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Design and analysis of Spool Drive For FSAE Vehicle

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Abstract - *Formula SAE is an annual international university-level design competition organized by the Society of Automotive Engineers. Formula SAE (FSAE) competitions offer a great opportunity for an engineering student where can practice and develop various engineering skills. This increases the practical and application-oriented approach toward a real engineering practice. The purpose of this project is to design and optimize the Formula SAE Vehicle Spool Drive. A Spool is a device that connects the two axles directly. A 3D cad model of the Spool Drive and its shape optimization is done using Fusion 360 and Solidworks 2021 software and analysis is to be done using the same software. All the design considerations are taken by keeping in mind the various rules of the formula student community. Different materials are used for manufacturing Spool Drives like Aluminum alloys Al 7075-T6 for lightweight applications, Al alloy 6061-T6 for a moderate weight, and moderate cost or steel in case of low-cost applications.*

Key Words: Spool Drive, Sprocket, Bearings, Fusion 360, Al alloy 6061 T6, Al alloy 7075 T6.

1. INTRODUCTION

The Spool Drive assembly consists of

Spool – Spool is a type of Differential. The spool can lock the axles together to provide 100% of the available torque to the wheel with traction.

Chain Sprocket -A sprocket is a toothed wheel designed to engage and directly move a flexible indented or perforated item, like a chain. The sprocket is assembled on a spool with a sprocket mount with fasteners.

Bearings – A bearing is a machine element that constrains relative motion to only the desired motion and reduces friction between moving parts. The bearing is press fitted on the spool and spool mounting is fitted on the bearing.

1.1 Material Selection

Spool Drive needs to be designed in such a way that it is capable to withstand the forces and moments acting on it due to bumps, braking, and acceleration. To obtain the possibly best riding characteristics of a vehicle and to achieve it, the unsprung mass of the vehicle should be reduced. So, our goal is to design a Spool Drive which has the lowest possible weight. During material selection, the main aim is to have high strength and less weight as compared to other commercially available materials. We are using Al 7075 T6 for Spool, Sprocket, and Spool Mountings.

Al 6061 T6

The composition of Aluminum 6061 T6 is Magnesium 0.80 - 1.20% ,Silicon 0.40 - 0.80%, Iron 0.0 - 0.70%, Copper 0.15 - 0.40% Chromium 0.04 - 0.35%, Zinc 0.0 - 0.25%, Titanium 0.0 - 0.15%, Manganese 0.0 - 0.15 %, etc. It offers better weldability but for knuckles, we need a material with good machinability. It is not as strong as Al 7075. It has no problem with corrosion as having less amount of copper.

Young's Modulus (GPa)	68.9
Density (g/cc)	2.7
Shear Modulus (GPa)	26
Poisson's Ratio	0.33
Ultimate Tensile Strength	310
Yield Tensile Strength	276

Mild steel A36

The composition of Mild Steel A36 is Carbon 0.25-0.29%, Copper 0.20%, Iron 97%, Manganese 1.03%, Phosphorous 0.04%, Silicon 0.2%, Sulfur 0.05%. It is one of the cheapest materials on the list. The material is easily available in the market. It is very heavy. The strength to weight ratio is very bad as compared to Al 6061 T6 and Al 7075 T6.

Young's Modulus (GPa)	200
Density (g/cc)	7.8
Shear Modulus (GPa)	79.3
Poisson's Ratio	0.26
Ultimate Tensile Strength	500
Yield Tensile Strength	250

Stainless Steel AISI 304

The composition of Stainless Steel AISI 304 is Iron 66.74-71.24%, Chromium 17.5-19.5%, Nickel 8-10.5% Manganese 2%, Silicon 1%, Nitrogen 0.11%, Carbon 0.07%, Phosphorus 0.05%, Sulphur 0.05%. The formability of AISI 304 is very good.

Young's Modulus (GPa)	195
Density (g/cc)	8
Shear Modulus (GPa)	86
Poisson's Ratio	0.29
Ultimate Tensile Strength	505
Yield Tensile Strength	215

All materials are mostly used where high tensile strength and toughness are required. So, Aluminum alloys are suited for the wheel assembly components. Due to this low weight of materials, it can decrease fuel consumption and it has a low density and sufficient yield strength. Al 7075 T6 being lighter and stronger than Al 6065 T6 makes it suitable to use for the manufacturing of Knuckle, Hub, and Brake disks.

Al 7075 T6

The composition of Aluminum 7075 T6 is 5.6–6.1% Zinc, 2.1–2.5% Magnesium, 1.2–1.6% Copper, and some other materials which are very less in composition like Silicon, Iron, Manganese, Titanium, Chromium, etc. The specific strength of Al 7075 is very high. Al 7075 offers better strength for the Spool drive. As in the table given below, we can see that yield and tensile strengths are higher than compared to other materials. It is one of the aluminum alloys with the highest strength.

Young's Modulus (GPa)	71.7
Density (g/cc)	2.81
Shear Modulus (GPa)	26.9
Poisson's Ratio	0.33
Ultimate Tensile Strength	572
Yield Tensile Strength	503

1.2 SPOOL DRIVE

The Spool Is essentially a solid axle connection between the left and right wheels, or a fixed differential. Some people weld their differential fixed, for instance, to allow easier drifting. a spool ensures both left and right tires rotate at the same speed. We are using a 70 mm diameter spool.

The axles are installed inside the snout of the spool, and the Sprocket is bolted directly to the larger diameter flange.

This setup eliminates the differential side gears and causes the rear axles to act as if they are welded together so that each axel turns at the same speed under any driving circumstance

1.3 Calculations

Gear Ratio 4:1
No. of teeth on driven Sprocket - 44

Chain No. 50
Chain Link pitch (P) - 15.875mm

Pitch Diameter of Driven Sprocket

Dp= P/Sin(180/T2)
Dp= 15.875/Sin(180/44)
Dp= 222.598 mm

Width of Teeth (to)

to = 0.56P-0.15
= 0.56*15.875 - 0.15
to = 8.7428 mm

Transverse pitch (A)

A = 1.1525P
= 1.1525*15.875
A = 18.3017 mm

corner relief (e)

e = 0.125*15.875
e = 1.985

6) Chamfer Radius (r)

r = 0.54*P

= 0.54*15.875
r = 8.5752

7) Outer Diameter (Do)

Do = 15.875[0.6+cot(180/44)
Do = 232 mm

8) Root Diameter (Dr)
Dr = Dp - 0.625P
= 223 - 0.625*15.875
= 213.075
Dr = 213 mm

1.4 Force on Sprocket:
Max Torque at motor = 68 Nm
Radius of sprocket = 0.033 m

Force on sprocket = 68/0.033
= 2060 N

1.5 Bearing Calculation Data
Bearing Used - 6208 2z

Basic Dynamic load C - 32.5 kN
Basic Static load C0 - 19 kN
Fatigue load limit Pu - 0.8kN
Reference speed - 18000 r/ min
Limiting speed - 9000 r/min
Minimum load factor kr - 0.025

2. Analysis

We use Fusion 360 for the analysis and acceptance of the design. The design has been topologically enhanced as it needed to be as fewer parts in the assembly weigh extra.

2.1 Analysis of Sprocket:

According to the selected final drive ratio of 4:1, the number of teeth of the driving sprocket is 11, and similarly, the driven sprocket has 44 teeth. The 520 chains were used. The sprocket has been designed on Fusion 360 considering the holes on the differential for mounting. After the design, the sprocket was analyzed on Fusion 360. The material Used for the Sprocket is Al 7075 t6.

Fig. Analysis of Sprocket

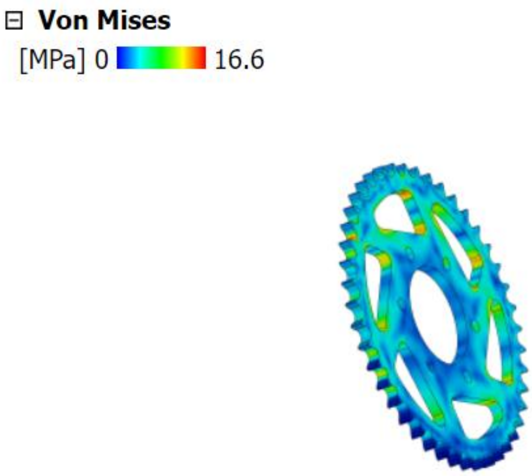

Fig. Von Mises

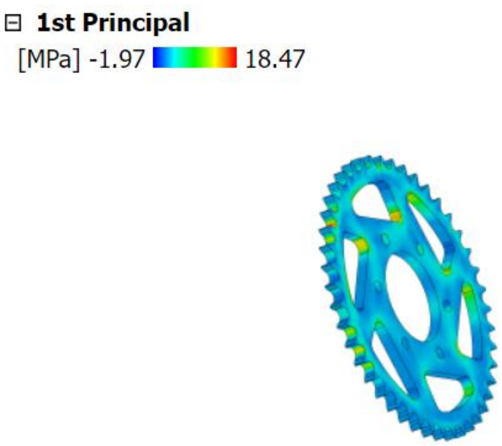

Fig. 1st Principle

2.2. Analysis of Spool

Material Used - Al 7075 T6
Outer Diameter of Spool - 70 mm

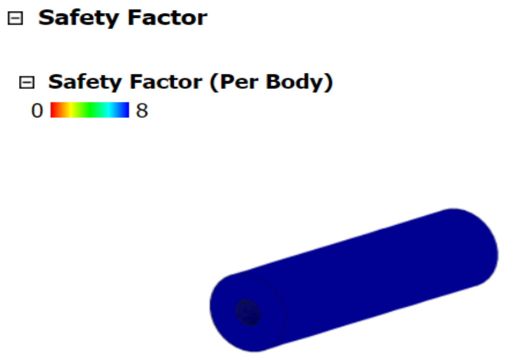

Fig.

Analysis of Spool

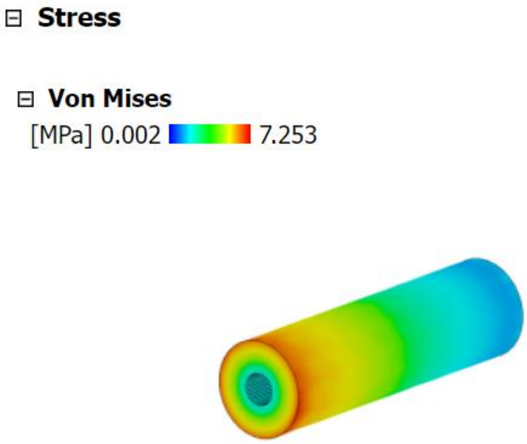

Fig. Von Mises

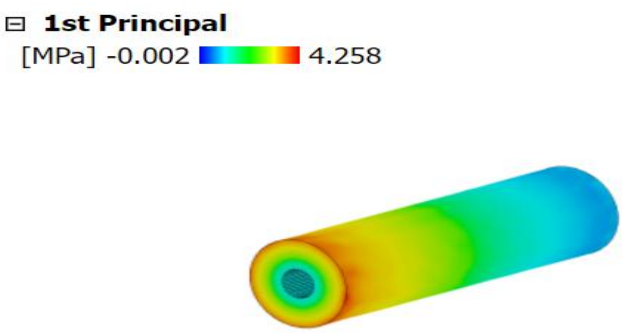

Fig. 1st Principle

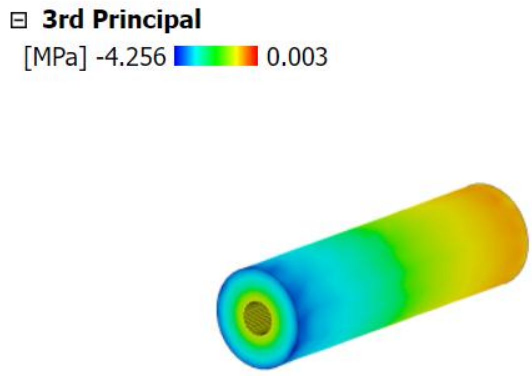

Fig. 3rd Principle

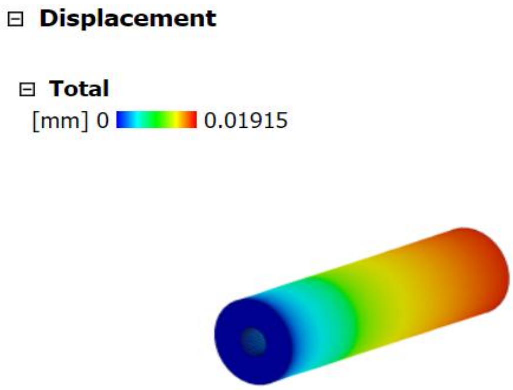

Fig. Total Displacement

Final Spool Drive Assembly :

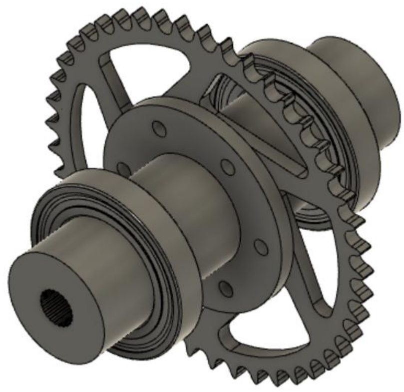

Fig. Final Spool Drive Assembly

3. CONCLUSIONS

We have designed the Spool Drive of an Electric Formula Student race vehicle. We have fulfilled all the criteria asked by the Formula Bharat Rulebook 2022.

The material Selected for the manufacturing of components of the Spool Drive is Al 7075 t6.

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