Characterisation of commercially available polymer-based composites for applications in demanding environments

M. Nikonovich[1], A. Ramalho[2], N. Emami[1]*

[1]Polymer-tribology group, Division of Machine Element, Luleå University of Technology, Sweden
[2] Department of Mechanical Engineering, University of Coimbra, Portugal

With the rapidly increasing energy consumption and growing climate concern, hydrogen is considered to become one of the alternative energy sources in the nearest future. Due to some limitations and safety reasons, the liquid hydrogen is more attractive energy carrier, than in gaseous state. Connections between various infrastructure components (sealings, compressors, etc.) are exposed to medium and extreme conditions like temperature and pressure gradients, fretting wear, and inapplicability of convenient lubricants. Therefore, need for new materials which are capable to perform steadily under these conditions has arisen. Hydrogen embrittlement of steels and other undesirable effects on metals has encouraged researchers to pay attention to polymer-matrix composites. The recent publications suggest the composites based on high performing thermoplastics, polyetheretherketones (PEEK), polyimides (PI), and polyamides (PA) to be promising materials for hydrogen applications.

In the present study, selected commercial PEEK, PI and PA composites were characterised. PEEK and PI matrices were reinforced with carbon fibres, solid lubricants (polytetrafluoroethylene (PTFE) or molybdenum disulphide (MoS_2)) and/or graphite; PA was blended with PTFE and reinforced with carbon fibres. Material properties and reinforcement type were characterised carefully using Fourier-Transform Infrared Spectroscopy. Microstructure and fracture surfaces, thermal (Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis), mechanical (nanoindentation, fracture toughness at room and cryogenic temperature), coefficient of thermal expansion and thermal conductivity of these materials were studied.

The investigated materials properties were found to be directly dependent on the polymer matrix and the fillers. The neat polymers demonstrated brittle fracture surfaces with “river-like” fracture. Addition of PTFE remained brittle fracture mode, but “fibre-like” structure appeared. The reinforcement with fibres, graphite or MoS_2 led to coarse brittle fracture surfaces, which was suggested due to weak interfaces between the matrices and the fillers. DSC revealed no significant effect on the glass transition and melting temperatures between neat and reinforced polymers. PEEK and PI composites showed thermally steady behaviour up to 510°C, while PA blended with PTFE was up to 340°C. Consequently, the obtained results are to be used as the reference in the future research, and the mechanisms of medium-composite interaction will be studied.

Keywords: wear, cryogenic temperature, fracture toughness, polymer tribology, self-lubrication.

*Corresponding authors: maksim.nikonovich@ltu.se, nazanin.emami@ltu.se