TO: Dr. Oman

FROM: SAE Baja Team #20F01

CLASS: ME486C-01

ASSIGNMENT: Hardware Review 01 Memo

DATE: February 12th, 2021

Introduction

As the spring 2021 semester progresses, the NAU SAE Baja team has continued manufacturing parts and assembling a rolling chassis. The frame, drivetrain, front end, and rear end teams have each made efforts to stay on schedule through sub team leads creating a white board with team members assigned to certain tasks and dates. This has helped our team visualize what we need to get done and has aided the manufacturing process for this first hardware review.

Frame

Over the past 6 months, the frame team has progressively worked together on all sub-components of what the frame is responsible for. We found that working together on designing and manufacturing would offer a more productive experience due to our team composition. The components that the team are responsible for the SAE Baja vehicle are the seat, seat belt mounting, cockpit ergonomics, fire extinguisher mounting, gas tank mounting, all panels, and the design of the frame. The frame sub-team requires the most collaboration within all the sub-teams for this project which allowed our team to break up into individual assignments for the rear-end, front-end, and drivetrain.

Brendan Paulo:

The rear-cage had a couple design integration issues with the shock mount and rear bushing placements. A requirement rear end had for the shock mount was to have the secondary member be parallel to the ground. It also needed to be a 20.81 degree's relative to the right-plane. In order to do so, I had to redesign the rear-end members accordingly shown in Figure 1. The shock mount angle is in collinear relation to the design of rear-end's control arm. With the shock mount being an inch from a perpendicular set of structural members, it provides itself with desirable support that optimizes our design for weight reduction. The design actually braces the rear cage to be 10% stronger than the original design, shown in a finite element analysis rear-end collision in SolidWorks. The rearrangement gives a considerably greater spacing for the gas tank and engine clearance. I also worked on making a mold for the seat (not shown), and helped lay out pre-preg for the steering wheel. I have been at Nova Kinetics the past 2 weeks making plugs, molds, and soon to lay out carbon fiber on the molds. Carbon should be 100% completed and cured by 2/21/2021.

Figure 1: Isometric view of Primary Members tack-welded together

Figure 2: CNC Machined Fiber Glass Hood

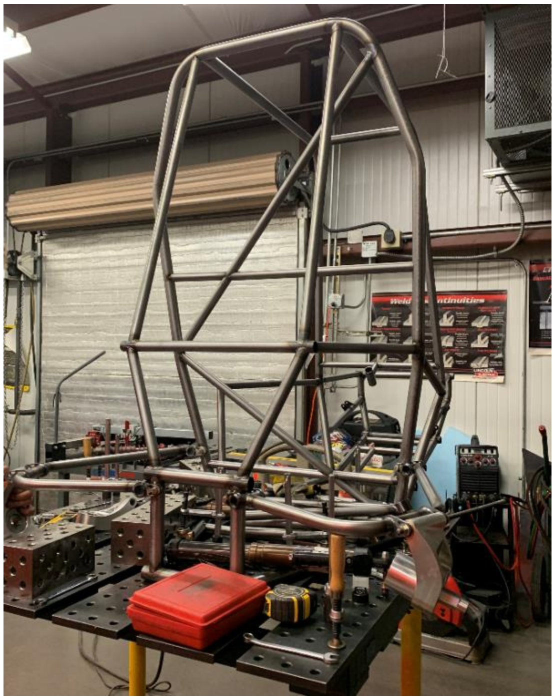

Figure 3: Rear-View of Chassis, Rear-End Shock Member

Figure 4: Nova Kinetics Facility, Steering Wheel Pre-preg Lay-out

Matthew Woodward:
The carbon fiber body panels for the Baja are a necessary part of the final Baja design. While it provides our Baja group with the opportunity to show off our sponsors it also provides protection to the

driver as well as protection to the interior parts. The process of the body panels is simple. We traced the Baja members with a sharpie and cardboard. Then once we had refined the cardboard down enough to where it fit appropriately, we then traced it over the sheet metal as seen in Figure 2. Then by working the sheet metal by bending, cutting and sanding it down until it too fits. We had a product that is ready to go through the carbon fiber process. We are currently unable to finish the carbon fiber process here at NAU due to the fumes the process produces. However, we are currently scheduled to go to Nova Kinetics on 2/18/2021. Here we will be able to finish the carbon fiber process for the body panels.

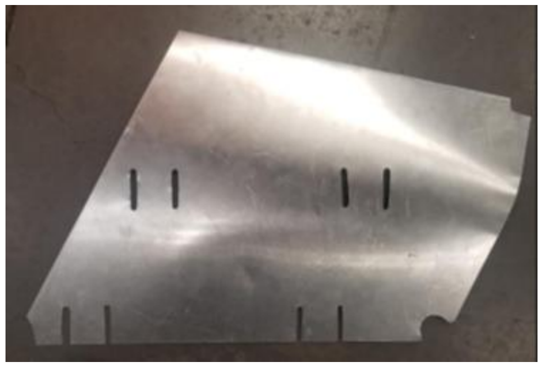

Figure 5: Front-Side Pannel Mold

Ashley Redmond:

The cockpit and front end of the frame was designed to optimize the ergonomics of the vehicle. The roll hoop, roll hoop overhead members (RHO), and side impact members (SIMs) were all primary members bent in accordance with the rulebook. The floor members of the cockpit were also cut and welded together with the seat mount about 7 inches above the floor. The firewall is set at 12 degrees from the vertical and consists of two diagonal members and two horizontal members to satisfy the rules. The upper horizontal members of the firewall were made to mount the seat belt harness with retaining rods. The lower horizontal members were only 6 inches above the floor and made to mount the CTV mount and seat. The front-end structure was angled 14 degrees above the horizontal. The floor members of the front-end were designed so the throttle and brake pedals will be as far forward as possible and allow for the mounting of all front-end systems.

Figure 6: Front View of Frame with Complete Roll Cage and Front Members

Brian Connors:

The frame involves various mounting tabs to be designed and cut, four of which had to meet specific design requirements defined within the SAE Baja 2021 rulebook. These include the mounting tabs for the fire extinguisher, lap belt, anti-submarine belt, and seat which all had to meet minimum dimensions and thickness. The rear tow point was also designed to be cut meeting the defined rules, however these could have weight saving cuts put into them, so they were reordered including these cuts. FEA was applied to the new design to ensure they would not fail during testing or competition. Once these were received, the flat surfaces had been polished using a surface grinder, and the edges were sanded to leave a clean area to weld on. If necessary, they were cut to meet the necessary length, and cleaned using acetone, and welded to the frame. Below is an example, showing the fire extinguisher mount attached to the frame.

Figure 7: Fire Extinguisher Mount

Drivetrain

The drivetrain sub team has been working alongside the other three sub teams in order to ensure that integration will happen smoothly as we begin the process of assembling the overall vehicle.

Tyler Trebilcock:

For the drivetrain manufacturing I was responsible for the gearbox, gears, shafts and bearings. I machined the gear blanks out of 9310 alloy steel to send out for gear teeth shaping and spline cutting. Unfortunately, lead times are causing timeline issues for the manufacturing of the gear box. Having a lot of manufacturing experience, I also machined front and rear hubs, rear bearing carriers, front uprights, brake pedal, master cylinder mount, steering wheel mold, lower motor mount, and the half shaft components (plugs, inboard U-joint yoke and outboard U-joint yoke). I also have spent significant time working composite molds and welding the chassis. Photos of the work done can be seen below.

Figure 8: Steering Wheel Mold

Figure 9: First setup for front upright

Figure 10: Front Upright’s Left and Right Sides

Figure 11: Master Cylinder Mount machined from 4130uyb

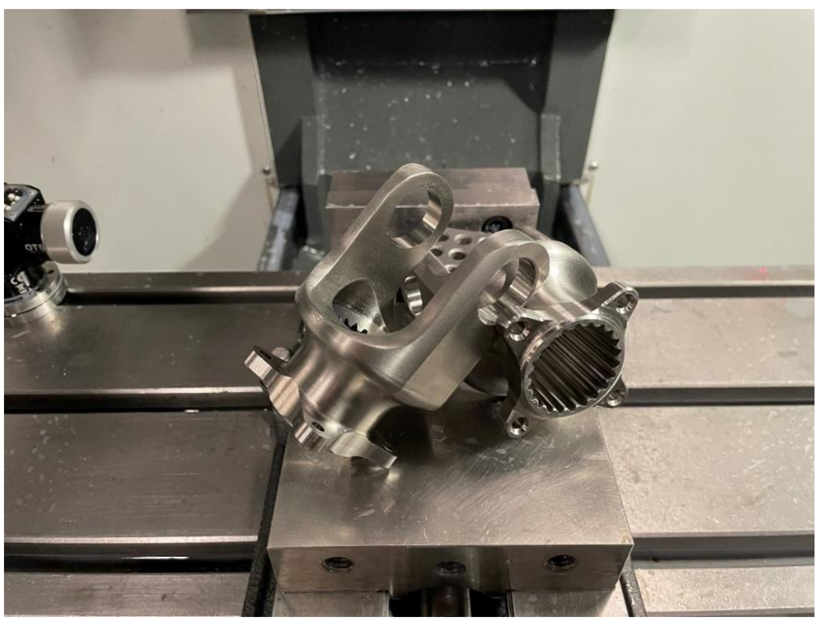

Figure 12: U-joint yokes machined from titanium

Figure 13: Gear Blanks Machined from 9310

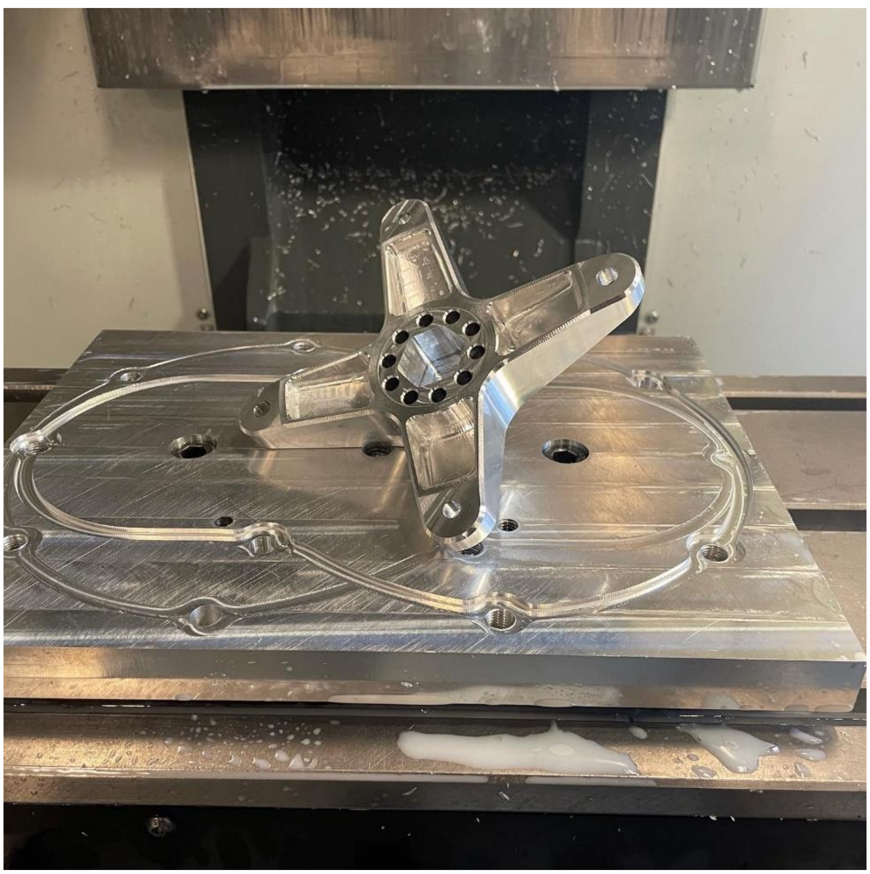

Figure 14: Rear Hub

Emily Kasarjian:

One of the first components that I worked on was creating the pillow block ball bearings for the front and intermediate shafts for the chain drive system. These were machined using the HAAS out of 6061 Aluminum. The CAM was done using Fusion 360. These bearings securely mount onto the body of the frame as a clamp shown in Figure 15 below. The lightning holes help decrease the overall weight of each clamp, and I made a total of four of these clamps, each with a bottom and top component. Another component that I manufactured for drivetrain was the intermediate shaft to mount the 22 tooth and 15 tooth sprockets onto with a keyway. I also was responsible for manufacturing the front shaft to mount the other 15 tooth sprocket shown in Figure 16 and 17. These shafts are machined out of titanium, which is a tougher material to manufacture than aluminum, therefore different cutting tools needed to be used. The keyway was created using the vertical mill and a quarter-inch drill. I also helped drivetrain with the outboard U-joints on the Lathe shown in Figure 18. Most of the machining I have done has been on the lathe, HAAS, and vertical mill. I have also begun manufacturing the sprockets made of 7075 aluminum using the lathe and HAAS as well.

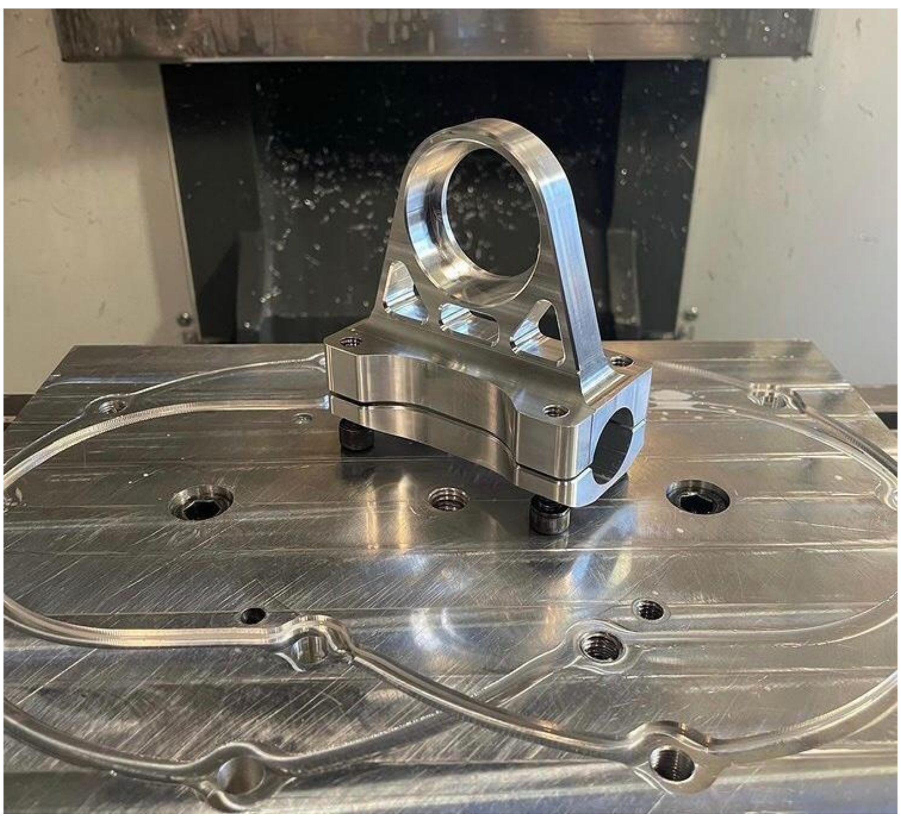

Figure 15: Pillow Block Bearing Clamp

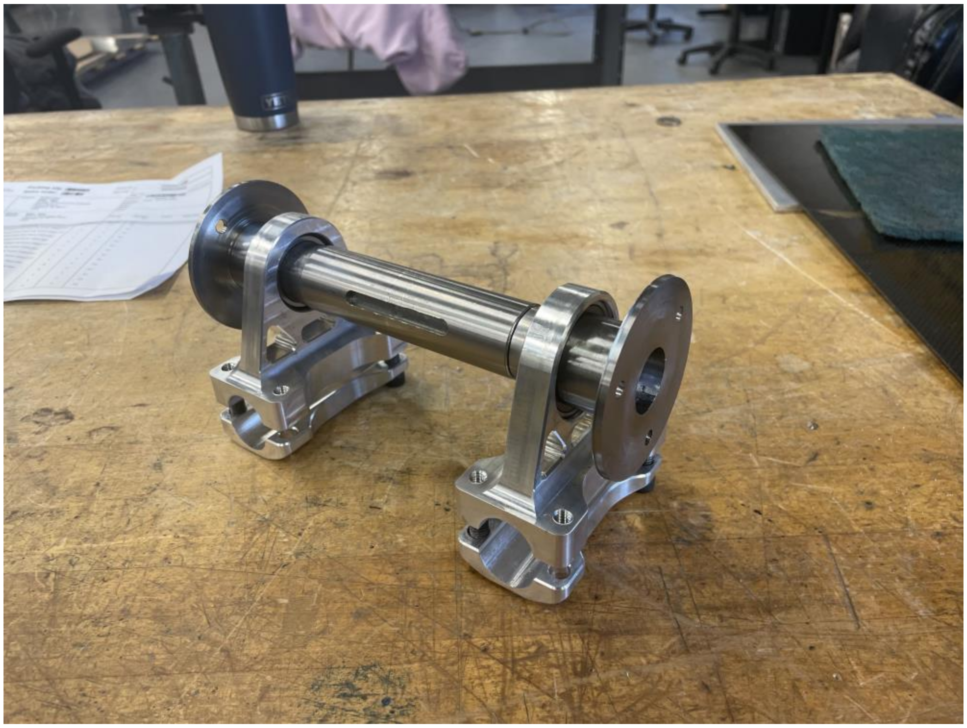

Figure 16: Front Shaft

Figure 17: Front Half-Shaft Joint

Fig 18: U-joint yoke

Figure 19: More Rear Hub and Pillow Block Bearing Clamps

Front-End

Jacob Kelsey – Primarily in charge of manufacturing the control arm bushings and lower control arms. We began with oil-embedded bronze for the bushings then decided to also use Delrin for a lightweight solution. Next was the control arms themselves that needed to be coped and welded to maintain a proper suspension geometry including the mounting tabs on the frame. As a sub team we assembled both sides of the front end with lower control arms, upper control arms, steering knuckles, and shocks as seen in Figure 10. The steering rack and tie rods were outsourced with a slight modification to extend the rack for a proper steering pick up point shown in Figure 21. We had one issue with the tie rod coming in contact with the lower control arm when the vehicle was at full droop and turned completely to one side. To adjust for this, we had to slightly increase the upper shock mount location. I also help to CNC machine aluminum nuts and bolts for other sub teams.

Figure 10: Passenger Side Assembly

Figure 21: Steering Rack

Figure 22: Rolling Chassis

Tanner Gill – The first items that I manufactured were the upper A-arms. Because of our unique geometry, the coping and jigging was much more challenging than in previous years. To achieve the correct angles with the copes, I projected the challenging cope to a parallel plane in Solidworks so that I could complete the spherical bearing cup cope on the vertical mill. For the simple 2D copes I used our standard coping jig. Then, the next challenge was jigging the coped tubes and spherical bearing cups so that they could be tacked in the correct placement. To aid in the tacking, I printed out four 3D printed jigs that would hold the cup down with a bolt and washer, and the tubes were held down in the jig with a simple press fit. Seen in the figure below are the printed jigs used for A-arm manufacturing. The final tacked products are seen in the following picture with only the shock mounts left to go.

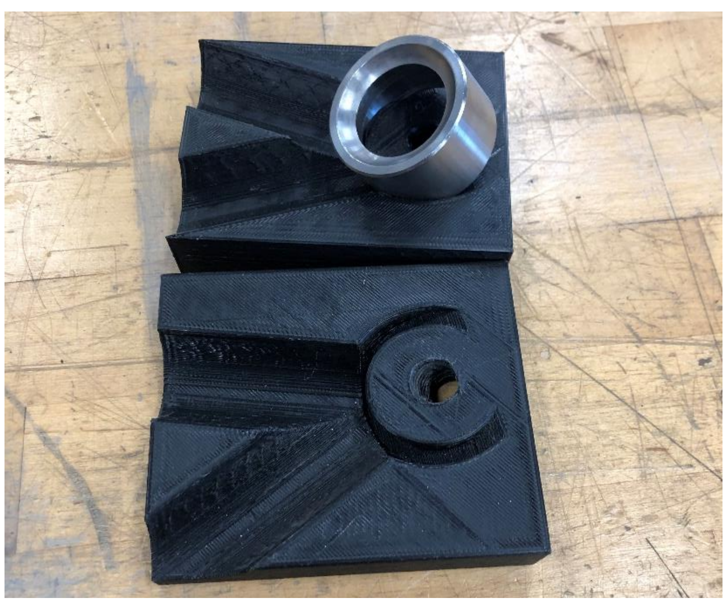

Figure 23: 3D Printed A-arm Jigs

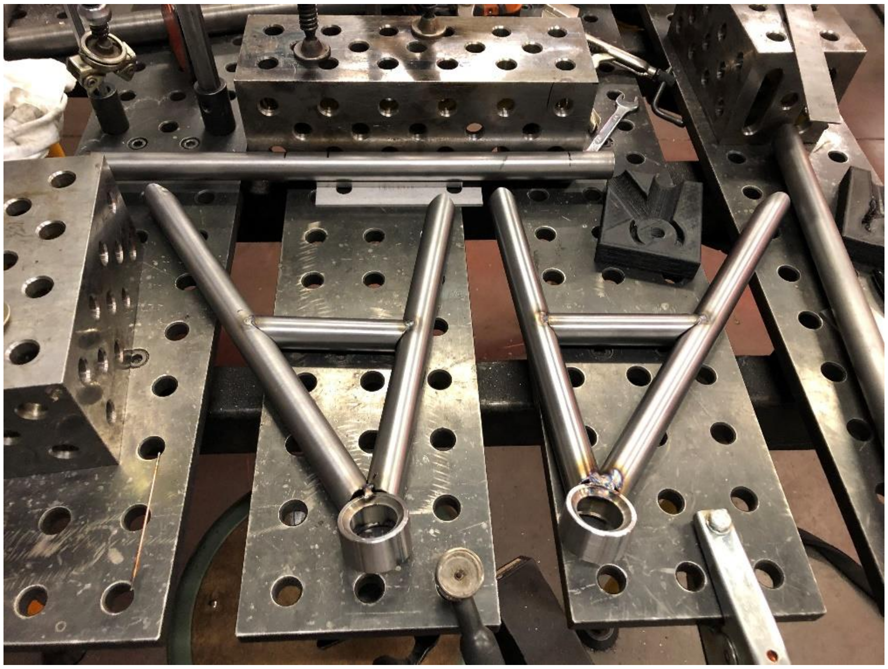

Figure 24: Tacked Upper A-arms

The next challenge was to drill the holes in the front knuckles for the upper and lower spherical mounts. As Tyler had already CNC milled out the knuckles, the holes were the only features left to be done. To properly hold the part on the vertical mill, I CNC milled out the profile of the upper mounting feature to seat down against a square piece of stock. Then I used the upper mounting hole to bolt the knuckle down. The jig is seen in the picture below. To reduce chatter a machinists jack was included to support the tie rod mount, but is not seen in the picture.

Figure 25: Knuckle Jig

Next, the front end team worked on mounting the shock mounts to the frame and the upper A-arms. The upper roll hoop mounts were designed by me and sent out to Vroom for laser cutting. However, I cut the upper box tabs in-house on our CNC plasma cutter. The 21 cut into the tabs act as lightening holes and also represent our vehicle's number as assigned by the SAE organization. Once the tabs were set to bottom out at full droop, the tabs were fully welded. Seen in the picture below are the welded tabs supporting the Afco coil-overs.

Figure 26: Upper Shock Mount

Once our components were finished, we assembled our front end design to in its near-completed state. The shocks were also switched out for simple trailer bars made to emulate ride height of the car. Once assembled, there was a fair amount of tuning to be done. The tie rod length needed to be set, the high misalignment spacers needed to be turned down for more travel, and the knuckle tie rod tabs needed to be filed down. Seen below is the current state of the vehicle's front end.

Figure 27: Front End Assembly

Ryan Meyer – Since many of the parts made is Solidworks are going to be manufactured in house, one of the first designs see the CNC machine was the driver side knuckle. This knuckle design was worked on through first semester and was finished manufacturing almost a month ago. Once the knuckle was completed, the brake lines needed to be mapped out through the interior of the car and ordered. The SAE Baja 2021 rulebook has many limitations on how of brake lines able to be ran and the type of brake line the team can use. For the interior of the car, we decided on 3/16 stainless steel brake line and 19-inch steel braided flex line for the front calipers. Due to the constant change in brake line throughout the car, and because we are using two master cylinders on for the brake pedal, many types of fittings are needed to run the line. Every mount for the upper control arm, lower control arm and shock needed manufacturing of extra Delrin bushings. These spare pieces were made on the lathe and due to the rigorous testing, the vehicle will endure we plan on using all of the extra bushings.

Figure 28: Passenger Side Knuckle

Rear-End:

Colton Lacey – Starting off manufacturing for the rear end suspension, I started by using the tubing bender and bending the rear arms into their final shape as seen in Figure 29: Rear Arm Tube. It became clear that the tubing bender being used was substantially inaccurate as the tubing had springbuck due to elastic deformation in the material. To make sure the angels where perfect to the dimensions designed, a 3d printed jig was made that could be used as a go-no go gauge to make the bends perfect.

Figure 29: Rear Arm Tube

Next the tabs needed to be placed on the arms in the correct spot and welded. With help from bailey, we mocked up the knuckle mounting tabs and welded those, as well as the tubes and frame side mounts as seen in Figure 30 and Figure 31.

Figure 30: Knuckle mounting Tabs

Figure 31: Rear Arm Knuckle Mounting Tube/Tabs

The mounting sleeves needed mounting holes to be cut and the sleeve to be welded in. With help from logan, we took the hole notching tool off its stand and used it as a mounting jig to cut a perfect hole through the frame members as shown in Figure 32 below. After cutting the holes the mounting sleeves were cut from a section of 0.065 wall tubing and welded into place.

Figure 32: Frame Mounting Sleeve Hole Saw Jig

At this point in time the rear end suspension was all ready for a mockup rolling car. From this mockup we realized that the rear arms do not articulate as much as they should. The cause of the issue was an interference fit with part of the arm and one of the frame tubing members. To combat this interference, I used a hole saw to cut a notch in the back mounting tubes of both arms to clear the tubing member as seen above in Figure 32. However before cutting a notch I made sure to add the changes into my FEA analysis of the arm to make sure the arm is structurally sound. As seen in Figure 33 is one side of the rear suspension mockup.

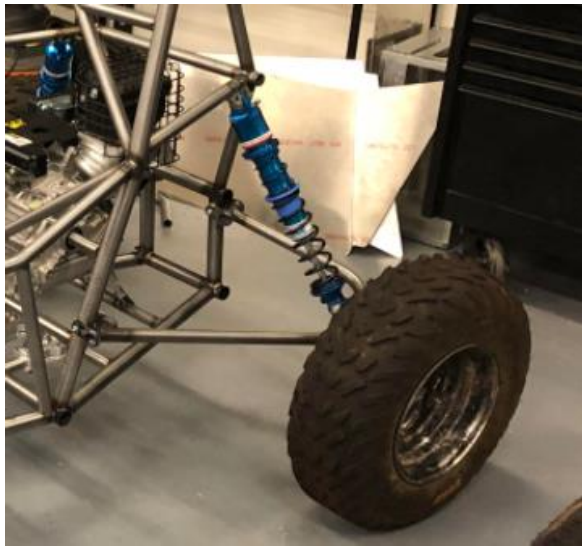

Figure 33: Rear Suspension Mockup

Once this was done the rear end suspension was done barring the half shafts. While waiting for the half shaft material to come in the rear end team devoted their efforts to helping the rest of the team in manufacturing. Since I am one of two people on the team proficient in tig welding, I helped the front-end sub team fully weld their a-arms as well as the frame sub team work to get the frame tubing and mounting tabs fully welded.

Bailey McMullen – Made most of the bushings for the rear end, using oil infused bronze, aluminum (temporary) and Delrin. A total of around 30 bushings have been made. Bailey has gained lots of experience turning down stock on the lathe, and has also helped other teams where necessary. An aluminum set of bushings had to be made as placeholders so the team could meet their rolling chassis deadline by February 1^{st}. The Delrin material arrived later and a full frame set of bushings have been made for the rear end. Bronze is being used in the knuckle bushings. Bailey has helped Colton in getting the .065” wall tubing bent, along with helping getting tabs lined up at the right angle so Colton can weld them on.

Logan Faubion – mainly focused on knuckle fitment and doing finish work on mounting tabs for the rear-end. Has also helped manufacture Delrin bushings for rear-end frame mounts. Outside of rear-end work, has been assisting Frame sub-team with cutting body panel templates, mounting smaller tabs for accessories, and configuring the wiring harness for the brake and kill switch systems. Oversaw selecting and ordering wheels and tires for the Baja, measured for and ordered a new throttle cable, and checked that brake and electrical components are within competition specifications.