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Wear of Dry Sliding Al 6061-T6 Alloy Under Different Loading Conditions

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ABSTRACT

In the present work, wear of Al 6061-T6 alloy under different normal loads, sliding speeds, and temperatures was investigated. Pin on disk type tribometer was used to conduct dry sliding experiments. Different load combinations comprising of normal loads (1 kg, 1.5 kg, and 2 kg), sliding speeds (1.25 m/s, 2 m/s, and 3 m/s), and temperatures (room temperature [31 ± 1 °C], 60 °C, 100 °C, and 150 °C) were applied during dry sliding experiments. Adhesive and abrasive wear mechanisms were observed in dry sliding of Al 6061-T6 alloy contacts from the microscopic analysis of worn contact surfaces. The wear rate was more influenced by increase in normal load than increase in sliding speed and temperature. Under normal loads of 1 kg and 1.5 kg, Al 6061-T6 alloy showed better wear resistance at higher temperatures when compared to that at room temperature.

KEYWORDS

Abrasive Wear, Adhesive Wear, Dry Sliding, Normal Load, Prow Mechanism, Sliding Speed, Temperature, Wear Rate

INTRODUCTION

Mechanical properties of aluminium were enhanced by alloying the aluminium with different elements such as silicon, magnesium, copper, manganese, tin, zinc etc. Aluminium alloys are replacing the steel in various industries due to their better strength to weight ratio, corrosion resistance and machinability properties when compared to steel (Sharma, 2001). Extensive studies on wear characteristics and friction characteristics of aluminium alloys are important to increase application of aluminium alloys in automobile industry. Researchers (Joy Mathavan & Amar Patnaik, 2016; Maciej Dyzia, 2017; Pathak & Mohan, 2005; Sarmistha Das et al., 2007) concentrated on applications of aluminium alloys in automobile bearing, engine pistons, cam followers and crank followers. Pathak & Mohan (2005) studied wear of bearings made with different aluminium alloys under lubricated sliding condition. Aluminium-lead alloy showed better wear resistance than aluminium-tin alloy even though strength of aluminium-lead alloy was lower than that of aluminium-tin alloy. Erol Feyzullahoglu & Nehir Sakiroglu (2010) worked on aluminium-based journal bearing materials under lubricated sliding condition. Joy Mathavan & Amar Patnaik (2016) observed lower coefficient of friction in aluminium-silicon alloy, aluminium-chromium alloy, higher coefficient of friction was observed in aluminium-nickel alloys.

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Frictional heat was more for aluminium-silicon alloys when compared to that of other alloys. Sarmistha Das et al., (2007) observed wear characteristics of aluminium-silicon alloy sliding against steel to study the wear mechanisms of cylinder and piston surfaces in automobile engines. Maciej Dyzia, (2017) manufactured cylinder pistons with aluminium metal matrix composites (AlSi7Mg2Sr0.03 / SiCp) to study friction characteristics of cylinder pistons. Kwok and Lim (1999) observed increase in wear of Al/SiCp composite with increase in normal load. Authors observed failure of Al/SiCp composite due to adhesion at higher normal loads and sliding speeds. Rise in contact temperature due to frictional heat at higher sliding speeds leads to change in friction and wear characterises and softening of material (Sharma, 2001). Wear characteristics of garnet particulate reinforced Al6061 were observed by Sharma (2001). The author observed negligible wear at lower normal loads (up to 30 N). Wear increased with further increase in normal load and sliding speed. The increase in wear at higher loading conditions was due to accumulation of friction heat at contact interface and softening of material. Basavarajappa et al., (2006) worked on wear characteristics of Al 2219 alloy hybrid composite reinforced with carbide and graphite particles. The increase in wear volume started at 20 N normal load and sudden increase in wear volume was observed at sliding speed of 4.5 m/s. Sarmistha Das et al., (2007) observed ultra low wear (up to 10 MPa applied contact pressure), mild wear (up to 70 MPa applied contact pressure) and severe wear in aluminium-silicon alloy.

Al-Qutub et al., (2013) observed improvement in wear resistance of Al 6061 alloy due to addition of carbon nanotubes at lower normal loads (5 N, 10 N, 15 N, 20 N, 25 N & 30 N). At higher normal loads (20 N, 25 N & 30 N), the monolithic alloys showed better wear resistance than carbon nanotube reinforced Al 6061 alloy. The sharp change in wear rate indicates the change in wear mechanism. In carbon reinforced Al6061 components, wear mechanism changed from mild to severe at 15 N normal load. In monolithic Al 6061 alloy wear mechanism changed from mild wear to severe wear at 25 N normal load. The pores present in the reinforced alloy initiate cracks at higher normal load which leads to poor wear resistance of carbon nanotube reinforced Al6061 alloy. Similar effect was observed by Lee et al., (1992) in SiC reinforced Al6061 alloy. Many researchers (Korkut, 2003; Sudarshan, 2008; Wang et al., 2001) concluded that the reinforcement in aluminium metal matrix composites results positive effect on wear resistance at lower normal load conditions whereas negative effect was observed at higher normal load conditions. Abrasive wear mechanism was characterised by appearance of small delaminated flakes. Appearance of large delaminated flakes represents the change of wear mechanism to delamination wear and sever wear. Adhesive wear and oxidative wear were dominant in monolithic Al6061 alloy. Delamination and surface fracturing were dominant in reinforced Al6061 alloy. Zhou et al., (2007) observed oxidative wear mechanism in carbon nanotube reinforced aluminium alloy which was characterized by identification of alumina layer on the contact surface and delamination wear mechanism. They also observed the addition of carbon nanotube reinforcement, improves the surface hardness and wear resistance, decreases the surface friction coefficient. Kim et al., (2009) found adhesive and abrasive wear mechanisms in carbon nanotube reinforced aluminium alloy composites whereas Choi et al., (2010) reported micro ploughing and delamination wear mechanisms in the same composite.

From the literature, various researchers differentiated the wear in aluminium alloys as mild wear, moderate wear and severe wear. Adhesion, abrasion and delamination are the main wear mechanisms in aluminium alloys. During sliding test, formation of smaller wear debris represents mild wear, formation of small delaminated flakes represents moderate wear and formation of large delaminated flakes represents severe wear. Oxidation of metal surfaces during sliding is one of the main causes for both abrasive and delamination wear mechanism. Softening of metal matrix due to frictional heat or due to other reasons during sliding is the main cause for adhesive wear mechanism. Strengthening of aluminium alloys with various reinforcing particles results in improving the frictional and wear characteristics of alloy at lower normal load but shows negative impact on the same at higher normal