XLI CILAMCE
XLI Ibero-Latin American Congress on Computational Methods in Engineering
16-19 November, 2020 FOZ DO IGUAÇU PARANÁ - BRAZIL

SIZING OF THE TRANSMISSION SYSTEM OF A COMPETITION FORMULA SAE PROTOTYPE

João Ferreira de Melo Neto[1], Koje Daniel Vasconcelos Mishina[2], Marcelo Cavalcanti Rodrigues[3], Abel Cavalcante Lima Filho[4]

[1]*Dept. of Mechanical Engineering, Federal University of Paraiba (UFPB)*
Campus I - Lot. Cidade Universitaria, PB, 58051-900, João Pessoa, Paraíba, Brazil
joaonetosan@hotmail.com.com
[2]*Dept. of Mechanical Engineering, Federal University of Paraiba (UFPB)*
Campus I - Lot. Cidade Universitaria, PB, 58051-900, João Pessoa, Paraíba, Brazil
kojemishina@gmail.com
[3]*Dept. of Mechanical Engineering, Federal University of Paraiba (UFPB)*
Campus I - Lot. Cidade Universitaria, PB, 58051-900, João Pessoa, Paraíba, Brazil
celo_cr@hotmail.com
[4]*Dept. of Mechanical Engineering, Federal University of Paraiba (UFPB)*
Campus I - Lot. Cidade Universitaria, PB, 58051-900, João Pessoa, Paraíba, Brazil
abel@les.ufpb.br

Abstract. The automotive industry is always seeking to improve its processes and technologies in order to obtain better performance and efficiency in its vehicles, accompanying this growing optimization arises the demand for professionals increasingly specialized and prepared to assume such responsibilities. One of the main subsystems in a competition prototype is the transmission system. The transmission system is responsible for converting the mechanical energy coming from the engines into kinetic energy. This work aims at an approach on the design of the transmission system of a Formula SAE racing prototype. For the sizing of the proposed system, the first step was to identify the loads that will act on the components. And from them it was possible to define the geometries of the projected components and the selection of components not projected. The design of the components not only involves the values of the loads, but also aspects such as weight, ease of assembly and maintenance, interactions with other subsystems such as structure and suspension, spatial dimension available for the transmission system, adaptation to the rules of competition, ease of manufacture and cost of material used. The use of CAD and CAE software in the dimensioning of the components was of paramount importance in terms of the need to know the behavior of complex components by means of loads, as well as to validate and verify the compatibility of the results found.

Keywords: Transmission system, Design, Prototype, CAD and CAE.

1 Introduction

The auto industry has long sought to optimize its processes and technologies to achieve better performance and efficiency in its vehicles. With this increasing optimization comes the demand for increasingly specialized engineers prepared to take responsibility. This optimization involves the transmission system that is responsible for the conversion of mechanical energy from the engines to kinetic energy.

The gearboxes, as can be seen in figure 1, are nothing but gear trains that vary the couplings between them as changes in the joystick generally transfer the rotational motion originated from the crankshaft to an output shaft on which rotation will be harnessed by other components. The joystick will define the gear ratio according to the required situation, with the highest ratios for situations requiring rapid acceleration and the lowest for situations requiring higher speeds. In popular cars it is external to the engine, whereas in motorcycles it is inside the engine. This second configuration is often found in a Formula SAE prototype.

Figure 1. Honda CBX 750F motorcycle gearbox.
Source: Design by the author

Throughout this work will be discussed the methods used in the design of the transmission system, involving assumptions of calculations and considerations employed. To design the transmission system, it is necessary to first know the loads involved in the system, and from there, determine configurations and select components.

2. Materials and Methods

2.1 Determination of Efforts

The transmission effort determination of a Formula SAE prototype can typically be done in three ways: through engine characteristics, extensometry or tire characteristics. It basically consists in determining the tensile force acting on the chain and then, through the interactions between the components, find out what other forces act on the other components of the system.

Scaling the transmission system by engine power is initially the most basic way to obtain the loads that occur on the system. Under current competition rules, the engine can have no more than 710 cubic displacement, ie engines that can have peak power in the 130 horsepower, but the rule also states that the engines must have in their intake system a airflow restriction of 20 mm for petrol engines and 19 mm for engines using ethanol, such a rule naturally requires engines to have their reduced horsepower. Generally with a well-designed intake and exhaust system, engines can reach about 90 hp. at best.

The Formula UFPB prototype uses a Honda CBR600rr engine, it is a 600 cubic displacement engine, which originally has 120 horsepower, but due to restrictions in the intake system has its power reduced to values around 60 hp. Importantly, the maximum power is given at a certain speed depending on the original design and construction of the engine.

The forces acting on a vehicle come in many forms. The most basic forces acting on the vehicle that are decisive for the dimensioning of a transmission system are presented in Figure 2.

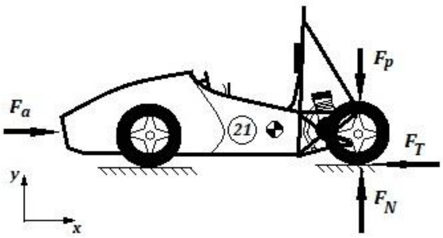

Figure 2. Diagram of forces acting on the vehicle.
Source: Design by the author

The values in Table 1 are data obtained from the Formula UFPB 2017 prototype. It is noteworthy that the value of μps is provided by the manufacturer of Hoosier tires and is also used for sizing the vehicle suspension system, this value is provided along with other data from tire characteristics that are obtained by the team upon their purchase. The indicated vehicle mass already includes the driver's weight giving rise to weight variations between the possible drivers.

Table 1. Prototype data Formula UFPB.

m	320 kg
g	9,81 m/s^2
μ_{ps}	1,4
r_w	250 mm
T_{pneu}	1098,72 N.m

The simulation allows each interaction performed to analyze the safety coefficient and choice of material used and especially the dimensions of the part, seeking to make a match between these factors in order to obtain a lightweight, resistant and easy to use. manufacturing. Care should also be taken to avoid stress concentrators, always leaving small corner radii between the faces of the part. The material considered for analysis was cold drawn SAE 1045 steel, which according to the literature has a yield limit of 530 Mpa and which according to the simulation of figure 3 was effective, which obtained a safety coefficient of approximately 2.5.

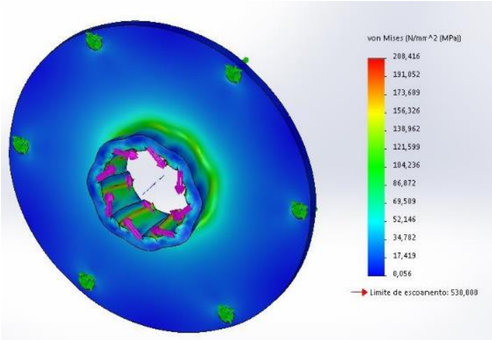

Figure 3. Crown flange simulation.
Source: Design by the author

2.2 Material employed

The principle is always the use of lightweight and resistant materials, as mentioned earlier, it is important to seek the reduction of mass of the vehicle, however more noble materials cost very expensive, example of this is the aluminum alloy 7075-T6 used in industry. naval and aviation because it is lighter than steel and has mechanical strength properties similar to SAE 1045 steel. Using a material of this type can produce a lighter bearing and good strength as well as being a material of good machinability.

In bearing design, the choice of material must also take into account the ease of finding it in the market. By performing simulations with SAE 1020 material with a material thickness of 6 mm, it was possible to obtain satisfactory performance, so it was sought to use SAE1020 Steel Sheet Bearings that had a commercial measurement of 6mm thickness, where by cutting the plasma the desired shape was obtained.

Figure 4 demonstrates the von Misses stress plot simulation for the left bearing plate, respectively.

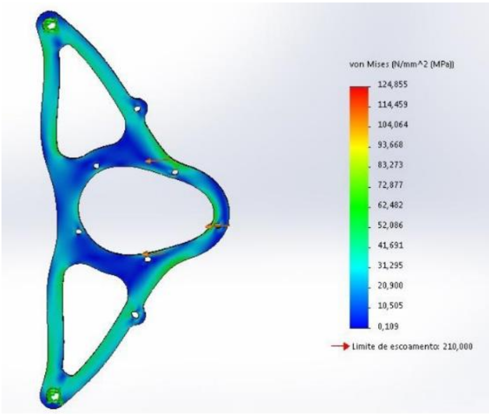

Figure 4. Simulation via finite element of the drive bearing plate.
Source: Design by the author

In the eccentric housings, an aluminum alloy (2024-O) was used which has, according to the literature, a yield limit of approximately 75 Mpa. Because it is a region with the least amount of material, the load FL =10866,47 N, was applied towards the mass reliefs of the part, as we can see in the image plotted in figure 5.

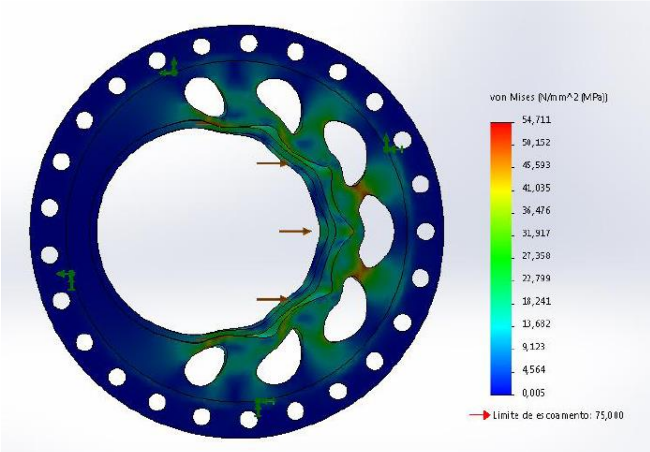

Figure 5. Simulation of the eccentric element of the left-hand drive bearing.
Source: Design by the author

3 Conclusions

The design of the transmission system of a SAE Formula, especially the UFPB Formula, appears to be simple, but becomes complicated at the time of implementation. A designer of this system should always be in contact with designers of other vehicle systems due to the interaction between them, always seeking a configuration that satisfactorily meets both parts. Consideration should also be given to the construction of the pieces, especially with regard to the availability of most of the system's manufacturing within the educational institution itself, where resource constraints mean that the designer has to have a waist set to create something simple. nevertheless effective.

As one of the objectives of a SAE Formula project, in addition to the academic aspect, is the participation and representation of the educational institution in a national competition, it is necessary that the system meets all the rules imposed by the competition and the understanding of the designer on such rules, as it will be tested if any of the judges judging in your system will point out irregularities, even if they do not exist.

The use of CAD and CAE software is very efficient when it is necessary to know the behavior of complex components through the loads imposed on it and so it is of utmost importance that there is validation of the simulations.

The design of the thrust bearing is the most extensive because it has a geometry and functionality that varies as the designer wishes, but so that the imposed conditions are met. In the design phase several changes are made even when designers of other systems, such as structure, decide to make some changes to their design and in such cases the transmitter has to be present to monitor the change and thus be able to evaluate any possible changes to their design.

Components that can be purchased to facilitate the project design process or simply to accelerate project progress can be purchased or obtained through sponsorship provided an analysis of the actual need for the purchase is made. Generally these parts will undergo interventions to fit the prototype unless they are custom made.

Improvement should be constant. with each year of competition a significant improvement should be sought in the project and this work also being directed to future transmission system designers, it is expected an optimization of the project reported in this work.

Acknowledgements

I thank all who contributed directly or indirectly to this work. In particular to all members of the SAE Formula Project.

References

[1] BUDYNAS, Richard G; NISBETT, J Keith. Elementos de máquinas de Shigley; tradução: João Batista de Aguiar, José Manoel de Aguiar, José Benaque Rubert. – 10. ed. – Porto Alegre: AMGH, 2016.
[2] BAKKER, Tom. Design of a drivetrain for a FS race car. Bachelor end project. Technische Universiteit Eindhoven. Department Mechanical Engineering. Eindhoven, March, 2009. Disponível em:< http://www.mate.tue.nl/mate/pdfs/10750.pdf>
[3] 2017 - 2018 Formula SAE® Rules (Update 09/13/2017). Disponível em: <https://www.fsaeonline.com/cdsweb/gen/DocumentResources.aspx>.
[4] DIAS, João. Curso de Especialização em Engenharia Automotiva, Módulo: Transmissões. Universidade Tecnológica Federal do Paraná. Paraná, 2011. Disponível em: <http://www.damec.ct.utfpr.edu.br/automotiva/downloadsAutomot/c1Transmissoes.pdf>.
[5] NSK Brasil LTDA. Catálogo Geral NSK. Disponível em: <www.nsk.com.br/upload/file/Catálogo%20Geral%20NSK(1).pdf >.
[6] THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. ASME B29.1M. Precision Power Transmission Roller, Chains, Attachments, and Sprockets. (Revision of ASME/ANSI B29.1M-1985). New York, 1993