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NUMERICAL DESIGN AND MECHANICAL PERFORMANCE OF INJECTED MOLDED CARBON FIBER/PEEK GEARS

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ABSTRACT

This work analyses the stress distribution in injected molded carbon fiber (CF) reinforced poly-ether-ether-ketone (PEEK) gears. The actual fiber orientation was assessed by simulation of the injection molding process. Welding line locations were identified for different injection configurations and dimension stability was compared. Fiber distribution was mapped to a finite element model in order to obtain the local constitutive behavior. The most critical parts in the gear are identified and their correlation with the obtained microstructure was discussed.

Keywords: PEEK, carbon fiber, gears, injection molding, FEM.

INTRODUCTION

Plastic gears appeared as a good metal replacement option due to inherent polymers advantages such as light weight, easy manufacturing and reduced noise. However, their application is often limited to lower loads and temperatures as a consequence of their reduced strength and low melting temperature (~150°C), respectively.

Over the last decade, PEEK gears were known for their excellent performance, especially at high temperatures (Kurokawa, 1999). Nevertheless, the increasing demands for improving the tribological behavior led to the addition of various solid lubricants and/or reinforcement with different types of fibers. Short CF's are usually employed to obtain an improved mechanical behavior. In this case, short fibers support the most of the load into the composites, increasing the matrix creep resistance (Rasheva, 2010). Despite the vast amount of published work, mainly related to tribological behavior, there is still a clear lack regarding the accurate assessment of integrity and failure with special focus on finite element simulations. This work is intended to present the first steps of a stress-based reliability analysis for an injected molded CF/PEEK gear, considering the manufacturing process as well.

Injection molding simulation was performed in SIGMASOFT® obtaining the welding lines location and shrinkage potential for three different inlets configuration (2, 4 and 8 gates). Fiber orientation distribution in the gear was characterized by means of a second-order orientation tensor (Advany, 1987) for the optimal injection configuration. The fiber orientation was then homogenized using a Mean-Field approach in Digimat-MF® and the local mechanical behavior was mapped onto a finite element mesh to carry out the structural analysis in ABAQUS/Standard®. Approximately 5×10^5 C3D10 (quadratic tetrahedra) elements were used in the stress analysis. A two-gear system was modeled, assuming frictionless contact between gears. Both gears were placed in their working positions; one of them pinned in its mass center while the other was forced with a small rotation (~3º). Both matrix and fiber constitutive behaviors were assumed as linear-elastic.

RESULTS AND CONCLUSIONS

The eight-gate configuration showed to be the optimal since higher welding line strength and dimension stability were achieved.

In order to identify the most critical stress, the path shown in figure 1 was selected. The analysis showed that as the time evolves bending stresses at the tooth root become more significant than those generated by contact with the counterpart.

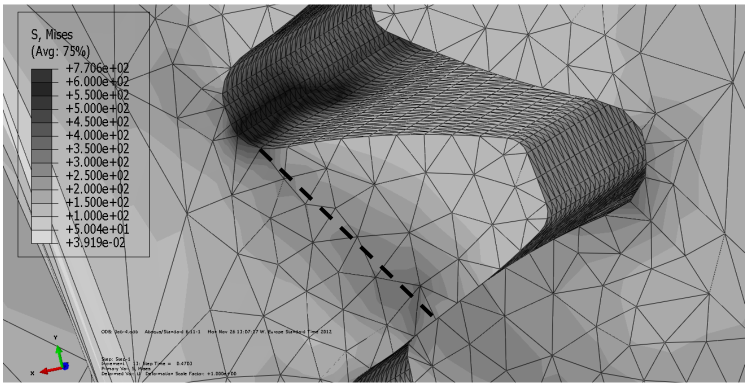

Fig. 1 - Mises stress distribution (analyzed path is shown dashed line).

Wear studies were not included in the present model but they should be a matter of future work to complement the present results. Nevertheless, the starting point for a more accurate, simulation-assisted reliability analysis of reinforced PEEK gears has been already set.

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