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Investigation of extrusion based printed gears of different polymer compounds

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Combining one of the oldest and one of the latest technologies, tribology and additive manufacturing, opens up new possibilities. With more freedom in geometry, new designs with material saving and load optimization can be realized. This is an attractive alternative to conventionally produced gears if low loads and low part numbers are required. Therefore, extrusion-based printed gears have a potential which has to be studied. Summarizing the comparison of cut- and printed samples, they differ depending on the layer orientation, the gears withstand medium load torques but show delamination of the teeth because of not efficient bonding between the layers.

Keywords: tribology, polymer, gears, additive manufacturing, MEX

1. Introduction

An often unnoticed but still one of the oldest and most complex fields of engineering is tribology. One of the latest fields of research is additive manufacturing as material extrusion (MEX) and powder bed fusion (PBF). MEX got popular due to the low prices of printers and the easy handling of the printer itself. The most known benefits of e.g. MEX are the cheap and fast way of producing prototypes, which required qualities are not only limited to industrial printers anymore [1-3].
The almost unlimited freedom of additive manufacturing could revolutionize the way the throwaway society, so long as the replacement is cheaper and faster than a completely new system.
This study aims to optimize the tribological behaviour of tribo-filaments and study the possible use for gears in low precision applications.

2. Methods

2.1. Basic tribological characterisation

The first characterization was conducted with a pin on disc (PoD) test setup at rotating tribometer of four materials – two special compounds based on tribological modified PA and POM and two commercially available tribo-filaments. The 3D printed samples were tested with 1 and 2 MPa, a sliding velocity of 0.5 m/s for 3 h, since this period showed a stable tribo-system without any further change of the friction or the temperature.

2.2. Gear testing with velocity ramps at different load torques

Further tests were done on MEX printed and conventionally manufactured gears, which were tested with a velocity ramp procedure at different load torques. All materials were tested with 100 rpm steps for the velocity at a fixed load torque for 20 min. If the gear showed no sign of damage a new gear was taken and tested with the next torque level. The levels were at 5, 10, 15, 20, and 25 Nm.

2.3. Damage Analysis

The damage analysis of the pins and the gears was conducted on a light microscope to correlate the tribological behaviour with the given damage on the running surfaces.

2.4. Results

The overall result from the basic characterization with the PoD test is an almost not affected coefficient of friction but a varying wear rate for extrusion-based printed samples compared to extruded samples. This also depends on the printing orientation, which is given by the printing process itself.
Even though the printed gears showed warpage, the testing on the gear test setup showed a more stable running behaviour at higher velocities. The gears start to transfer material to the counter gear in the running-in phase, which results in a tribological more stable state afterwards. The gears fail due to break off the teeth in a combination of torque and heat, resulting in deformation. In Figure 1 the worn surfaces of pins and teeth are shown.

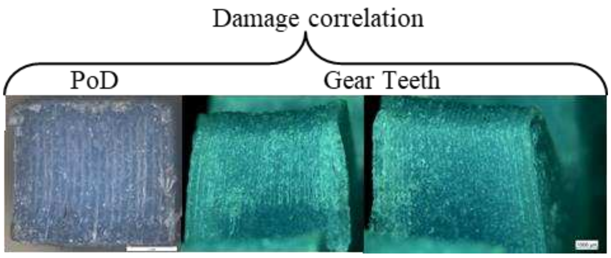

Figure 1: Comparison of the damage of running surfaces from pins (32x magnification) and gear teeth (10x magnification).

3. Discussion

The damage analysis shows a comparable picture for running surfaces of the pins and the worn area of the teeth. The teeth of printed gears withstood up to a middle torque depending on print settings and the degree of filling from the teeth itself. In the future, a printed gear can be used as a replacement for low load applications with a simultaneous mass reduction.

4. References

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