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Contact analysis of spur gears made of PLA carbon fiber reinforced

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Abstract—In this work numerical calculations are performed in order to perform an analysis of the contact between spur gears made of PLA carbon fiber reinforced. Analysis was carried on under aligned and misaligned conditions. Three different moment were applied with magnitudes of 1, 3 and 5 Nm. Results show that maximum pressure contact is presented in the driven gear near the tip zone, and this occurs when contact starts. Contact region changes in driving gear due to misalignment.

Keywords—Spur gears, contact, carbon fiber reinforced, finite element.

I. INTRODUCTION

Spur gears are mechanism which transmit power and motion between shafts. The magnitude of transmitted power can vary from high to low. In the case of high loads spur gears are made of steel, whereas for low loads are made of polymers materials in order to reduce its weight and manufacture costs. Polymer materials are a good option to design spur gears with low loads. The contact pressure between teeth gears can cause damage and the resulting failure which is most common in polymer gears [1]. Special attention should be paid to operation conditions and working environment in order to avoid premature wear. Research has been conducted in order to study several aspects of polymer spur gears. Senthilvelan and Gnanamoorthy [2] perform an experimental investigation to study the transmission efficiency in gears made of nylon and nylon reinforced with carbon fiber manufactured by means of injection mold. They found that transmission efficiency is sensitive to operating load and that is reduced due to surface deterioration and reduction of stiffness. Gurunathan et al. [3] study the wear characteristics of pristine polyamide 6 and polyamide 6 nano composite (PA6NC) spur gears. They evaluate the performance of gears at different torques using a power absorption test rig. They conclude that the surface temperature affects the useful life and the wear rate. Also, the properties of PA6NC leads to a spur gears with less wear and more useful life. Mao et al. [4] perform a research to study the thermal contact behavior of machine cut acetal gears. They report that wear rate increases when the load reaches a critical value, whereas wear rate increases slowly under this value. This is attributed to increasing of surface temperature which can lead to reach the gear melting point. These findings highlight the importance of spur gears made of polymer materials. Faults can be appearing when spur gears are installed [5]. The most critical is the misalignment which causes a non-uniform contact pressure over teeth surface [6]. This off-design operation condition can lead to accelerate wear, premature failure, and excessive vibrations. In this work finite element method (FEM) was employed to compute pressure contact between spur gears made of PLA reinforced with carbo fiber. Numerical calculations were performed under both design and off-design condition with misalignment in radial direction.

II. METHODOLOGY

The mechanism consists of two gears, driving and driven, with a gear ratio *i*=1 Characteristics of spur gears are presented in Table 1. The gears were modeled in a CAD software. Only one quarter of gear was modeled in order to reduce the computational time during FEM simulations. In Figure 1 the CAD model is presented.

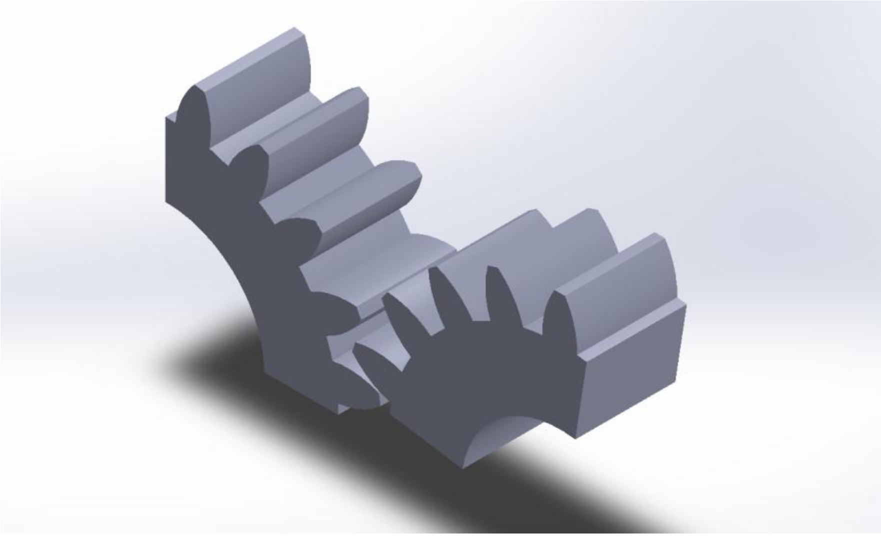

Figure 1.- Gears model.

Table-1 Properties of spur gear

Module (mm)	2.5
Z_p	24
Z_g	24
D_p (mm)	60
D_g (mm)	60
φ (°)	20
n (rpm)	2500

Contact between gears was simulated in a transient study during 36° in order to have results for two teeth pairs with time steps of 50. The FEM model was constructed with quadrilateral elements and the mesh size was of 11,976. To describe the movement of the gears, a condition of moment joint and rotational joint (Figure 2). This type of boundary conditions allows to characterize the rotation of gear mechanism.

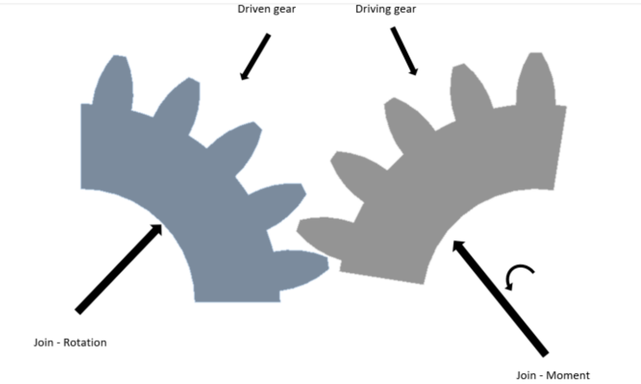

Figure 2.- Conditions applied to gear mechanism.

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The load was of 1, 3 and 5 Nm and was applied in the center of driving gear through the moment joint. This level of magnitudes is due to this type of materials are used in cases which the torque transmitted is low.

The gear mechanism was evaluated under design and off-design conditions. The off-design condition was a misalignment measured in radial direction, as is showed in Figure 3. Two values were set for misalignment: +/- 2.5 mm.

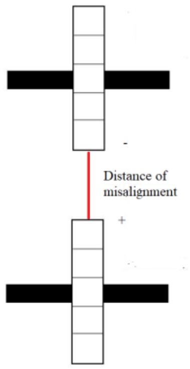

Figure 3.- Description of misalignment

III. RESULTS

In Figure 4 the results of maximum contact pressure during contact cycle for driving gear are presented. The aligned condition in Figure 5a shows that the contact pressure concentrates at the middle of the gear teeth. In misaligned conditions the contact area moves near to the gear root. Maximum contact pressure was found in the gear with negative misalignment due to increases the amount of area, which is in contact, instead, in positive misalignment the contact pressure decreases due to contact area is smaller.

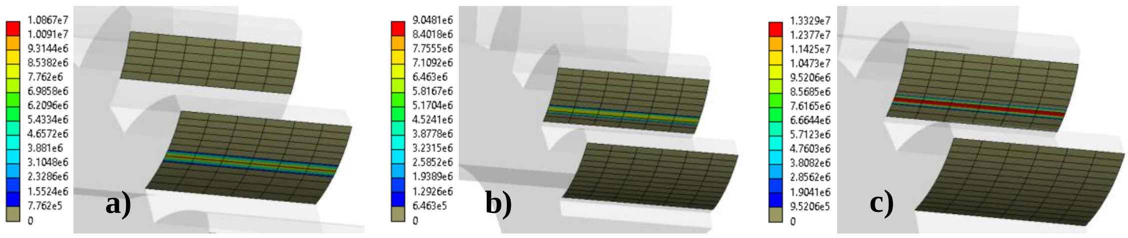

Figure 4.- Contact pressure in driving gear at 1 Nm, a) aligned, b) positive misalignment, c) negative misalignment.

Figure 5 presents results of maximum contact pressure at 3 Nm. Magnitude of contact pressure is doubled compared to case with 1Nm. Also is observed that the contact region was located near the tip of gear teeth in the aligned case.

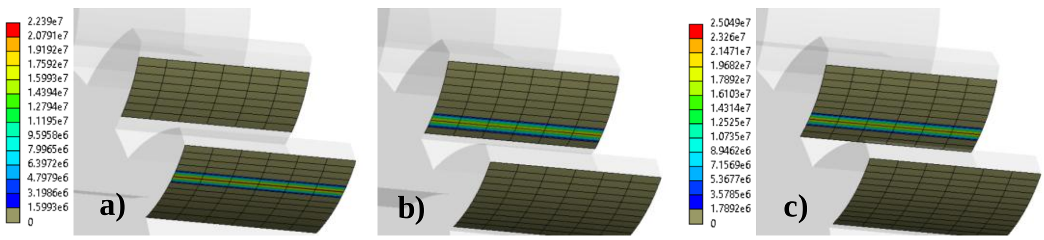

Figure 5.- Contact pressure in driving gear at 3 Nm, a) aligned, b) positive misalignment, c) negative misalignment.

Figure 6 shows that at 5Nm the increment of contact pressure magnitude is higher in negative misalignment is around 100% than in 3Nm. This load is shared with the previous teeth which is also in contact which indicates that the contact ratio is >1 at this position. The position of contact zone in positive misalignment changes around the middle of gear teeth. This behavior was observed also in the aligned case. Magnitude of contact pressure presents the same trend like in previous cases being lower in the positive misalignment.

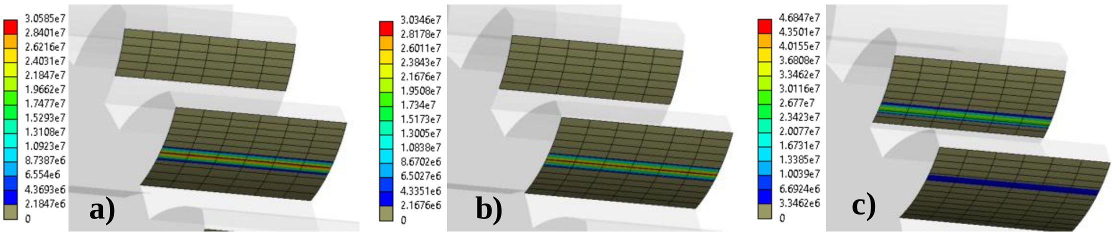

Figure 6.- Contact pressure in driving gear at 5 Nm, a) aligned, b) positive misalignment, c) negative misalignment.

Results for contact pressure in driven gear are presented are presented below. Figure 7 presents magnitudes of contact pressure for 1Nm. In all cases is observed that pressure concentrates in the tip of the gear teeth, which indicates that occurs in the start of contact. Positive misalignment presents lower pressure magnitude, whereas in alignment and negative misalignment cases magnitudes is around 2.7e7 Pa.

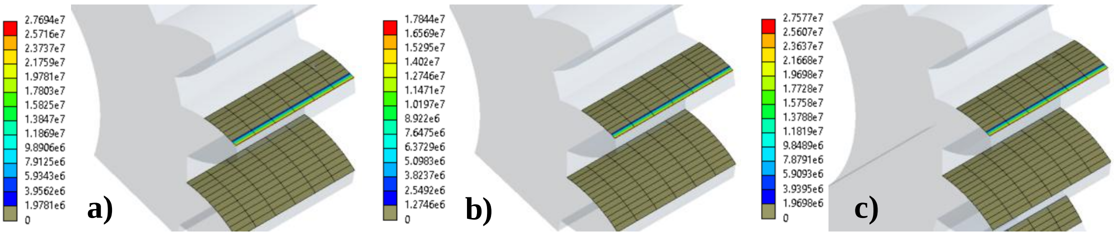

Figure 7.- Contact pressure in driven gear at 1 Nm, a) aligned, b) positive misalignment, c) negative misalignment.

Figures 8 and 9 present results for 3Nm and 5 Nm respectively. As in 1Nm case, maximum contact pressure is located at the tip of teeth. This is because in this time the driving gear transmit the load in a small zone of the driven gear which increase the value of the contact pressure. In aligned and positive misalignment cases at 3 Nm the load is shared between two teeth, whereas in the case of 5 Nm this occurs in the three conditions. Pressure contact is slightly higher in negative misalignment than in aligned condition. Negative misalignment remains lowest values of pressure contact.

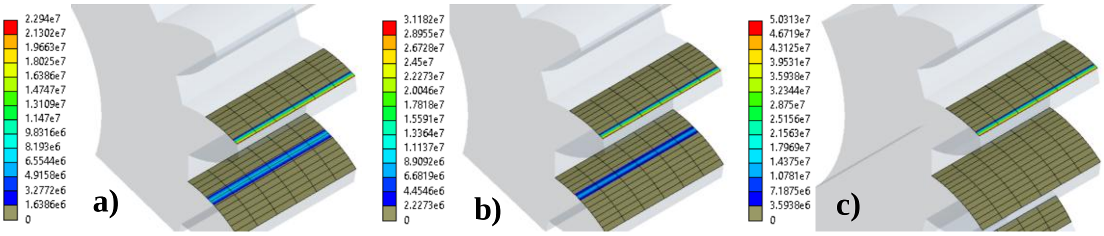

Figure 8.- Contact pressure in driven gear at 3 Nm, a) aligned, b) positive misalignment, c) negative misalignment.

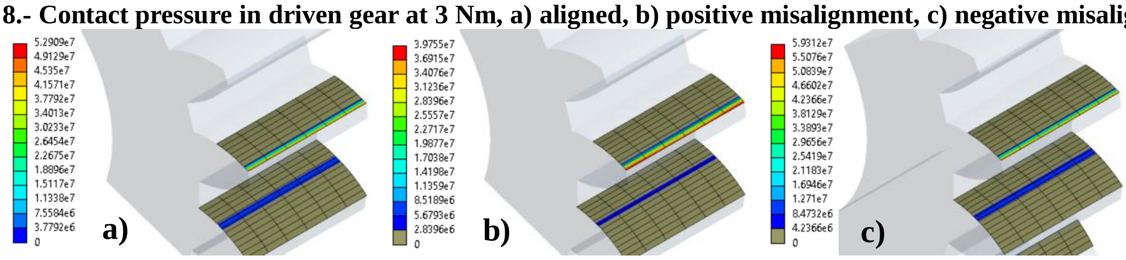

Figure 9.- Contact pressure in driven gear at 5 Nm, a) aligned, b) positive misalignment, c) negative misalignment.

IV. CONCLUSIONS

This paper study the contact pressure between spur gears made of PLS carbon fiber reinforced using finite element calculations under alignment and misalignment conditions. A drastic change occurs in contact zone when spur gears are misaligned. Positive misalignment presents low magnitude of pressure due to contact than other cases. On the other hand, negative misalignment does not present a remarkable increment of pressure with respect to aligned case. PLA is suitable to implement as material in the design of spur gears.

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