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Sustainable tribological composites through Circular Economy: using recycled carbon fibers as an alternative reinforcement in UHMWPE-based composites

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Polymer composite materials represent a large volume of engineering materials though recycling of such has only recently gained considerable attention. In tribological applications, lightweight materials with long service life are sought after for reducing cost and emissions among other advantages. This project aims at providing an understanding of how recycled carbon fibers (CF) could be a part in this endeavor. Investigations of mechanical and tribological performance of Ultra High Molecular Weight Polyethylene (UHMWPE) composites reinforced with virgin and recycled short CF show an equally good performance, indicating at the possibility for replacement of the virgin materials without sacrificing performance.

Keywords (from 3 to 5 max): circular economy, recycled carbon fibers, tribology, polymer composites

1. Introduction

Polymeric composites present a large share of engineering materials, especially using carbon fibers as reinforcement due to their outstanding specific strength, low weight and known beneficial effect regarding tribological performance [1]. Critical aspects, such as the composites' disposal, environmental impact, and cost of production became more relevant nowadays. One pathway for improving this is transiting to a circular economy for improving resource efficiency [2].

However, characterization of recycled carbon fiber composites (rCF) for tribological applications is scarce. This investigation is focused on the characterization of Ultra High Molecular Weight Polyethylene (UHMWPE) composites reinforced with virgin and recycled short carbon fiber (SCF) (vSCF/rSCF).

2. Methods

Composites were manufactured using a formerly developed procedure based on ball milling and compression molding obtaining samples in the required geometries for the various characterizations. Compositions contained different amounts of virgin or rSCF in UHMWPE for means of comparison.

2.1. Mechanical evaluation

Tensile tests were performed using a universal testing machine for evaluation of the mechanical performance, while microhardness measurements were performed for

2.2. Morphological and microstructural evaluation

SEM was used for characterizing filler dispersion, cross-sections, worn surfaces and wear tracks.

2.3. Tribological evaluation

Pin-on-disk experiments were carried out under water lubricated conditions for 24 h at 88.72 N load, 0.13 m s^{-1} velocity resulting in 11.27 km sliding distance with an LVDT sensor for assessing the wear rate.

3. Discussion

Mechanical properties increased upon incorporation of up to 30 wt% of either type of SCF.

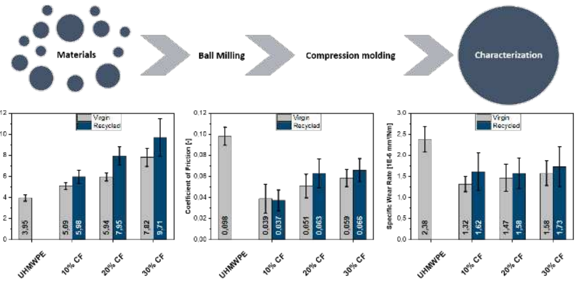

Figure 1 Manufacturing procedure, Vickers hardness, coefficient of friction and specific wear rate of UHMWPE/CF composites.

Hardness increased by 98 % (vSCF) vs. 146 % (rSCF) compared to pure UHMPWE. The tensile strength increased by 98 % (vSCF) vs. 105 % (rSCF), the Young's modulus by 251 % (vSCF) vs. 208 % (rSCF), indicating comparable performance for both composites at the highest reinforcement concentration. No statistically significant difference was found for tribological performance. Both SCF showed improvement for coefficient of friction (- ~62 % for rSCF) and specific wear rate (- ~32 % for rSCF) at the lowest content of 10 wt% SCF. This is explained through increased hardness of the composites and with the presence of a transfer film on the counter surface, which was not identified for the experiment with pure UHMWPE. These results indicate that rSCF are a suitable replacement for vSCF on the way to an improved resource efficiency.
In a scenario of replacing 20 % of the overall SCF demand with rSCF, a possible cost saving of ￡623 MM/year could be achieved.

4. References

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