

Tribology of Polymer Composites and Nanocomposites

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1. Introduction

Low mass density, self-lubricating behavior or high friction coefficient, and low wear rate of polymer composites at dry friction, have made them promising for tribological applications in bearings and brakes. Surface adhesion, shear and deformation of polymers at the real area of contact are the main factors affecting their tribological behavior and operation performance [1,2]. Flexibility in usage of various fillers and additives make polymer composites very promising components of tribosystems in a wide variety of applications [1-4].

2. Polymer Composites in Tribology

Composites with thermoplastic matrix have gained applications mainly for their self-lubricating properties [3]. The best example of such materials is polytetrafluorethylene (PTFE). Self-lubricating PTFE-based materials contain various reinforcing fillers improving the strength of polymer matrix (fibers, powders, fabrics, etc). PTFE is also applied as antifriction filler for other polymers. One popular application is lining consisting of a metal substrate (steel) and an upper porous layer (bronze) impregnated with PTFE-based composition. Bearings with such materials are widely used for bearings in automotive industry and they are most efficient under heavy pressure at low sliding velocity without lubrication.

Polyamides are also used to fabricate sliding bearings with reinforcing fillers and dry lubricants. They are often applied for polymer gears as well as thin coatings on aluminum alloys in aviation equipment. Polyolefins are widely used as a matrix for antifriction composites and additives to other polymers, even their disadvantage is low thermal resistance.

Among the thermosetting polymers used for self-lubricating composites are polyimides which have a high operating temperature (up to 220–260 °C). Polymer gears, bushings, and sliding bearings are also made of polyformaldehyde, polycarbonate, and polyarylates. Epoxy and phenol resins are applied as matrices for self-lubricating composites filled with solid lubricants like graphite or molybdenum disulfide, so they are often used in linings of machine guides. Thermosetting polymers also serve as matrices of materials for brakes, clutches, and other frictional units.

Elastomers such as rubbers and polyurethanes are often used as abrasion-resistant linings of metal components in mining and road construction industries as well as for contact seals in mechanical engineering. But the most important applications of elastomers are automotive tires and various dampers.

3. Polymer Nanocomposites

Nanocomposites with polymer matrix are typically formed while filling the polymer by particles or fibers with the size in nanometer scale. Carbon nanofillers (nanotubes, fullerenes) are very attractive for such purpose. Homogeneous distribution of nanotubes and fullerenes in matrix can be achieved by extrusion of polymers with high shear rates. Polymer composites with metal nanofillers can be formed by introduction of particles into the melt matrix or by mixing them with the polymer powder and further melting and pressing. Another way is the using of decomposition of metal compounds in polymer melt. The price of carbon nanofillers is a limiting factor in their applications for polymer composites. Recently graphene has become a target of

potential applications as filler for polymer nanocomposites and there is also information on successful use of exfoliated graphite.

Polymer-clay nanocomposites are very prospective due to their low price and availability of mass-production [2]. But the laminated silicates used as nanofillers need compatibility with the polymer matrix, so their surface should be modified by surface-active agents. Chemosorption of them reduces the surface energy of filler and increases its compatibility to polymer matrix.

Polymer nanofilms, monolayers and grafted structures can be considered as specific nanocomposites. They have applications in MEMS and NEMS systems where the price of nanopolymer is not a limiting factor.

4. Tribotests of Polymer Materials

Practical tribology is based on testing the materials under conditions close to real operation in a wide range of parameters and environments. Most of the traditional methods in tribotesting of materials can be applied to polymer composites, but such testing needs to take account of visco-elasticity and thermal behavior of polymer matrix [4].

Nowadays it is common to define the working area of polymers limited by their operation temperature and pressure-velocity limit related to certain wear rate. Pressure-velocity factor (PV) characterizes both the area of contact, load, and velocity, as well as power transfer in the tribosystem, so with taking account of heating it looks the most important for characterization of polymers in tribotests. The mechanical properties of polymer matrices are dramatically affected by temperature. So, in forecasting the stable friction at given range of load-velocity, we need to find the correlation of the PV factor and the effective range of friction coefficient.

5. Conclusions

Research in structure, chemical and mechanical properties of polymers and polymer composites has made possible the improving efficiency of polymer tribosystems. Significant progress is made in development of polymer composites with nanofillers produced at commercial scale as well as polymer nanostructured coatings and films.

Methodology of tribotesting the polymers is developing with taking account of the important part of heating in their tribological performance

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