

EFFECT OF PARTICLE COATING ON MATRIX-REINFORCEMENT BONDING

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Abstract

A crucial step in the liquid state processing of particulates reinforced metal matrix composites is the incorporation of the ceramic particles into molten matrix alloy. The development of SiO₂ coating on fly ash particles is demonstrated as an effective way to improve matrix-reinforcement bonding during the manufacturing by a liquid route of Al matrix composite. Coated structures on fly ash particles were produced by liquid stirring of colloidal SiO₂ followed by different heat treatment process. Surface study was carried out by means of scanning electron microscope. Similar studies on uncoated particles were performed for comparative purposes. Microstructural studies were also applied to determine the influence of the SiO₂ coating on the interfacial bonding of the composite microstructure. SEM observation shows the SiO₂ coating on the fly ash particles has successfully produced and contributes a better interfacial matrix-reinforcement bonding.

Keywords: Aluminium, composites, Fly ash particles, Silica coating, Heat treatment, Interfacial bonding

Introduction

Fly ash-reinforced aluminium (Al) matrix composite exhibits a great promising material especially for automotive applications. The cost reduction and its tailorable properties makes this material was very popular in research and development as automotive industrial materials [1]. The basic problem encountered in the fabrication of this composite by stir casting method is the rejection of the ceramic phase by the liquid metal due to their lack of wettability [2]. Ceramic reinforcement particles are very difficult to incorporate in liquid metal and it can be observed by the lack bonding of matrix-reinforcement interface [3, 4]. In order to improve the weakness of this bonding, some of the research groups have carried out the heat-treatment on reinforcement particles [5, 6]. However, the problems associated with particulates incorporation in molten Al were still not much to satisfy. A possible approach to overcome this problem is the application of metal coating on ceramic particles whereas metals that frequently used were nickel and copper [7]. Unfortunately, metal coating on ceramic particles was an expensive technique and has a limited number of equipments in order to perform this type of coating in our country. Therefore, the development of liquid silica (SiO₂) coating on fly ash particles was seemed to be a suitable method to overcome this constraint and indirectly improves the incorporation of ceramic particles in liquid metal during the manufacturing of fly ash-Al matrix composite by stir casting technique. The aim of this study was to design an active silica (SiO₂) coating to reach a higher increase of incorporation of fly ash particles into molten aluminium. This paper particularly discusses a production of SiO₂ coating and its effect on the matrix-reinforcement interfacial bonding of Al/fly ash composite that fabricated by stir-casting techniques.

Experimental Procedure

The fly ash particles used in this study were supplied by the Sultan Sallahudin Abdul Aziz Generation Station, Kapar, Klang, Selangor. As-received fly ash powder was seized at 10 µm and ultrasonically cleaned by acetone. It was then dried at 70°C for 8 hours. The fly ash was heat-treated at 750°C for 3 hours. For coating procedures, heat-treated fly particles were immersed into AS-30 colloidal SiO₂ (Aldrich Chemical Co. Inc). The mixture was kept under agitation for 2 hours and it was then sediment for 30 minutes. Pre-coated particles were filtered and dried at 70°C for 8 hours. Finally, thermal treatment was carried out at 600-700°C for 5 hour. Metal matrix composite (MMC) samples were fabricated by using A356 Al alloy reinforced by 10 wt. % coated fly ash particles by using stir-casting technique. The morphology characterization was studied by means of scanning electron microscope (SEM); FEI QUANTA 400.

Results and Discussion

Figure 1 shows the morphological of as-received and heat-treated fly ash particles. The as-received fly ash particles (Figure 1a) show smooth surface surrounded by precipitate nanoscale nodules. Considering the fact that the fly ash particles were composed by variable size of oxide compounds [5], thus it was believed that the nanoscale nodules were also one the fly ash oxide compound that attracted to larger particles resulted by moisture activity during sampling. After heat-treatment process, these nodules were found diffused to larger particles (Figure 1b). This occurrence was likely similar to the sintering mechanism where oxide nodule coalesced to larger particles as explained by interparticle necking growth mechanism [8].

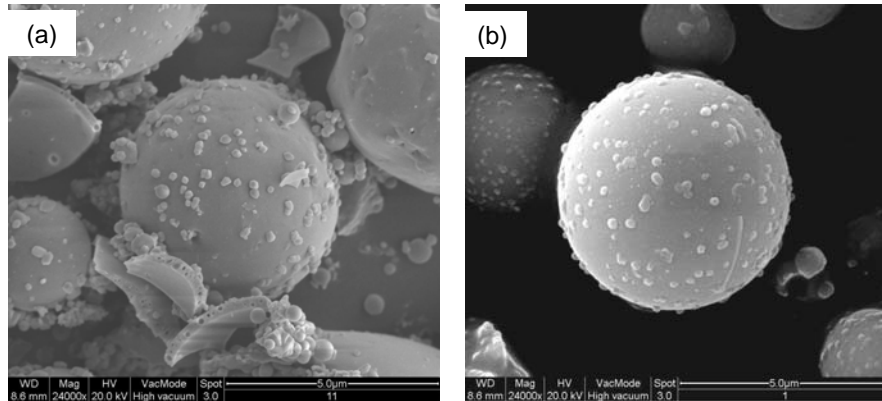


Figure 1: SEM micrographs on (a) as received, (b) heat-treated fly ash particle.

Figure 2, shows the appearance of fly ash particles that coated by difference amount of SiO_2 colloid. Compare to uncoated particles morphology in Figure 1, it clearly shows that the SiO_2 coating on the fly ash particles has successfully produced. It was found that by using 1 wt.% of colloidal SiO_2 , the morphology of coating layer was formed smooth and skinny as shown in Fig. 2a. In contrast, by using large amount of colloidal SiO_2 (20 wt.%), thick layer was formed. The morphology of coated structure was found jagged and irregular surface (Fig.2b).

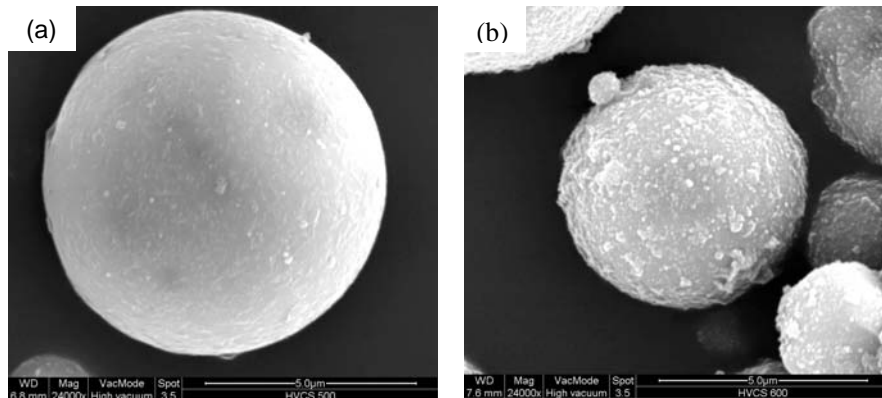


Figure 2: SEM micrographs on coated fly ash particles with (a) 1 wt.% and (b) 20 wt.% colloidal SiO_2 .

The incorporation of fly ash particles in the Al matrix was showed by interfacial bonding of matrix-reinforcement morphology. For as-received fly ash particles (Figure 3a), it found that a large cracking gap that propagates surroundings the reinforcement particles. This occurrence reveals that there was no wettings occur between uncoated as-received particles and Al matrix. Furthermore, the fly ash particles were also found attracted-off from its matrix during grinding and polishing processes. Thus, it proof that the rejection of uncoated particles from molten Al was occur even the incorporation of particles into matrix was aided or forced by aggressive stirring during fabrication. In Figure 3(b), the heat-treated particle was found incorporates in Al matrix. This incorporation was due to the formation of oxidation layer that envelops the particles surface during heat treatment process as explained by Urena et. al [5].

This oxidation layer was a very thin oxide film that favours the interfacial contact between matrix and reinforcement. However, this very thin film character was believed to be brittle, fragile and hence broken-down during vigorous stirring. This lower character of coating layer makes it unable to protect the underlying particles from abrasive stirring action in semi solid state. For that reason, the particles was found to be wounded and degraded. This occurrence was anxious will devastating the load transfer from matrix to reinforcement completely, consequently it will contributes to a low performance during its operation.

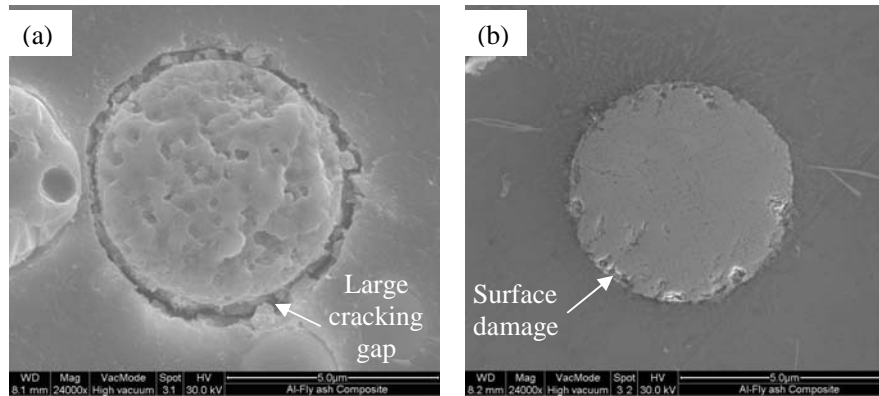


Figure 3: Typical SEM micrographs on interfacial matrix-reinforcement bonding of (a) as-received and (b) heat-treated fly ash particles.

The influence of the SiO_2 coating on the incorporation of ceramic reinforcement was showed by the typical SEM micrographs of interfacial matrix-reinforcement bonding (Figure 4). It was clearly observed that particles coating results a significant effect on matrix-reinforcement bonding. Figure 4(a) shows the typical interfacial bonding morphology of a resulting Al/fly ash composite that constituted by 1 wt.% of colloidal SiO_2 coating on fly ash particles. Morphological observations shows that the fly ash particles was significantly incorporated in the Al matrix and there was high continuity between Al and fly ash particles interface with a low proportion of faults of contact or voids produced by a pour wetting between the matrix Al and the fly ash particles. The morphological characteristics are signs of a proper wettability between both composite components, whereas there was no defect can be observed. From this study, observations of this morphology have made possible to propose a mechanism for the interfacial reaction that considers the reaction between molten Al and SiO_2 to form a strong alumina-silicate glassy phase that creates a strong and wider continuous thickness and free stress structure as explained by Rams et. al [9]. This coating layer structure protects the degradation of underlying reinforcement particles. In contrast, a high amount of colloidal SiO_2 was observed results the degraded of interfacial bonding as shown by bondless morphology between matrix and reinforcement (Figure 4b) which evidences of non-wetting characteristic between both surfaces. In other words, there was no matrix-reinforcement bonding can be observed by using high amount of SiO_2 colloid.

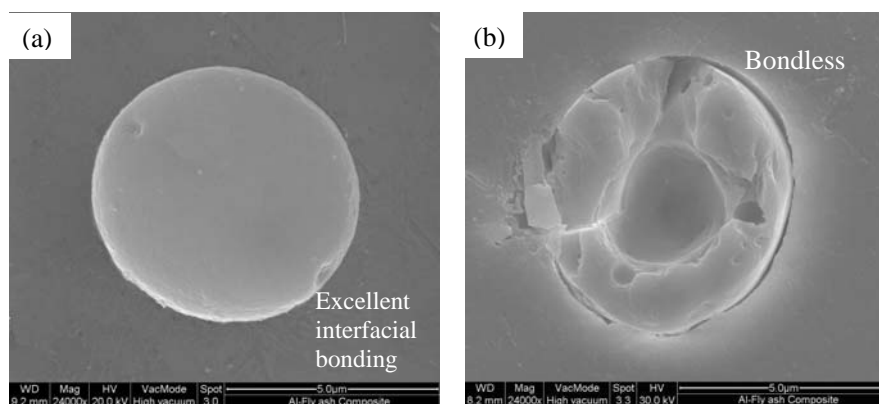


Figure 4: SEM micrographs shows the interfacial matrix-reinforcement bonding of coated particles with (a) 1 wt.% and (b) 20 wt.% of AS-30 colloidal SiO_2 .

Conclusion

Coating of fly ash particles by colloidal SiO₂ has successfully produced. It acts as a reaction barrier preventing degradation of the particles from abrasive action during stirring in semi solid state. It was suggested that the lower amount of colloidal SiO₂ generates a continuous and homogeneous coating and skinny layer of coating induce more active action to enhance the matrix-reinforcement bonding.

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References

- [1] P. K. Rohatgi and R. Q. Guo, "Low Cost Cast Aluminium – Fly Ash Composites for Ultralight Automotive Application", *TMS Annual Meeting, Automotive Alloys*, (1997), 157-168.
- [2] V.M. Kevorkijan. 1999. Stabilisation in and rejection of ceramic particles from molten aluminium alloy: modelling and experimental testing. *Comp. Sci. Tech.* 59; 2363-2374
- [3] Asthana R, Rohatgi PK. 1993. A study of metal–ceramic wettability in SiC–Al using dynamic melt infiltration of SiC. *Key Eng. Mater.* 79–80;47–62.
- [4] Banerji A, Rohatgi PK, Reif W. 1984. Role of wettability in the preparation of metal-matrix composites (a review). *Metall Tech.* 38; 656–61.
- [5] A. Urena, E.E. Martínez, P. Rodrigo, L. Gil. 2004. Oxidation treatments for SiC particles used as reinforcement in aluminium matrix composites. *Comp. Sci. Tech.* 64 (2004) 1843–1854
- [6] J. Hashim, L. Looney, M.S.J. Hashmi. 2002. Particle distribution in cast metal matrix composites— Part II. *J. Mater. Proc. Tech.* 123; 258–263
- [7] C.A. León, R.A.L. Drew. 2002. The influence of nickel coating on the wettability of aluminum on ceramics. *Composites: Part A.* 33; 1429–1432
- [8] Composite Materials Handbook. 2002. *Metal Matrix Composites*. Department of US Defense. Vol. 4. Mil-Hdbk-17-4a
- [9] J. Rams*, A. Urena, M. Campo. 2006. Dual layer silica coatings of SiC particle reinforcements in aluminium matrix composites. *Surf. & Coat. Tech.* 200; 4017–4026