ABSTRACT

High-performance polymer composites have become integral parts of various sectors such as automobiles, aerospace, ballistics, medical implants, space, sports, tribo-components (gears, bushes, bearings), etc. Researchers are striving to attain higher performance from the existing system of the matrices by appropriate selection of constituents to tailor the composites and their filler-matrix interfaces equipped with the right processing technology. The major themes focused on developing high-performance composites for the current work are as follows.

- To develop erosion and abrasion-resistant composites based on Ultra-high molecular weight polyethylene (UHMWPE) using nanoparticles (NPs) and microparticles (MPs) of carbides.
- To critically assess the potential of two solid lubricants viz. graphite and PTFE (Polytetrafluoroethylene) in varying PAEK (Polyaryletherketone) composite combinations to understand which property of a lubricant is more important for superior tribo-performance.
- To explore the potential of spherical NPs of alumina and siloxane functionalized version to improve performance properties of PAEK composites for adhesive wear performance.
- To develop novel composites using Zylon fibers in PEEK (Polyetheretherketone) for superior strength and tribo-performance.
- To explore in-situ grown Ag NPs on carbon fabric for improvement in Epoxy composite

The developed composites were evaluated for physical, thermal, mechanical, and tribological performance. Microstructural analysis was done by X-ray micro-computed tomography. The characterization of worn surfaces and interfaces was done with various techniques such as field emission scanning electron microscopy (FE-SEM), Atomic force microscopy (AFM), Energy dispersive spectroscopy (EDS), Raman spectroscopy, and X-ray photoelectron spectroscopy (XPS). The thesis is divided into nine chapters. Each chapter starts with a literature survey, the theme of work, experimentation, results, analysis, and conclusions.

Chapter 1 introduces concepts of tribology, polymers, and composites as tribo-materials, their applications, and their performance in various wear modes. It further discusses the literature on the specific themes for UHMWPE, PAEK, PEEK, and Epoxy-based composites. It leads to research gaps, implementation strategies, and objectives.

Chapter 2 deals with the general experimental characterization techniques and methods for evaluating performance.

Chapter 3 aims at two main themes – to compare various hard carbide particles (WC, TiC, ZrC, SiC) in UHMWPE for strength and tribo-performance for a constant amount (0.5 vol.%) and varying sizes (micro and nano). The order of potential was; WC > TiC > ZrC> SiC. NPs proved superior by a wide margin.

Chapter 4 explores the simultaneous inclusion of two efficient solid lubricants – Graphite (20 – 0 wt.%) and PTFE (0 – 20 wt.%) in short glass fiber reinforced (30 wt.%) PAEK composites for possible synergism. Graphite proved superior compared to its combinations with PTFE.

Chapter 5 focuses on modifying a composite with short glass fiber (35 wt.%) reinforced PAEK and graphite (15%) by two strategies. First by incorporating spherical alumina NPs (2 wt.%) and second, its siloxane functionalized version. The performance in adhesive wear mode improved due to treated NPs compared to untreated ones and those without NPs.

Chapter 6 focuses on exploring Zylon fibers (50 wt.%) in PEEK by developing novel bi-directional composites by braiding technique followed by compression molding. The developed composites were characterized for mechanical strength and adhesive, abrasive, and erosive wear modes and showed significant improvement in all wear modes.

Chapter 7 explores the braided fiber-based Zylon (50 wt.%) -PEEK composites in both unidirectional (UD) and bi-directional (BD) forms to compare its performance with neat PEEK. The major theme was to compare the performance of UD and BD composites. UD composite proved superior in all properties.

Chapter 8 discusses the effect of Silver NPs decorated carbon fabric (55 %) on the performance enhancement of Epoxy composite. The decorated fibers and the developed composites were characterized for various properties, followed by tribo-evaluation in adhesive wear mode, leading to substantial improvement in all performance properties.

Chapter 9 concludes the overall work with comments on key findings for each objective. It also discusses the scope for future work.

Keywords- High-performance composites, PEEK, PAEK, braiding, Zylon, UHMWPE, Epoxy