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Review paper

Overview of wear performance of aluminium matrix composites reinforced with ceramic materials under the influence of controllable variables

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Abstract

This paper summarizes the wear behaviour of Al-composites reinforced with ceramic materials. The influence of the mechanical parameters such as applied load, sliding velocity, sliding distance, temperature, and counterface hardness; and the material factors such as reinforcement type, size, shape and fraction, on the wear performance of Al-composites have been reviewed and discussed. It has been revealed that these parameters can influence the surface and subsurface behaviour of Al-composites during sliding wear conditions. It has also been observed that the ceramic reinforcements improve the wear resistance of the Al-composites under two-body abrasive or adhesive wear. However, the wear resistance of these composites is similar to the matrix alloy under intermediate load conditions due to three-body abrasive wear. Reduction in wear rate due to formation of oxide layers on the wear surface has also been reported in literature. Literature also reveals that the use of solid lubricant (Gr) particles and hard ceramic particles (SiC or alumina) as hybrid reinforcements can effectively improve the wear properties of the sliding system. The study indicates that the Al-composites especially the hybrid composite can be considered as an outstanding material for design of various automotive components, which require high strength and wear resistance.

Keywords: Aluminium matrix composites (AMCs); Ceramic reinforcements; Sliding wear; Tribolayers; Counterface; Delamination

Contents

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1. Introduction

The aluminium matrix composites (AMCs) are low-weight and high-performance materials that have potential to replace conventional materials in many advanced applications. These materials can provide excellent combination of properties such as high specific strength, high specific stiffness, low density, improved dimensional stability and greater wear resistance [1–3]. Moreover, the properties of these composites can be tailored by changing the fraction, size and type of reinforcing particles. Because of which, the AMCs are widely used to manufacture various automotive components, which require enhanced frictional and wear resistance [4,5]. The utilization of AMCs in transportation sector will provide significant benefits such as improvement in the life of component, lower energy and maintenance requirements, and lower emissions levels. It has also been reported that the use of AMCs in engine components can significantly reduce the overall weight, fuel consumption, and pollution in automobiles and aircrafts [6,7]. Generally, the ceramics reinforcements such as silicon carbide (SiC) and alumina (Al_2O_3) are incorporated in the Al-matrix for fabrication of composites. Also, it has been observed that the processing technique and dispersion of reinforcing particles also have significant influence on the resultant characteristics [8–11].

According to earlier investigations [12–21], the AMCs reinforced with ceramic materials generally exhibit superior wear resistance than their respective unreinforced alloy. However, under certain conditions the wear performance of AMCs is either comparable to or lower than the pure alloy [22–25]. This is due to the fact that the addition of hard reinforcements in the Al-alloy increases the counterface wear rate and thereby reducing wear performance of a tribosystem [26–28]. Also, Al-composites reinforced with self-lubricating particles have significant potential as a tribocomponent. But, the addition of these particles deteriorates the mechanical and tribological properties of the AMCs. Under such conditions, the hybrid Al-composites containing both hard-ceramic and solid-lubricant particles can exhibit improved wear performance [29–33]. The presence of hard ceramic materials can provide adequate strength level to the composites, while the lubricating particles smears the wear surface under sliding conditions, thereby reducing the wear rate. Graphite particulates are well suited to these applications, and their addition improves the machinability and wear resistance of ceramics reinforced Al-composites. However, the content of Gr-particles is a key factor affecting the tribological behaviour of hybrid composites.

Therefore, the selection of material for a particular application requires a careful identification of these conditions and the same can be done by understanding the influence of operating parameters on wear behaviour. The principal parameters that control the wear performance of AMCs are mechanical and physical parameters, and the material factors [34]. As far as the mechanical parameters are concerned, applied load, sliding velocity, sliding distance, temperature, and hardness of counterface are the major factors influencing the wear performance of Al-composites [35,36]. The reinforcement contents, type, shape and size are the material factors which have strong influence on the wear properties [37,38]. According to the magnitude of these parameters, different wear regimes have been observed and accordingly various theories have been presented giving the influence of these parameters on wear mechanisms. Therefore, the wear behaviour of AMCs can be known by analyzing the influence of all these parameters, wear mechanisms encountered by the composites, and the morphology of worn surfaces.

Section 2 reviews the microstructural features of Al-composites, while Section 3 discusses the influence of various parameters on the wear behaviour, wear mechanisms and the morphology of worn surfaces. Section 4 summarizes the literature reviewed in present study regarding the wear performance of Al-composites and the conclusion has been given in Section 5.

2. Microstructural characteristics

The distribution of reinforcing particles and the morphology of composites have significant influence on the mechanical and tribological properties [39]. Therefore, the main task during the fabrication of AMCs is to obtain uniform distribution of reinforcing particles. Further, it is also essential to identify the different components and particles of the composite. Time to time various authors have analyzed the microstructural features of these composites and some of them have been listed here. Mondel and Das [40] have examined the distribution of reinforcing particles and the interface between matrix and particles in Al/SiC composites. The composites were produced