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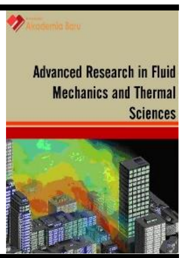

Materials for Tribology's Application: A Mini Analysis

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ABSTRACT

The exploitation of advanced material in a miscellaneous area can improve the performance and value of material engineering. The tribological applications are analyses based on the natures of materials utilized, for example, polymers, and polymer composite also ceramics, and ceramic composites. Specifically, the study on the behaviour of polymer-composite, surface interaction and polymer are due to the development of the composite nowadays become widely attention and noticeable worldwide in various industry. In conjunction, the friction effect on those materials is not directly relatable with the material characteristic but based on their tribology behaviour. The friction is not directly influencing the material characteristic but has affected the tribology behaviour of the material.

1. Introduction

To protect and preserve natural resources, people worldwide progressively campaign called "eco-material." The eco-material defines as friendly material towards human and environment. The growing reinforcement of natural fiber as composite for the industry worldwide become demand due to its cost-effective, readability, renewable properties, high mechanical properties and importantly safe for the environment [1,2]. The natural fiber can be used as the alternative for other composites of other human-made fiber used to produce a composite [3–5]. "Tribology" is word coming from tribos by Greek ancient means rubbing [6]. The tribology defines as the technology related to the interaction of surface in relative motion, especially in lubrication technology, friction controlling system, and prevention of relative movement between the surfaces. The tribology knew as the solution of preventing the operation problem such as maintenance and friction from the small application (household) to the more significant use (industry and spacecraft) [7]. It represents run of the mill model relating wear process because of relative movement, human-related tribology, and

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rocket related tribology. Figure 1 represents tribology models built across the scale, known as finite and boundary elemental approach, multiscale techniques together with the dynamics of discrete dislocation and atomistic technology.

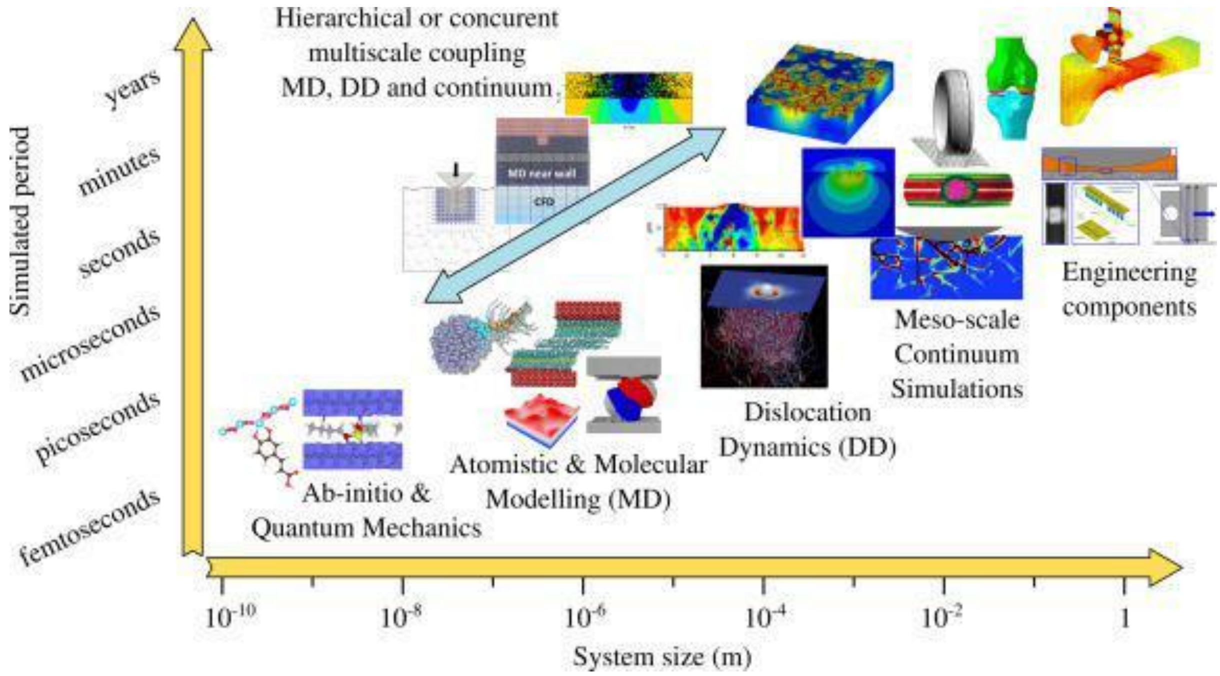

Fig. 1. Map of simulated period versus length scales of tribology models built across the scale, for application in engineering sector as prediction tools [7]

There is no limitation on material for tribology application, and all of the material such as ceramic, polymer, metal and other composites can be used as tribology's material. Each group of material has its unique properties in term of mechanical and chemical properties. For example, metal has high thermal conductivity, high hardness level and high tensile strength compared to the ceramic material which is low fracture characteristic, high elastic feature and their hardness depending on the temperature effect [8,9]. Besides that, in term of low density, low mass, higher performance resistance of abrasion and better tribology behaviour the material such as ceramic is advantageous compared to metal [10,11]. However, the ceramic also has disadvantages such as high contact pressure, high fragile, high shear stress, and lastly increase the friction characteristic as the temperature elevated due to the low thermal conductivity characteristic [12,13]. The low fracture strength may likewise prompt the unconstrained development of wear particles under load. Polymeric materials are helpful when contrasted with metals in regard to their low interfacial grip vitality, for instance, PTFE, PE, prompting low friction.

Notwithstanding by reducing the Hertzian pressure will not give advantage to those materials because of the effect of deformation and viscoelastic under the load. Therefore, the use of a coating such as the thin coating will improve the tribology behavior of the material according to their function needed [14–16]. Determination of tribological phenomena occurrence in between solids interfaces and within the solids are by the presence of atomic interactions. This interaction ascends to a variety of physics available at macroscale by distinct concepts and models, the tribological interface is known as a “paradise” for Multiphysics (conjoining multiple fields; as in Figure 2). Phenomena below could occur in its immediate proxy such as mechanical for both solid and liquid, metallurgical, thermal, quantum, electromagnetic and others, or at an interface [17].

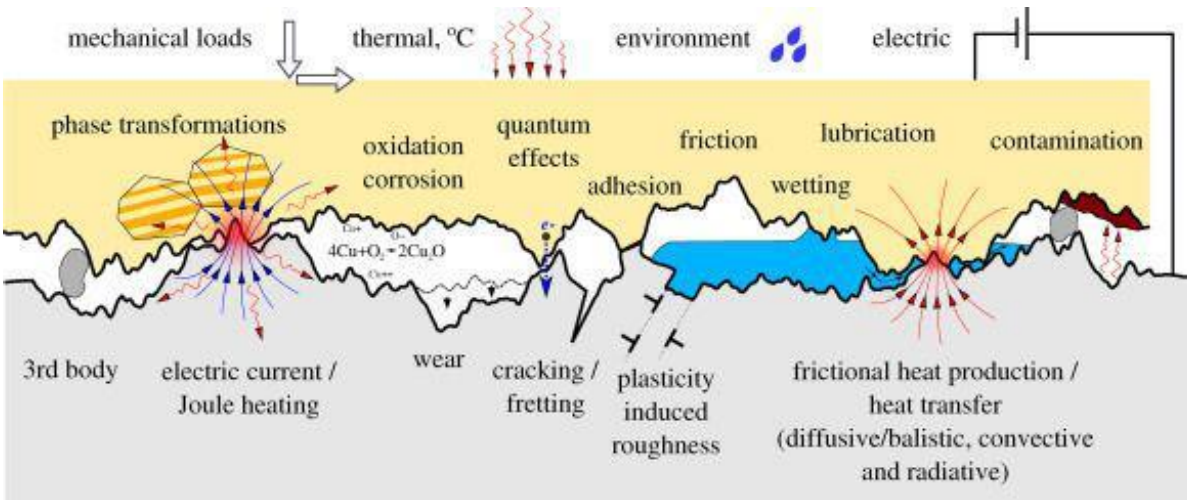

Fig. 2. Illustrations for tribological phenomena multiphysical nature in which two solids having coarse surfaces and related microstructural material are having contact and exposure to variety of loads: electrical, thermal, environmental and mechanical [7]

Nowadays, conventional metal material can be substitute with human-made material like Fiber reinforced polymers (FRPs). The FRPs characteristic consist of the better strength properties compares to the metal. Moreover, the FRPs also offers a more promising and effective fatigue damage rate compare to the other material and composite. Therefore, the FRPs currently well-known by having their class of material structure and their application has been dominant in every appliance such as furniture, packaging, automotive and other industries as well [18,19]. Fibers like cellulose, fleece, silk and so forth abundantly accessible are likewise utilized in composites. Cellulosic filaments like wood, jute, sisal, cotton, coconut fiber (coir), palm, bamboo and henequen in their normal conditions. It is outstanding that regular filaments grant high explicit solidness, quality and is biodegradable to polymeric composites. Additionally, cellulosic strands are promptly accessible from conventional sources and above all, they have minimal effort per unit volume [20,21].

2. Material Properties for Tribology

The tribology properties in composites are based on the arrangement (filler, fibrous reinforcement, matrices, and production) in which was made according to its application [17]. For example, for the structural use such as building and aircraft required the high tensile strength properties of composites. Meanwhile, the polymer material characteristic is low thermal conductivity, low fracture characteristic, medium tensile strength characteristic, and low density. Therefore, the composite with high tensile strength must be fabricated to sustain the structure. Besides, the component that required low friction such as bearing need the low friction composites to be manufactured [19,22]. In Figure 3, sustainable or feasible tribology focuses on crucial aspects of sustainable development, in which practicality of engineering problem for improving the efficacy and durability is addressed, to minimize the system cost to profit the consumers by reducing materials and consumption of energy for environmental protection. Benefit from this sustainable tribology is the enhancement of social progress, where health and life quality of human can be improved.

Fig. 3. The effects of sustainable tribology towards sustainable development [15]

In conjunction, the polymer tribology properties to fabricate dependent on the application of material going to be used. As mentioned earlier, there are four classes of material and only one class shows the significant and promising based on their characteristic, which is PMC. The PMC material has low density, low wear rate, high corrosion-resistance, made of organic solvent, can reduce wastes and have the self-lubrication properties [23]. The polymeric matrix in PMCs commonly is used to transmit stress to the filler. In the process to fabricate PMCs, there are various polymer matrices used, for example, thermosets (epoxy, polyester, and phenolics) just as thermoplastics (polyimides, polypropylene) and elastomers [24]. The thermoplastic with higher temperature and effectiveness are used to fabricated component with several characteristics. Those characteristics are high temperature, high survival rate, and high speed [25].

Generally, epoxy-based composite usually uses for moulding manufacture, especially as wax for polymer injection in tooling technology [26]. As the application using polymer is promising in future, the foundation element is the selection of appropriate dispersed phases and analysing their effect on the composite characteristic to enhance the polymer matrix and adjust its characteristic based on specifications. There are two critical parameters to increase the effectiveness and quality of the mould, which is thermal conductivity and wear rate. One of the methods to increase the thermal conductivity is by using a metal filler [6,27]. On the other hand, the application also can be used by having polymer-matrix coatings [6,11]. The arrangement of polymer-matrix coating function reduces the wear rate, friction and extend the facility life [14]. Widely, there is various industry such as electrical, civil, chemical, mechanical, spacecraft that use polymer-matrix coatings (epoxy-based coating) due to high mechanical and better thermal conductivity. Notwithstanding, epoxy-based coatings also have a limitation with low impact and high stress cracking resistance. Therefore, to resolve this limitation, there are several attempts by the researcher by having modification epoxy-based coating. The amendment includes proposing different reinforcing agent and different filler by using inorganic nanoparticles [28]. For instance, the research conducted by Kishore *et al.,* [29] manage to improve the wear rate and friction coefficient of the epoxy-based coating using glass fabric as a filling. The glass fabric-epoxy resin composite relies on material type and amount of filler.

In term of mechanical properties, the polymer mechanical properties can be improved using natural fiber with specific requirement and increase the surface characteristic. The improvement using natural fiber for fiber polymer composite based on a few parameters such as strength properties, physical properties, orientation, adhesion, impurities, volume fraction, and moisture absorption. This is based on several investigations by the researcher that determine the correlation of mechanical properties of the fiber polymer composite relies on the fiber-matrix interface [18,30,31]. The effect of the polymer and its mechanical properties using various natural fiber. The result shows that the use of natural fiber for polymer composite produces a better mechanical property of the polymer composite. Additionally, jute fiber functions to the polymer-lactic acid composite display the improvement of about 75% of strength properties. On the other hand, the same PLA when combine with flax fiber resulted in reducing the strength properties by 16%. There are several natural fibers like jute fiber that give positive impact to the polymer composites such as the cotton, hemp, and kenaf [32–34]. Combination of epoxy-based composite with natural fiber such as jute fiber can increase the tensile strength but reduce the compressive strength at the same time. Other than polymers composites, the jute fiber also gives an outcome with the positive effect on the mechanical behaviour of composites based on polyester [35,36]. The combination of jute fiber and polyester composites impact on increase about 121% of tensile strength compared to the pure. The improvement of mechanical properties using natural fiber firmly relies on the surface adhesion between the polymer composites and natural fiber because of the natural fiber itself that contain high hydroxyl group (cellulose, lignin, hemicellulose, etc.) [37–39]. The hydroxyl group in natural fiber function as hydrophilic material and make it become strong polar while the polymer composites act as hydrophobicity. Therefore, they are still critical issues related to the compatibility between the natural fiber and matrices in which that effect on the low interface area.

3. Tribology Behaviour

Previously, there is more research on tribology behaviour of metal with metal and metal with the ceramic relationship. Notwithstanding, the use of polymer as a metal substitute for any applications attract great attention for tribology study. Polymers are human-made material that can be readily produced and replace the metal structure and widely accepted for any appliances. Besides, the polymers are natural to form and produce essential waste that conceives the polymer material is lighter, low density, excellent corrosion resistance and exclusion the regular maintenance [11,19]. Consequently, the tribology behaviour must switch the attention and direction for metal with polymer and polymer with polymer relationship. There a few explanations behind this condition which includes the overall delicate quality of polymers contrasted with metals, lower thermal conductivity, and low melting point. This issue is crucial and needs to be solved to avoid any problem for polymer application, such as bearing and sliding [40].

Referring to Figure 4, a stylus is installed against a flat surface, and then adhesion strength is obtained by calculating the force required to separate the surfaces. The measurement of adhesion force data for various metals against iron is taken at a contact load of 0.2 mN and chamber pressure of 10−10 Torr [41]. In conjunction, the result cannot be used because there is a limitation on the wear condition, for example, under the heavy abrasion. Still, there is various type of polymer that can be used under the different condition that has their strength characteristic, the temperature range properties and the friction properties [42]. Also, the arrangement of molecular structure polymer can be altered according to their mechanical properties needed, temperature range and operating cost. The high-performance polymer has been formed by developed countries with a high melting point, high mechanical properties and high corrosion resistance properties with cost about 113 V/kg. These converge into the 'Ultra-High-Performance Polymers' with high softening focuses and higher quality. For example, the polyaramids and the PAEK family which incorporate Polyetheretherketone with a melting point of 343°C and sB up to 100 MPa and the temperature is around 250 °C, created by companies with costs starting in the locale of 113 V/kg and upwards. The inclusion, such as polybenzimidazole (PBI), has high-temperature resistant thermoplastic of 427 °C.

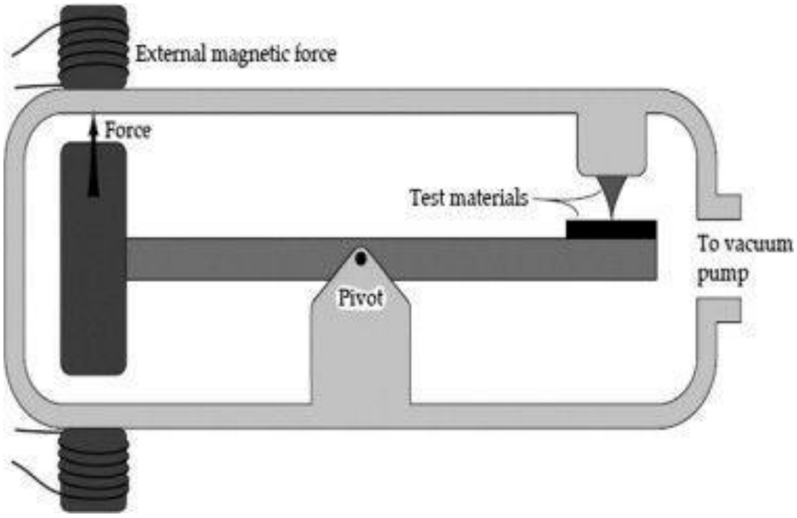

Fig. 4. Illustrations of measurement apparatus to determine adhesion between metals [41]

The wear and friction behaviour of polymer material can be enhanced through the improvement of strength and reduce the adhesion using special fillers [6]. For lowering adhesion of polymer material, the use of lubricants such as graphite or PTFE functions to reduce friction on the surface of the material [17,36]. Meanwhile, to improve the polymer material strength, the glass fiber or carbon can be used due to the heat generated during the contact sliding that turns into temperature in the contact area to be increased. Increase in temperature at the contact area affect the mechanical properties of the polymer. Therefore, a polymer material with high-temperature resistant is a more suitable option. Additionally, the used of thermally conductive filler can change the tribology characteristic of polymer.

4. Conclusions

There are several studies on tribology engineering focusing on the tribology behaviour of the polymer-fiber composite which show that the tribology behaviour relies on several aspects such as physical properties of the polymer, interfacial adhesion of fiber, contact area and additives used. Additionally, there are several experiments to determine the tribology behaviour of polymer-based fiber composite such as oil palm, sisal, cotton, jute fiber, kenaf, bamboo, betelnut. As per results, application of advanced material in a diverse area can enhance the performance and quality of material engineering [43]. For the polymer tribology, their rubbing and wear instruments are more complicated compared to metal. In the case of tribology of metal and ceramic contacts in relative movement, also polymer with metal contacts, they are entrenched with 'Laws of Friction' however, for the most part, they do not pursue these laws.

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