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The challenge of temperature measurement in tribology experiments

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ABSTRACT – Surface temperature is an important factor controlling tribological behavior of sliding pair. Various techniques were used to measure the surface/interface temperature in tribological tests. The limitations of each technique are highlighted.

1. INTRODUCTION

Frictional motion in various tribological applications and manufacturing processes (cutting, grinding, etc.) generates heat. Frictional heat causes various effects such as oxidation of the surface, changes in the structure and properties of the sliding materials, softening or melting of materials, and also thermo-elastic instabilities in the contact zone [1-2]. The resulting high contact temperatures can affect the friction and wear behavior and performance of the parts/components in sliding motion. Therefore, it is important to know the amount of heat generated from frictional heating in order to prevent/predict failure of machine and/or to improve the performance of the tribo-system. In this paper, the various temperature measurement techniques normally used in tribological experiments and their associated challenges are reviewed and highlighted.

2. TECHNIQUES FOR TEMPERATURE MEASUREMENT IN TRIBOLOGICAL APPLICATIONS

Several techniques have been used for the measurement of temperature in tribological application. They included: 1) Thermocouples, 2) Optical infrared radiation pyrometers, 3) Change in microstructure with temperature.

2.1 Thermocouples

Embedded thermocouples and dynamics thermocouples are commonly used in temperature measurement by tribologists. This is mainly due to their: (1) low cost, (2) ease of in operation and signal processing, and (3) simple in construction [3].

Embedded thermocouple is one of the oldest techniques used for temperatures measurement in different tribological and manufacturing applications. Under this technique, the thermocouples are inserted to tiny holes drilled in different interior locations of the targeted friction surface (usually stationary surface). The surface contact temperature is then estimated by extrapolation or calibration. Temperature measurement using embedded thermocouples were used extensively in tribological experiments [4-8]. However, several concerns are to be considered when this technique is selected for temperature measurement. These concerns are: (i) A tiny hole of diameter around 0.8-2 mm, depending on the size of the thermocouple is required to be drilled underneath the surface. This hole alters the original heat flow and temperature distribution of the specimen which affects the accuracy of the temperature results. (ii) The tiny hole is difficult to be machined, especially on hard and/or brittle materials such as ceramics, and tungsten carbides. (iii) Measuring junction of thermocouple is required to be inserted and fixed in the holes. To prevent the loosening of the thermocouples junction from the specimen during sliding tests, adhesive materials are required to fix the thermocouples in the hole. (iv) Since the embedded thermocouple is embedded underneath the friction surface, this technique can only provide temperature reading underneath the surface. Thus, interpolation is required to estimate the temperature of the contact surface. (v) The distance between the sliding surface and the measuring point, y in Figure 1 is reducing with sliding time, and this causes error in temperature estimation when using simple interpolation method, and (vi) Thermocouples have high time constant and limited transient response.

Dynamic thermocouples are also named as tool-work thermocouple or Herbert–Gottwein technique [1]. Under this technique, the tool is considered as one component of the thermocouple and the workpiece as the other component. With the tool–work material interface of two different metals forming the junction, the electromotive force is then generated. Calibration of the tool-work thermocouple is done using the normal procedure. Dynamic thermocouples were used in temperature measurement in some tribological related researches [9-11]. The limitations of dynamic thermocouples were widely reported in previous literatures [3, 12]. Some of the limitations or concerns are: (i) Calibration is conducted in a static situation but actual measurement is in a dynamic situation. This might cause error in measurement. (ii) Dynamic thermocouple measures the mean temperature over the entire contact area and unable to provide reading of a simple contact point. (iii) Oxide layers or contaminants formed on surface during sliding might alter the calibration of the tool–work thermocouple. (iv) A separate calibration is needed for each tribo pair combination.

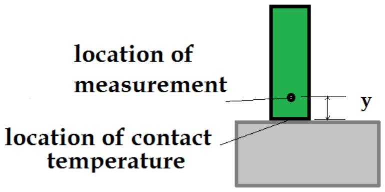

Figure 1 Locations of contact temperature and measured temperature.

2.2 *Optical and Infrared Radiation Pyrometers*

This technique determines the temperature of a body through measurement of the thermal radiation emitted by the body [13]. Since this technique requires no direct contact, it does not disturb the original temperature distribution of the specimen. Beside this, it can also be used to measure temperature at remote area and easy to be used. Due to these advantages, pyrometers are used in previous researches [14-17]. Nevertheless, pyrometer can only measure the surface temperature, and not the interface temperature of the tribo-pair. Accuracy of the temperature measurement depends on the correct emissivity setting of the pyrometer and a correct setting of emissivity value in pyrometer remains a challenge in pyrometry. A good pyrometer is expensive and requires correct calibration to provide reliable results.

2.3 *Metallographic Method*

Metallographic technique is the least popular method among tribologists, in comparison to other techniques. The maximum temperature during sliding process of a tribo pair can be estimated by comparing the microstructure of the specimen after sliding with the standard (microstructure at known temperature). This method was used by Wright and Trent [18] to obtain the temperature distribution of cutting tool in machining. However this postmortem method can only provide a rough estimation of maximum temperature reached after a test and is unable to provide exact temperature value and instantaneous temperature reading during a test [1]. In addition, this method can only be used on metals that show a change in microstructure with temperature. Moreover, microstructure is depends on cooling rate also [19-20].

3. CONCLUSION

Thermocouples (embedded and dynamics), infrared pryometry and metallographic method are commonly used in temperature measurement of frictional heating in tribological studies. Selection of a temperature measurement method depends on several factors, such as: accuracy, budget (cost), dynamic or static. However, all existing techniques are not able to provide accurate results in measuring the contact temperature. Therefore, development of a new temperature measurement technique for tribology experiment is crucial.

4. REFERENCES

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