Chapter

Friction, Lubrication, and Wear

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Abstract

The surface properties of a bulk material are not accepted totally and independently. The tribology is the most important field that comprises the component design with static and dynamic relations for a reliability and performance. Hence, it is believed that the surface contacts, atmosphere, and lubrication significantly change the wear resistance of the material surface. However, the wear process is more complicated, in that a surface wear properties based on many tribological factors namely sliding type, mode of loading and working atmosphere. In this chapter, will explore the tribology fundamental, friction, various lubrication, wear types and mechanism on the wear process.

Keywords: tribology, friction, lubrication, wear, mechanism, wear resistance

1. Introduction

Tribology is defined as the science of sliding two surfaces in relative motion. It comprises the investigation and application of the wear, friction and lubrication. The term called tribology has been realized for thousands of years. In the year of 1966, the well-known 'Jost Report' was released to the government of British. Since, the term called 'tribology' has been broadly used and the investigation on this topic has been highly explored. This is an interdisciplinary area and related with materials, wear, friction, surface analysis, wear mechanism and working atmosphere [1]. Also, the surface properties of the base material cannot be measured totally as independent. It involves the component shape with contact types i.e., static or dynamic for the essential performance and reliability. The wear resistance of the material is mainly depending on the loading type, sliding and working environment. However, the phenomena are more complicated, in that a surface wear properties based on many tribological factors namely sliding type, mode of loading and working atmosphere [2]. Further, the wear behavior examination includes wear rate, coefficient of friction, volume loss, worn-out morphologies examination and studies of the mechanical properties and microstructure. Jeyaprakash et al. performed the laser coating and studied the wear resistance, friction behavior and various wear mechanisms [3]. Jin et al. performed high entropy alloy coating and studied the mechanical and wear properties [4]. Si et al. produced the Fe–Mo–Cr–Co coating and studied the wear resistance and corrosion resistance properties [5]. From the above literature, it has been recognized the importance of tribological properties. The main objective of this chapter is to study the tribology fundamental, friction, lubrication, wear, mechanism.

2. Fundamentals of tribology

2.1 Surfaces in contact

The friction and wear are mainly dependent on the characteristics of two sliding surfaces. The difficulty to predict and to clarify with more accuracy such phenomena reveals the complex nature of the surfaces, which can be evaluated through material properties such as microstructure, presence of organic molecules and oxides, water vapor, geometrical irregularities and other impurities which can be adsorbed from the atmosphere. Hence, while the two bodies are coming in to closer contact, the significant features of their sliding surfaces define the nature of the interaction, which includes mechanical character, with the development of a stress-strain on the sliding area, with the strong establishment of physical or chemical bonds [6]. To calculate the contact stresses, the smooth surface concept can be introduced, i.e., the surfaces are free from geometrical irregularities. Generally, the formation of smooth surfaces is difficult at a molecular level. The relation for contact stresses and deformations can be obtained through theoretical analysis which is developed by Hertz for linear elastic bodies. This can be employed while the two bodies are in frictional or elastic contact, with the assumption that the contact body radius is higher while compared with contact zone size.

2.1.1 Elastic contact

The viewpoint of geometrical, the contact between two solid bodies can be classified in to conformal or nonconformal as shown in **Figure 1**. From the **Figure 1 (a)**, it can be observed that the conformal contact happens while mating surfaces fit closely together. This kind of contact can be seen while bearing sliding on shafts and between wire and tool in drawing processes. The **Figure 1 (b)** shows the contact between two bodies which is nonconformal and this can be theoretically occurred. For example, with the presence of point contact in rolling bearing (between seat and ball), whereas a line contact happens in gears (between tooth and tooth). In another case, the contact area has a limited extension and it can be easily determined.

2.1.2 Viscoelastic contact

In the case of polymers, the deformation behavior can be occurred that is affected by plastic, elastic and viscoelastic processes. For example, the polypropylene (PP) sphere hard pressed on the transparent plane with the function of contact deformation displacement (δ) and time. In polymer plate the viscosity influence is

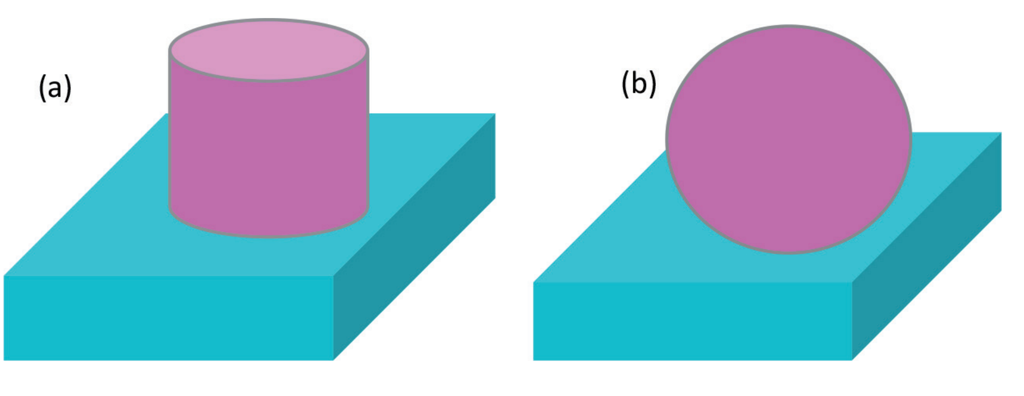

Figure 1.
The conformal contact between a plane and the base of a cylinder (a) and nonconformal contact between a plane and sphere (b).

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mainly noticeable while holding the amorphous phase and the heat may be higher than glass transition temperature. Further, the loss of energy is related to the viscoelastic loading and unloading processes. This energy dissipation may create the temperature on the material due to lesser thermal conductivity of material. However, the creation of plastic deformation is stable. Besides, the plastic processes and viscoelastic are based on the temperature and while increasing the temperature their intensity also increased [7]. **Figure 2** shows the various loads displacement and time while polypropylene sliding on a plane.

2.1.3 Elastic and plastic contacts

The material behaves with ductile way; the provided contact load can be induced the plastic deformation. At the same time, the equivalent stress at the critical point influence the material uniaxial yield stress. In this case, the material is not as elastic stage; however, it must be an elastic-plastic condition [8].

Figure 3 illuminates the elastic-plastic contact in detail with sphere and plane contact. In this case, the sphere has a higher hardness while compared with plane. If the applied load is increases, the plastic zone size can be increased. The applied load is taken out while the contact pressure with the below specific limit, then with the same magnitude of additional load, which are applied possibly, results the increase in elastic deformation only.

2.2 Friction

The frictional forces can be recognized as good or bad, without this friction, there is no possibility to use vehicle tires on a road, walking on the road or pickup objects. In some cases, such as machine application like clutches, vehicle brakes and transmission of power (belt drives), friction is increased. But, in many cases like rotating and sliding components such as seals and bearings, friction is unwanted. The higher friction makes more material loss (i.e., wear rate) and energy loss. In these kinds of working atmosphere, the friction is reduced [9].

The term friction is called as the force resisting the relative motion of two mating surfaces in contact with a fluid. The two sliding surfaces move relative to each

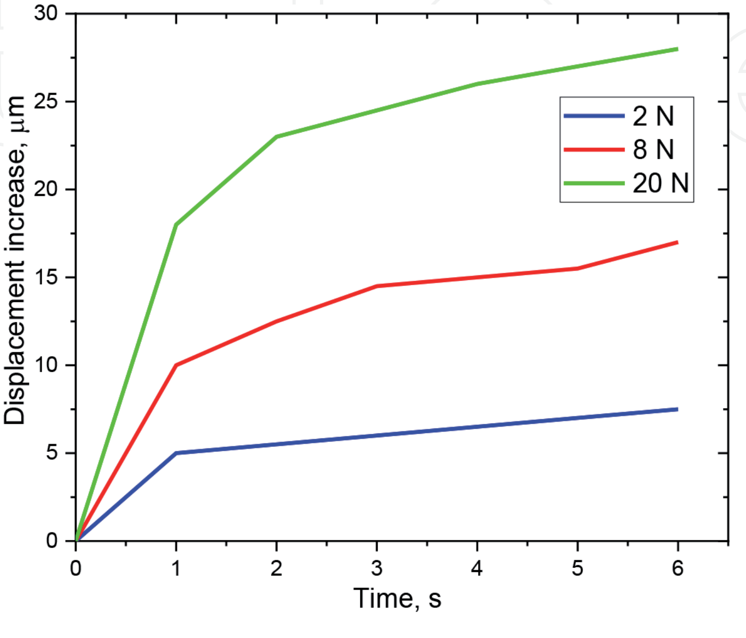

Figure 2.
Polypropylene sphere sliding on a plane with respect to load displacement and time.

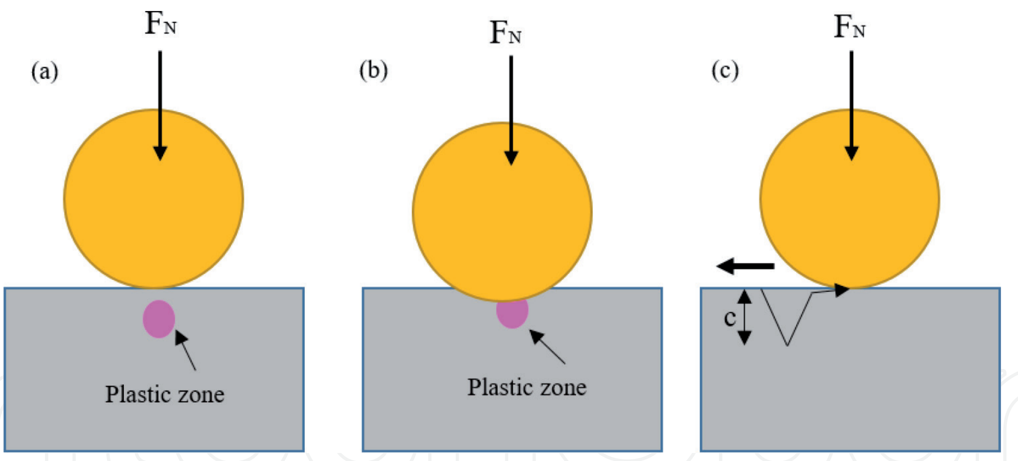

Figure 3.
Elasto-plastic (a) complete plastic, (b) brittle-type contact, and (c) between plane and a sphere.

other, the friction between the mating surfaces converts the kinetic energy in to heat or thermal energy. Generally, the term used to describe the friction is the coefficient of friction. It is denoted with dimensionless scalar value (μ) and explaining the ratio of the friction between two mating surfaces (F) and the applied force on them (F_n). It is described in Eq. (1):

$$F = \mu(F_n) \quad (1)$$

In a sliding condition, it is normally required to monitor or calculate the frictional behavior during the experiment. The changes in friction with wear data normally offer the beneficial data regarding modeling and mechanisms. The friction is generally classified as two categories: (a) static friction and (b) dynamic friction. In the case of two objects is not sliding each other is called as static friction. In another hand, both the mating objects sliding relatively to each other is called as dynamic friction [10]. **Table 1** shows the required parameters which need to be considered while performing wear experiments.

2.2.1 Metal surfaces

Generally, the asperities contact in metal surfaces is normally plastic. The metals such as titanium, cobalt, magnesium with hcp (hexagonal closed packed) crystal lattice provides the coefficient of friction nearly 0.5 while sliding against themselves. In addition to that the hcp metals possess a reduced ability to deform

Parameter/condition	Example
Material	Nonmetal: composites, polymers, ceramics and bio glass Metal: Nickel alloy, iron, stainless steel, cobalt alloy and titanium alloy
Lubrication	Oil, saliva, synovial fluid and blood
Geometry	ball-on-socket, plane-on-plane and point-on-plane
Motion type	Rotation motion, unidirectional, freeing, multidirectional
Loading type	Cyclic loading, constant loading, etc.
Atmosphere	Room temperature, high temperature and corrosive medium

Table 1.
Necessary input parameters to be considered for wear experiment.

plastically with relatively lower temperature. Hence, while sliding the asperity junctions deform with lesser intensity and the adhesion forces is not developed at the junctions [11]. While sliding between two metal alloys, the coefficient of friction is to be lesser than in the corresponding pure metals. In the case of bronze material (Cu-8% Sn), while sliding in dry condition, the coefficient of friction is around 0.6 while the typical value of 1 was recorded for the Cu/Cu pair. In the case of steel, the coefficient of friction value is around 0.6–0.8 while using two steel alloys, i.e., which is lesser than the pure steel-steel pairs.

2.2.2 Ceramic surfaces

In ceramics material the contact at the asperities is normally mixed. This may be fully in elastic while the surface roughness shows with less [6]. Else, if the surface roughness is high, it may be shows with plastic stage. Generally, the coefficient of friction must be independent for the normal applied load in elastic contacts. For example, the alumina balls sliding on the alumina surface and the friction showed around 0.4. It can be noted that the friction coefficient in ceramics material with dry atmosphere is lesser around 0.3–0.7 while applying the minimum load with less than 200°C temperature. The obtained frictional values are relatively similar to metal alloys and this may seem to be quite surprise. In case, the ceramics material is characterized with higher hardness and elastic modulus, and lesser values of the surface energy [12].

Besides, the surface energy of ceramics material is reduced through the surface reactions with water vapor and the presence of other substances on the working atmosphere. Hence, the lesser frictional force can be expected from the sliding wear experiment. Though, while continuous sliding with real contact area is notably increases with increase in friction. Further, the applied load is considered as major input parameter in the ceramic material. If the applied load is increased, the brittle contact may establish, and this will increase the coefficient of friction as much as high around 0.8. Specifically, the brittle contact can be occurred while the tangential stresses owing to higher friction due to the occurrence of critical microcracks on the surfaces. This type of microcracks can be seen on the ceramics surfaces normally and producing the defects such as porosity, flaws and inclusions. The cracks can be initiated from the development of asperity because of continuous applied load during the tribological study. **Figure 4** represents the coefficient of friction and applied load for alumina sliding on the alumina.

2.2.3 Polymer surfaces

The polymer like polytetrafluoroethilene (PTFE) is produces very low friction around below 0.1 while sliding on the same material or other metals. Thus, this material behaves as solid lubricant while sliding with counterpart [13]. Generally, most of the polymer material friction coefficient ranges from 0.2 to 1 while sliding in dry condition. In the case of the work of adhesion in polymer was lesser than in ceramics and metals. However, their stiffness and hardness of the material is lesser, and these two effects are nearly proportional.

Figure 5 indicates the correlation between adhesion and coefficient of friction for various polymers sliding against PA. These experiments were conducted on flat to flat surface contacts with lower sliding speed of 0.24 μm/s. So that the thermal effects on the polymers can be avoided [14]. It can be observed that the coefficient of friction was increased with the work of adhesion. In this kind of working condition, the adhesion was considered as a most important factor in friction determination. In the case of point or line interactions, the produced deformations may be higher and therefore the effect of viscoelastic can play a major role.

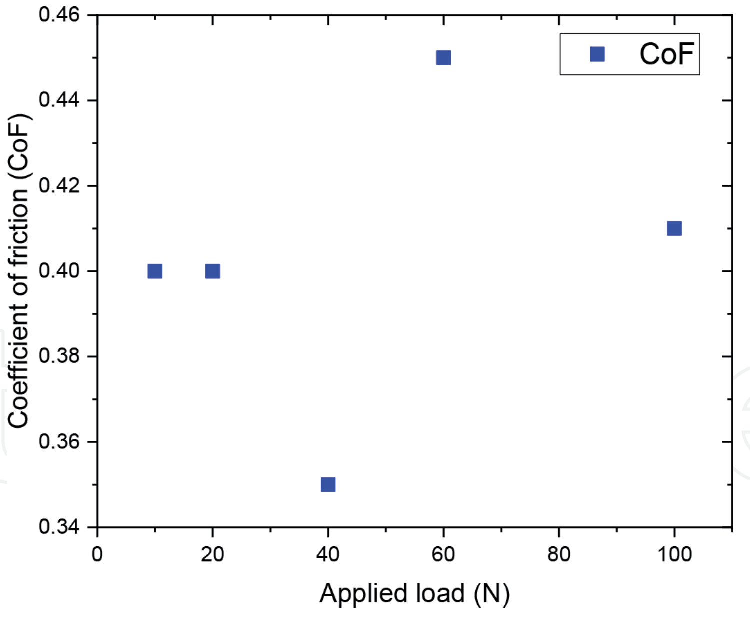

Figure 4.
Coefficient of friction and applied load for alumina sliding on the alumina.

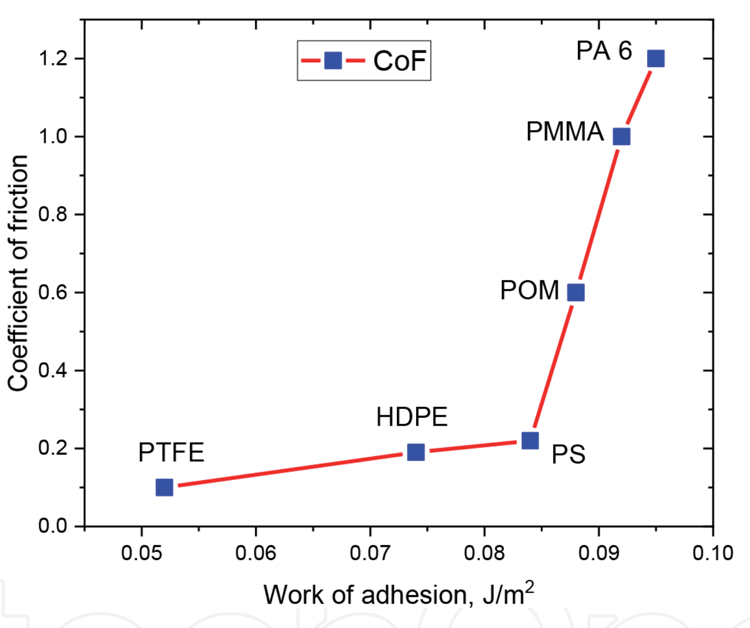

Figure 5.
Work of adhesion and friction coefficient for some polymers sliding against PA 6.

2.3 Lubrication

Two solid components/parts are sliding between surfaces is normally considered through a maximum coefficient of friction and higher wear rate because of the surface properties such as reactivity, lesser hardness, mutual solubility and higher surface energy. The clean surfaces without any rust is freely adsorb traces of other substances from the atmosphere. In addition, the newly manufactured surfaces normally produce the lesser wear and coefficient of friction while compared with clean surfaces. However, there may be chances of external material on the interface of bulk material which can increase the coefficient of friction during continuous sliding process. Hence, the lubricants can be applied to reduce the wear rate and coefficient of friction [8]. The term called lubrication can be applied to two various conditions: namely solid lubrication and fluid film lubrication (liquid or gaseous).

In any kind of material, the solid lubricant such as solid film and powder was used to protect the sliding surface from the unexpected damages during the sliding process and reduce the wear rate and coefficient of friction. The solid lubricants were used in sliding applications. For example, the bearing was operated with low speeds and higher loads, and the hydrodynamically lubricated bearings demanding the start and stop processes. The solid lubricant holds the higher variety of material which can produce the lower wear rate and coefficient of friction [15]. In addition to that the hard materials also were used as lubricant to reduce the friction and wear in extreme working atmosphere.

2.3.1 Fluid film lubrication regimes

A thick film of lubrication was maintained in the region between two solid surfaces with no relative motion or lesser motion through an external pumping agency is called as hydrostatic lubrication [16]. The lubrication regimes which are noticed in fluid lubrication with self-acting can be recognized in the Stribeck curve as shown in **Figure 6**. This graph provides the hypothetical fluid-lubricated bearing structure with coefficient of friction as a function of the rotational speed (N) and absolute viscosity (η) divided by the applied load (P). This curve has a lowest with providing the recommendation that higher than one lubrication system is presented. In some cases, the lubrication regimes can be recognized through lubricant film parameter [17].

2.3.1.1 Hydrostatic lubrication

In hydrostatic bearings, the supporting load on the thicker film provided from an external source, a pump, which can induce the fluid pressure toward the film. Based on this reason, those kinds of bearings are called externally pressurized. Generally, the hydrostatic bearings are considered for usage in compressible and incompressible fluids. Subsequently, the hydrostatic bearings are no need of any relative motion on the surface of bearings to create the load supporting pressures as it essential in the hydrostatic bearings [18]. Further, this type of hydrostatic bearings is used in application with no relative motion or lesser motion between the sliding surfaces. Besides, the hydrostatic bearings offer great stiffness though, this type of lubrication needed the high-pressure equipment and pumps for the cleaning of fluid, which is occupying more space with higher cost.

2.3.1.2 Hydrodynamic lubrication

The hydrodynamic lubrication is called as thick film or fluid film lubrication. The convergent type of bearings starts to move in the direction of longitudinal from the initial position, a less thickness of layer is pulled due to viscous entrainment. Further, it is compressed between the two bearing surfaces and generating the necessary pressure to support the load with no other external devices as indicates in **Figure 6**. This hydrodynamic lubrication mechanism is necessary for the effective working of the hydrodynamic journal and the thrust bearings are extensively used in the modern manufacturing industry [19, 20].

In addition, the hydrodynamic lubrication films thickness is ranging from 5 to 500 μm and referred as the ideal lubricated contact condition. Also, the friction coefficient of the hydrodynamic contacts is as lesser as 0.001 which represents the **Figure 6**. Sometimes the frictional force can be increased slightly while increase in sliding speed due to the viscous drag. Generally, the physical interaction can be

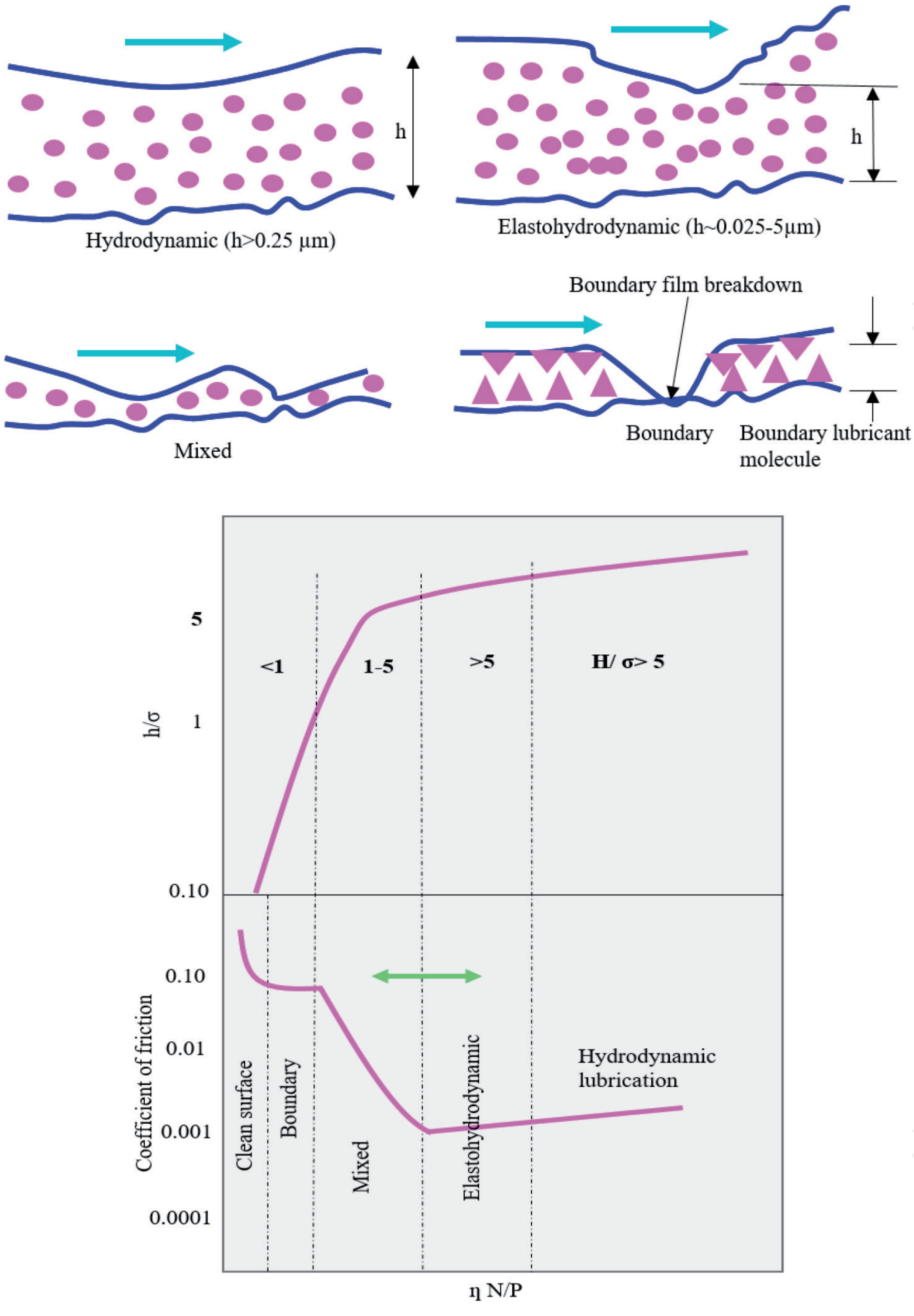

Figure 6.
Coefficient of friction and lubricant film parameter as a function of Stribeck curve showing various lubrication regimes observed in fluid lubrication without an external pumping agency.

occurred while starting and ending up with lesser sliding speeds. The behavior of the interaction is directed through the lubricant bulk properties i.e., viscosity, and the frictional force can be developed based on the shearing of the viscous lubricant. Besides, the corrosive wear can be occurred on the bearing surfaces due to the presence of lubrication. The adhesive wear also was possible while initial and ending up the processes. The corrosive wear can be reduced through lubricant precipitation and formation of film on the bearing surface.

2.3.2 Boundary lubrication

While increasing the load, the fluid viscosity or speed is decreased in the Stribeck graph as shown in **Figure 6**. In this situation, the friction coefficient can be increased as high as 0.1 or higher than this. This situation may also arise in a starved contact. When the solid surfaces are nearby that surface contact between the multi-molecular or monomolecular films of gases or liquids and the dense solid asperities may rule the contact. For more understanding, the cross section of the films and the asperity area contacts is shown in **Figure 6** [21]. Further, with the absence of gases and boundary lubricants (without oxide films), the produced frictional forces may be higher than one. In case with failure in boundary lubrication, causes corrosive and adhesive wear. Generally, the boundary lubricants can easily form the sheared film on the bearing surfaces. Therefore, this formed shear film can be reduced the corrosive and adhesive wear. The major physical properties of the films are hardness, melting point and shear strength. The other properties are cohesion, tenacity or adhesion and formation rates. Also, the viscosity of the lubricant can show a minor impact on the wear and friction behavior [22, 23].

2.3.3 Mixed lubrication

The transition between the boundary lubrication and the hydrodynamic regimes is a gray zone known as mixed lubrication. In this regime, the both mechanisms such as boundary lubrication and hydrodynamic lubrication may be in operational condition. There might be possible for the higher solid contacts, however, a minimum portion of the bearing surface leftover through partial hydrodynamic film. The hard solid interaction between the new metal surfaces can cause to a wear debris formation, adhesion of particle with counterpart, metal transfer from bulk to counterpart and eventual seizure. But, in the case of liquid condition, the chemically formed films protect the surfaces from adhesion during the sliding experiment. This mixed regime is called as thin film lubrication, partial fluid and quasi-hydrodynamic lubrication [21].

2.4 Wear

2.4.1 Introduction

Generally, the term wear is defined as material removal or surface damage on the one or two surfaces while rolling, sliding or impact motion relative to one another. Particularly, the wear happens through surface interactions at asperities. While two objects/components in relative motion, the material can be displaced from the interacting surfaces. Consequently, the properties of the material may be changed at least or interface region. But, there is a possibility for less or no material losses. Then, the displaced material can be removed from the interacting surfaces and may cause the material transfer to the counterpart surface or may break as small wear debris. When material transfer from bulk to counterpart, the net mass or volume loss of the interacting surface is zero while the bulk material surface is worn. The wear loss leads the real material loss, and this may occur sometimes independently.

Generally, the wear is a system output and it is not a material property. In addition to that the working atmosphere affect the interface wear. In some cases, mistakenly assumed that the higher frictional force displays the increase in wear rate. For example, the polymers and solid lubricant interfaces showed with higher wear and lesser friction, whereas ceramic material showed the lower wear but moderate frictional force. In all the dynamic machine components such as cams, bearings and seals, the wear is almost undesirable one. Those components or machines need to be replaced after a small damage or material loss or if the surface showed with higher roughness. If the system is well defined in tribology, the material removal will be very slow and at the same time it must be continuous with steady process.

2.4.2 Classification of wear mechanism

The wear occurs chemically or mechanically means and is normally induced through frictional heat. Mainly, the wear contains six principal quite distinct phenomena that have only one thing in common; the removal of material from the rubbing interface [24, 25]. The wear can be classified as follows: (1) abrasive; (2) adhesive; (3) fatigue; (4) impact by erosion; (5) corrosive; (6) electrical-arc-induced wear. The other commonly raised wear is fretting corrosion and fretting. However, the wear such as abrasive, adhesive and corrosive are the major combinations of wear. Based on the previously encountered issues, the abrasive and adhesives are the major wear mechanisms in the industry.

2.4.2.1 Abrasive wear

The abrasive wear happens while asperities of a rough and hard particles slides on the softer surface and remove the softer material and finally damages the surface through fracture or plastic deformation. Most of the ceramic and metallic materials with high toughness and hard particles result in the plastic stage of the soft material. Even the metal interfaces will deform plastically while applying higher loads. The abrasive wear can be occurred generally in two different situations as shown in **Figure 7**. In the beginning, the hard surface is the harder of two rubbing surfaces like two body abrasion. For example, in cutting, grinding and machining. In another case, the hard surface is the third body. Particularly, this must be small abrasive particle, identified in between the other two surfaces and this may be sufficiently harder. This may be able to scratch either one or both the sliding surfaces.

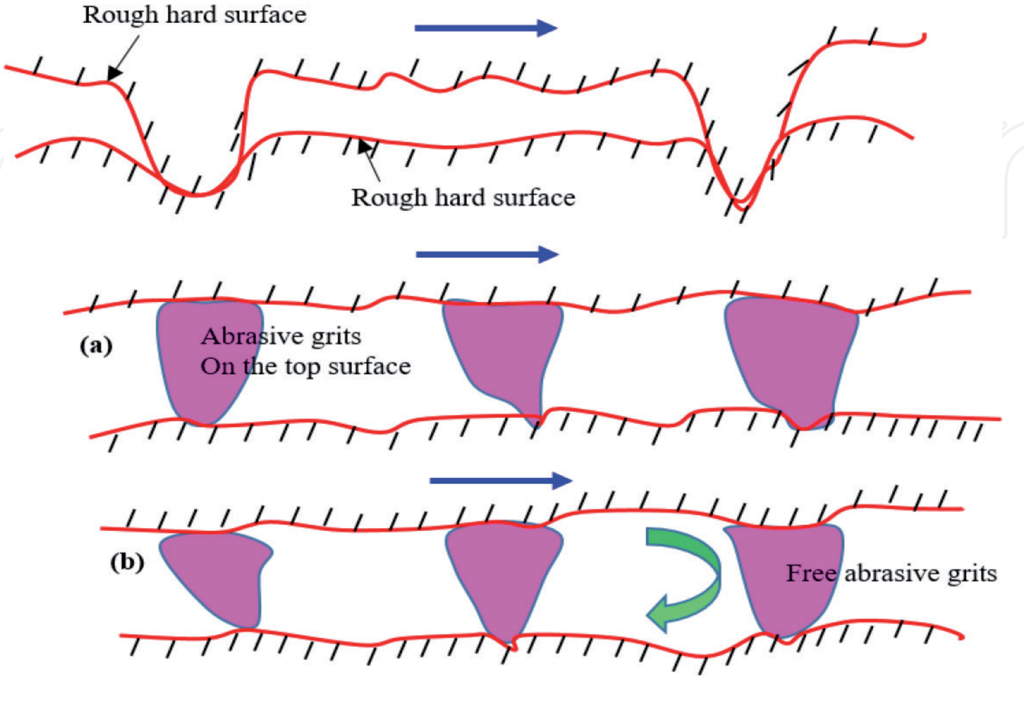

Figure 7.
(a) Schematics of hard rough surface mounted with abrasive grits sliding on a softer surface and (b) free abrasive grits caught between the two surfaces.

In most of the cases, the adhesive is the begging mechanism of wear on the sliding surface and this wear debris get trapped into interfaces of mating surfaces, subsequently resulting the three-body abrasive wear [26]. Further, the scratching can be observed in many cases as a continuous groove which is parallel to the sliding direction. The worn-out surface of steel against hardened steel disc with dry condition is shown in **Figure 8**. From the scanning electron micrograph (SEM), the continuous scratching is visible parallel to the sliding direction.

2.4.2.2 Adhesive wear

Generally, the adhesive wear can be occurred while two solid body sliding on the flat surfaces with dry or lubrication. The bonding of metals is happening at the asperity contacts at the interface, and these contacts is sheared through sliding process, which may produce the plowing of material from softer surface to harder surface. With continuous sliding process, the transferred wear debris is stop on the transferred surface and the same debris may return to original surface or else this may be loose as wear debris particle. In some cases, the debris may have fractured through fatigue process with continuous loading and unloading process and causes with loose particle formation.

There is some mechanism was explained for the fragment detachment of a material. However, still the well identified mechanism for adhesion is shearing of the two solid bodies or the weakest surface from one of the two surface [27]. The schematic representing the two possible way of metal breaking through shearing process as shown in **Figure 9**. Normally, the interface adhesion strength is assumed to be lesser while compared with breaking strength of nearby regions; hence, the break through shearing arise at the interface regions (path 1) in many cases and there will be no material loss happen during these sliding process. In another case, with lesser fraction of contacts, break may happen in any one of the two solid bodies (path 2) and a minor piece of material (the blue dotted semi-circle) can be attached to the harder other surface.

The SEM picture (**Figure 10**) shows the steel worn out surface with adhesion wear. From the **Figure 10**, it can be seen clearly that the adhesive debris pullout from the softer surface. During the sliding process, the surface asperities severely suffer from fracture or plastic deformation. Further, the subsurface also underwent strain hardening and plastic deformation. The SEM micrograph of worn-out surface shows the severe pull out material with plastic deformation. In the picture, the yellow

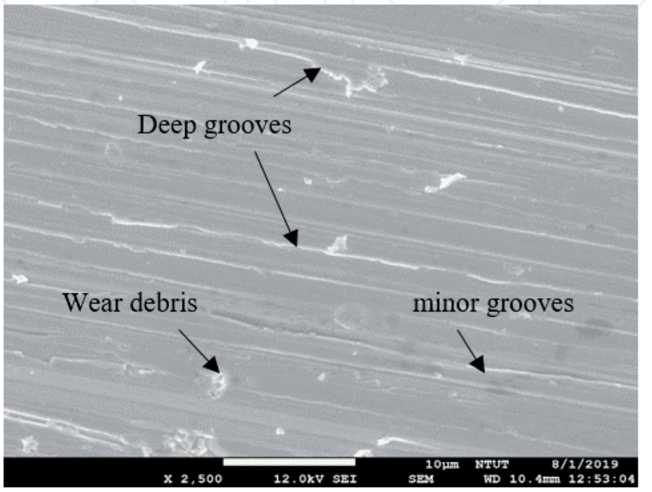

Figure 8.
SEM picture of steel surface after abrasive wear with dry condition.

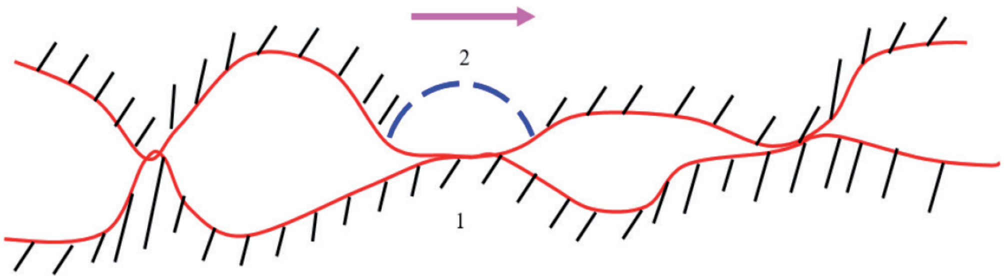

Figure 9.
Schematic representing the two possible ways of metal breaking through the shearing process.

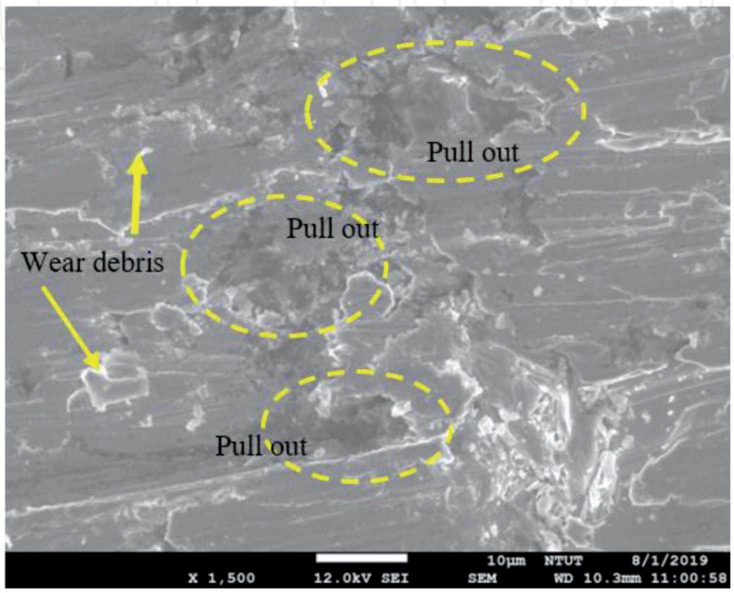

Figure 10.
SEM picture of steel surface after adhesive wear under dry condition.

dotted semi-circle indicates the extensive structural changes by adhesive wear. In addition to that severe type of adhesion wear is called as smearing, galling and scuffing and also this terms are used to describe other type of wear in sometimes.

2.4.2.3 Fatigue wear

Generally, the fatigue wear on surface and subsurface level can be noticed through continuous sliding and rolling atmosphere. The continuous loading and unloading processes, which will induce the surface and subsurface to form the cracks after critical repeated cycles. Then, the surface of the material will breakup into lager fragments and producing the larger pits on the softer surface. However, the material removed through fatigue wear is not considered as major parameter. There are much relevant is the beneficial life in terms of time or revolutions prior occur the fatigue wear.

2.4.2.4 Erosive wear

The erosive wear can be occurred due to impingement of solid hard particle with high velocity on the specimen surface. **Figure 11 (a, b)** shows that the hard particle impinging toward the specimen surface and removes the material from the top surface of the specimen. The contact stresses produce from the particle kinetic energy in liquid or air stream as it meets the surface. In erosive wear, the impingement

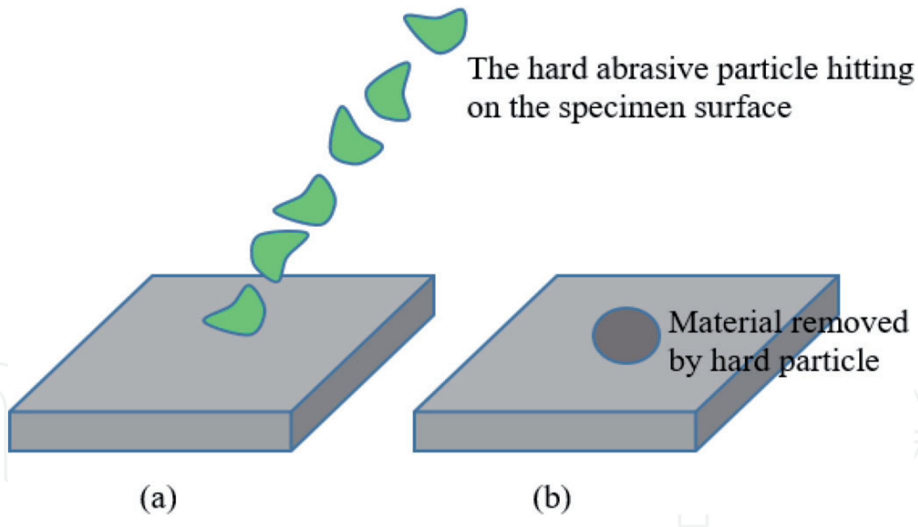

Figure 11.
Schematic of erosive wear with hard particle hitting on the surface; (a) hard abrasive particle hitting the surface, (b) material removed by hard particle.

angle and particle velocity combined with abrasive sizes and provide the measure of kinetic energy for the impinging particle. The wear particles/debris are formed in erosion arises as an outcome of repetitive impacts [28].

2.4.2.5 Corrosive wear

The corrosive or chemical wear happens while sliding takes place in a chemical atmosphere. The oxygen is considered as a most dominant corrosive medium in air atmosphere. So that the corrosive wear in air atmosphere is normally called as oxidative wear. The corrosive wear is significant in many factories such as slurry handling, chemical processing, mining and mineral processing. The chemical wear can arise due to the electrochemical or chemical interaction of the surfaces with the atmosphere. However, the chemical corrosive wear occurs in extremely high corrosive atmosphere and in high humidity and high temperature atmosphere. The electrochemical corrosive wear can occur with chemical reaction accompanied of an electric current. The potential variations can be observed between those two regions. The high potential region and low potential region is known as cathode and anode, respectively. There will be a current flow between the cathode and anode over an electrolyte conductive medium, the metal dissolve at the anode side in the form of liberates electrons and ions [29].

While conducting the experiment, the electron transfers via metal to the cathode and minimize the oxygen or ions. After corrosion test, these surfaces changes to some other appearance with corroded region. Further, the electrochemical corrosion is influenced through the electro potential. The aqueous is a most common liquid environment in corrosion atmosphere. In this working atmosphere, the less amount of gases may dissolve, normally carbon dioxide or oxygen may influence the corrosion. **Figure 12** indicates the electrochemical corrosion testing setup and corroded micrograph with layer formation.

2.4.2.6 Electrical arc-induced wear

While the presence of higher potential on the thin air film during the sliding condition, a dielectric breakdown gives that leads to arcing. The higher power density can be produced with short time during the arcing period. The produced

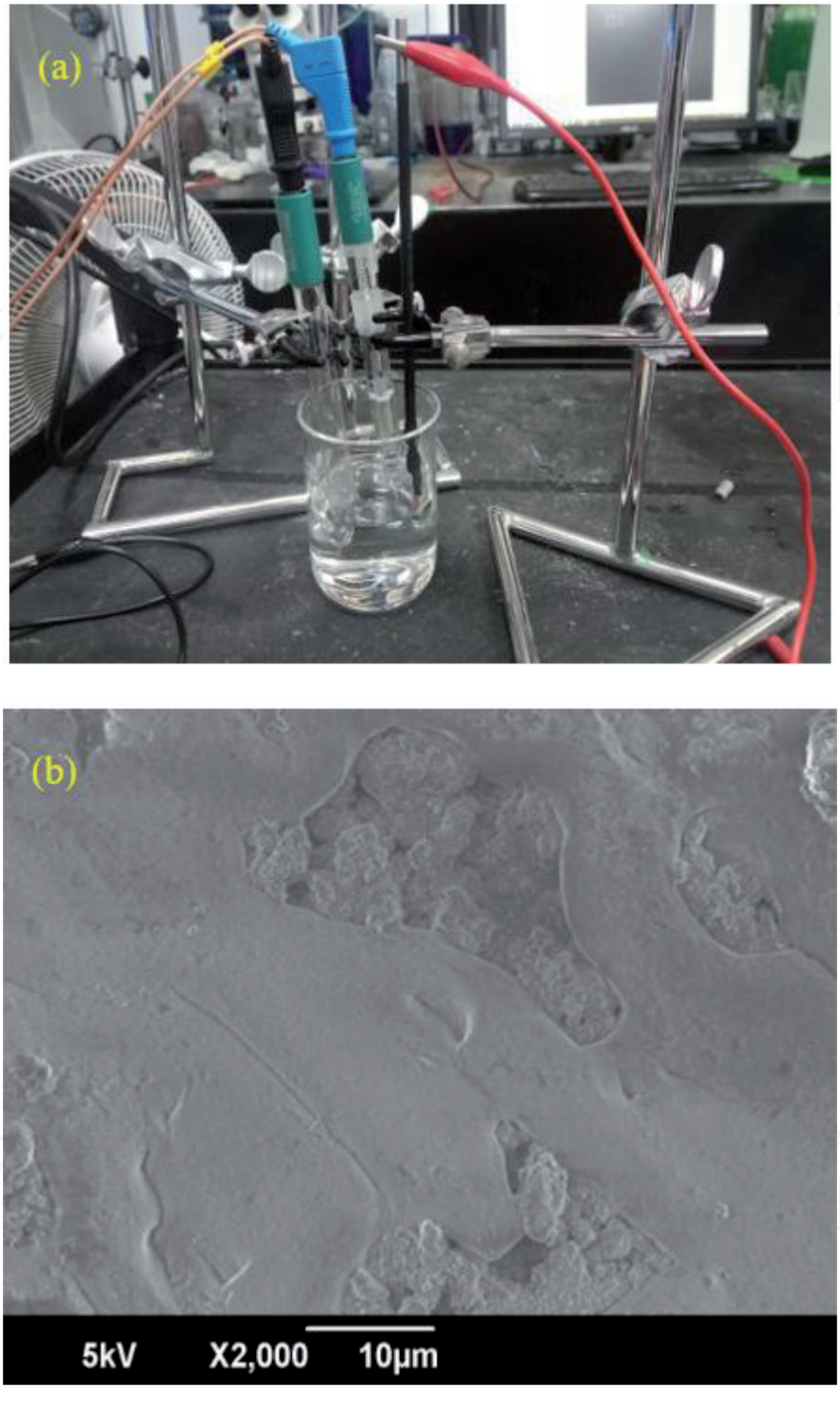

Figure 12.
Macropicture of electrochemical corrosion testing setup (a) and corroded micrograph with layer formation (b).

heating results in extensive melting, solidification, surface corrosion, phase changes and hardness changes, and sometimes ablation of metal can be occurred. This arcing creates the higher craters and after sliding either fracture or shears the material lip, causing the three-body abrasion, surface fatigue, corrosion and fretting. Arcing may create the many type of wear mode and resulting catastrophic failure in the electrical equipment's [30].

3. Conclusion

In this chapter, the fundamentals of tribology, friction, lubrication, and types of wear and mechanism are briefly described. The friction and wear are mainly dependent on the characteristics of two sliding surfaces. The metals such as titanium, cobalt, and magnesium with an hcp (hexagonal closed packed) crystal lattice provide the coefficient of friction of nearly 0.5, while sliding against themselves. In the case of steel, the coefficient of friction value is around 0.6–0.8 while using two steel alloys, i.e., which is lesser than that of the pure steel-steel pairs. Further, the alumina balls sliding on the alumina surface and the friction showed around 0.4. The friction coefficient in ceramics material with dry atmosphere is lesser around 0.3 to 0.7 while applying the minimum load with less than 200°C temperature. The polymer material friction coefficient ranges from 0.2 to 1 while sliding in dry condition. Besides, the solid lubricant, such as solid film and powder, was used to protect the sliding surface from the unexpected damages during the sliding process and reduce the wear rate and coefficient of friction. Wear is defined as material removal or surface damage on the one or two surfaces while rolling, sliding or impact motion relative to one another. Particularly, the wear happens through surface interactions at asperities. Therefore, the wear characteristic must be taken into account while performing the sliding wear processes in mechanical components.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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