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Continuous control as alternative route for wear monitoring by measuring penetration depth during linear reciprocating sliding of Ti6Al4V alloy

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ABSTRACT

Continuous wear monitoring during linear reciprocating sliding was investigated. Tribological tests with Ti6Al4V alloy against alumina, at nanotribometer, on microscale, were realised in dry conditions over a range of loads (100–1000 mN) and velocities (4–12 mm/s). Wear factors were calculated, for each conducted test, in two different ways. Wear factors calculated according to observed geometry of the worn tracks (according to ASTM G133 standard) were compared to values calculated according to penetration depth parameter continuously recorded by nanotribometer and results were highly correlated. Penetration depth curves and wear factor curves were obtained and analysed. Wear mechanisms based on examinations of worn surfaces by optical microscopy, were analysed in comparison with trends of penetration depth curves. Development of wear mechanism over time was further investigated. The obtained results showed that the wear factor values are strongly influenced by the applied load.

1. Introduction

Wear measurements in tribological testing usually involve measurements of mass loss or a worn track dimension after experiment is finished. Wear amount can be described in terms of mass loss (g), linear dimensional change (mm) or volume loss (mm^3). The mass loss of observed triboelement can be determined by weighing it before and after tribological testing. It gives information about final wear amount. Volume loss of the sample can be calculated after the test, by measuring wear track length and average cross-sectional area of the wear track, using optical microscopy. Volume loss of the sample can also be derived from the mass loss. Continuous wear monitoring can be realised by interrupting tribological test to perform wear measurements at certain periodic time intervals [1–3]. However, these procedures can influence testing due to necessary removing, cleaning and measuring of the samples. It is also time consuming process. For instance, measurement of the mass loss requires the test to be stopped and the sample removed for weighing.

There is a need to continuously monitor wear during sliding in many applications where development of wear mechanisms are important to control and predict, such as in case of biomedical implants [4]. It is important to simulate development of wear process and to distinguish changes in wear mechanisms during the motion of articulating surfaces. Very low wear rates are present in modern tribological systems, such as in case of hip joint tribo-system (wear rates of order of 10^{-7} mm^3/Nm). Precise measurements of mass loss in such cases involve sophisticated and expensive equipment and still needs more reliable solutions in many real applications. It is, therefore, especially important to continuously monitor change of the wear level at microscale.

Long and Rack [4] used ultrasonic pulse-echo technique for continuous wear measurement of orthopaedic titanium alloys. They showed that changes of the length loss parameter (dimensional change) can be used as a parameter indicating wear rate. Meozzi [5] validated a procedure for analysis of the wear behaviour (continuous wear monitoring) during sliding on the basis of geometrical experimental variables of the contact pair (ball and disc). Baets et al. [6], showed that continuous measurement of the normal approach of samples during relative contact can be used to obtain wear curves separately for both contact materials. They developed mathematical wear model by which normal approach measurements can be converted to wear volume curves (ball-on-flat type of contact). Since nanotribometer records penetration depth parameter during sliding, as a variable related to normal approach between surfaces in relative contact, it is possible to use it for continuous wear monitoring.

Total hip replacement using an alumina (Al_2O_3) head and socket and titanium alloy stem have been used for years in medical practice. Problems in relation to prosthetic failure still represent the major clinical problem for hip replacement, where the wear of materials in contact is the dominant reason leading to revision

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