

Development Processes of Cost Effective Aluminium Metal Matrix Composite - A Review

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Abstract

Aluminium Composites and their processing has the vast development in the current scenario of materials research to overtake the need of low cost, light weight and to exhibits high mechanical properties and improved strength to weight ratio. The low cost processing method and uniform distribution of reinforcement particulate in aluminium is a demanding challenge in this area. Wettability of reinforcement which is one of the major challenge has been studied which is a key factor for uniform property of the output. Recently there are several grades of aluminium and different reinforcement material are in use to develop aluminium composite but choosing low cost reinforcement and optimum process is a considerable factor. Three decades of research have proved that Aluminium Metal Matrix Composites (MMCs) are able to withstand the demand of high mechanical strength, wear resistance, better tribological properties. In this paper, cost effective processes of Aluminium MMCs and their unique futures are discussed to understand the future scope to develop low cost Aluminium Metal Matrix Composites for various applications.

Keyword: MMCs, Reinforcement, Aluminium.

1. Introduction

Aluminium metal matrix composite has established a new recognition towards unconventional material research. The conventional materials are replaced by aluminium MMCs widely used in the various Automobile, Aerospace and Military applications. The processing cost is the main concerned in the fabrication of MMCs

suitable for end users. S A Sajjadi et al (2012) reported that the cost of manufacturing Setup and reinforcement material selection is a considerable element for cost effective development of Al MMCs. which exhibits better strength to weight ratio, high strength and ductility, good tribological properties, heat resistance, wear resistance and atmospheric corrosion resistance. Yoshida K and Morigani (2004) reports that the main challenge which has been encountered so far during the processing of aluminium metal matrix composite by Stir and compo casting processing methods is the non wetting characteristics, non uniform distribution of reinforcement particulate and undesirable interfacial reaction which leads in difficulty to limit greatly the improvement of thermal properties of Carbon/Metal and diamond/metal composite. David Raja et al (2013) has reported that among various reinforcement used fly ash is one of the cheapest available reinforcement and its advantage includes low density which clears the way for the development of cost effective Al MMCs. P K Rohtagi et al (2007) and Liu HJ et al (2003) had shown that there are various processes available for the processing of MMCs such as High Energy Laser Melt Injection, Plasma Spraying, Cast sinter and Electron Beam Irradiation . M Rodriguez Reyes et al (2006) and Sato Y S et al(1999) reports that the stir casting incorporate low setup cost, easy handling, quick to access and its suitability for mass production without damaging the reinforcement particles, so it is in demand in the current scenario. In this review paper an initiative has been taken for the cost effective development processes of Aluminium MMCs and the optimal selection of process, parameters to enhance mechanical properties and the effect of various processes.

2. Processing of MMCS

The MMCs are processed by various processing methods and they are categorized in two groups as

2.1 Solid state processing methods in which reinforcement and matrix which are in solid phase includes mainly Diffusion bonding and Powder metallurgy

2.1.1 *Diffusion bonding processing methods*: Smith P.R et al (1998) has defined that the diffusion bonding process is mainly produced by adopting foil-fibre-foil route or by the evaporation of relatively thick layers of the aluminum on the surface of the fibre. Its suitability is limited to produce complex shapes and components and difficulty reveals in obtaining high fibre volume fraction and homogeneous fibre distribution. this process require high setup and process cost.

2.1.2 *Powder metallurgy*: PM process proceeds by blending of aluminum alloy powder with ceramic particulate, short fibre or whisker particle carried out in dry mode or liquid suspension mode followed by canning, degassing, cold compaction and high temperature consolidation stage such as hot isostatic processing(HIP).Strainer L G (1989) reported that development of Al MMCs by PM process avoids deformation at much lower temperature than the melting point of matrix material and prevents chemical reaction occurring at interphase boundary of composite. The main limitations adhered to this process is the occurrence of porosity which may render in decrease of mechanical properties.

2.2 Liquid state processing methods where matrix is in liquid state includes Infiltration process, and Stir casting processing methods.

2.2.1 *Infiltration process*: This process involves the injection of liquid aluminum into the porous pre forms of continuous fibre, short fibre or whisker or particle to produce MMCs. Using this process, a wide range of reinforcement volume fraction varies between (10-70)% can be produced with the help of various infiltration techniques. A. Mattern et al (2004), G.G Kang et al (1996) and J. Sobczak (2001) reported that the process make it possible to obtain precise shape, high degree of surface finish. It is suitable for mass production.

2.2.2 *In-Situ Processing*: This process includes a variety of processes such as Liquid-Gas, Liquid-Solid, Liquid-Liquid and Mixed salt reactions. One of the example is directional oxidation of aluminum known as DIMOX Process in which the alloy of Al-Mg is placed on the top of ceramic perform in a crucible and now entire assembly is heated to a suitable temperature in the ambient air of free flowing nitrogen gas bearing mixture. J.R.R.M and Aikin (1997) and Maity and Panigrahi (1995) reported that the process is suitable for processing reinforcement in order of 0.5-0.05 μ m and this results in achieving better distribution of particles and high mechanical properties. Ahmad Changizi (2005) examined that the main difficulty in the process is the reaction of particle size of less than 1mm and the problem there is the problem of agglomeration and health hazards reveals.

2.2.3 *Stir Casting Process*: This process involves mixing of molten metal along with the reinforcement particulate and allowing them to solidify. A.A Adebisi et al (2011) reported that the stir casting is very unique processing method for the development of reinforced Aluminium metal matrix composite. This is widely acceptable due to its conveniency, low set up cost and easy portability to overcome the problem of expensive processes. The development of this dominating fabrication process evolved as a result of recent technological advancement in material application and the demand for light weight material with improved mechanical and thermal properties at low cost. J.hashim et al (1997) reported that there are limitations which reveals during the process are non-uniform distribution, poor wet ability between reinforcement particulate and matrix material, porosity in casted MMCs and chemical reaction between particulate and matrix. The research work is needed to overcome the limitations of the process to develop cost effective metal matrix composites.

3. Effect of Processing Technique

Metal Matrix composite is processed by various processes as reported so far. In this review paper the attention is drawn for cost effective processes for the development of aluminium metal matrix composites which exhibits better mechanical properties to meet the requirement of various industries. The cost effective processing of MMCs involves the selection of low cost reinforcement material as well as the optimum process. The cost comparison of material is shown in Table.1. It is also reported the mechanical properties varies by varying the reinforcement material and processing methods. Hai Zhi Ye et al (2004), Jagannath K et al (2010) and Duralcan D (1995)

examined the effect of processes and reinforcement material during the development of Metal Matrix Composite which is shown in Table.1.

Table 1: Effect of processing techniques on mechanical properties.

S No	MMCs	Reported Enhanced Mechanical Properties
1	Mg ₂ Si	UTS-506MPa
2	Tin-Graphite	Cumulative wear rates (mm ³ /Nm)-0.002
3	Al-Zr	Compressive strength-248MPa
4	Al-Fly Ash	Hardness-114 VHN

4. Conclusion

Stir casting method is widely acceptable due to its advantages like low setup cost ,easy portability, incorporate mass production and to achieve better mechanical properties. During the review of development of cost effective processes of aluminium metal matrix composite some important facts can be summarized as below

1. Casting property of aluminium is widely used for the MMCs to gain the advantage of better specific strength.
2. Fly ash is the attractive reinforcement to get the better quality of MMCs, This is reducing the MMCs development cost effectively.
3. Stir casting method is effective casting method to develop the MMCs,to uniform distribution of the reinforcement and homogeneous properties of the casting. The cost of setup is also very less.

References

- [1] Adebisi A A, Maleque M A, Rahman M M (2011), IJAME, 4, pp. 471-480.
- [2] Ahmad Changizi (2005), A thesis to the graduate school of natural and applied sciences, Middle East Technical University.
- [3] David Raja Selvam J, Robinson Smart , Dinaharan D S I, (2013), Journals of Composite, 34, pp. 637-646.
- [4] Duralcan D,(1995), Mechanical and Physical Property Data, pp. 199-203.
- [5] Kang G G and Y H Seo,(1996),Journal of Material Processing Technology,61, pp. 241-249.
- [6] Hai Zhi Ye and Xing Yang,(2004), Journal of Material Science,34, pp. 6153-6171.
- [7] Jagannath K, Sharma S S, Mohan N S and Prabhu P ,(2010), World Journal of Engineering, 7, pp. 1708-5284.
- [8] Hashim J, Looney L and Hashmi M S J,(1997), Journal of Material Processing Technology, pp. 92-93.
- [9] J R R M and Aikin J, (1997), Metals, 8,pp. 35.

- [10] J Sobczak,(2001), Metal Foundry Composite Institute.
- [11] Liu H J, Fujii H, Maeda M and Nogi K,(2003), Journal of Material Science Letter, 22, pp. 106-1063.
- [12] Mattern A, Huchler B, Staudenccker D, Oberaccer R, Nagel A, Hofmann M J, (2004) Journal of European Ceramic society, 24, pp. 3399-3408.
- [13] Maity P C and Panigrahi S C, (1995), Key Engineering Material, pp.104-107.
- [14] Rodriguez-Reyes M, Pech-Canul I, Rendon-Angeles J and Lopez-Cuevas J,(2006),Composite Science Technology,66, pp. 1056.
- [15] Rohtagi P K ,Ravi KR, Sreekumar VM,Pillai RM,Chandan Mahato,Amaranathan KR, Arul Kumar R et al ,(2007), Journal Of Materials, 28, pp. 871-881.
- [16] Sato Y S, Kokawa H, Enomoto M and Jogan S,(1999), Metall Mater Trans A, 57, pp. 2429-2437.
- [17] Sajjadi S A, Ezatpour H R and Torabi Parizi M, (2012), Journal of Composites,34, pp.106-111.
- [18] Smith P R and Froes F H, (1984), Journal of Metals, 36, pp. 19-26.
- [19] Strainer L G (1989), Journal of Composites, 20, pp. 441-449.
- [20] Yoshida K and Morigani H,(2004), Micrielectrons reliab, 34,pp. 303-308.

