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DESIGN AND FABRICATION OF DRIVETRAIN FOR FORMULA STUDENT VEHICLE

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Abstract -The driveline of an automobile is the group of components that transfer or deliver power to the wheels and ultimately mobilize the vehicle. This excludes the engine or engine that is producing the power. While the drivetrain includes both the engine and the drivetrain. The goal of the powertrain is to couple the motor that generates the force to the drive wheels that use that mechanical force to rotate the axle. This connection involves the physical connection of the two components, which may be on opposite ends of the vehicle and therefore require a long drive shaft. The operating speed of the engine and wheels is also different and must match the correct gear ratio. If the vehicle speed changes, the ideal engine speed must remain approximately constant for efficient operation, and therefore this gear ratio must also be changed either manually, automatically or by an automatic continuous change.

In this project, we want to design and manufacture the key components of the drive train, including the sprocket, intermediate shaft, tripod housing, half-shafts, hubs and overhangs. Various analyzes were carried out during the iteration in order to obtain the best possible design suitable for our vehicle. All load conditions were taken into account and an optimal design was achieved. In the further course of the project, we will explain the various considerations for manufacturing and how they were shortlisted in order to meet our requirements and our budget at the same time. This project also explains the material selection that was made during the design process. The entire component design and the production of the drive train components for our vehicle have been carried out and tested and have proven to be reliable under all possible working conditions.

***Key Words*: Drivetrain, overhanging, sprocket, hubs.**

1.INTRODUCTION

Team Super Ignite is a motorsport team that participates in various Formula Student competitions. The competition consists of static events that include three different presentations on the design, cost and business aspects of the vehicle. There are also dynamic events like the brake pad, acceleration, autocross, endurance and fuel consumption. This partnership was very successful in these competitions because it focused on the events where the team can collect the most points. This can partly contribute to the TSI design philosophy. This philosophy states that we should design the car to win the competition (earn the most points), and to win the competition, we need to design products that are simple and reliable and whose simulations are validated by physical tests. To be successful, we have to consider this philosophy in every design decision. This includes decisions to prioritize the improvement of parts of the car that are most point sensitive. One project that is considered point-sensitive enough to prioritize as a senior project is the powertrain design.

The powertrain is the area of the car that converts the power generated by the engine into power that turns the car's wheels. The results for this project are a propulsion system that helps the team win the competition. A design helps the team win the competition by being a lightweight, reliable design that enhances the design used for the 2020 design. The approach of the past year has been to reduce the weight of the car, the cost and the number of parts of the car. This year the approach is to further improve the spool design compared to last year and to check whether there are ways to transfer the design to the wheels more efficiently and reduce the weight while still being reliable. Reliability is one of the most important factors for this part of the car because the car will not work without a powertrain.This fact only makes this project relevant and meaningful to the team. The benefits to the team after the project are completed include weight savings and improved energy transfer efficiency, which would result in cost savings and better performance in dynamic events, resulting in more points in competitions.

2. METHODOLOGY

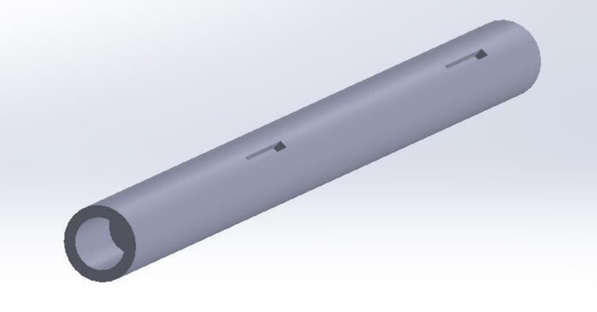
Power losses

In our last year's vehicle, we had mainly two issues regarding power losses, they are.

1) Power loss due to the unbalanced shaft
2) Power loss due to frictional forces

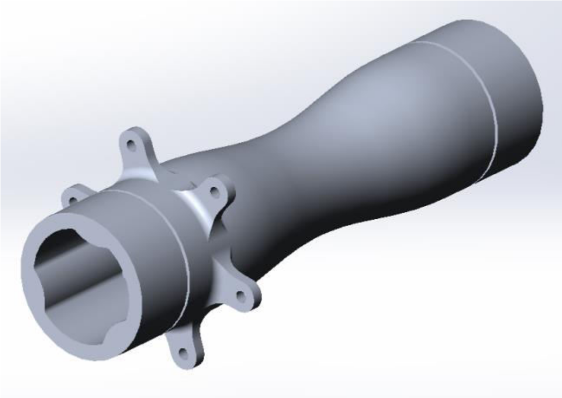
Power loss due to the unbalanced shaft

For last year's we used hub assembly for both sprockets and brake rotor, to lock the axial motion in the hubs of brake and sprocket we have to use the key ways to restrict the axial degrees of freedom in the hubs. Because of the key ways and keys the shaft became unbalanced, there are some losses while rotating in high RPMs.



Preliminary Design of Intermediate Shaft

To rectify the above issue this time, we made the shaft design such that we do not require any hubs to mount the sprocket to the shaft so that the shaft was utterly balanced and with minimum rotational losses.

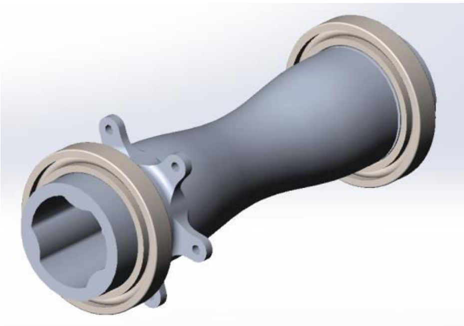


Modified Design of Intermediate shaft

Power loss due to frictional forces

Previously we used a journal bearing setup to mount the shaft to the frame Directly since we used journal bearings they are hydrodynamic bearings which will have a floating film around the bearing but while in static conditions the film around the bearing will come to the bottom of the journal so that it required more torque to get the motion in the vehicle. The journal bearings are not suitable in the radial loading conditions.

To compensate for all the above issues, we used spherical ball bearings to and overhanging plates to mounts the shaft to the chassis.



Intermediate Shaft with Bearings Setup

More rotating parts

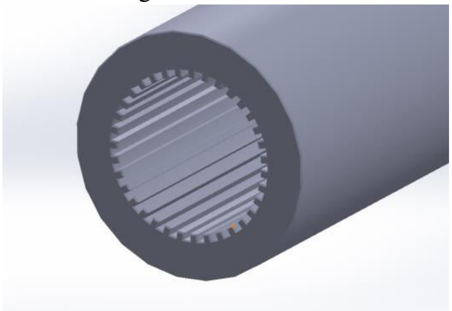
In our older design, we have many rotating parts for our drivetrain assembly. They are two hubs for both brake disc and spool, one rotating shaft, two keys, and grub screws, brake rotor, spool.

This time we reduced the total number of components as minimum as possible. We have a shaft, ball bearings, spool; they are the only rotating parts this year.

Spool drive Assembly

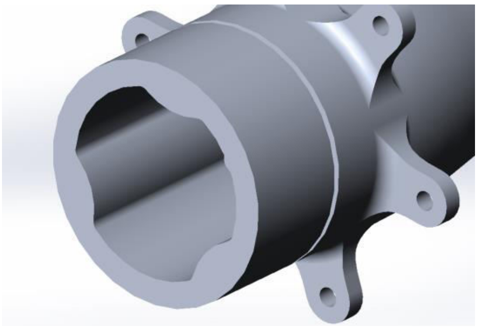
Half shafts assembly

In our previous setup, we used splines to transmit the power from the intermediate shaft to half-shafts, but the splines got damaged under the long-term use.



Preliminary Design of Shaft with Splines

So, this time, we decided to use a tripod set up on two sides of the intermediate shaft so that we won't get any backlash in the assembly.

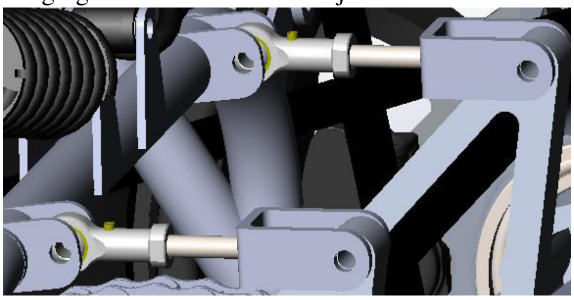


Modified Design of Shaft with Tripod Housing

Chain tensioners

Because of our rigidly mounted drivetrain, we cannot use the adjustable tensioners for the chain., so we had an issue with the loss chain while running the setup.

So, this time we used the adjusters connected to the overhanging arms so that we can adjust the chain tension.

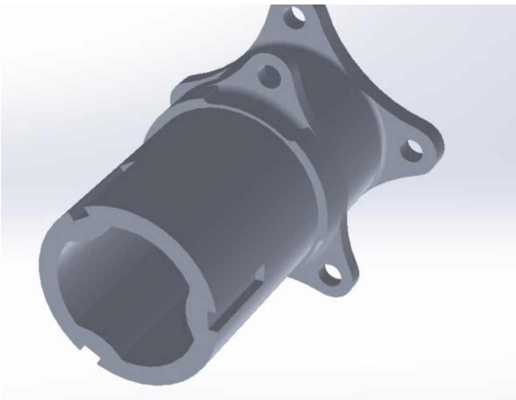


Chain Tension Adjusters

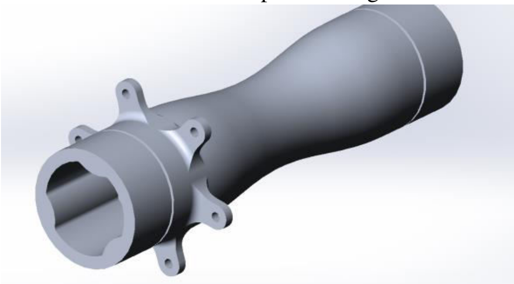
Design optimization of CV joints

In our previous Drivetrain setup, we used a Rzeppa joint to transmit the power from an intermediate shaft to the hubs since they are OEM CV joints; they are heavy and have very high FOS.

In order to make components lighter and compact, we have designed the intermediate shaft and wheel hubs with tripod housings. This reduced the mass of Rotating components considerably and also helpful in ease of assembly and disassembly of the drivetrain setup.



Hub with Tripod housing



Intermediate Shaft with Tripod housing

3.LITERATURE REVIEW

Ian Watson, B. Gangadhara Prusty and John Olsen found in a research report entitled "Optimizing the Conceptual Design of a Constant Speed Coupling" that the Thompson coupling works using the robust double Cardan mechanism. A spherical current collector maintains constant speed and certain linkage kinematics. This mechanism forms an additional loop attached to the intermediate shaft in the double cardan linkage and consequently limits this shaft to cut the input and output axes in half. Expressions in closed form for its movement and the rotation of the double Cardan joint are derived taking into account the kinematics of the spherical link. These terms are then used to drive the fundamental optimization of the concept design, the goal of which is to reduce the induced vibration of the powertrain. The results of this optimization are discussed with regard to the current design of the Thompson connection. Improvements in the induced powertrain vibration are possible provided other clutch design criteria are met.

Chul-Hee Lee and Andreas A. Polycarpou in their research report entitled "A Phenomenological Friction Model of Constant Speed (CV) Tripod Joints" suggested that constant speed (CV) joints are preferred for automotive applications over universal joints for their superiority torque transmission at constant speed and the ability to immerse. High-speed and sport utility vehicles with large joint angles require less immersion in their constant velocity joints to meet the noise and vibration requirements, and therefore require a more thorough understanding of their internal friction properties. A phenomenological CV joint friction model was developed to model the friction behavior of tripod CV joints using an instrumented CV joint friction device with tripod joint assemblies. The experiments were carried out under different operating conditions of oscillation speeds, joint angles of the constant velocity joint, lubrication and torque. The experimental data and physical parameters were used to develop a physics-based phenomenological dynamic friction model for CV joints. The proposed friction model was found to capture the experimental data well, and the model was used to predict the externally generated axial force, which is the main source of force that causes vehicle vibration problems.

Majid Yaghoubi, SeyedSaeidMohtasebi, Ali Jafary and Hamid Khaleghi have introduced a new mechanism in their research entitled "Design, manufacture and evaluation of a new and simple mechanism for power transmission between intersecting shafts up to 135 degrees (Persian joint)" is designed for the transmission of power between two crossing shafts. The mechanism consists of a drive shaft and a driven shaft, six guide arms and three connecting arms. The cutting angle between the input shaft and the output shaft can be varied up to 135 °, while the speed ratio between the two shafts remains constant. Research also includes kinematic analysis and simulation using Visual NASTRAN, Autodesk Inventor Dynamic and COSMOS Motion. The software has shown that this mechanism can transmit constant speed ratios at all angles between two shafts. The validity of equations was demonstrated by comparing the graphs of the analytical analysis and the simulation analysis.

Katsumi Watanabe and Takashi Matsuura, in their research report entitled "Kinematic Analysis of the Rzeppa Joint at Constant Velocity Using a Bilaterally Symmetrical Arc-Rod Connection", proposed this mechanism, the elements of which are bilaterally symmetrical with respect to the bisecting plane of the drive and the driven rotation axes can be used as a constant speed joint. The constant speed joint, which consists of input and output shafts, two circular elements and the frame, is an extremely elementary joint. The closed-loop equation of the arc-bar connection, whose kinematic constants are arbitrary values, is derived in the form of the quadratic equation of the starting angle. The Rzeppa constant velocity joint consists of several sets of the ball and two circular arc grooves. A relative movement of the ball to two circular arc grooves is analyzed and the output angle error in a practical application, which contains sinusoidal fluctuations with periods 2π, 2π / 3 and 2π / 6, is simulated by the constant speed of the circular arc joint.**Tae-Wan Ku, Lee-Ho Kim and Beom-Soo Kang** researched in their research entitled "Multi-stage cold forging and experimental investigation of the outer ring of joints at constant speed" that it is an important load-bearing automotive part that is being transmitted The torque between the gearbox and the driven wheel, the outer race of constant velocity joints with six inner ball grooves, has traditionally been produced by multi-stage hot forging processes that involve various operations including forward extrusion, upsetting, backward extrusion, sizing and necking, and additional machining. There is no alternative but to manufacture the complex-shaped components differently than by this hot forging process. As an alternative, a multi-stage cold forging process is presented that replaces this traditional hot forging. The multi-stage cold forging process is first considered through a process assessment in relation to the traditional multi-stage hot forging process. Then the process is simplified and redesigned as one process to create the forged outer ring and backward profiles of the traditional process, and the sizing and necking are also combined into a single sizing process.

Suhaimi et al. Static analysis eliminated some parts of the post, maintaining the allowable structural strength through stages such as design, analysis, manufacture and customization, and achieved 55.82 percent of the weight reduction. Tagade et al. Expanded the scope of static analysis from previous researchers. In the analysis, the geometric modeling was carried out with CREO 2.0 and ANSYS. The analysis ended with a 67% reduction in mass of the steering knuckle, with the security factory being kept between 3 and 4. Cast iron, which has recently been used, and aluminum alloy, which is proposed as the material.

4. CONCLUSIONS

In this project, we designed and manufactured the key components of the drive train, including the sprocket, intermediate shaft, tripod housing, half-shafts, hubs and overhangs. Various analyzes were carried out during the iteration in order to obtain the best possible design suitable for our vehicle. All load conditions were taken into account and an optimal design was achieved. This time we reduced the total number of components as minimum as possible. We have a shaft, ball bearings, spool; they are the only rotating parts this year also, we decided to use a tripod set up on two sides of the intermediate shaft so that we won't get any backlash in the assembly. In order to make components lighter and compact, we have designed the intermediate shaft and wheel hubs with tripod housings. This reduced the mass of Rotating components considerably and also helpful in ease of assembly and disassembly of the drivetrain setup. The benefits to the team after the project was completed included weight savings and improved energy transfer efficiency, which resulted in cost savings and better performance in dynamic events.

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