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Design and Analysis of a Velocity Joints for a Formula Student Vehicle

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Abstract - *The purpose of this paper was to design the 2022 Formula student vehicle velocity joint for Team Stallion Motorsport Electric. The goal of this paper was to discussed the theory and analysis of the velocity joints of a Formula Student Vehicle that incorporated a student-developed system. The paper discusses the theory and basic design criteria of the velocity joints that is used to transmit the power and torque from differential to the hub. The main objective of the paper is to design a feasible, achievable, less weight velocity joint with the budget, we have to complete the vehicle in to compete in the Formula Bharat 2022 Competition.*

***Key Words*: Velocity Joints, Differential, Hub, Stallion Motorsport, Formula Bharat, Universal Joint, Rzeppa CV Joint, Tripod CV Joint, Angular Articulation, Plunging.**

1.INTRODUCTION

While designing, developing and fabricating any vehicle, the velocity joints play a vital role. As it makes power transmission accessible. Power transmission has to be through various components and parts. It depends on us actually to design this system of various components and parts in such a way that maximum power is transmitted with minimum loss and gives the vehicle the motion it requires. This velocity joint system consists of a joint housing setup with the half-shaft rear axle system. Considering the affordability and feasibility of the project while being competitive as well, we have researched every option available in the selection of material and components and customized to suit our best interests. After the completion of designing the velocity joint, we must meet the requirements we approached first and to ensure that several design and analyses methods and software were applied.

1.1 METHOD APPROCHED

The study of each type of velocity joints are done from various books and google articles. The joints are classified into various categories, and select one velocity joint as per our requirement for design and analysis. The modelling of each component was mostly made in SolidWorks. The stress analysis and Factor of Safety Distribution of the components was done in either Ansys or SolidWorks.

All our results are verified with all the software and calculations with the datasheets available of each material and components that we have used while considering the performance and durability.

1.2 REQUIREMENTS OF VELOCITY JOINTS IN FORMULA STUDENT VEHICLE

1. Angular Articulation (velocity transfer at an angle)

2. Plunging Movement (linear motion of shaft)

3. Rotary Motion

2. SELECTION OF TYPE OF VELOCITY JOINTS

2.1 UNIVERSAL JOINT

A universal joint is a joint connecting rigid rods whose axes are inclined to each other, and is commonly used in shafts that transmit rotary motion[1]. Universal joints allow drive shafts to move up and down with the suspension i.e., angular articulation. But due to rigid assembly it not allows the plunging moment.

Table -1: Universal joint specification

Angular Articulation	Less than 25°
Plunging Moment	No
Rotary Motion	Yes

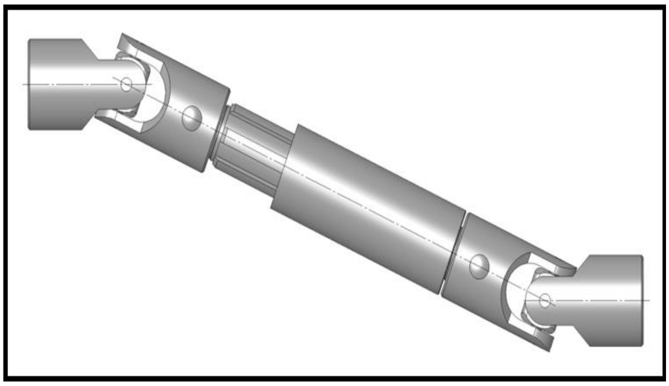

Fig-1 Universal Joint

2.2 RZEPPA CONSTANT VELOCITY JOINT

The Rzeppa joint is a specific type of constant velocity joint, the ball and socket design involve 6 balls working with inner and outer races to transmit constant velocity torque from many different angles. Especially when the angle of the intersecting rotating shafts is expected to change frequently during service. Rzeppa joints are used in applications where even flexible shaft couplings would not have the misalignment capabilities needed. They can typically operate at angles up to 48° and sometimes even higher[2]. But it does not allow the plunging moment to the shaft.

Table -2: Rzeppa CV joint specification

Angular Articulation	More than 48°
Plunging Moment	No
Rotary Motion	Yes

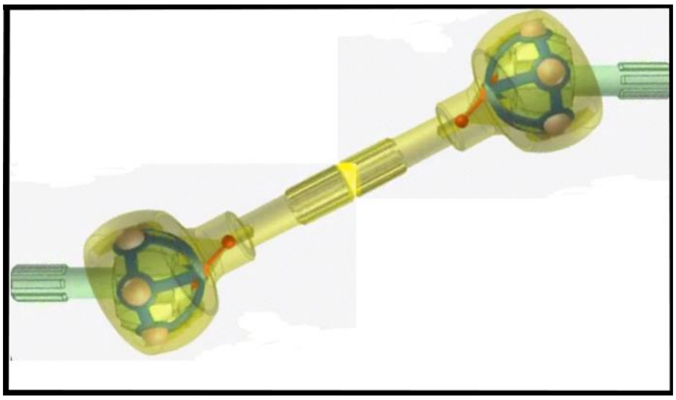

Fig -2: Rzeppa CV joint

2.3 TRIPOD CONSTANT VELOCITY JOINT

The tripod is a plunge joint that allows the length of the CV shaft to change slightly as you drive over dips and bumps. As well as on the time of turning of vehicle, the assembly experiences an inner ward force. Due to that it has chances to shifting the assembly inner ward. But as we know tripod CV joint allows plunging movement up to 50mm and the angular articulation is more than 26°, the shifting of assembly is restricted up to 50mm[3]. And it is sufficient length of plunge to keep the assembly safe at the time of turning and bump on the track. Additionally, we added less stiffness spring on both side of tripod CV joint, to place the shaft perfectly in the middle of assembly[4].

Table -3: Tripod CV joint specification

Angular Articulation	More than 26°
Plunging Moment	Up to 50mm
Rotary Motion	Yes

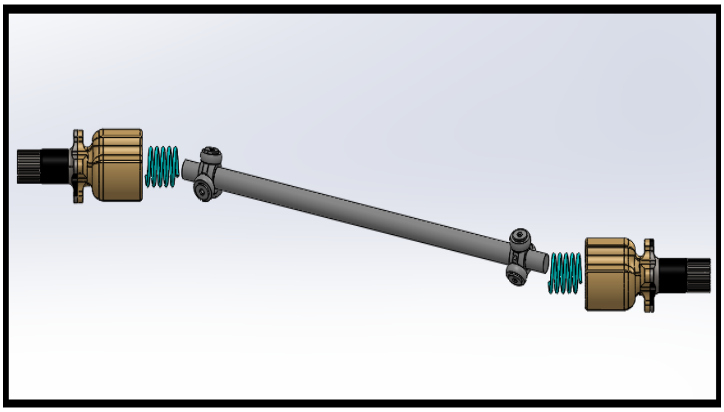

Fig -3: Tripod CV joint

3. DESIGN AND ANALYSIS OF TRIPOD CV JOINT

The use of Tripod CV joint in formula student vehicle is to, the transfer the torque or power from differential to the hub. For that we required following components in Tripod CV joint assembly.

1. CV flange
2. CV cup
3. Tripod
4. Tripod bearings
5. Shafts
6. Springs

After designing of each component in SOLIDWORKS, we analyse the Equivalent stress concentration and Total deformation of each component in ANSYS software. Keeping the mesh triangular and fine, we did ANSYS of components.

3.1 CV FLANGE

CV Flange stands for constant velocity flange used to connect the differential to the CV Cup. On one side of CV flange there is splines which is in mesh with the differential gear, and other side bolted with the four bolting points with CV Cup. The material we select for the CV flange is EN19.

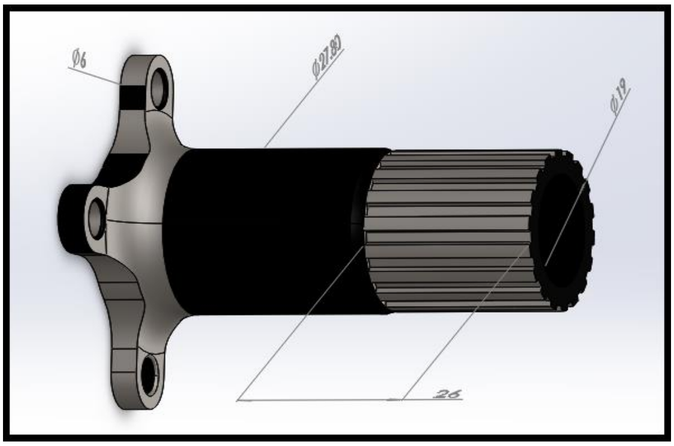

Fig -4: CV Flange

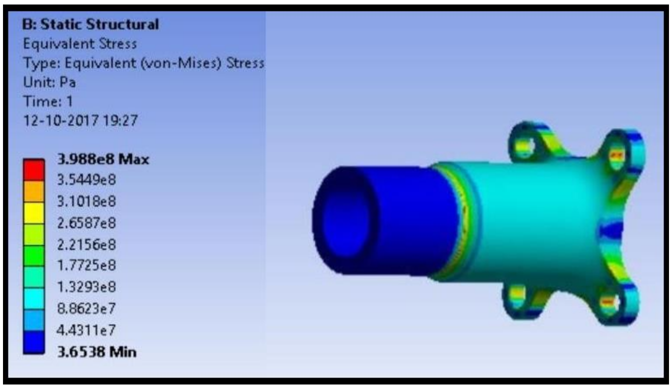

Fig -5: CV Flange Equivalent Stress

Description	Maximum Stress (MPa)	Maximum Deformation (mm)	Meshing
CV Cup	186.45	0.211	Triangular

Table -4: FEA Result

3.2 CV CUP

CV Cup is the housing of tripod and tripod bearings. Tripod and tripod bearings are placed inside the CV Cup. As the CV flange rotates with the differential the CV Cup also start rotating. Due to the three-point contacts of tripod bearing in each CV Cup, the force exerted on CV Cup at the three points. The material we select for the CV cup is Al7075. For lighter weight assembly.

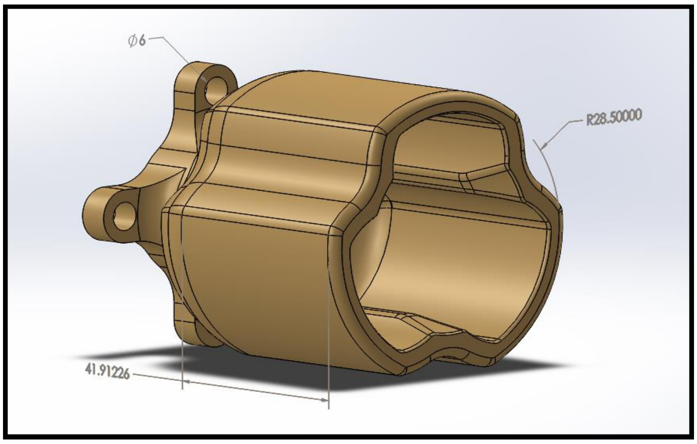

Fig -6: CV Cup

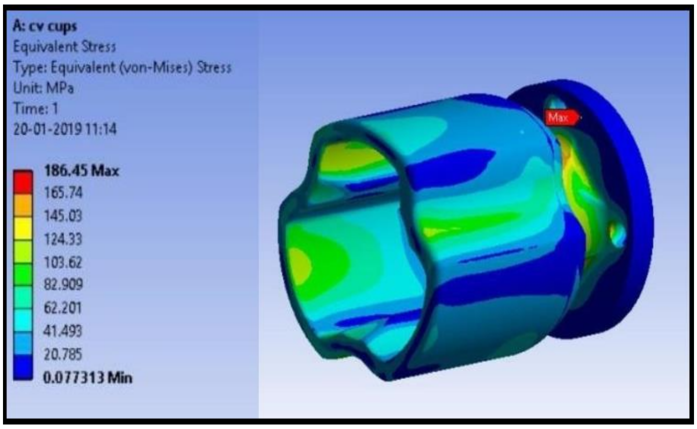

Fig -7: CV Cup Equivalent Stress

Table -5: FEA Result

Description	Maximum Stress (MPa)	Maximum Deformation(mm)	Meshing
CV Flange	398	0.106	Triangular

3.3 TRIPOD

Tripod is the torque transmitting element in the Tripod CV joint assembly. Tripod stands for three legs. The tripod placed inside the CV Cup, having tripod bearing on each leg of tripod. Which allows tripod to rotary motion as well as linear motion in CV Cup housing. The material we select for the tripod is Al7075. For lighter weight assembly.

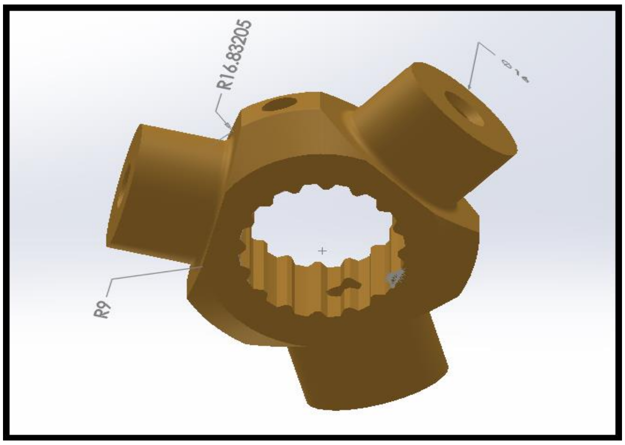

Fig -8: Tripod

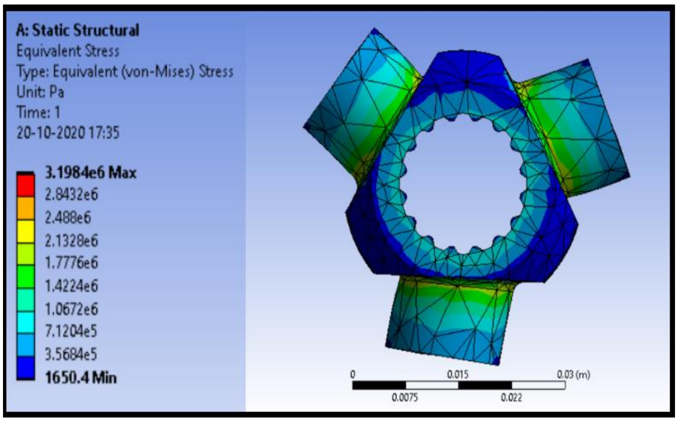

Fig -9: Tripod Equivalent Stress

Table -6: FEA Result

Description	Maximum Stress (MPa)	Maximum Deformation (mm)	Meshing
Tripod	3.1984	0.00048	Triangular

3.4 TRIPOD BEARING

To provide the linear motion to the tripod inside the CV Cup housing we use tripod bearing. The tripod bearing is the ring shape component fitted freely on the tripod legs. The material we select for the tripod bearing is Al7075. For lighter weight assembly.

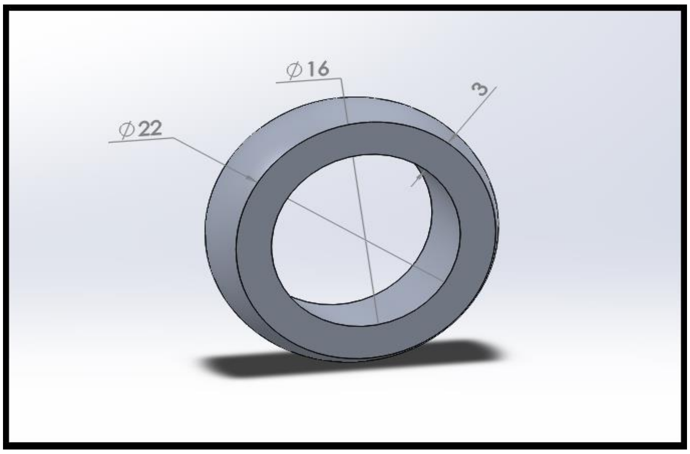

Fig -10: Tripod Bearing

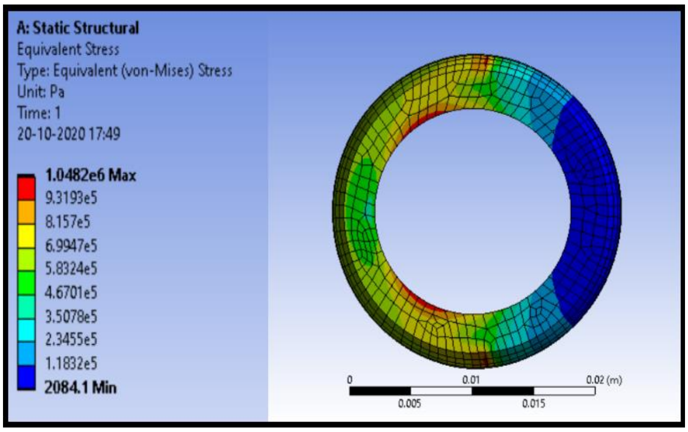

Fig -11: Tripod Bearing Equivalent Stress

Table -7: FEA Result

Description	Maximum Stress (MPa)	Maximum Deformation (mm)	Meshing
Shaft	1.0482	0.00409	Triangular

3.4 SHAFTS

In the formula student vehicle, generally half shafts are use in both side in rear wheel drive. In the Tripod CV joint assembly at the end of each shaft there are one tripod in each end, mesh with the splines of shaft. The material of shaft is titanium Grade 5. Which is stronger among aluminum and steel shaft.

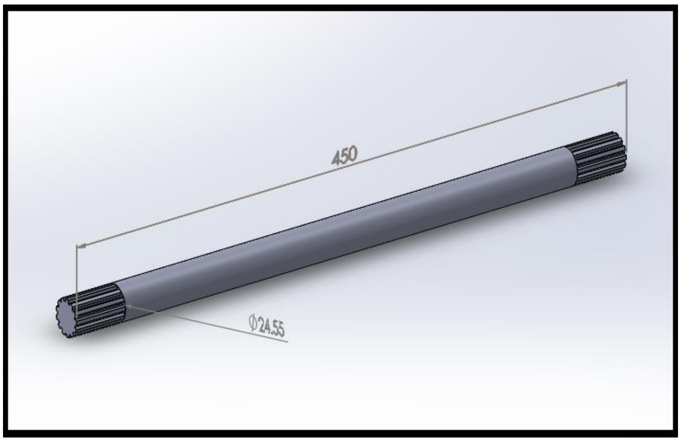

Fig -12: Shaft

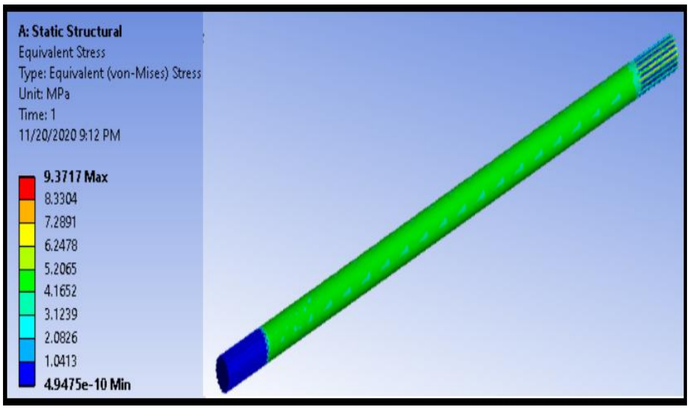

Fig -13: Shaft Equivalent stress

Table -8: FEA Result

Description	Maximum Stress (MPa)	Maximum Deformation (mm)	Meshing
Tripod Bearing	9.3717	0.014	Triangular

3.5 SPRINGS

It is important to place the shaft in the middle of Tripod joint assembly. That's why we place one spring in each CV Cup having less stiffness.

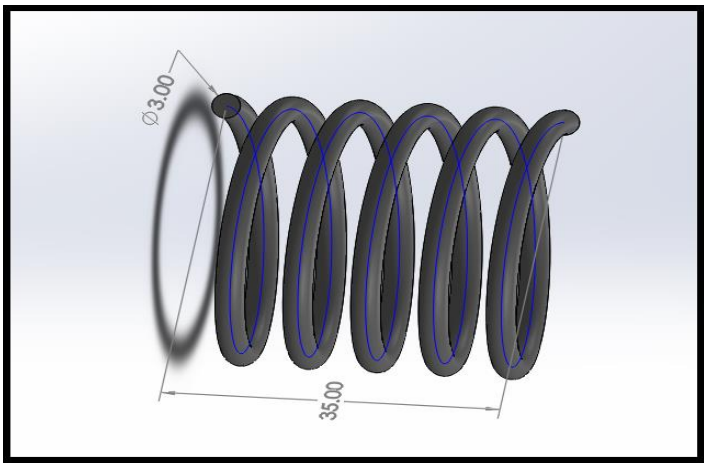

Fig -14: Spring

Maximum stress is within permissible limit. Our design is safe.

4. CONCLUSIONS

We designed the Velocity Joint for a Formula Student race vehicle. We compare various types of velocity joints. And selected velocity joint fulfilled all the requirement which is required to formula student vehicle for better velocity transfer by velocity joint, without compromising reliability of vehicle.

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[4] F. Doberauer and D. Högberg, "Torque and joint angle collective for driveshafts," p. 58.

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