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Corrosion behaviour of TiB_2 reinforced aluminium based in situ metal matrix composites[☆]

G.S. Pradeep Kumar^{a,*}, R. Keshavamurthy^b, Prachi Kumari^a, Chirag Dubey^a

^a Automobile Engineering, Dayananda Sagar College of Engineering, Bangalore, Karnataka, India

^b Mechanical Engineering, Dayananda Sagar College of Engineering, Bangalore, Karnataka, India

Received 13 January 2016; accepted 4 April 2016

Available online 23 April 2016

KEYWORDS

Al6061;
 TiB_2 ;
Salt spray test;
Forging

Summary This paper focuses on corrosion characteristics of cast and forged aluminium 6061 based composites reinforced with TiB_2 particles. Composites were synthesised by in situ technique using potassium hexafluorotitanate salt (K_2TiF_6) and potassium tetrafluoroborate (KBF_4) halide salts by stir casting route at a temperature of 850°C . Cast aluminium alloy and its in situ composites were subjected to open die drop forging at a temperature of 500°C . Both cast and forged alloy 6061 and in situ composites were then subjected to microstructure studies, salt spray test. Salt spray test was conducted as per ASTM B117 standard test procedure using 5% sodium chloride test solution. Result reveals that, forged alloy and its in situ composites exhibited improved corrosion resistance compared to cast ones.

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Introduction

Aluminium 6000 series alloys are being used extensively for various engineering applications due to its superior strength to weight ratio. Possessing dimensional stability, excellent structural rigidity and a low thermal expansion

coefficient (Kumar et al., 2008), its excellent formability allows easier usage for secondary processes such as hot extrusion, rolling and forging (Ramesh et al., 2011; Ramesh and Safiulla, 2007). The properties of pure aluminium can be improved to a great extent by using reinforcements in the form of ceramic such as SiO_2 , Al_2O_3 and SiC as particulates to name the more common ones (Zou et al., 2003; Birol, 2007). Aluminium alloys are used in the automobile industry for production of pistons, connecting rod etc. (Bharath et al., 2014; Pradeep Kumar et al., 2015) Research now also extends to aluminium composites that use continuous/discontinuous fibres, whiskers with

[☆] This article belongs to the special issue on Engineering and Material Sciences.

* Corresponding author. Tel.: +91 9538661599.

E-mail address: pradeepgs.87@gmail.com (G.S.P. Kumar).

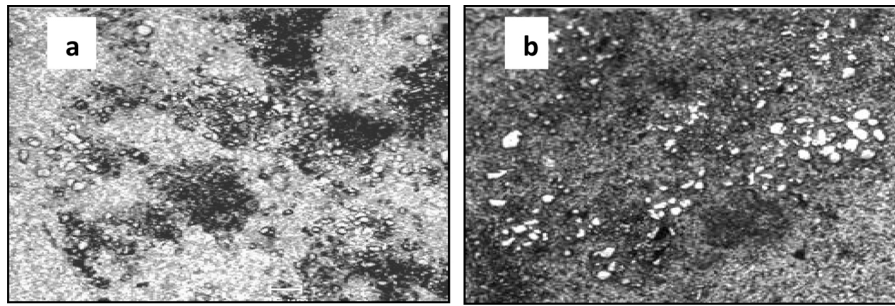


Figure 1 (a, b) Optical micrographs of Al6061-TiB₂ in situ composites.

varying volume fractions. Compared with the commonly used ceramic reinforcements, TiB₂ takes the higher stand due to its exceptional characteristics in terms of higher thermodynamic stability, higher modulus (530×10^3 GPa), higher hardness and low density (Gao et al., 2015; Tee et al., 1999). In recent years, researchers are focusing on development of aluminium–TiB₂ in situ metal matrix composites owing to its several advantages over ex situ technique. The exothermic reaction and better wettability of TiB₂ with aluminium is causative for improved in situ preparation of aluminium alloys allowing a better interface bonding and less differences between thermo physical properties during heating between the two (Tee et al., 1999; Smagorinski et al., 1998). Poor wettability of ceramics leads to uneven dispersion, lower mechanical properties and high porosity (Bharath et al., 2014). Selection of fabrication method is important as the mechanical properties of the resulting alloy depend on it (Ramesh and Safiulla, 2007; Bharath et al., 2014). Amongst various in situ fabrication methods utilizing liquid metallurgy, the more prevalent method is to use halide salts. On the other hand, it is reported that secondary process such as extrusion, forging rolling are commonly used methods to processing aluminium alloys for many engineering applications. Further, secondary processing of aluminium based composites offers several benefits like uniform dispersion of reinforcements, elimination of casting defects, excellent union between matrix and reinforced phase etc. Among all secondary process exist; forging method induces a significant improvement in terms of strength and stiffness of aluminium components. Literature review reveals that limited work been carried out in terms of characterizing corrosion behaviour of cast and forged aluminium–TiB₂ composite processed by in situ reaction technique. In light of above, the present work focuses on development of cast and hot forged Al6061-TiB₂ in situ metal matrix composites and characterizing its microstructure and corrosion behaviour by using salt spray test.

Experimentation

Al6061-TiB₂ composites were prepared by first melting the base aluminium 6061, obtained in a graphite crucible using electric resistance furnace. Molten aluminium alloy maintained at a temperature of 860 °C was added with halide salts, potassium hexafluorotitanate salt (K₂TiF₆) and potassium tetrafluoroborate (KBF₄) in a stoichiometric ratio to obtain, 5 wt% TiB₂, 10 wt% TiB₂. The cast alloy and its

composites were subjected to open die hot forging. More details on the composite preparation and forging are available in our earlier works (Pradeep Kumar et al., 2015). Cast and forged samples of alloy and its composites were machined to the size of 10 × 10 × 10 mm cubes and polished metallographically. The polished samples were then subjected to salt spray test as per ASTM B 117 standard test procedures, using salt spray chamber (Make-Culture Instruments, Model-NSSOI-01). The test samples were suspended in salts spray chamber at 30° from the vertical, containing dissolved 5% NaCl (AR Grade) in distilled water for a period of total of 96 h and weight loss was recorded at an interval of every 12 h. The pH and the temperature of the solution were maintained at 7.08 and 35 °C respectively. After the test, the samples were cleaned with running water and air dried before measuring for weight loss.

Results and discussion

Optical microstructure

Fig. 1(a) and (b) shows optical micrographs of cast and forged Al6061-alloy and Al6061-TiB₂ in situ composites. It is seen from the micrographs that TiB₂ particles are dispersed in aluminium matrix in a fairly uniform manner under both cast and forged conditions. However, when compared with the cast composites, forged composites shows more uniformity in distribution of TiB₂ particles, which can be attributed to thermo-mechanical deformation during forging.

Salt spray corrosion test

Fig. 2 shows variation of weight loss in salt sprayed specimens of cast and forged Al6061 alloy and its composites. It is observed from the graph that weight loss increases with increase in test duration for all the specimens. It is also observed that, composites exhibited marginally lower weight loss compared with alloys in cast and forged conditions.

Corrosion resistance of the in situ metal matrix composites increases with increase in TiB₂ content in cast and forged conditions. On the other hand, forged composites shows least weight loss compared to cast ones which may be attributed to the fact that, during thermo-chemical processing, TiB₂ particles are distributed more homogeneously compared with agglomerated cast composite which is evident from micro-structure studies. Further,

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