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

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***Abstract*:-The present study reviews tibological perfomance of PEEK (Polyetheretherketone)coating on metallic parts for several environment coditions in automotive, petrochemical, Oil and Gas industries. Protection of metallic components under wear and corrosive condition is the main challenge for industies. 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 perfomance of PEEK coating under critical operating conditions like load, environmental pressure and temperature, wear and corrosive environment.Several tests were performed to evaluate the perfomance of PEEK on steel and alumina substrate by thermal spray technology. It can be stated the used PEEK have satisfactorily perfomance 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 nowdays attracted by industries in order to improve the surface perfomance 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.[1]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 perfomance material which is widely used as a tribo-material[2].PEEK is being used nowdays for high perfomance sliding materials due to its excellent thermal stability and good tribological perfomance, especially high wear resistance. The good properties of PEEK promotes the development of PEEK coatings on metallic substrates, which have poor tribological perfomances. PEEK is good resistant to hydrolysisto water, steam and seawater andnon-toxic (sustain corrosive and hazardous environment), also hydrolytic stability with moisture absorption limited to about 0.2 per cent.[3]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 issubjected to temperature above its T_g, its mechanical properties decreases.[3]By increasing the crystallinity of PEEK, its tribological andmechanical properties improved compared to its amorphous counterpart. The overall mechanical properties of PEEK could also beimproved by the addition of fillers such as carbon fibers, glassfibers, silica, various oxides or polymer lubricants. Solid lubricants improve thermal resistanceof PEEK, and same time it can icrease $T_g$of PEEK by blending with another polymer of higher T_g.This method can be veryeconomical andeffective. [13]

2. COATINGS BY THERMAL SPRAYING

Due to extreme working conditions occured 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.[18]The quality of a thermally sprayed coating depends on a many factors and also on the surface preparation of the substrate.[8]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 soit is impossible to coat small, deep cavities into which a torchor gun will not fit.[18][19]

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 0.2µm to 450 µm.[16][17]

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Figure 1 Powder form of PEEK

Figure 2 Pellets form of PEEK[16]

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 meltedto filter into unfilled pellets, milled into fine powders. Table 1 and table 2 show the general characteristics of powder form of PEEK. [6][16][17]

Table 1.General characteristics of PEEK Powder[6][16][17]

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

Table 2.General Characteristics of PEEK coatings[6]

Characterisics	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, ismore complex than for metal and less well understood. Whereasthere are well-established 'Laws of Friction' for the tribology ofmetal and ceramic contacts in relative motion, polymer/metalcontacts generally do not follow these laws. The reasons for this areseveral, including the relative softness of polymers compared tometals, their much lower thermal conductivities associated withheat generation in contacts and also significantly lower meltingpoints.[11]

4.1 Microhardness measurement

Microhardness measurementtestings were perfomed on ball-on-disc sliding wear test under different loading conditions and for seperte dwell timing. The tests were carried out at room temperature.[10][3][4] The specific wear rate of the coatings generally calculated using Eq. (1)

$$W=V/FL \quad \ldots\ldots\ldots(1)$$

Where, W is the specific wear rate(mm^3/Nm),

V is the volume (mm^3)

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.[5]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

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PEEK shows wide wear scatches, running parallel to the sliding direction. The SEM observations revealed tracess of material plastic deformation and micro-abrasion present on all surfaces. [13] Topography profiles of the substratesshow 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_e).The temperature rise in PEEK under cyclic loading is due to the self-heating resulting from low thermal conductivity and high damping characteristics. The fractrography analysis determines microstuctural inclusions responsible for fatigue crack initiation and uses to observe crack propogation 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. Toincrease in available surface area for adhesion or more mechanical interlocking sites for the PEEK to adher would explain the behavior of PEEK coating.[9]

5. CONCLUSION

High perfomance polymer based materials have become popular nowdays for its wide range of tribological applications. Due to its important characteristicssuch as acceptable wear resistance,low frictional behavior, self-lubrication abilityand good stability against corrosion, PEEK material has becomeone of the few sought after advanced materials.Although there remainsa concern with regard to fundamental understanding and engineeringdesign issues.[8] However, further effortsare needed to be explored in order to understand the full potential of reinforcedpolymeric materials in the field of tribology.

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