

# A Review- Tribological Performance of PEEK (Polyether-Ether-Ketone) Coating

Niyati Shah<sup>a</sup>, Pina Bhatt<sup>b</sup>

<sup>a</sup>Mechanical Engineering, Government Girls Polytechnic, Ahmedabad

<sup>b</sup>Mechanical Engineering, Aditya Silver oak Institute of Technology, Ahmedabad

**Abstract:** The present study reviews tribological performance of PEEK (Polyetheretherketone) coating on metallic parts for several environment conditions in automotive, petrochemical, Oil and Gas industries. Protection of metallic components under wear and corrosive condition is the main challenge for industries. Alloys and ceramic coatings are expensive alternatives and the same time they are proven not only effective way to reduce wear and corrosion. It is an attempt to discuss the performance of PEEK coating under critical operating conditions like load, environmental pressure and temperature, wear and corrosive environment. Several tests were performed to evaluate the performance of PEEK on steel and alumina substrate by thermal spray technology. It can be stated the used PEEK have satisfactorily performance in wear and corrosion tests promising to be a very effective solution for wear and corrosion applicaton.

**Keywords:** PEEK, Wear, Corrosion, Coating

## 1. INTRODUCTION:

Advanced polymer coatings are nowadays attracted by industries in order to improve the surface performance of metallic parts, like wear resistance, friction coefficient and erosion resistance. PEEK is a colorless organic and crystalline thermoplastic material. It has an excellent toughness-stiffness combination, therefore it becomes one of the most attractive thermoplastics.<sup>[1]</sup> Thermoplastic materials have potential in replacing metal component in various applications. Due to their light weight potential, excellent self lubricating ability and design flexibility, polymer materials are increasingly applied where friction and wear are major concern. Polyetheretherketone(PEEK) is a high performance material which is widely used as a tribo-material<sup>[2]</sup>. PEEK is being used nowadays for high performance sliding materials due to its excellent thermal stability and good tribological performance, especially high wear resistance. The good properties of PEEK promotes the development of PEEK coatings on metallic substrates, which have poor tribological performances. PEEK is good resistant to hydrolysis to water, steam and seawater and non-toxic (sustain corrosive and hazardous environment), also hydrolytic stability with moisture absorption limited to about 0.2 per cent.<sup>[3]</sup> PEEK has a the glass transition

temperature ( $T_g$ ) of 143 °C, a melting temperature ( $T_m$ ) of 343 °C and a working temperature of up to 200 °C. When PEEK is subjected to temperature above its  $T_g$ , its mechanical properties decreases.<sup>[3]</sup> By increasing the crystallinity of PEEK, its tribological and mechanical properties improved compared to its amorphous counterpart. The overall mechanical properties of PEEK could also be improved by the addition of fillers such as carbon fibers, glass fibers, silica, various oxides or polymer lubricants. Solid lubricants improve thermal resistance of PEEK, and same time it can increase  $T_g$  of PEEK by blending with another polymer of higher  $T_g$ . This method can be very economical and effective.<sup>[13]</sup>

## 2. COATINGS BY THERMAL SPRAYING

Due to extreme working conditions occurred in several industries leads the polymer industry for development of advanced materials and their blends. Thermal spray is a group of coating methods in which principal of melting and acceleration of fine particles and their rapid solidification after impact on the substrate. This method uses the thermal energy to heat the coating material to a molten or semi-molten state.<sup>[18]</sup> The quality of a thermally sprayed coating depends on a many factors and also on the surface preparation of the substrate.<sup>[8]</sup> The main advantage of thermal spray technique is the wide variety of material can be used to produce coatings, particularly those material which melt without decomposing. Another advantage is the ability to apply coatings to substrates without significant heat input. The limitation of these deposition processes is that coating can be done by the torch and gun. There are size limitations of torch so it is impossible to coat small, deep cavities into which a torch or gun will not fit.<sup>[18][19]</sup>

## 3. CHARACTERISTICS OF PEEK

Unfilled and filled grades of PEEK are available in the form of Pellets, Coarse powder or ultra-fine powder. Different grade of PEEK is available for different applications. Ultra fine powder is available in market; grain size range is 0.2 $\mu$ m to 450  $\mu$ m.<sup>[16][17]</sup>



Figure 1 Powder form of PEEK



Figure 2 Pellets form of PEEK<sup>[16]</sup>

These materials are offered with different melt viscosities to meet specific thermoplastic process requirements: melt viscosity increases from the high flow PEEK 90 polymer, PEEK 150 and the standard viscosity PEEK 450 polymer. Products may be melted to filter into unfilled pellets, milled into fine powders. Table 1 and table 2 show the general characteristics of powder form of PEEK.<sup>[6][16][17]</sup>

Table 1. General characteristics of PEEK Powder<sup>[6][16][17]</sup>

Characteristics	PEEK Powder
Glass Transition Temperature	143 °C
Melting Temperature	343 °C
Maximum Operating temperature	250 °C
Typical crystallinity	35%
Density amorphous	1260 kg/m <sup>3</sup>
Density crystalline	1320 kg/m <sup>3</sup>
Water absorption percentage	0.50%
Thermal expansion co-efficient	4.7 × 10 <sup>-5</sup> °C <sup>-1</sup>
Particle (grain size) of Powder	0.2µm- 200 µm

Table 2. General Characteristics of PEEK coatings<sup>[6]</sup>

Characteristics	PEEK coating
Thickness	300±50 µm
Roughness	0.39 µm
Adhesion	12.5±1.5 MPa
Microhardness	18.5±0.2 HV0.5

#### 4. TRIBOLOGY OF PEEK COATING UNDER EXTREME WORKING CONDITION

Polymer tribology, as their friction and wear mechanisms, is more complex than for metal and less well understood. Whereas there are well-established ‘Laws of Friction’ for the tribology of metal and ceramic contacts in relative motion, polymer/metal contacts generally do not follow these laws. The reasons for this are several, including the relative softness of polymers compared to metals, their much lower thermal conductivities associated with heat generation in contacts and also significantly lower melting points.<sup>[11]</sup>

##### 4.1 Microhardness measurement

Microhardness measurement testings were performed on ball-on-disc sliding wear test under

different loading conditions and for separate dwell timing. The tests were carried out at room temperature.<sup>[10][3][4]</sup> The specific wear rate of the coatings generally calculated using Eq. (1)

$$W = V / FL \dots\dots\dots(1)$$

Where, W is the specific wear rate (mm<sup>3</sup>/Nm),

V is the volume (mm<sup>3</sup>)

F is the applied load (N)

L is the sliding distance (m)

Despite the differences in velocity and in experimental implementation, minor increase in the friction coefficient was observed by increasing the test pressure.<sup>[5]</sup> To find the friction and wear behaviour of pure PEEK under different load conditions, the worn surfaces of the materials were examined by optical microscope. The surface appearance of the PEEK shows wide wear scratches, running parallel to the sliding direction. The

SEM observations revealed traces of material plastic deformation and micro-abrasion present on all surfaces. [13] Topography profiles of the substrates show the maximum wear depth of PEEK coated substrate to be 4µm. [14]

### 4.2 Cyclic deformation and fatigue behavior

Uniaxial strain-controlled fatigue experiments were conducted on PEEK coating using constant amplitude loading with various ratio of minimum to maximum strain ( $R_c$ ). The temperature rise in PEEK under cyclic loading is due to the self-heating resulting from low thermal conductivity and high damping characteristics. The fractography analysis determines microstructural inclusions responsible for fatigue crack initiation and uses to observe crack propagation behaviour of PEEK. [12]

### 4.3 Surface roughness

The quality of coating depends on surface parameters like substrate preparation, chemistry and topology of the substrate. Surface treatment namely degreased, Etched, Steel grit were done. After surface coating of PEEK by thermal spraying technique need to be carried out. Scratch tester with spherical diamond indenter is used for scratch testing. To increase in available surface area for adhesion or more mechanical interlocking sites for the PEEK to adhere would explain the behavior of PEEK coating. [9]

## 5. CONCLUSION

High performance polymer based materials have become popular nowadays for its wide range of tribological applications. Due to its important characteristics such as acceptable wear resistance, low frictional behavior, self-lubrication ability and good stability against corrosion, PEEK material has become one of the few sought after advanced materials. Although there remains a concern with regard to fundamental understanding and engineering design issues. [8] However, further efforts are needed to be explored in order to understand the full potential of reinforced polymeric materials in the field of tribology.

## REFERENCES

- [1] Ga Zhang, Hanlin Liao, Christian Coddet, "Friction and wear behavior of PEEK and its composite coatings", *Tribology of Polymeric Nano composites*, ELSEVIER, 649-686
- [2] Annelise Jean-Fulcrand, Marc A. Masena, Tim Bremner, Janet S.S. Wong, "Effect of temperature on tribological performance of polyether-ether-ketone polybenzimidazole blend", *Tribology International* 129 (2019) 5-15
- [3] J. Tharajak, T. Palathai, N. Sombatsompop, "Recommendations for h-BN loading and service temperature to achieve low friction coefficient and wear rate for thermal-sprayed PEEK coatings", *Surface & Coatings Technology* 321 (2017) 477-483
- [4] Leyu Lin, Xian-Qiang Pei, Roland Bennewitz, Alois K. Schlarb, "Friction and wear of PEEK in continuous sliding and unidirectional scratch tests", *Tribology International* 122 (2018) 108-113
- [5] Emerson Escobar Nuneza, Reza Gheisari, Andreas A. Polycarpou, "Tribology review of blended bulk polymers and their coatings for high-load bearing applications", *Tribology International* 129 (2019) 92-111
- [6] Carlos R.C. Lima, Natalia F.C. de Souza, Flavio Camargo, "Study of wear and corrosion performance of thermal sprayed engineering polymers", *Surface & Coatings Technology* 220 (2013) 140-143
- [7] K. Friedrich, "Polymer composites for tribological applications", *Advanced Industrial and Engineering Polymer Research* (2018) 1-37
- [8] Krishal Patel, Colin Doyle, "Effect of surface roughness parameters on thermally sprayed PEEK coatings", *Surface and Coating Technology*, ELSEVIER, 204(2010)3567-3572
- [9] Philipp Werner, Volker Altstadt, Romy Jaskula, "Tribological behavior of carbon-nano fibre-reinforced poly(ether ether ketone)" *Wear*, ELSEVIER 257 (2004) 1006-1014
- [10] K. Friedrich, "Polymer composites for tribological applications" *Advanced Industrial and Engineering Polymer Research KINGFA Innovation Change Life* (2018) 1-37
- [11] Rakish Shrestha, Jutima Simsiriwong, Nima Shamsaei, "Mean strain effects on cyclic deformation and fatigue behavior of polyether ether ketone (PEEK)" *Polymer Testing ELSEVIER* 55(2016) 69-77
- [12] M.Kalin, M.Zalaznik, "Wear and friction behavior of PEEK filled with Graphene, WS2 and CNT nano particles" *Wear*, ELSEVIER (2014)
- [13] Yuanyuan Wang, Elon J. Terrell, "Influence of coating thickness and substrate elasticity on the tribological performance of PEEK coatings" *Wear ELSEVIER*, 303 (2013) 255-261
- [14] Pixiang Lan, Emerson Nunez, "Advanced polymeric coatings and their applications: Green Tribology" *Encyclopedia of Renewable and sustainable materials*, ELSEVIER (2019)
- [15] [https://www.victrex.com/media/literature/en/victrex\\_automotive\\_brochure\\_en.pdf](https://www.victrex.com/media/literature/en/victrex_automotive_brochure_en.pdf)
- [16] <https://www.solvay.com/en/brands/ketaspire-peek>
- [17] O.C.Brandt, "Mechanical Properties of HVOF coatings" *Journal of Thermal spray technology*, ASM International 4:147-152 (1995)
- [18] H. Singh, M. Kaur, N. Bala, "High velocity oxy-fuel spraying and surface finish" *Comprehensive material finishing*, volume 3, ELSEVIER(2017)