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FINITE ELEMENT ANALYSIS OF PROJECT PARAMETERS OF A COUPLING SLEEVES OF MANUAL TRANSMISSIONS

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Abstract. *The mechanical transmission applied to the design and development of vehicles are constantly evolving into its components and mechanisms seeking options more economical, environmentally friendly, durable and lighter, increasing torque capacity and performance, lower fuel consumption and reducing emissions of pollutants . This work aims to develop a finite element model of a sleeve applied in mechanical transmission vehicle to compare the sleeve obtained by the current manufacturing with a new manufacturing process that uses sintered material. This new manufacturing process aims to reduce the manufacturing cost of the component, providing equal or better performance to the current project. The object of the work was the transmission model C510 adopted in vehicles from Fiat to 1.8cc. The finite element model was developed to assess the sleeve manufactured using sintered material FLN-4405-19HT, to compare the performance of the current material (steel 19CrMn5).*

Keywords: *Tribology, Mechanical Transmission, Coupling Sleeves, Finite Elements.*

1. INTRODUCTION

The automotive industry over the last years is undergoing a process of change as a result of technological innovation, investment in research and development, intensified industry competition and the economic and environmental pressures imposed by governments. Through these inevitable pressures and the new reality of the global automotive market and specifically in Brazil, this work longs contribute to the improvement of design, process, quality and cost of mechanical vehicular transmission systems.

Currently, it is considered normal for the engine of a vehicle has a useful life of approximately 150,000 km, while less than 25 years ago, the expected life was only one third of this value. It is interesting to note that a modern car contains over 2,000 tribological contacts, so it is not surprising that tribology is an issue of increasing importance to engineers (Ludema, 1996).

The success and reliability of the application of mechanical transmission vehicle requires the investigation of a range of phenomena involving tribological aspects. According Perponcher (2009), approximately half of the energy produced in the world is used to overcome the friction, which can be deduced that the best tribological projects have considerable significance for companies. For this reason, governments of industrialized societies have given increasing emphasis on economic aspects of tribology.

The vehicular mechanical transmission system was initially conceptualized in 1895 by brothers Lanchester, who developed the drive shaft, the gearbox with planetary gears and shaft transmission cards. Later, the automatic transmission was launched in the United States by Sturtevant. Although mechanical transmission system is adopted for years, trends in application of this type of transmission in the market demonstrate that mechanical transmission will still be one of the types of system most widely used in the coming years assuming a sizeable stake of 40% worldwide market (Lechner,1994). The large market share of this type of transmission system is justified by the good efficiency and low cost of manual transmission system, but these numbers show the importance of further studies in this area.

This work aims to develop a finite element model of a sleeve applied in mechanical transmission vehicle to compare the sleeve obtained by the current manufacturing with a new manufacturing process that uses sintered material. This new manufacturing process aims to reduce the manufacturing cost of the component, providing equal or better performance to the current project. The object of the research work was the transmission model C510 adopted in vehicles from Fiat to 1.8cc.

2. METODOLOGY

This work was performed using a three-dimensional model of sleeves used in the model C510 transmission adopted in vehicles from Fiat to 1.8cc. Initially the two manufacturing methods to the sleeve were presented. The first process refers to the current manufacturing process of the sleeve. The second refers to an alternate process that aims to reduce

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manufacturing costs sleeve. Then, a finite element model was developed to compare the results of the application of the sleeve manufactured by the two processes. For this purpose, it was used the mechanical properties of the sleeves and the operating conditions.

2.1 Manufacturing Process of the sleeve

The current sleeve is produced by manufacturing processes of forging, machining, tumbling and heat treatment according to the following steps:

- Cut of the pre-blank.
- Cold forging of the blank.
- Machining of outer diameter and groove coupling fork.
- Machining of grooves coupling.
- Machining of internal stops.
- Machining of grooves side 1 internal coupling.
- Machining of Side 2 of the internal coupling grooves.
- Machining tooth coupling.
- Tumbling.
- Heat Treatment.

In observation of manufacturing steps, the blank from the forging process involves subsequent steps in the manufacturing process which are:

- Machining of outer diameter.
- Machining of groove fork mounting coupling.
- Machining of internal tooth flanks.
- Machining of limit contact of the synchronizer ring
- Machining of profile of tooth engaging
- Process deburring
- Heat treatment

The second process for manufacturing the sleeve uses the sintering process of the piece, to replace some machining steps, reducing manufacturing costs. The sintering process uses a uniaxial compression tooling that is composed of four components: the matrix, the top punch, bottom punch and male to design the internal diameter of the sleeve. This tooling works with four basic movements: filling, compacting, extracting and removing (Senad, 2011).

- The filling stage is when the tooling is fed with the mixture of metallic powder.
- The compacting step is the stage in which the sintered powder is compacted in the shape tooling.
- The extraction step completes the cycle of compression to perform the removal of the piece within the tooling.
- The removal step is to withdraw the piece of the place of compression before it starts a new cycle of compression.

2.2 Finite Element Analysis

The method of finite element analysis proposed in this paper used the Abaqus software. As a basis for calculation criterion, it was used the method of Von Mises, which analyzes the volumetric strain by the analysis of the distortion energy.

The components involved in the calculation for assembling the virtual model are: the sleeve, the shaft of the transmission, the group synchronizer and gear shift fork. The components were assembled to virtually finite element analysis as shown in figure 2.

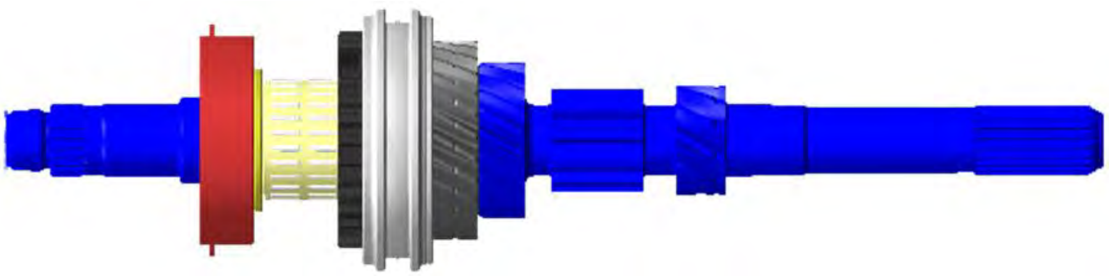

Figure 2. Virtual assembly to the model.

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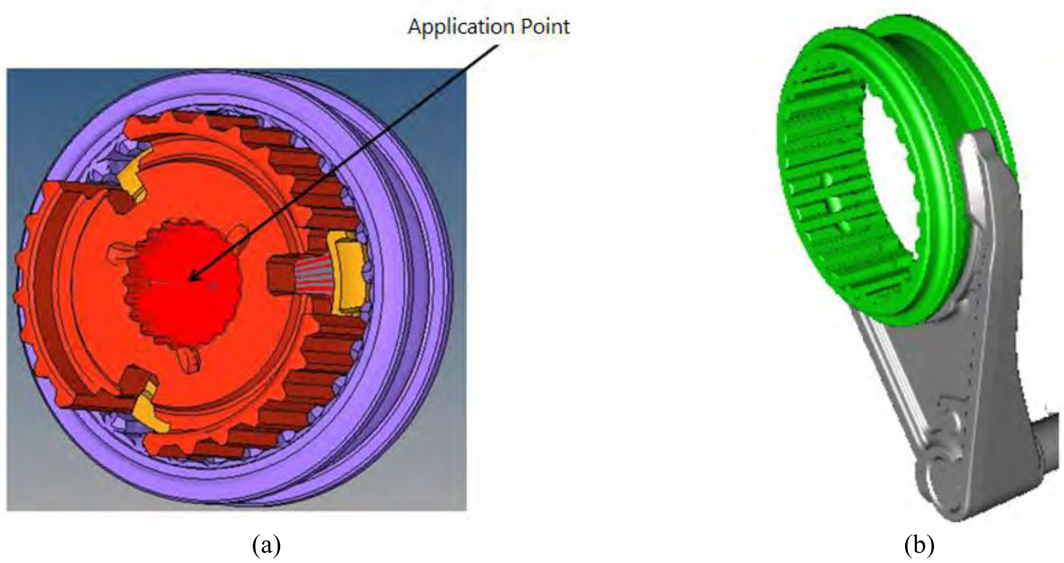
The finite element analysis was performed considering two different materials, namely: (a) chromium-manganese 19mncr5 (SAE 51-20H), (b) sintered FLN2-4405-19HT. The first is the steel currently used on the sleeve transmission. The second is the alloy metal powder sintered proposed as a new material for sleeve. The material was isotropic, in other words, shows the same mechanical properties in all directions. Table 1 shows the properties of the materials.

Table 1. Properties of materials (MPIF,2003).

	Chromium-Manganese Steel 19mncr5	Sintered FLN2-4405-19HT
Ultimate strength [N/mm²]	1100 a 1400	1450
Yield Strength [N/mm²]	880	1240
Elongation (%)	7.0	0.5
Longitudinal Young's modulus [N/mm²]	206,000	150,000

The acting forces were used for the calculation, according to standard fatigue transmission adopted in the transmission of C510 by Fiat. For sleeve 5th gear was considered a torque T = 246.5 Nm and a force of F = 120Nm for the coupling when it is done a gear shifting. The point of application of force was considered the center axis position of the synchronizer, because the torque sleeve being received from the transmission shaft which is connected to the engine and which is driven by the transmission (Fig. 3a).

The support and fixing points are dimensioned according to the assembly of the transmission sleeve (Fig. 3b). The sleeve attachment points were defined by the region outside of the fork and the point in the center of the sleeve, allowing proximity to simulate the actual operation of the system.



(a) (b)

Figure 3. (a) Point of force application on the sleeve. (b) The points of support and fixing of the sleeve.

For the finite element model was used a mesh with tetrahedral typology and the following characteristics: uniaxial element, three-dimensional, with capacities to act in tension, compression, torsion and bending. This element allows a section not necessarily symmetrical between the start and end of the element. This type of mesh also allows a better modeling according to the geometry of the part, improving the ability to solve problems of deformations due to shear (Hutton,2003).

Through software HyperMesh, the mesh was generated for the model. In the study it was chosen a mapped mesh type because of the geometric shape of the piece. To confirm the quality of the mesh, was inspected with Hyperform tool to check the quality criteria, visual inspection of the elements, removing elements deformed connectivity between elements and removing duplicate elements. The resulting mesh can be seen in Figure 4.

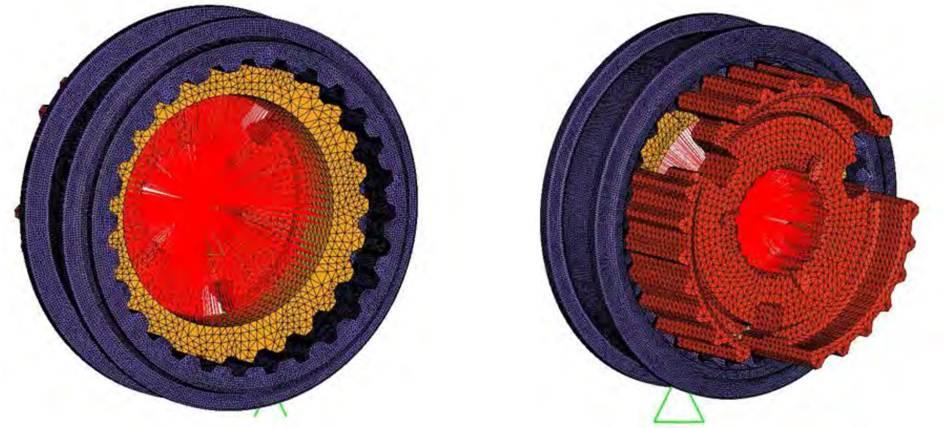


Figure 4. Mesh for the finite element model

3. RESULTS AND DISCUSSIONS

The sintering process for manufacturing the sleeve allows a reduction of 5 machining operations being:

- Machining of groove the sleeve
- Pre-machining of the external face.
- Machining of the external face.
- Machining teeth the sleeve.
- Machining of coupling profile of the sleeve tooth.

The density value found by the principle of Archimedes was 7.4 g/cm^3. The density increased after the piece go through a process of shooting, increasing to 7.7 g/cm^3. The hardness of the material used for sintered was 110 HB.

3.1 Result for the Finite Element Model

Have been identified two regions on the sleeve with higher request contact pressure and effort. The two regions called region 1 and region 2 (Fig. 5), suffer higher demand due to the operating conditions of the system. The first region is at the end limit stop cursor cube transmission. Region 2 is located in the teeth coupling operating with the synchronizer ring, being a most requested region from the standpoint of fatigue due to the efforts of energy dissipation during coupling. The results were presented for the contact stress and distortion stress of Von Mises.

Figure 5. Critical region for analysis

The results from the finite element calculations for the two material conditions, steel 19CrMn5 and sintered steel FLN-4405-19HT are shown in Table 4.

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Table 1. Finite elements results

Material	Von Mises Stress (MPa)		Contact Stress (MPa)	
	Cube	Tooth	Cube	Tooth
Steel 19CrMn5	838	686	1178	792
Sintered FLN-4405-19HT	879	718	1112	808

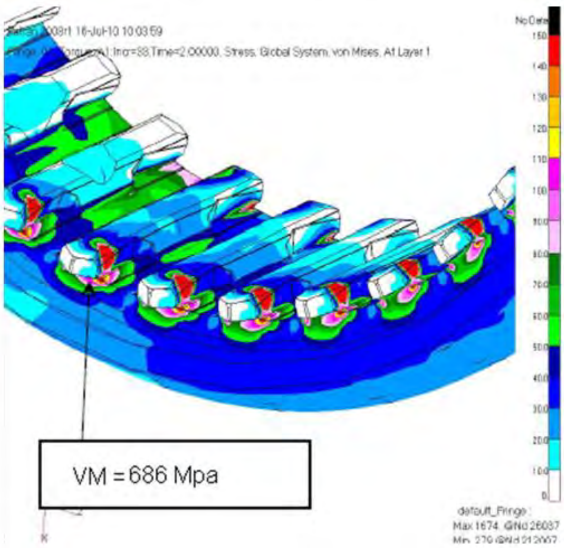

Figure 6. Von Mises Stress for the steel tooth (19MnCr5 T = 686 Mpa).

4. CONCLUSIONS

The finite element model was developed in order to assess the sleeve coupling applied in transmissions C510, manufactured using material FLN-4405-19HT, to compare the performance of the current material (steel 19CrMn5).

Comparing the overall result of sintered FLN-4405-19HT with the steel 19CrMn5, it is observed that steel 19CrMn5 showed a better performance of energy absorption with lower values for fatigue of the material, in other words, the distortion that this material has undergone was lower than in sintered (Fig. 6), but comparing the values with the yield stress of the steel 19MnCr5 and sintered FLN-4405-19HT the two materials in terms of calculation, have values within the ranges of yield strength of the materials specification. A more complete evaluation of these results can be accomplished with an experimental test of the sintered FLN-4405-19HT for testing the fatigue life of the sleeve.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

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