminum Alloy > Compressive Ultimate Strength

Compressive Ultimate Strength psi

0

TABLE 34
Aluminum Alloy > Compressive Yield Strength

Compressive Yield Strength psi
40611

TABLE 35
Aluminum Alloy > Tensile Yield Strength

Tensile Yield Strength psi
40611

TABLE 36
Aluminum Alloy > Tensile Ultimate Strength

Tensile Ultimate Strength psi
44962

TABLE 37
Aluminum Alloy > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature F
71.6

TABLE 38
Aluminum Alloy > Isotropic Thermal Conductivity

Thermal Conductivity BTU s^-1 in^-1 F^-1	Temperature F
1.5247e-003	-148
1.926e-003	32
2.2068e-003	212
2.3406e-003	392

TABLE 39
Aluminum Alloy > S-N Curve

Alternating Stress psi	Cycles	R-Ratio
40001	1700	-1
34998	5000	-1
29994	34000	-1
25005	1.4e+005	-1
20001	8.e+005	-1
16998	2.4e+006	-1
13000	5.5e+007	-1
12000	1.e+008	-1
24743	50000	-0.5
20247	3.5e+005	-0.5
15751	3.7e+006	-0.5
12750	1.4e+007	-0.5
11251	5.e+007	-0.5
10499	1.e+008	-0.5
21001	50000	0
17506	1.9e+005	0
14997	1.3e+006	0
13500	4.4e+006	0
12499	1.2e+007	0
10499	1.e+008	0
10750	3.e+005	0.5
10250	1.5e+006	0.5
9624.7	1.2e+007	0.5
8999.6	1.e+008	0.5

TABLE 40
Aluminum Alloy > Isotropic Resistivity

Resistivity ohm cmil in^-1	Temperature F
1.2184	32
1.3387	68
1.82	212

TABLE 41
Aluminum Alloy > Isotropic Elasticity

Young's Modulus psi	Poisson's Ratio	Bulk Modulus psi	Shear Modulus psi	Temperature F
1.0298e+007	0.33	1.0096e+007	3.8713e+006	

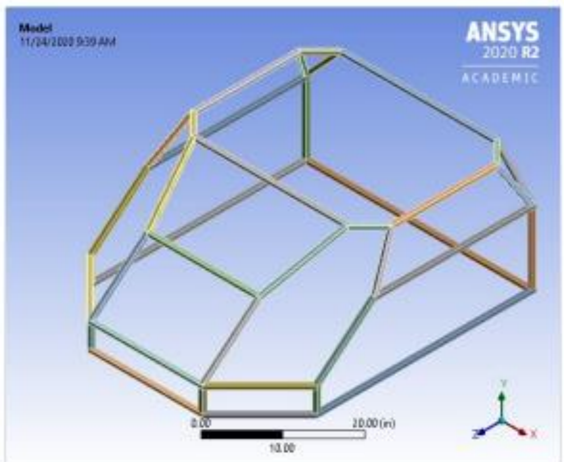
TABLE 42
Aluminum Alloy > Isotropic Relative Permeability

Relative Permeability
1

0 psi to 100000 psi (Pressure Loading) Static Structural Simulation

Project

First Saved	Thursday, November 12, 2020
Last Saved	Friday, November 13, 2020
Product Version	2020 R2
Save Project Before Solution	Yes
Save Project After Solution	Yes



Contents

Units

TABLE 1

Unit System	U.S. Customary (in, lbm, lbf, s, V, A) Degrees rad/s Fahrenheit
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Fahrenheit

Model (A4)

Geometry

TABLE 2
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\streetl3\Documents\ENT497 MPMT Project Files\MPMT Static Structural\Static Structure Cage (ANSYS).stp
Type	Step
Length Unit	Inches
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	40.097 in
Length Y	20.098 in
Length Z	47.796 in
Properties	
Volume	117.95 in³
Mass	11.803 lbm
Scale Factor Value	1.
Statistics	
Bodies	38
Active Bodies	38
Nodes	500963
Elements	240720
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	No
Parameters	Independent
Parameter Key	ANS;DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Clean Bodies On Import	No
Stitch Surfaces On Import	Program Tolerance
Decompose Disjoint Geometry	Yes

Enclosure and Symmetry Processing	Yes

TABLE 3
Model (A4) > Geometry > Parts

Object Name	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 27.234|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 27.209|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.33849583|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 18.38036945|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.346|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.346_1|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 18.38|Solid1*
State	Meshed						
Graphics Properties							
Visible	Yes						
Transparency	1						
Definition							
Suppressed	No						
Stiffness Behavior	Flexible						
Coordinate System	Default Coordinate System						
Reference Temperature	By Environment						
Treatment	None						
Material							
Assignment	Aluminum Alloy						
Nonlinear Effects	Yes						
Thermal Strain Effects	Yes						
Bounding Box							
Length X	27.234 in	27.209 in	4.3052 in	0.75 in	4.3102 in		0.75 in
Length Y	0.75 in						
Length Z	0.75 in		4.3052 in	18.38 in	4.3102 in		18.38 in
Properties							
Volume	5.7333 in³	5.7015 in³	1.0044 in³	3.8534 in³	1.0487 in³		3.8534 in³
Mass	0.57375 lbm	0.57056 lbm	0.10051 lbm	0.38562 lbm	0.10495 lbm		0.38562 lbm
Centroid X	-5.5844e-002 in		15.231 in	16.967 in	15.152 in	-15.263 in	-17.078 in
Centroid Y	20.028 in	20.029 in	20.043 in	20.03 in	20.032 in		20.03 in
Centroid Z	2.1339 in	-23.422 in	-21.592 in	-10.639 in	0.39472 in		-10.639 in
Moment of Inertia Ip1	34.707 lbm·in²	34.132 lbm·in²	0.19753 lbm·in²	10.554 lbm·in²	0.22122 lbm·in²	0.22147 lbm·in²	10.554 lbm·in²
Moment of Inertia Ip2	34.707 lbm·in²	34.133 lbm·in²	0.19696 lbm·in²	10.554 lbm·in²	0.22146 lbm·in²	0.22122 lbm·in²	10.554 lbm·in²
Moment of Inertia Ip3	8.4091e-002 lbm·in²	8.362e-002 lbm·in²	1.4668e-002 lbm·in²	5.6503e-002 lbm·in²	1.5345e-002 lbm·in²		5.6503e-002 lbm·in²
Statistics							
Nodes	22334	22812	4953	16139	5046	5001	16204
Elements	10782	11008	2337	7772	2379	2356	7777
Mesh Metric	None						

TABLE 4
Model (A4) > Geometry > Parts

Object Name	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 11.805|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 12.921|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.998|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.998_1|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 3.5|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 12.938|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 12.93787324|Solid1*
State	Meshed						
Graphics Properties							
Visible	Yes						
Transparency	1						
Definition							
Suppressed	No						
Stiffness Behavior	Flexible						
Coordinate System	Default Coordinate System						
Reference Temperature	By Environment						
Treatment	None						
Material							
Assignment	Aluminum Alloy						
Nonlinear Effects	Yes						
Thermal Strain Effects	Yes						
Bounding Box							
Length X	0.75 in		10.428 in		0.75 in		
Length Y	11.805 in	8.8799 in	0.75 in		3.5 in	8.8908 in	
Length Z	0.75 in	10.38 in	10.428 in		0.75 in	10.393 in	
Properties							
Volume	2.5124 in³	2.6852 in³	2.8686 in³	2.9147 in³	0.74487 in³	2.6203 in³	
Mass	0.25143 lbm	0.26871 lbm	0.28707 lbm	0.29168 lbm	7.4541e-002 lbm	0.26222 lbm	
Centroid X	19.467 in		14.558 in	14.631 in	9.5692 in	9.572 in	-9.6836 in
Centroid Y	7.0552 in	9.2839 in	5.0275 in	0.77754 in	2.9025 in	9.3614 in	
Centroid Z	-23.421 in	8.9005 in	18.867 in	18.789 in	23.625 in	18.71 in	
Moment of Inertia Ip1	2.9385 lbm·in²	3.5836 lbm·in²	4.3721 lbm·in²	4.5787 lbm·in²	8.1555e-002 lbm·in²	3.3451 lbm·in²	
Moment of Inertia Ip2	2.9385 lbm·in²	3.5836 lbm·in²	4.372 lbm·in²	4.5787 lbm·in²	8.1555e-002 lbm·in²	3.345 lbm·in²	
Moment of Inertia Ip3	3.6838e-002 lbm·in²	3.9379e-002 lbm·in²	4.2056e-002 lbm·in²	4.2745e-002 lbm·in²	1.0921e-002 lbm·in²	3.8349e-002 lbm·in²	

						Statistics	
Nodes	10837	11188	12168	12016	3627	14526	14601
Elements	5177	5328	5826	5742	1687	6959	7011
Mesh Metric	None						

TABLE 5
Model (A4) > Geometry > Parts

Object Name	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.998_3|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 4.25_1|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 37.898_1|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 28_1|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 11.805_1|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 39.796|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 3.5_1|Solid1*
State	Meshed						
						Graphics Properties	
Visible	Yes						
Transparency	1						
						Definition	
Suppressed	No						
Stiffness Behavior	Flexible						
Coordinate System	Default Coordinate System						
Reference Temperature	By Environment						
Treatment	None						
						Material	
Assignment	Aluminum Alloy						
Nonlinear Effects	Yes						
Thermal Strain Effects	Yes						
						Bounding Box	
Length X	10.428 in	0.75 in				39.796 in	0.7
Length Y	0.75 in	4.25 in	0.75 in		11.805 in	0.75 in	3.5 in
Length Z	10.428 in	0.75 in	37.898 in	28. in	0.75 in		
						Properties	
Volume	2.9147 in^3	0.86762 in^3	7.9594 in^3	5.9323 in^3	2.5124 in^3	8.3164 in^3	0.74487 in^3
Mass	0.29168 lbm	8.6825e-002 lbm	0.79652 lbm	0.59366 lbm	0.25143 lbm	0.83224 lbm	7.4541e-002 lbm
Centroid X	-14.743 in	-19.579 in	-19.582 in	-19.579 in		-5.5844e-002 in	-9.6808 in
Centroid Y	0.77754 in	3.1923 in	0.77754 in	13.334 in	7.0552 in	0.77754 in	2.9025 in
Centroid Z	18.789 in	13.735 in	-4.7386 in	-9.8627 in	-23.421 in	-23.425 in	23.625 in
Moment of Inertia Ip1	4.5787 lbm·in^2	0.1272 lbm·in^2	92.771 lbm·in^2	38.454 lbm·in^2	2.9385 lbm·in^2	105.86 lbm·in^2	8.1555e-002 lbm·in^2
Moment of Inertia Ip2	4.5787 lbm·in^2	0.12722 lbm·in^2	92.771 lbm·in^2	38.454 lbm·in^2	2.9385 lbm·in^2	105.86 lbm·in^2	8.1555e-002 lbm·in^2
Moment of Inertia Ip3	4.2745e-002 lbm·in^2	1.2699e-002 lbm·in^2	0.11675 lbm·in^2	8.7e-002 lbm·in^2	3.6838e-002 lbm·in^2	0.12198 lbm·in^2	1.0921e-002 lbm·in^2
						Statistics	
Nodes	12028	4098	31768	23204	10837	33204	3627
Elements	5752	1904	15464	11217	5177	16097	1687
Mesh Metric	None						

TABLE 6
Model (A4) > Geometry > Parts

Object Name	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 8.10845212|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 8.108|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.10070407_1|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.91634287|Solid1*	*Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.91634287_1|Solid1*
State	Meshed				
			Graphics Properties		
Visible	Yes				
Transparency	1				
			Definition		
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Treatment	None				
			Material		
Assignment	Aluminum Alloy				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
			Bounding Box		
Length X	3.3326 in		3.3897 in	4.3545 in	
Length Y	7.3052 in		7.4579 in	7.4667 in	
Length Z	4.455 in		6.1336 in	12.183 in	
			Properties		
Volume	1.5233 in^3		1.7688 in^3	2.8547 in^3	
Mass	0.15244 lbm		0.17681 lbm	0.28568 lbm	
Centroid X	18.288 in	-18.379 in	-18.409 in	11.371 in	-11.483 in
Centroid Y	16.895 in		16.796 in	16.737 in	
Centroid Z	-21.494 in		1.1058 in	8.1123 in	
Moment of Inertia Ip1	0.67353 lbm·in^2		1.0349 lbm·in^2	4.3065 lbm·in^2	
Moment of Inertia Ip2	0.67428 lbm·in^2		1.0352 lbm·in^2	4.3066 lbm·in^2	
Moment of					

Inertia Ip3	2.2225e-002 lbm·in²		2.5845e-002 lbm·in²	4.1837e-002 lbm·in²	
Statistics					
Nodes	7163	7210	8148	12172	12099
Elements	3419	3429	3904	5841	5801
Mesh Metric	None				

TABLE 7
Model (A4) > Materials

Object Name	Materials
State	Fully Defined
Statistics	
Materials	2
Material Assignments	0

Coordinate Systems

TABLE 8
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. in
Origin Y	0. in
Origin Z	0. in
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Connections

TABLE 9
Model (A4) > Connections

Object Name	Connections
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes

TABLE 10
Model (A4) > Connections > Contacts

Object Name	Contacts
State	Fully Defined
Definition	
Connection Type	Contact
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Auto Detection	
Tolerance Type	Slider
Tolerance Slider	0.
Tolerance Value	0.16386 in
Use Range	No
Face/Face	Yes
Face-Face Angle Tolerance	75. °
Face Overlap Tolerance	Off
Cylindrical Faces	Include
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies
Statistics	
Connections	74
Active Connections	74

TABLE 11
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region*	*Contact Region 2*	*Contact Region 3*	*Contact Region 4*	*Contact Region 5*	*Contact Region 6*	*Contact Region 7*	*C*
State	Fully Defined							
Scope								
Scoping Method	Geometry Selection							
Contact	1 Face		3 Faces		1 Face	2 Faces		
Target	1 Face					2 Faces		
Contact Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 27.234|Solid1				Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 27.209			
Target Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.346|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.346_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.91634287|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.91634287_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.33849583|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.338|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.161|Solid1	160[illegible]
Protected	No							
Definition								

Type	Bonded
Scope Mode	Automatic
Behavior	Program Controlled
Trim Contact	Program Controlled
Trim Tolerance	0.16386 in
Suppressed	No
Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 12
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 12*	*Contact Region 13*	*Contact Region 14*	*Contact Region 15*	*Contact Region 16*	*Contact Region 17*	*Contact Region 18*	*Cc*
State	Fully Defined							
Scope								
Scoping Method	Geometry Selection							
Contact	1 Face							
Target	1 Face							
Contact Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 18.38036945|Solid1			Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.346|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.346_1|Solid1		Frame 1603995912769|ASTI	
Target Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.346|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.10070407|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 8.10845212|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.10070407|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 18.38|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.10070407_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 5.338|Solid1	1603 A 83/1
Protected	No							
Definition								
Type	Bonded							
Scope Mode	Automatic							
Behavior	Program Controlled							
Trim Contact	Program Controlled							
Trim Tolerance	0.16386 in							
Suppressed	No							
Advanced								
Formulation	Program Controlled							
Small Sliding	Program Controlled							
Detection Method	Program Controlled							
Penetration Tolerance	Program Controlled							
Elastic Slip Tolerance	Program Controlled							
Normal Stiffness	Program Controlled							
Update Stiffness	Program Controlled							
Pinball Region	Program Controlled							
Geometric Modification								
Contact Geometry Correction	None							
Target Geometry Correction	None							

TABLE 13
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 23*	*Contact Region 24*	*Contact Region 25*	*Contact Region 26*	*Contact Region 27*	*Contact Region 28*	*Contact Region 29*	*Cc*
State	Fully Defined							
Scope								

Scoping Method	Geometry Selection							
Contact	3 Faces	1 Face	3 Faces					
Target	1 Face							
Contact Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 28|Solid1					Frame 1603995912769|ASTM A513 - 3/4		
Target Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 11.805|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 12.921|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.161|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.10070407|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 8.10845212|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 4.25|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 11.805|Solid1	160 A 1
Protected	No							
Definition								
Type	Bonded							
Scope Mode	Automatic							
Behavior	Program Controlled							
Trim Contact	Program Controlled							
Trim Tolerance	0.16386 in							
Suppressed	No							
Advanced								
Formulation	Program Controlled							
Small Sliding	Program Controlled							
Detection Method	Program Controlled							
Penetration Tolerance	Program Controlled							
Elastic Slip Tolerance	Program Controlled							
Normal Stiffness	Program Controlled							
Update Stiffness	Program Controlled							
Pinball Region	Program Controlled							
Geometric Modification								
Contact Geometry Correction	None							
Target Geometry Correction	None							

TABLE 14
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 34*	*Contact Region 35*	*Contact Region 36*	*Contact Region 37*	*Contact Region 38*	*Contact Region 39*	*Contact Region 40*	*Co Reg*
State	Fully Defined							
Scope								
Scoping Method	Geometry Selection							
Contact	1 Face			3 Faces	4 Faces	3 Faces		
Target	3 Faces		1 Face		2 Faces	3 Faces	1 Face	
Contact Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 4.25|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 11.805|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 12.921|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.998|Solid1			Frame 1603995912769|AS A513 - 3/4 x 3/4 x 83/100 13.998_1|Solid1	
Target Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.998_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 39.796|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.10070407|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 3.5|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 12.938|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 20_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 3.5|Solid1	160 A 83
Protected	No							
Definition								
Type	Bonded							
Scope Mode	Automatic							
Behavior	Program Controlled							
Trim Contact	Program Controlled							
Trim Tolerance	0.16386 in							
Suppressed	No							
Advanced								
Formulation	Program Controlled							
Small Sliding	Program Controlled							
Detection Method	Program Controlled							
Penetration Tolerance	Program Controlled							
Elastic Slip Tolerance	Program Controlled							
Normal Stiffness	Program Controlled							
Update Stiffness	Program Controlled							
Pinball Region	Program Controlled							

	Geometric Modification
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 15
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 45*	*Contact Region 46*	*Contact Region 47*	*Contact Region 48*	*Contact Region 49*	*Contact Region 50*	*Contact Region 51*	*Co*
State	Fully Defined							
	Scope							
Scoping Method	Geometry Selection							
Contact	1 Face	5 Faces	2 Faces	1 Face		5 Faces	2 Faces	
Target	3 Faces	6 Faces	2 Faces	3 Faces		6 Faces	2 Faces	
Contact Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 12.938|Solid1		Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 12.93787324|Solid1				Frame 1603995912769|AST x 83/1000 - 19.32772	
Target Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 20_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.91634287|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 19.32772998|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 20_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.998_2|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.91634287_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.91634287|Solid1	1603 A 13.9
Protected	No							
	Definition							
Type	Bonded							
Scope Mode	Automatic							
Behavior	Program Controlled							
Trim Contact	Program Controlled							
Trim Tolerance	0.16386 in							
Suppressed	No							
	Advanced							
Formulation	Program Controlled							
Small Sliding	Program Controlled							
Detection Method	Program Controlled							
Penetration Tolerance	Program Controlled							
Elastic Slip Tolerance	Program Controlled							
Normal Stiffness	Program Controlled							
Update Stiffness	Program Controlled							
Pinball Region	Program Controlled							
	Geometric Modification							
Contact Geometry Correction	None							
Target Geometry Correction	None							

TABLE 16
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 56*	*Contact Region 57*	*Contact Region 58*	*Contact Region 59*	*Contact Region 60*	*Contact Region 61*	*Contact Region 62*	*Co*
State	Fully Defined							
	Scope							
Scoping Method	Geometry Selection							
Contact	3 Faces	1 Face	3 Faces		1 Face	3 Faces	1 Face	
Target	1 Face	3 Faces	1 Face				3 Faces	
Contact Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 20_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.998_2|Solid1		Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.998_3|Solid1			Frame 1603995912769|AST x 83/1000 - 4.25_	
Target Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 3.5_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 4.25_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 3.5_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 4.25_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 37.898_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 3.5_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 37.898_1|Solid1	1603 A 1
Protected	No							
	Definition							
Type	Bonded							
Scope Mode	Automatic							
Behavior	Program Controlled							
Trim Contact	Program Controlled							
Trim Tolerance	0.16386 in							
Suppressed	No							
	Advanced							

Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 17
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 67*	*Contact Region 68*	*Contact Region 69*	*Contact Region 70*	*Contact Region 71*	*Contact Region 72*	*Contact Region 73*	*Co*
State	Fully Defined							
Scope								
Scoping Method	Geometry Selection							
Contact	1 Face	3 Faces			1 Face		2 Faces	
Target	1 Face				3 Faces	1 Face	2 Faces	
Contact Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 28_1|Solid1				Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 11.805_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 12.921_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.161|Solid1	1603 A
Target Bodies	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 12.921_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.161_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 8.108|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.10070407_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 39.796|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 9.10070407_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 8.10845212|Solid1	1603 A 83/1
Protected	No							
Definition								
Type	Bonded							
Scope Mode	Automatic							
Behavior	Program Controlled							
Trim Contact	Program Controlled							
Trim Tolerance	0.16386 in							
Suppressed	No							
Advanced								
Formulation	Program Controlled							
Small Sliding	Program Controlled							
Detection Method	Program Controlled							
Penetration Tolerance	Program Controlled							
Elastic Slip Tolerance	Program Controlled							
Normal Stiffness	Program Controlled							
Update Stiffness	Program Controlled							
Pinball Region	Program Controlled							
Geometric Modification								
Contact Geometry Correction	None							
Target Geometry Correction	None							

Mesh

TABLE 18
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	0.25 in
Sizing	
Use Adaptive Sizing	Yes

Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	65.545 in
Average Surface Area	4.0225 in²
Minimum Edge Length	1.431e-003 in
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	500963
Elements	240720

TABLE 19
Model (A4) > Mesh > Mesh Controls

Object Name	*Patch Conforming Method*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	38 Bodies
Definition	
Suppressed	No
Method	Tetrahedrons
Algorithm	Patch Conforming
Element Order	Use Global Setting

Named Selections

TABLE 20
Model (A4) > Named Selections > Named Selections

Object Name	*Bottom of Frame*	*Entire Frame*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	6 Faces	706 Faces
Definition		
Send to Solver	Yes	
Protected	Program Controlled	
Visible	Yes	
Program Controlled Inflation	Exclude	
Statistics		
Type	Manual	
Total Selection	6 Faces	706 Faces
Surface Area	88.594 in²	2775.4 in²
Suppressed	0	
Used by Mesh Worksheet	No	

Static Structural (A5)

TABLE 21
Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	71.6 °F
Generate Input Only	No

TABLE 22
Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined

Step Controls	
Number Of Steps	21.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Off
Output Controls	
Stress	Yes
Surface Stress	No
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	C:\Users\streetl3\Documents\ENT497 MPMT Project Files\MPMT Static Structural\MPMT Static Loading (Pressure)_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	Bin

TABLE 23
Model (A4) > Static Structural (A5) > Analysis Settings
Step-Specific "Step Controls"

Step	Step End Time
1	1. s
2	2. s
3	3. s
4	4. s
5	5. s
6	6. s
7	7. s
8	8. s
9	9. s
10	10. s
11	11. s
12	12. s
13	13. s
14	14. s
15	15. s
16	16. s
17	17. s
18	18. s
19	19. s
20	20. s
21	21. s

FIGURE 1
Model (A4) > Static Structural (A5) > Analysis Conditions

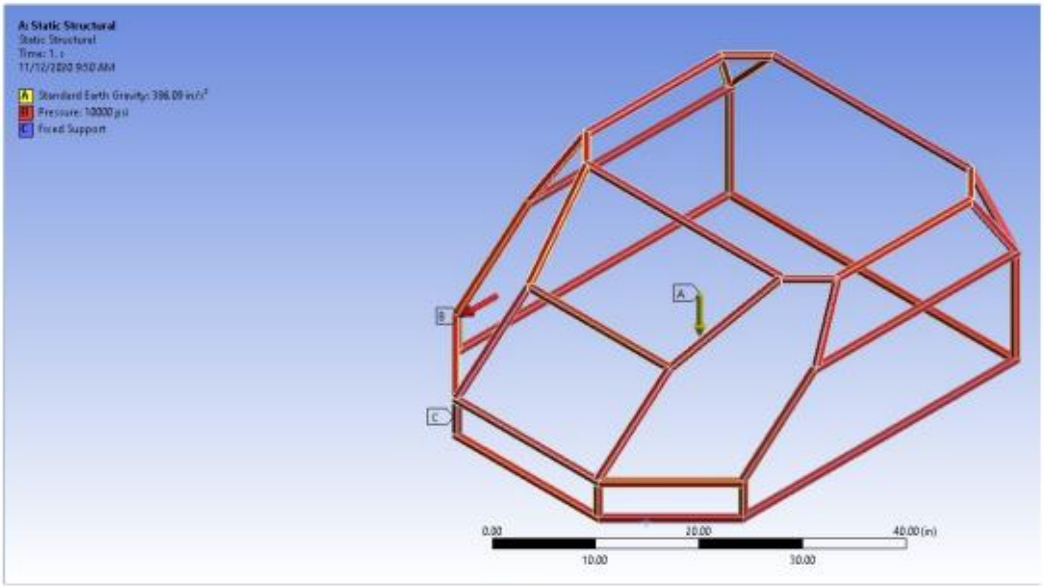


TABLE 24
Model (A4) > Static Structural (A5) > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
Coordinate System	Global Coordinate System
X Component	0. in/s² (ramped)
Y Component	-386.09 in/s² (ramped)
Z Component	0. in/s² (ramped)
Suppressed	No
Direction	-Y Direction

FIGURE 2
Model (A4) > Static Structural (A5) > Standard Earth Gravity

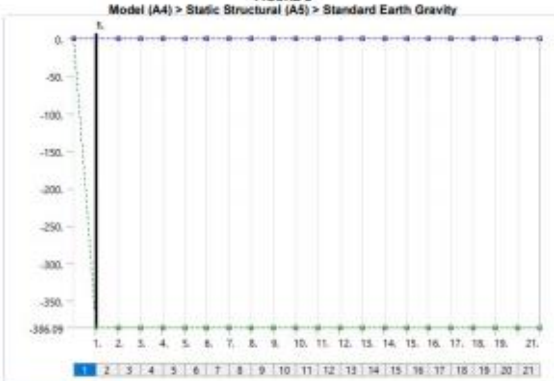


TABLE 25
Model (A4) > Static Structural (A5) > Loads

Object Name	*Pressure*	*Fixed Support*
State	Fully Defined	
Scope		
Scoping Method	Named Selection	
Named Selection	Entire Frame	Bottom of Frame
Definition		
Type	Pressure	Fixed Support
Define By	Normal To	
Applied By	Surface Effect	

Loaded Area	Deformed	
Magnitude	Tabular Data	
Suppressed	No	
Tabular Data		
Independent Variable	Time	

FIGURE 3
Model (A4) > Static Structural (A5) > Pressure

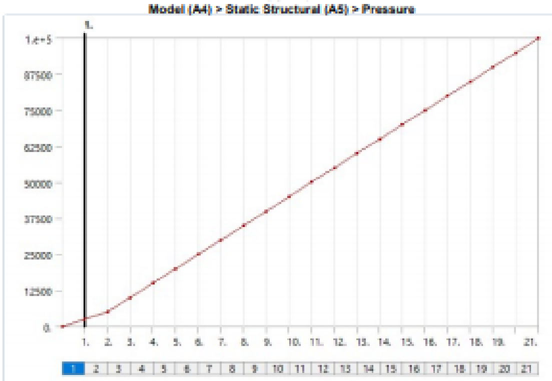


TABLE 26
Model (A4) > Static Structural (A5) > Pressure

Steps	Time [s]	Pressure [psi]
1	0.	0.
	1.	2500.
2	2.	5000.
3	3.	10000
4	4.	15000
5	5.	20000
6	6.	25000
7	7.	30000
8	8.	35000
9	9.	40000
10	10.	45000
11	11.	50000
12	12.	55000
13	13.	60000
14	14.	65000
15	15.	70000
16	16.	75000
17	17.	80000
18	18.	85000
19	19.	90000
20	20.	95000
21	21.	1.e+005

Solution (A6)

TABLE 27
Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	13 m 53 s
MAPDL Memory Used	6.8379 GB
MAPDL Result File Size	2.4369 GB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 28
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes

Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 29
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Equivalent Elastic Strain*	*Equivalent Stress*	*Total Deformation*	*Maximum Shear Stress*	*Equivalent Plastic Strain*	*Structural Error*
State	Solved					
Scope						
Scoping Method	Geometry Selection					
Geometry	All Bodies					
Definition						
Type	Equivalent Elastic Strain	Equivalent (von-Mises) Stress	Total Deformation	Maximum Shear Stress	Equivalent Plastic Strain	Structural Error
By	Time					
Display Time	Last					
Calculate Time History	Yes					
Identifier						
Suppressed	No					
Integration Point Results						
Display Option	Averaged			Averaged		
Average Across Bodies	No			No		
Results						
Minimum	2.719e-007 in/in	1.2483 psi	0. in	0.68994 psi	0. in/in	1.3754e-016 BTU
Maximum	1.8804e-002 in/in	1.8745e+005 psi	0.13689 in	1.0385e+005 psi	0. in/in	2.862e-005 BTU
Average	1.1356e-003 in/in	10863 psi	6.8955e-002 in	5818.1 psi	0. in/in	
Minimum Occurs On	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 27.234|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 20_1|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 37.898|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 20_1|Solid1		Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 27.234|Solid1
Maximum Occurs On	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.998_3|Solid1		Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 27.209|Solid1	Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 13.998_3|Solid1		Frame 1603995912769|ASTM A513 - 3/4 x 3/4 x 83/1000 - 20|Solid1
Total						3.4043e-002 BTU
Minimum Value Over Time						
Minimum	1.7072e-008 in/in	5.6692e-002 psi	0. in	2.8346e-002 psi	0. in/in	1.2687e-018 BTU
Maximum	2.719e-007 in/in	1.2483 psi	0. in	0.68994 psi	0. in/in	1.3754e-016 BTU
Maximum Value Over Time						
Minimum	4.6901e-004 in/in	4675.9 psi	4.8219e-003 in	2590.5 psi	0. in/in	1.7811e-008 BTU
Maximum	1.8804e-002 in/in	1.8745e+005 psi	0.13689 in	1.0385e+005 psi	0. in/in	2.862e-005 BTU
Information						
Time	21. s					
Load Step	21					
Substep	1					
Iteration Number	21					

FIGURE 4
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain

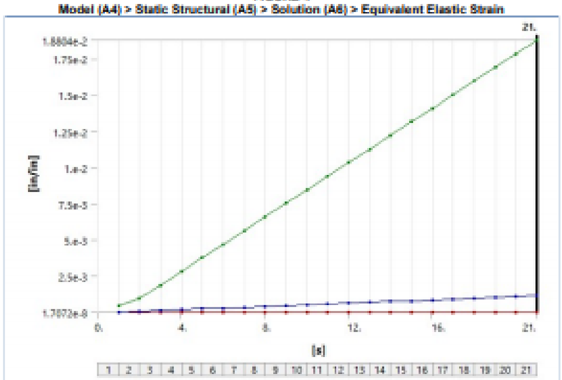


TABLE 30
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain

Time [s]	Minimum [in/in]	Maximum [in/in]	Average [in/in]
1.	5.7871e-008	4.6901e-004	2.9026e-005
2.	4.6018e-008	9.3913e-004	5.7233e-005
3.	1.7072e-008	1.8794e-003	1.1391e-004
4.	2.8565e-008	2.8196e-003	1.7064e-004

5.	2.846e-008	3.7599e-003	2.2739e-004
6.	1.2845e-007	4.7001e-003	2.8415e-004
7.	1.0406e-007	5.6404e-003	3.4091e-004
8.	8.0309e-008	6.5806e-003	3.9767e-004
9.	8.1125e-008	7.5209e-003	4.5444e-004
10.	8.9417e-008	8.4611e-003	5.112e-004
11.	1.0195e-007	9.4014e-003	5.6797e-004
12.	1.1679e-007	1.0342e-002	6.2474e-004
13.	1.1821e-007	1.1282e-002	6.815e-004
14.	1.1873e-007	1.2222e-002	7.3827e-004
15.	1.1664e-007	1.3162e-002	7.9504e-004
16.	1.2e-007	1.4103e-002	8.5181e-004
17.	1.3857e-007	1.5043e-002	9.0857e-004
18.	1.449e-007	1.5983e-002	9.6534e-004
19.	1.674e-007	1.6923e-002	1.0221e-003
20.	2.1588e-007	1.7864e-002	1.0789e-003
21.	2.719e-007	1.8804e-002	1.1356e-003

FIGURE 5
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain > Strain

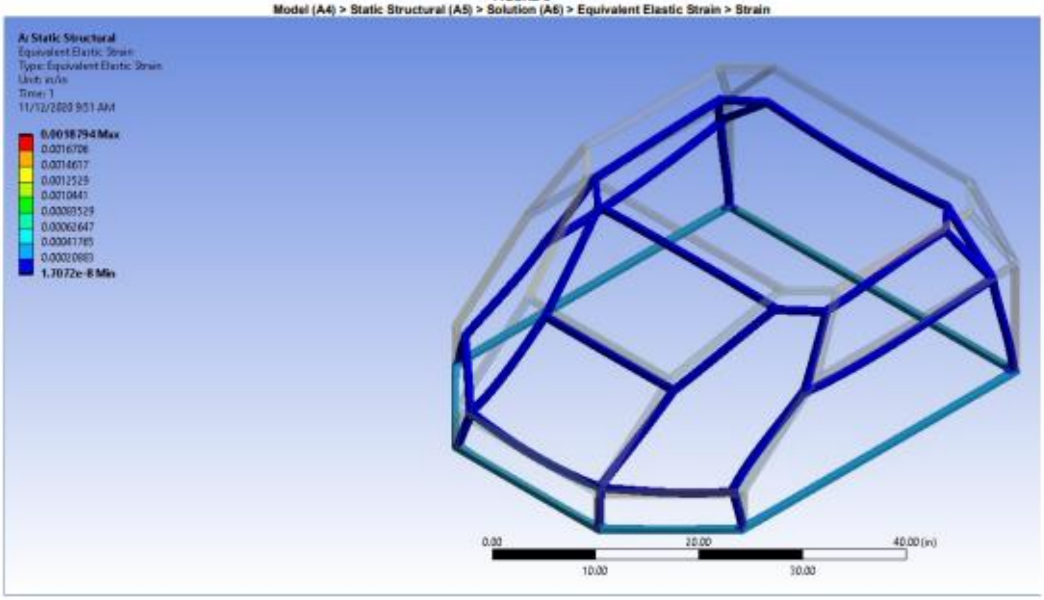


FIGURE 6
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

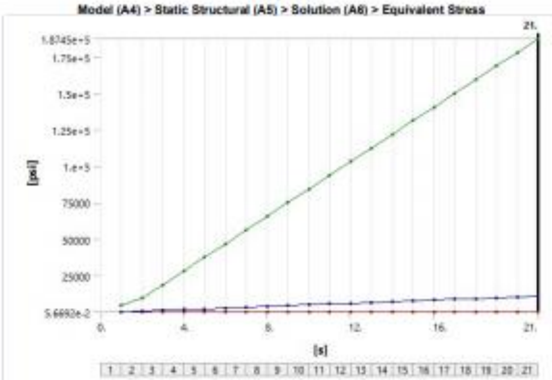


TABLE 31
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

Time [s]	Minimum [psi]	Maximum [psi]	Average [psi]
1.	0.13432	4675.9	277.63
2.	7.7391e-002	9362.5	547.46

3.	7.2004e-002	18736	1089.5
4.	0.23028	28109	1632.2
5.	5.6692e-002	37482	2175.1
6.	9.6298e-002	46855	2718.
7.	0.18508	56229	3260.9
8.	0.2138	65602	3803.9
9.	0.19058	74975	4346.9
10.	0.20869	84348	4889.9
11.	0.34557	93722	5432.8
12.	0.41201	1.0309e+005	5975.8
13.	0.34297	1.1247e+005	6518.8
14.	0.29723	1.2184e+005	7061.9
15.	0.21546	1.3121e+005	7604.9
16.	0.21585	1.4059e+005	8147.9
17.	0.21887	1.4996e+005	8690.9
18.	0.33739	1.5933e+005	9233.9
19.	0.36107	1.6871e+005	9776.9
20.	0.84704	1.7808e+005	10320
21.	1.2483	1.8745e+005	10863

FIGURE 7
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress > Stress

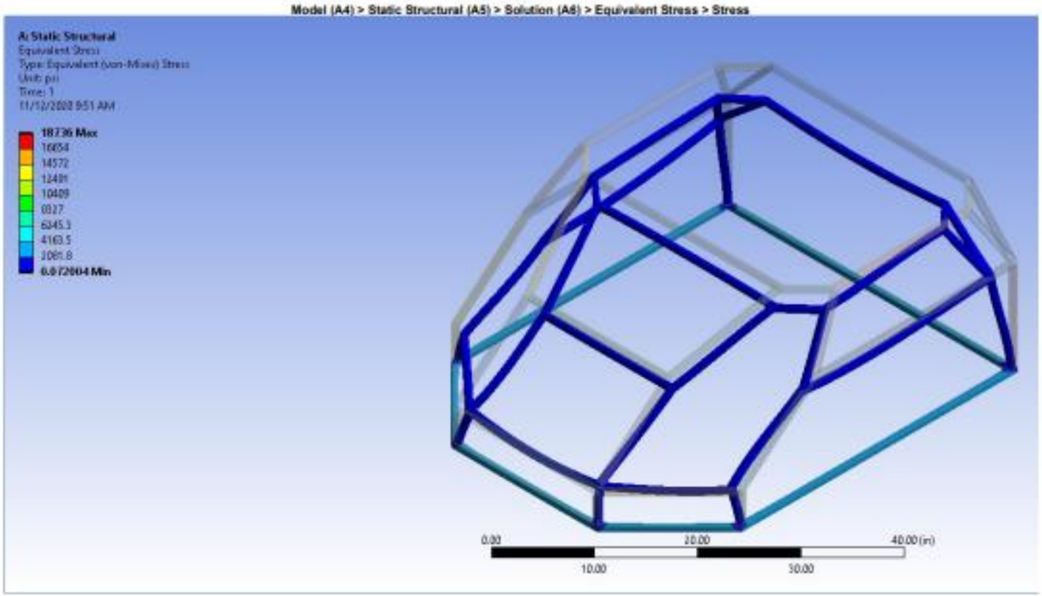


FIGURE 8
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

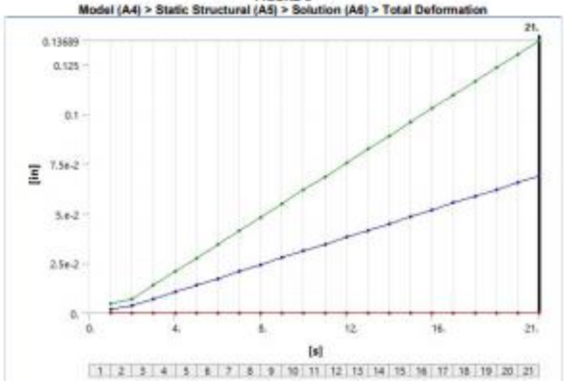


TABLE 32
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [in]	Maximum [in]	Average [in]

1.		4.8219e-003	2.0329e-003
2.		7.1834e-003	3.7126e-003
3.		1.3926e-002	7.1273e-003
4.		2.0732e-002	1.0556e-002
5.		2.7553e-002	1.3988e-002
6.		3.438e-002	1.7422e-002
7.		4.1209e-002	2.0856e-002
8.		4.8041e-002	2.4291e-002
9.		5.4873e-002	2.7726e-002
10.		6.1706e-002	3.1162e-002
11.	0.	6.854e-002	3.4597e-002
12.		7.5374e-002	3.8033e-002
13.		8.2208e-002	4.1469e-002
14.		8.9043e-002	4.4904e-002
15.		9.5877e-002	4.834e-002
16.		0.10271	5.1776e-002
17.		0.10955	5.5212e-002
18.		0.11638	5.8648e-002
19.		0.12322	6.2084e-002
20.		0.13006	6.5519e-002
21.		0.13689	6.8955e-002

FIGURE 9
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation > Deformation

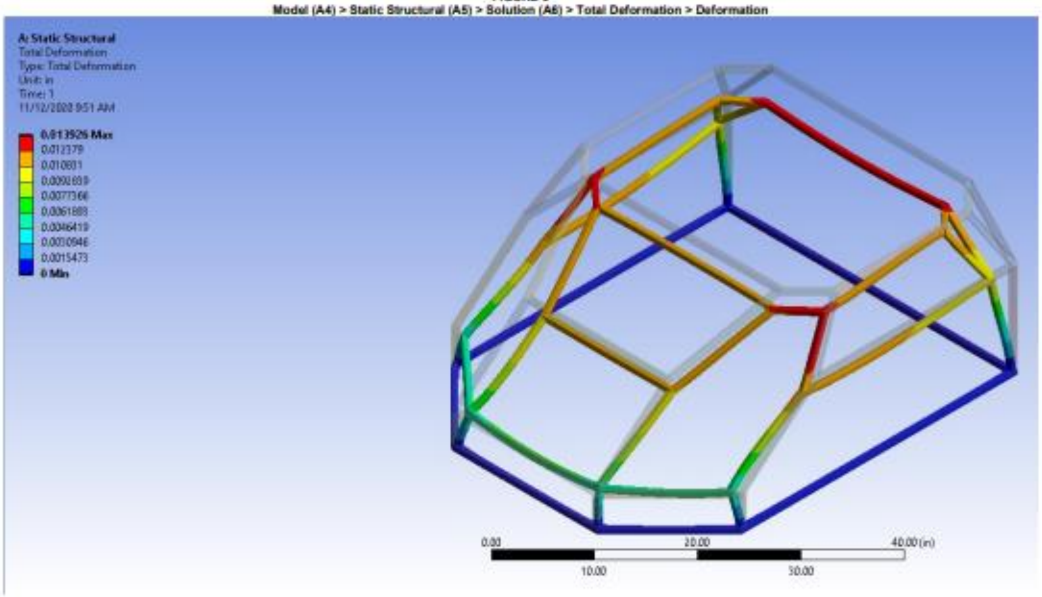


FIGURE 10
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Shear Stress

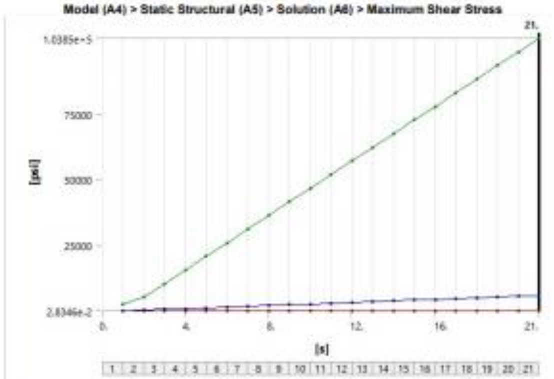


TABLE 33
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Shear Stress

Time [s]	Minimum [psi]	Maximum [psi]	Average [psi]
1.	7.7443e-002	2590.5	148.56
2.	4.25e-002	5186.9	293.1
3.	3.6002e-002	10380	583.44
4.	0.11514	15573	874.1
5.	2.8346e-002	20766	1164.8
6.	4.8149e-002	25959	1455.6
7.	9.2538e-002	31152	1746.4
8.	0.1069	36345	2037.3
9.	9.529e-002	41538	2328.1
10.	0.12049	46731	2618.9
11.	0.17279	51924	2909.7
12.	0.206	57117	3200.6
13.	0.17148	62310	3491.4
14.	0.14861	67503	3782.2
15.	0.10773	72696	4073.1
16.	0.10792	77889	4363.9
17.	0.10943	83081	4654.7
18.	0.19479	88274	4945.6
19.	0.18054	93467	5236.4
20.	0.48904	98660	5527.2
21.	0.68994	1.0385e+005	5818.1

FIGURE 11
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Shear Stress > Shear Stress

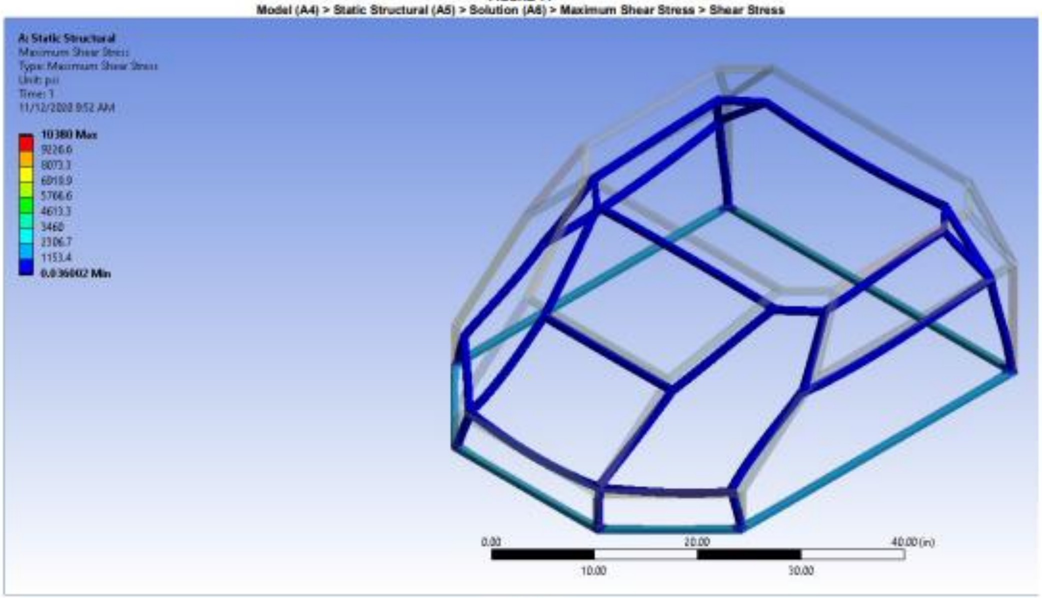


FIGURE 12
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Plastic Strain

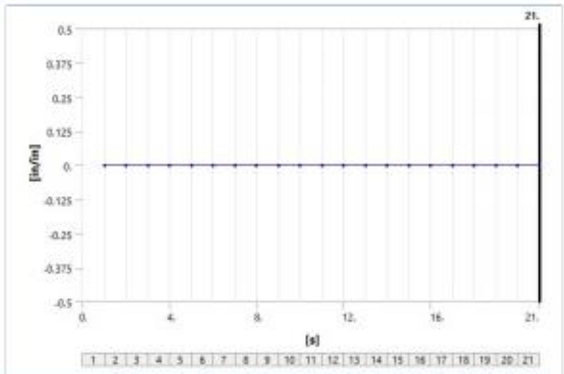


TABLE 34

Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Plastic Strain

Time [s]	Minimum [in/in]	Maximum [in/in]	Average [in/in]
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.	0.	0.	0.
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.			
20.			
21.			

FIGURE 13

Model (A4) > Static Structural (A5) > Solution (A6) > Structural Error

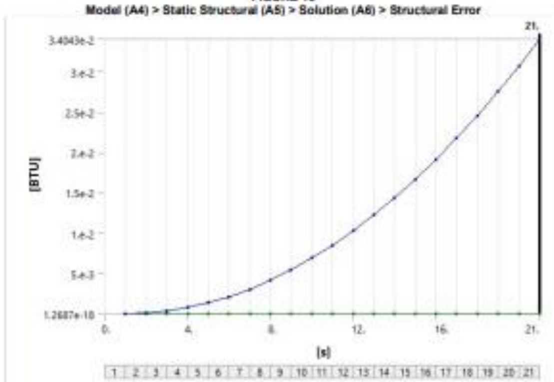


TABLE 35

Model (A4) > Static Structural (A5) > Solution (A6) > Structural Error

Time [s]	Minimum [BTU]	Maximum [BTU]	Total [BTU]
1.	1.2687e-018	1.7811e-008	2.1269e-005
2.	2.1889e-018	7.1402e-008	8.5055e-005
3.	5.1505e-018	2.8592e-007	3.403e-004
4.	7.7552e-018	6.4356e-007	7.6577e-004
5.	1.1167e-017	1.1443e-006	1.3615e-003
6.	1.5386e-017	1.7882e-006	2.1274e-003
7.	1.8422e-017	2.5752e-006	3.0635e-003
8.	2.1867e-017	3.5053e-006	4.1699e-003
9.	2.6594e-017	4.5785e-006	5.4465e-003

10.	2.9529e-017	5.7948e-006	6.8933e-003
11.	3.3323e-017	7.1543e-006	8.5104e-003
12.	3.8517e-017	8.6589e-006	1.0298e-002
13.	4.5151e-017	1.0303e-005	1.2255e-002
14.	5.3083e-017	1.2091e-005	1.4383e-002
15.	6.235e-017	1.4023e-005	1.6681e-002
16.	7.3362e-017	1.6098e-005	1.9149e-002
17.	8.5825e-017	1.8317e-005	2.1787e-002
18.	9.9291e-017	2.0678e-005	2.4596e-002
19.	1.146e-016	2.3182e-005	2.7575e-002
20.	1.2699e-016	2.583e-005	3.0724e-002
21.	1.3754e-016	2.862e-005	3.4043e-002

Material Data

Aluminum Alloy

TABLE 36
Aluminum Alloy > Constants

Density	0.10007 lbm in^-3
Coefficient of Thermal Expansion	1.2778e-005 F^-1
Specific Heat	0.20899 BTU lbm^-1 F^-1

TABLE 37
Aluminum Alloy > Color

Red	Green	Blue
138	104	46

TABLE 38
Aluminum Alloy > Compressive Ultimate Strength

Compressive Ultimate Strength psi
0

TABLE 39
Aluminum Alloy > Compressive Yield Strength

Compressive Yield Strength psi
40611

TABLE 40
Aluminum Alloy > Tensile Yield Strength

Tensile Yield Strength psi
40611

TABLE 41
Aluminum Alloy > Tensile Ultimate Strength

Tensile Ultimate Strength psi
44962

TABLE 42
Aluminum Alloy > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature F
71.6

TABLE 43
Aluminum Alloy > Isotropic Thermal Conductivity

Thermal Conductivity BTU s^-1 in^-1 F^-1	Temperature F
1.5247e-003	-148
1.926e-003	32
2.2068e-003	212
2.3406e-003	392

TABLE 44
Aluminum Alloy > S-N Curve

Alternating Stress psi	Cycles	R-Ratio
40001	1700	-1
34998	5000	-1
29994	34000	-1
25005	1.4e+005	-1
20001	8.e+005	-1
16998	2.4e+006	-1
13000	5.5e+007	-1
12000	1.e+008	-1
24743	50000	-0.5
20247	3.5e+005	-0.5
15751	3.7e+006	-0.5
12750	1.4e+007	-0.5
11251	5.e+007	-0.5
10499	1.e+008	-0.5
21001	50000	0
17506	1.9e+005	0
14997	1.3e+006	0
13500	4.4e+006	0
12499	1.2e+007	0
10499	1.e+008	0
10750	3.e+005	0.5
10250	1.5e+006	0.5
9624.7	1.2e+007	0.5
8999.6	1.e+008	0.5

TABLE 45
Aluminum Alloy > Isotropic Resistivity

Resistivity ohm cmil in^-1	Temperature F
1.2184	32
1.3387	68
1.82	212

TABLE 46
Aluminum Alloy > Isotropic Elasticity

Young's Modulus psi	Poisson's Ratio	Bulk Modulus psi	Shear Modulus psi	Temperature F
1.0298e+007	0.33	1.0096e+007	3.8713e+006	

TABLE 47
Aluminum Alloy > Isotropic Relative Permeability

Relative Permeability
1