Lumberjack Motorsport SAE B-074
Cost Reduction Report

Introduction

This report consists of potential ways our team plans to reduce the overall cost of manufacturing Lumberjack Motorsport's SAE B-074. The 2023 team is designing the SAE B-074 vehicle to handle rigorous terrain while also emphasizing driver safety. Reducing cost and manufacturing time is key to the success of the vehicle due to the limited time and money available. During the beginning processes of forming this report the goal was to identify as many places as possible in the design that could potentially be edited to reduce cost. The two main changes that would have the biggest positive impact on reducing the cost were the designs for the front and rear knuckles.

Research

When brainstorming ways to reduce costs, while still maintaining performance capabilities, the NAU Baja Team came up with several potential areas of improvement. The first and potentially most obvious was the front steering knuckles. This was something that the team noticed immediately due to its grotesque size and weight. These 2021-2022 front knuckles were far larger than necessary. These knuckles utilized an approximate 12" x 8" x 6" aluminum block to be CNC milled down to its actual part size. A block of 6061 Aluminum with these dimensions weighs 56lbs and cost $800 per knuckle. On top of the large material cost. These front knuckles took eight hours to CNC mill to its final shape. This machining was done in-house at our NAU machine shop, but with labor prices estimated (on the low end at $60/hr.) it would have costed $480 per knuckle. An image of this front knuckle can be seen in Figure 1 located in Appendix A.

In addition to the front steering knuckle, the team also saw the potential in optimizing the cost of the rear knuckle. Last year's rear knuckles also utilized an aluminum design which required an approximate 7" x 5" x 5" block to also be CNC milled down to its final part size. The aluminum block with those dimensions would have weighed 17lbs and costed $243 per knuckle. Once again, it's important to consider labor costs for machining these. These rear knuckles took 5 hours to machine to their final shape, totaling $300 per knuckle in labor costs. For reference, an image of this rear knuckle can be seen in Figure 2 located in Appendix A.

Another idea that our rear end team came up with is minimizing the stock size used within the rear hub. Last year's Baja used hubs with inside a thickness of 1.75" and an outside thickness of 2". This year's team wanted to reduce the amount stock used without ruining the integrity of the hub and maintained its strength having thicknesses of 1.25" towards the center and 1.5" towards the outsides of the hub. This may have increased labor time for producing this design but overall was cheaper than using more aluminum stock.

Design

To monetarily optimize the Front Steering Knuckle the design was entirely scrapped from the 2021-2022 design and completely re-envisioned. For our current knuckle design, the goal was use as little material as possible, which would in turn cut down on material cost, and likely

machining time. Our front knuckle design utilizes a 9” x 6” x 6” block of 6061 Aluminum, which weighs just under 32lbs. This material was donated to us, however if we were to purchase this material it would cost $360 per knuckle. As far as machining time goes, we are in the process of writing the G-code to be run in the CNC. From what we can tell so far, we expect the labor time to be far less than last year’s as well, somewhere around 5 hours per knuckle. This design also still allows us to run an upper and lower control arm, as well as a front mounted tie rod. As far as functionality is concerned the new part is identical to the prior years. An image of this current Steering Knuckle can be seen in Figure 3 located in Appendix A.

The design that was implemented for rear suspension by Baja 2022 team was the knuckle that hung off the control arm. This design utilized the control arm to stabilize the knuckle. The benefit of this design was that the knuckle is an easily serviceable part in the event of a hard landing or crash that breaks the knuckle. The downfall of this is that the knuckle becomes a larger part to be able to still function as a knuckle and to mount to the control arm. This utilized a block of aluminum that was 7” x 5” x 5”. This year Baja 2023 team selected a trailing arm design. By doing this the control arms became larger but also gave an opportunity to make the knuckle smaller. The new knuckle is now integrated within the control arms. This makes the knuckle stronger and protected by the control arms. This utilized a steel tube that is three inches in diameter by one inch thick. This reduced material by over 50% and made the part stronger. This is no longer a serviceable part but with an FEA analysis within SolidWorks, we are very confident that this part is not going to fail under all predictable loads.

Analysis & Testing

Once we had the new designs modeled it was time to test them. For both the front and rear new knuckles we chose to conduct SolidWorks Stress analyses to verify that our smaller, lighter designs could still withstand the forces we could see in a real-world application. Within the simulation we applied 3000N or 665lbf to the front knuckle dispersed over the various surfaces of the part. Those surfaces include the upper and lower control arm mounting points, along with the center hole for the CV axle to pass through. Upon conducting the simulation the largest deflection, we saw was 1.935×10^{-4} mm, an extremely small amount that virtually results in no movement. The screenshot of this simulation can be seen in Figure 3 within Appendix A.

Utilizing FEA analysis tool within SolidWorks we were able to apply forces to specific areas of the rear end knuckle. This analysis proved that we were able to use the knuckle with the new design. Within Appendix A, Figure 4 shows a high amount of force applied to specific areas showing our team the deflection was very minimal even at the highest point where we would experience force within the knuckle housing. At this section we also plan to press fit bearings on each side as well as adding a spline to accommodate for the CV axle we also plan to run. These will disperse more of the load path validating our design.

Appendix A: Figures and Tables

Figure 1: 2021-2022 Front Steering Knuckle

Figure 2: 2021-2022 Rear Knuckle

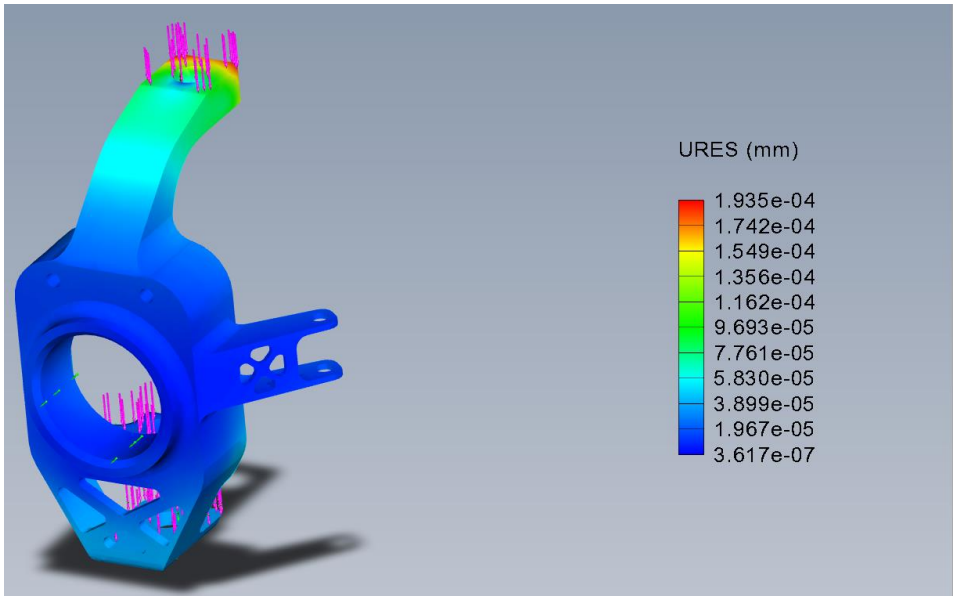

Figure 3: 2022-2023 Front Steering Knuckle

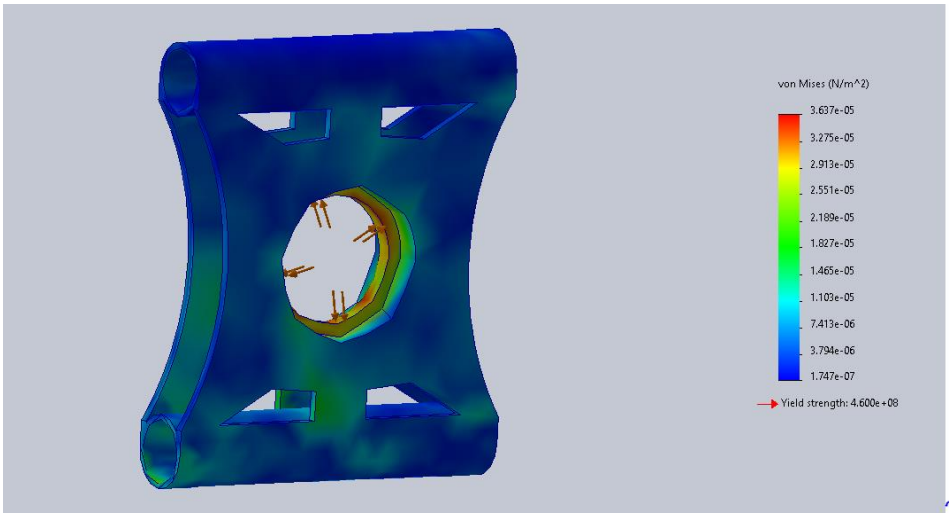

Figure 4: 2022-2023 Rear Knuckle