Comparison of the sliding behaviour of several polymers in hydrogen

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The work presented here deals with the friction and wear behaviour of polymer materials in hydrogen. Commercially available grades of PEEK, PA, PPA, PAI, PI and PBI were investigated at room temperature in air and hydrogen gas (H_2) as well as in liquid hydrogen at - 253°C (LH_2). The samples were arranged in a pin-on-disc continuously sliding against a rotating steel disc (AISI 304). The focus of the study is to evaluate the effect of supplier, molecular weight and/or fillers on the friction and wear rates of selected polymer materials in hydrogen.

Keywords: hydrogen, polymers, friction, wear, cryogenic temperature

1. Introduction

The development of hydrogen technologies entails high safety requirements in distribution and dispensing infrastructure. As it is well known that the environment is an important issue on the tribological behaviour of polymer materials, researches on material compatibility in hydrogen is crucial for safety and reliability purpose.
High performance polymers composites have been intensively investigated for tribological applications in air, but rarely in hydrogen environment. Author's previous work in hydrogen (H_2) focused on the effect of filler types [1, 2] and of cryogenic temperature [3] on the sliding performances of PEEK and PI materials.
The purpose of this study is to evaluate the effect of supplier and molecular weight on the sliding performance of composites as well as to compare further polymer materials in gas and liquid hydrogen.

2. Methods

2.1. Materials

Commercially available grades of Polyether ether ketone (PEEK), Polyamide (PA), Polyphthalamide (PPA), Polyamide-imide (PAI), Polyimide (PI) and Polybenzimidazoles (PBI) were selected from different suppliers. Filled and unfilled polymers were chosen as indicated in table 1.

Table 1 Material composition

Name	Matrix	Fillers
PEEK1, PEEK2, PEEK3	PEEK	-
PEEK30-1, PEEK30-2	PEEK	Carbon fibers, Graphite, PTFE
PA	PA	-
PA GF	PA	Glass fibers
PPA	PPA	-
PPA TF	PPA	PTFE
PAI	PAI	-
PAI GrTF	PAI	Graphite, PTFE
PI1, PI3	PI	-
PBI	PBI	-

2.2. Friction tests

Polymer samples were arranged in a pin-on-disc configuration continuously sliding against a rotating disc.

Polymer composites were cut into pins (4x4x12 mm^3) for friction measurements. Steel discs (304) with a roughness of Ra = 0.2 µm and an outside diameter of 60 mm were used as counterface. Sliding velocity was set to v = 0.2 m/s and the normal force to 50 N.

2.3. Wear measurements

Specific wear rate was calculated by using equation (1):

$$W_s = \frac{\Delta m}{\rho \times F_N \times L} \left[\frac{mm^3}{N \times m}\right] \qquad (1)$$

Where Δm was mass loss of the sample during the test, ρ was density, F_N was applied normal force and L was total sliding distance.

2.4. Surface analyses

Worn surfaces of the polymer composites and transfer films formed on the discs were inspected by means of optical microscope, 3D profilometry and scanning electron microscope. Chemical analyses were performed by micro-ATR-IR (attenuated total reflection).

3. Results

The results obtained indicated that the tribological characteristics of polymer materials are generally improved in hydrogen environment, particularly in LH_2. The effect of molecular structure could be detected in both air and hydrogen conditions. The influence of the environment and cryogenic temperature are discussed in terms of surface analyses and transfer film formation.

4. References

[1] Theiler G, Gradt T. Tribological characteristics of polyimide composites in hydrogen environment. Tribology International 92(2015) 162-171

[2] Theiler G, Gradt T. Environmental effects on the sliding behaviour of PEEK composites. Wear 368-369 (2016) 278-286

[3] Theiler G, Gradt T. Friction and wear behaviour of polymers in liquid hydrogen. Cryogenics 93 (2018) 1–6