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Design of Upright Assembly for SUPRA Vehicle

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Abstract
SUPRA SAEINDIA is an annual national university-level design competition organized by the Society of Automotive Engineers, India. The goal for the 100+ teams from all over the country is to design, manufacture, and compete with a small open-wheel, open cockpit type race cars. The purpose for this investigation is to design and manufacture the SUPRA vehicle upright. The purpose of an upright is to provide a physical mounting and links from the suspension arms to the hub and wheel assembly, as well as carrying brake components. It is a load bearing member of the suspension system and is constantly moving with the motion of the wheel. For the use on a high performance vehicle, the design objective for the upright is to provide a stiff, compliance-free design and installation, as well as achieving lower weight to maximize the performance to weight ratio of the vehicle. This is the goal for the optimization process. The design of the 2018 upright achieved a total weight reduction of over 380gm, which translates to a 46% reduction overall. This is achieved with no loss in stiffness according to the Finite Element Analysis in the computer.

Keywords:SUPRA SAEINDIA, Upright, Finite Element Analysis.

Introduction
The SUPRA SAEINDIA is a competition design series even that tests the ability of students to design, manufacture and tune an open wheel race car under a strict set of rules. For the SUPRA SAEINDIA 2018 Students were required to design and manufacture different sus-system of the Vehicle [6]. The competition emphasizes on the design of a light weight vehicle such that the power to weight ratio of the vehicle gets increased. Under this, a major role is played by upright assembly. The upright design already available in the market is heavy in weight. Hence the solution lies in customizing the design of upright assembly. The objectives while designing the upright assembly included:

• Light weight to maintain good performance to weight ratio of the race car.

• Optimum stiffness to ensure low system compliance and maintaining designed geometries.

• Ease of maintenance for enhancing serviceability and setup repeatability.

And for the purpose of this team, ability to manufactured the components in house to reduce turnaround time and outside dependability. [1]

With the aid of the SolidWorks, Catia, Altair and Ansys as the Computer Aided Design (CAD) and Finite Element Analysis (FEA) program of choice in this project, the goal is to design the 2018 FSAE Upright based on the similar layout in 2017 car to meet the a fore mentioned criteria. Quantitatively, the finalized 2018 upright should be lighter and maintain similar level of stiffness as the 2017 design. It is also the aim of this project to attempt to correlate and validate the FEA results with some form of physical testing.

Design Expectations:
The suspension is designed so as to satisfy following design criterion:
a. Easy to design and manufacture
b. Usable wheel travel of at least 50.8 mm, 25.4 mm jounce and 25.4 mm) rebound.
c. Roll centre sufficiently above ground for good lateral stability.
d. Small variations in camber and toe angles during the desired wheel travel. [2]

Design Process and Methodology:
Suspension Geometry:
As the upright being the primary suspension component at the wheel side, its key geometries are driven by the vehicle suspension parameters. [3]
For the 2018 car, the geometries of the suspension system are evolution of the 2017 design. The system is designed with moderate amount of front camber compensation in roll to keep

the tire perpendicular to the ground when the vehicle is rolled and/or steered. Particular attentions have been paid to steering geometry to reduce KPI from the 2017 design as it induces unwanted camber change when the front wheels are steered. By relocating the lower ball joint further towards the inboard direction while doing the opposite to the upper ball joint, the KPI has been reduced from 10 deg on the 2017 car to 6 deg in the 2018 car. Caster values of 6 deg have been retained from the 2017 design. The Ackermann adjustment method of the 2017 car have also been retained with 3 different steering pickup point representing 0-100% Ackermann steering, as opposed to –25% - 75% adjustment of the 2017 car. This change has been driven by 2017 season's on track testing results, with observation made that the Hoosier tire performs better with more positive Ackermann setup.

Mechanical Design:

With the suspension geometries fixed the focus shifts to the mechanical layout and design of the upright assemblies. Taking into consideration the design constraints in terms of manufacturability, CNC aluminium-based design is not feasible for the purpose or the capability of the team. Therefore, CNC based mild steel design of the 2017 upright was retained. With the manufacturing process being further refined to improve on manufacturing time. One major change from the 2017 design was the wheel bearing size. This is driven by the drive train design of the new vehicle. For 2018 season, the drivetrain design moves away from the traditional tripod style CV joint on the outboard side in favor of the DOJ-type CV advantage being the reduction in CV size. Hence the wheel hub size was reduced accordingly and thus facilitates the reduction in wheel bearing size. This allows the 2018 upright to be smaller in width, and contributes to the goal of weight reduction.

With 2017 and 2018's suspension design, which moves from 2016's pull rod actuated suspension system to pushrod-based design, the bottom ball joint becomes the primary source of loading in the upright. This allows for a reduction in spherical bearing size for the upper ball joint. The 2018 upright uses a ¼" ID upper ball joint and a 5/16" ID lower ball joint. The upper ball joints are loaded in double shear to ensure the reliability of the device, while the bottom ball joints are loaded in single shear to provide for extra clearance for the steering requirement.

Finite Element Analysis:

Finite Element Analysis or FEA is the method used to optimize the design of the 2018 upright. The FEA package of choice for this project is Ansys, the FEA suite for the CAD software Solidworks. This arrangement allows for easy integration between the CAD model to the FEA software and quick changes and analysis can be performed in the design process to optimize the design.

The accuracy of the FEA results is largely dependent on the constraints and setup for the analysis. Since real world loading conditions and constraint can be incredibly complex, simplified representative conditions are often used to model the real world constrain. "Fake" parts are usually including in the FEA model to replace those parts in which may exist on the real assembly but their performance are not important to the model of interest. The results of the FEA then require the designer to interpret with that knowledge in mind.

In Ansys, the sheet metal faces on the upright are analysed using "shell element", which is used specifically to model parts with thin cross sections. While certain internal features and bearing bosses are modelled as solid elements.

The FEA package allows for the computation of stresses in different ways, the stresses can be represented in principle stress, component stress, or Von Mises stress. Since it is important to know the yield and material limit, as well as the computation of safety factor, Von Mises stress is used in presenting the stress results.

Calculations of Forces Acting [7,8]:

Lateral acceleration (lat. Acc.) = 1.7g

Weight Distribution in Front = 0.46

Self-weight of vehicle on each wheel = Total mass * g * 0.46/2 = 732.55 N

Total lateral weight transfer = Total mass × lat. acc. * CG * 0.46 *Track Width = 611.88 N

Elastic weight transfer = SM * lat. acc. * (SMCG – RC height) * 0.46 *Track Width = 495.8 N

Lateral suspended weight transfer = SM * lat. acc. * SM cg * 0.46 *Track width = 551.57 N

Geometric weight transfer = SM * lat. acc. * RC height * 0.46 *Track Width = 55.75 N

Non - suspended weight transfer = NSM * lat. acc. * NSMCG * 0.46 *Track Width = 48.28 N

Ride rate(KRF)=$Self\text{-}Weigh\,t/Rebound\quad Travel$=34.95 N/mm

Wheel rate (KW) = $KT* KRF$ / ($KT - KRF$) = 58.98 N/mm

Spring Rate (KSF) = $KW* MR2$ = 36 N/mm

Ride Frequency = $12\pi\sqrt{KRF} * 1000 * 9.81 Self\ Weigh\,t$ = 2.65 HZ

The loads applied to model are based on the data collected in the previous years from the vehicle data acquisition system. The system records the maximum cornering force and this information is used in conjunction with the vehicle layout and weight distribution to determine the forces on the front and rear tires. For the cornering scenario, a lateral force (model y-axis) of 400N is applied to the front upright at the contact patch center, along with a 800N of combined bump and lateral weight transfer caused by the lateral acceleration of the vehicle, applied to the vertical direction at the contact patch center (model z-axis). For the rear upright, the load is scaled back to account for the smaller loads experienced by the rear tire.

Result and Conclusion:

The CAD Models of upright assemblies are as follows:

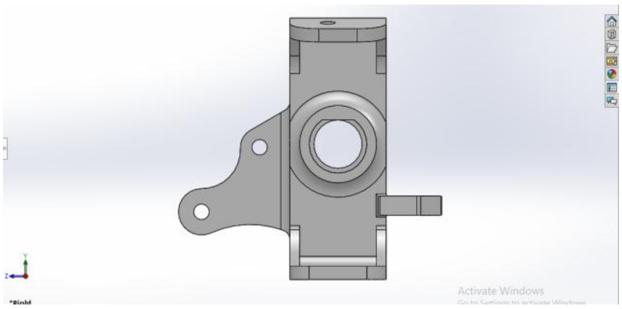

Fig 1.Front View of upright

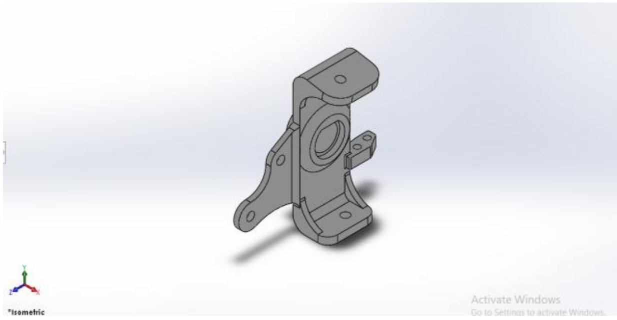

Fig 2.Isometric view of upright

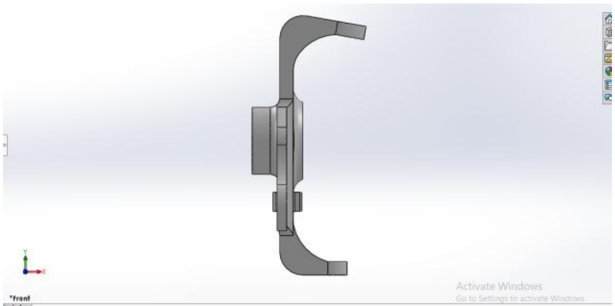

Fig 3.Side view of upright

The von-mises stress distribution, factor of safety and deformation analysis are as follows:

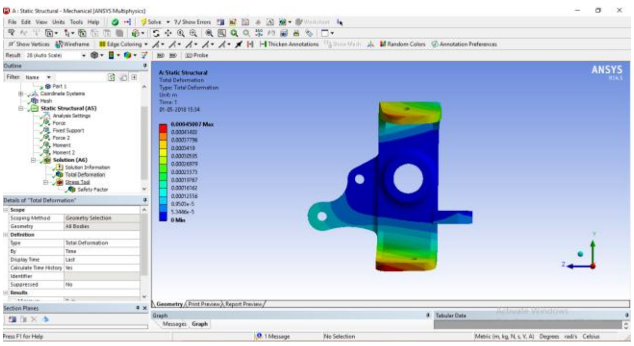

Fig 4.Von Misses Stress Analysis (Pattern 1)

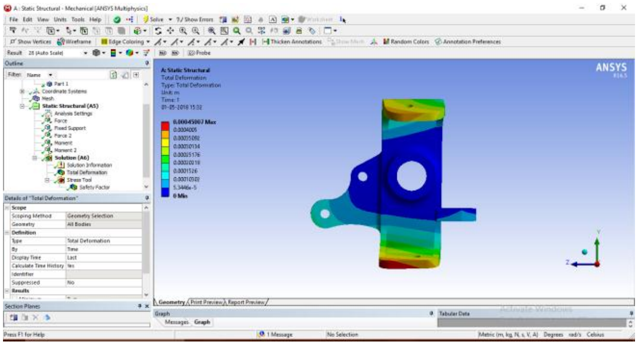

Fig 5.Von Misses Stress Analysis (Pattern 2)

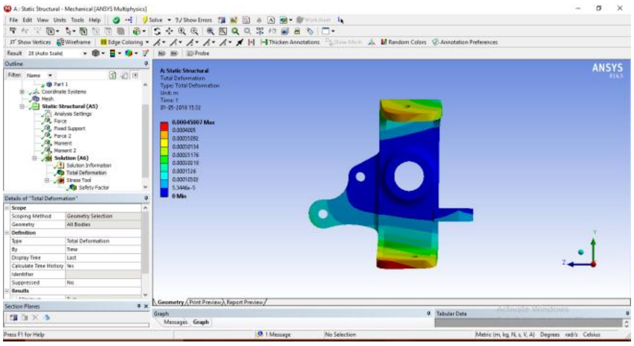

Fig 6.Von Misses Stress Analysis (Pattern 3)

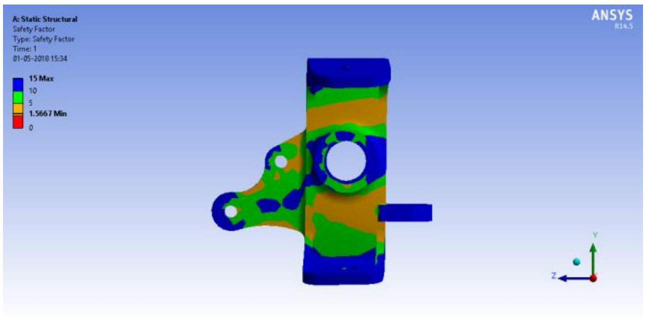

Fig 7.Factor of Safety

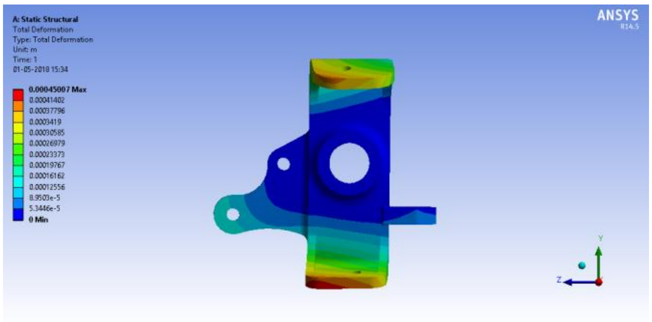

Fig 6.Deformation of upright

Knowing the issue with FEA results interpretation in the boundary region of the mating edges between solid and shell element, the focus then is on the region that's around the boundary. As such, the stresses in those region combined with calculated endurance limit resulted in the fatigue safety factor of 1.5 for the upright. The value may sound to be too risky, but knowing the conservative estimate for the fatigue cycle, as well as the actual joint design being more robust with multiple weldments, these values should be more than adequate.

Physical Testing and Validation:

With majority of the design work being done on computer, it is necessary to ensure that the design method is representative of real world conditions, as well as ensuring the completed part are to the designed standard. To this extend, two types of physical testing methods are used to validate the design and manufacturing processes. First is the non-destructive dye penetration testing for welding quality, and the second is a physical testing to validate FEA results.

Non-Destructive Testing

With the limited time allocated for the construction of the SUPRA vehicle as well as the limited resources available for manufacturing any component on the car, any destructive testing for the fabricated components will not only be undesirable, but not feasible as well.

So, the normal visual inspection test was performed for any flaws and defect under microscope.

Physical Testing

The upright assembly was assembled in SUPRA 2018 vehicle and the vehicle was run for nearly 200 km. without failure in upright assemble.

References

[1] "Virtual Prototype of Upright Assembly of A Race Car for SUPRA SAEINDIA Competition", Das Abhijeet, International Journal of Mechanical and Industrial Technology ISSN 2348-7593 (Online) Vol. 2, Issue 2, pp: (79-86), Month: October 2014 - March 2015.
[2] "Design of Suspension System for Formula Student Race Car", Samant Saurabh Y., Kumar Santosh, Jain K. K., Behera S.K., Gandhi D., R. Sivapuram , Kalit K., 12th International Conference on Vibration Problems, ICOVP 2015 Procedia Engineering 144 (2016) 1138 – 1149E.A. Gorbashko. "Quality Management and Competitiveness". St. Petersburg: Publishing House SPbGUEF, 2008.
[3] Smith, Carroll. 1984, Engineer to Win, Fallbrook CA: Aero Publishing Inc.
[4] Callister, William D. Jr 2002, Material Science and Engineering: An Introduction 6th Edition: Wiley.
[5] Norton, Robert L. 2017, Machine Design: An Integrated Approach 3rd Edition, Upper Saddle River NJ: Prentice Hall
[6] SUPRA Rules Committee 2018, 2018 SUPRA SAEINDIA Rule Book, SAE India.
[7] Gillespie T.D., "Fundamentals of Vehicle Dynamics", Society of Automotive Engineers.
[8] Aurora Bearing Company 2000, Rod End and Bearing Catalogue, Aurora II: Aurora Bearing Company