Chapter 32
Tribocorrosion in Metal Matrix Composites

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ABSTRACT

One of the biggest motivations behind the development of the metal matrix composites (MMCs) is the improvement of the mechanical wear resistance of the unreinforced metallic matrix material mainly by the load-bearing effect of the hard reinforcement phases. However, in a large number of applications, MMCs are also required to operate in intimate contact with aqueous environments, which may lead to complex electrochemical phenomena that eventually may result in the degradation or pulling out of the reinforcement phases. Therefore, under these circumstances, MMCs may suffer a catastrophic degradation due to the joint action of electrochemical corrosion and mechanical wear (i.e. tribocorrosion), which is a multifaceted irreversible process where synergism or antagonism effects between the mechanical and electrochemical degradation phenomena may occur. Thus, this chapter aims to give an overview of the current knowledge of the mechanisms involved in the tribocorrosion degradation of MMCs and on the available testing procedures.

1. INTRODUCTION

During the last decades, metal matrix composites (MMCs) have been extensively studied in order to achieve better mechanical and tribological properties at lower weight. As a result, various MMC systems found commercial applications mainly in the automotive and aerospace industries, but as well in the other fields, such as engine piston, cylinder liner, driveshaft, connecting rod in automobiles; brake discs in automobiles and high speed trains, fan-exit guide vane, fuselage struts in commercial aircrafts, blade sleeves in helicopters, roller cone bit in oil well drilling applications and many others (Nikhilesh Chawla & Chawla, 2006; Jamaati, Toroghinejad, Szpunar, & Li, 2011). During their lifetime, many of these components come into contact with other parts that form a sliding couple or are under vibration

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interactions resulting in fretting (Benea, 2009; Jamaati et al., 2011). Moreover, in many cases these materials couples are required to be operated in aqueous environments (i.e. corrosive media) which results in tribocorrosion (Bratu, Benea, & Celis, 2007; Reyes & Neville, 2003).

Tribocorrosion has been defined by Landolt et al. (D Landolt, Mischler, & Stemp, 2001) as "an irreversible transformation of a material resulting from simultaneous physico-chemical and mechanical interactions that occur in a tribological contact". It means that tribocorrosion is a degradation process involving tribological contacts in the presence of a chemical (electrochemical) aggressive environment. An important idea to keep in mind is that in tribocorrosion systems the total degradation rate is most of the times different from that estimated from the sum of the corrosion rate and of the wear rate measured individually (Celis & Ponthiaux, 2012; Jemmely, Mischler, & Landolt, 1999). In fact, synergistic or antagonistic effects may arise from the complex interactions between tribological and electrochemical influence. For instances, the formation of self-lubricating, self-healing or thick and compact oxide layers can result in a positive synergism (antagonism), with a decrease of the overall degradation of the system. Nevertheless, a negative effect is often observed. In fact, the presence of a corrosive environment can amplify the material loss level by wear mechanisms, while wear can increase the corrosion rate, for instances by removing the protective passive film from the surface of the material. Actually, as discussed below, a tribocorrosion system can be affected by an extensive number of factors and occurs at different length scales (including at nano-scale). For instances operational parameters such as the stability of the contact between parts can deeply affect the tribocorrosion results. Further, the characteristics of the surface and sub-surface regions of the materials in contact will determine tribocorrosion performance, this aspect being extremely important even because the properties of the surfaces can be altered through the tribocorrosion process, for instances due to plastic deformation, increase of temperature or nano-structuring induced by deformation. Additionally, the tribological and electrochemical mechanisms may interact one with the other, having a strong influence on the tribocorrosion degradation process.

This complexity and interplay of all parameters involved in tribocorrosion phenomena explains why while tribological behaviour and corrosion mechanisms of MMCs have been extensively studied, tribocorrosion behaviour and mechanisms of MMCs has yet to be clearly understood.

2. TRIBOCORROSION OF METAL MATRIX COMPOSITES

2.1. Tribological Aspects

Most of the studies regarding the tribological behaviour of MMCs are focused on particle-reinforced composites. It is well known that the addition of hard ceramic particles result in a substantial improvement on the wear resistance. Even so, wear should always be considered as a system property, more than a material property. Thus, tribological behaviour of MMCs depends on the particular wear conditions and materials brought in contact (Nikhilesh Chawla & Chawla, 2006; Froyen & Verlinden, 1994). The main factors that dictate the tribological performance of MMCs can be classified into two categories (Duque, Melgarejo, & Suárez, 2005; C. S. Lee, Kim, & Han, 1992; Muratoğlu & Aksoy, 2000; Onat, 2010; Rosenberger, Schvezov, & Forlerer, 2005; Sannino & Rack, 1995; Shipway, Kennedy, & Wilkes, 1998; Zhang, Zhang, & Mai, 1995):