Effect of Temperature on the Tribological Properties of the Polyimide Composites Reinforced with Different Fibres in Sliding and Erosive Conditions

Gai Zhao[1,2], Maksim Antonov[1*], Irina Hussainova[1], Qihua Wang[2], Tingmei Wang[2]

[1)] Department of Materials Engineering, Tallinn University of Technology, 19086 Tallinn, Ehitajate tee 5, Estonia
[2)] State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, 730000, Lanzhou Tianshui Middle Road 18, China

[*]Corresponding author (Maksim.Antonov@ttu.ee)

1. Introduction

Polymers are extensively used in mechanical engineering, structural and tribo-materials, etc., because of their outstanding properties, such as high strength, light weight, excellent thermal stability, as well as anti-wear and solvent resistance. To further improve the wear-resistance of neat PI and facilitate its application, many researchers made great efforts to develop PI-based composites by mixing appropriate additives into PI matrix, such as solid lubricants, nanoparticles and fibers, etc. Although many tribological investigations on PI composites have been carried out, there is little information on the comparison of tribological behaviour of neat PI and PI with varied fillers in different conditions, especially at elevated temperatures. According to authors knowledge there is no information regarding elevated temperature of PI composites up to date. The aim was to investigate the effect of carbon, glass and aramid fibres addition on friction, wear rate and wear mechanisms of composites with PI matrix at various temperatures.

2. Materials and experimental details

The composites made from polyimide powders, with addition of either carbon, glass or aramid fibres were fabricated by means of conventional hot press molding technique. A fixed volume content of the fibres of 15 vol.% was chosen. Neat polyimide specimens were also made for comparison. The mixtures were compressed and heated to 380ºC in a mould with intermittent deflation. The pressure was held at 20 MPa for 60 min to allow full compression sintering. Then specimens were cooled in the stove in air and cut into preset size.

Dry sliding (block-on-ring configuration; temperature 20, 50, 100, 150 and 200ºC; circumferential velocity was $1\ m\,s^{-1}$; load was 30 N; counterbody - GCrl5 (GB/T18254-2002) steel disk) and erosive (impact angle was 30 and 90º; impact velocity was 50 ms^{-1} ; abrasive - silica sand with mean size of 0.3 mm; temperature 20, 100 and 200 ºC) tests were performed.

Dynamic mechanical analysis and thermal gravimetric analysis as well as investigation of morphologies of surfaces by scanning electron microscope were performed.

3. Results

The glass transition temperature was found to be close to 250 ºC for polyimide matrix. The polyimide began to decompose at 564 ºC.

Glass and carbon fibre reinforcement is efficient only in sliding conditions. Aramid fibers having lowest compressive, flexural and shear strength comparing to glass and carbon are not efficient in sliding conditions.

In erosion conditions at speed 50 m s^{-1} all types of reinforcement studied were inefficient and their addition to the polyimide matrix was leading to reduction in wear resistance. Oblique angle of impact was resulting in higher wear rate of neat polyimide and reinforced composites.

Neat polyimide and reinforced composites exhibited higher wear rate at elevated temperature in both sliding and erosive tests comparing to room temperature results. This may be attributed to frictional heating during sliding leading to significant rising of surface temperature and reaching critical temperatures when polyimide matrix abruptly softens. Glass and carbon fibres are able to provide protection in sliding conditions being in contact with steel wheel and carrying most of the load that prevent the direct contact between polyimide of sample and polyimide transferred to the wheel (i.e. reduce adhesion). Loss modulus of polyimide matrix is constantly decreasing with temperature that is indicating the increased possibility of transferring deformation into heat. Fatigue, adhesive and abrasive wear are characteristic wear mechanisms during sliding.

Abrasive particles (mostly those being crushed and smaller) are found attached to the surface and forming mechanically mixed layer during erosion that is leading to the reduction in wear rate of materials. High storage modulus of polyimide matrix at 100 ºC is thought to be responsible for reduced ability to form protective layer that resulted in highest wear rate at this temperature. Impact and cutting wear are characteristic wear mechanisms during erosion.

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