

DESIGN AND DEVELOPMENT OF GRAPHITE FABRIC- PAEK TRIBO-COMPOSITES AND NANO-ADHESIVES FOR PERFORMANCE AUGMENTATION

ABSTRACT

Composites have penetrated every aspect of our life to the extent that we hardly use pure metals, polymers, or ceramics for fulfilling ever-increasing demands for better and better performance of the materials as a consequence of advancement in technology in various sectors such as automobiles, aircraft, space, sports, tribo-machine elements such as gears, bushes, bearings, etc. High-performance polymer composites are growing expeditious due to their versatile properties such as highest specific strength, resistance to corrosion, wear and impact, self-lubricity, absorption of noise and vibration, ease of manufacturing, and eco-viability. The performance of composites depends mainly on the type and amount of matrix and reinforcement, a form of reinforcement (if nano-particles, then their size, shape, de-agglomeration, etc.), fiber-matrix interface, processing technology, etc. Each aspect has a significant weightage on the final performance.

Specialty polymers such as Polyaryletherketone (PAEK), Polyetheretherketone (PEEK), Polyetherketoneketone (PEKK), Polyetherimide (PEI), polyethersulfone (PES), etc. are at the forefront of the design and development of high-performance super-composites. The higher the aspect ratio of fibers, the higher the performance, and hence fabric is more reliable than short fibers for performance augmentation.

Graphite fabric having very high strength with additional advantages of self-lubricity and high thermal conductivity was selected as reinforcement for PAEK matrix. Series of composites were developed keeping in view the following objectives.

- Influence of fiber-matrix adhesion by treating fibers with a novel technique
- Influence of novel sizing agent and its concentration to get most performing composite
- Influence of processing techniques on performance leading to a selection of a correct technique

The composites were evaluated for physical, mechanical, and tribological performance. The characterization of worn surfaces and interfaces was done with various techniques such as field emission scanning electron microscopy (FE-SEM), interlaminar shear strength (ILSS), etc.

Another research module was on the design and development of nano-adhesives and nano-composites based on matrices such as Polyetheretherketone (PEEK), Polyaryletherketone (PAEK), Polyetherketoneketone (PEKK), and epoxy using various nano-particles (NPs) such

as metal carbides (TiC, SiC, ZrC, and WC), MWCNTs (Multi-walled carbon nanotubes), and Titanium nitride (TiN) in varying concentrations. The adhesives showed excellent performance, nano-adhesive with 0.3 wt. % MWCNTs showed improvement by 150 %, proving to be the best choice.

The thesis is divided into nine chapters. Each chapter (barring the first two and last) starts with a pertinent literature survey, the theme of work, experimentation, results, analysis, and conclusions.

Chapter 1 The chapter starts with the introduction to tribology and tribo-materials, in particular to the polymers and composites. It further explores the processing techniques for fabric-reinforced high-performance polymer composites, more explicitly for polyetheretherketone (PEEK), polyaryletherketone (PAEK), and polyetherketoneketone (PEKK) as matrices and related literature review. The chapter further explores the utility of tribology in the adhesive application, including a literature review. Moreover, the chapter ends up with research gaps, strategies, and objectives.

Chapter 2 This chapter deals with the details of materials selected, broad methodology to develop composites and adhesives followed by characterization techniques used.

Chapter 3 focusses on two main aspects. The first was to remove the existing sizing agent on the graphite fibers to be treated further for enhanced surface properties and compatibility with the selected thermoplastic PAEK (Polyaryletherketone) polymer. The second was on applying a simple but novel treatment to the fabric to physically, chemically, and mechanically change its surface. Furthermore, the composites were developed with desized and treated fabric. The developed composites were characterized for various performance properties.

Chapter 4 commenced with an introduction to processing techniques of high-performance composites and limitations, followed by the processing of the same composite with two different techniques and their comparative aspects, especially the superiority of one over the other.

Chapter 5 is on a maiden effort to size the graphite fibers with a solution of PEI with various concentrations to optimize to render the best performing composite using PAEK as a matrix. It describes the process of composite development, followed by characterization, performance analysis, and conclusions.

Chapter 6 focuses on the exploration of MWCNTs, for enhancing the performance of PEK-based adhesive. It starts with a literature status followed by a brief methodology of development of nano-adhesives and their characterization. It ends with salient conclusions.

Chapter 7 starts with a small introduction to high-performance adhesives, especially thermoplastics filled with hard nanoparticles (NPs). It then presents the development, characterization, and performance analysis of nanocomposites and nano-adhesives based on NPs of Titanium carbide (TiC), Silicon carbide (SiC), Zirconium carbide (ZrC), and Tungsten carbide (WC) in Polyaryletherketone (PAEK) matrix. It is divided into two parts; part A deals with various % of NPs of TiC in PAEK-based adhesives, while Part B deals with various types of carbides in a fixed % (0.5 vol. %) in PAEK-based adhesives.

Chapter 8 starts with an introductory literature survey of epoxy-based adhesives reinforced with hard NPs, particularly those of nitrides, followed by material selection, methodology of developing adhesives, their characterization results, and discussions. Finally, it ends with brief conclusions.

Chapter 9 is the concluding chapter, with conclusions on the whole work and overall comments with scopes of future work.

Keywords: Graphite fabric, PAEK composites, Nano- adhesives, Nanocomposites