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A REVIEW ON FABRICATION OF ALUMINIUM ALLOY BASED METAL MATRIX NANO COMPOSITES THROUGH ULTRASONIC ASSISTED CASTING

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ABSTRACT

Nanotechnology is spreading in the various demanding fields of engineering and medicines like electronics, defence, aerospace, energy, materials, environment, biotechnology, chemistry, information technology and communication. It created development of new generation nano materials with advanced features and wide range of their applications. Addition of submicron or nano sized particles with aluminium matrix yields superior mechanical and physical properties and changes morphology and interfacial characteristics of nano composites. Aluminium metal matrix composites reinforced by nano particles are very promising materials, suitable for a large number of applications. A wide range of research has been done on the implementation of processing methods. Recently, ultrasonic assisted casting method is used for the production of aluminium alloy based metal matrix reinforcing with nano ceramic particles. In which the formation of clusters were minimized and the nano reinforcements were distributed uniformly in the liquid state aluminium metal matrix composite. The ultrasonic assisted casting process can control the grain size by minimizing agglomeration of nano particles and retaining the enhanced microstructure. This paper reviews the properties and morphology of aluminium based metal matrix nano composites fabricated through ultrasonic assisted casting process.

***KEYWORDS:** Metal Matrix Composite, Mechanical Properties, Aluminium, Nano-Reinforcements, Ultrasonic Assisted Casting*

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INTRODUCTION

The applications of light weight and high performance of aluminium alloy based metal matrix composites and nano composites in automobile industry, aircraft, aerospace applications and consumer related industries have been hindered by high costs of producing components of even minimally complex shape. Casting process plays the key to overcome this problem, although several technical challenges exist. Achieving a uniform distribution of reinforcement within the matrix is a big challenge, which directly influences the properties and quality of the composite materials. In order to achieve better mechanical properties in aluminium metal matrix composites especially through casting process, it is necessary that the ceramic reinforcement particles are homogeneously distributed in molten metal. The low ductility of aluminium and aluminium alloy metal matrix composites is generally due to the presence of a high percentage of coarse and brittle reinforcement phases in the matrix. It has been shown that properties of nano composites can be greatly improved with incorporation of even small amounts of nano particles. The fine reinforcement particle dispersion using impeller mixing alone tends to form larger clusters. Most commonly used nano composite manufacturing techniques such as high energy ball milling;

electroplating, sputtering and rapid solidification cannot be used for mass production and near net shape fabrication of complex structural components. Also majority of such methods the weights of the components are restricted and high volume production has got been investigated [1]. Recently ultrasonic assisted casting technique was found to be helpful in the de-agglomeration and dispersion of fine and nano particles in aluminium and aluminium alloys [2]. It has been shown that high intensity continuous ultrasonic treatment (20 kHz) when used in melt processing can have a marked effect on uniform distribution of nano particles and reduce their agglomeration [3]. The high intensity continuous ultrasonic treatment effects including acoustic streaming and ultrasonic cavitation are associated with growth, pulsation and implosion of discontinuities and small bubbles. Various reports have been shown that these phenomena will result in grain refinement, structural uniformity and prevention of nano particles agglomeration [4].

This paper is aimed at through review of aluminium and aluminium based alloy metal matrix composites reinforced with ceramic particles fabricated by ultrasonic assisted casting and investigation of mechanical properties, tribological properties and morphology during last two decades.

ULTRASONIC ASSISTED CASTING METHOD AND MORPHOLOGY

The method of ultrasonic assisted casting combines solidification processes based on dispersion of nano particles in aluminium and aluminium alloy metal melts. Ultrasonic cavitation can produce transient micro, hot spots that can have temperatures of about 5000˚C, pressures above 1000 atmosphere, heating and cooling rates above 1010 K/s. The strong impact coupling with local high temperatures can break the nano particle clusters and clean the particle surface. The ultrasonic assisted casting machine has shown in Figure 1.

Figure 1: Ultrasonic Assisted Casting Machine Setup (NITW)

Even the nano particle clusters are loosely packed together, air would be trapped inside the voids in the clusters which serve as nuclei for cavitation. The size of clusters ranges from nano to micro due to the attraction force among nano particles and the poor wettability between the nano particles and metal melt (Suslick et al. (1999) [5]. G I Eskin et al. (2003) fabricated composites of Al6063/SiCp by ultrasonic cavitation treatment with electromagnetic stirring. It was shown that Al-Si natural composites promotes the formation of structures suitable for further deformation. This method improves the size and spatial distribution of ceramic particles in metal matrix composites. The results are shown in Fig 2 (a) & (b) that the effects based on the fact that cavitation promotes the wetting of nonmetallic inclusions and particles by liquid aluminum and involves them into solidification process [6]. Yong Yang et al. (2004) produced composite materials of A356/ nano SiC by ultrasonic fabrication method. The microstructural studies was carried out with an optical microscope, SEM, EDs mapping, and XPS, it validates dispersion of nano sized SiCp in metal matrix as shown in Figure 3 [7]. Through ultrasonic assisted casting process the reinforcement SiCp particles were distributed uniformly as shown in Figure 3 (b). The composites produced through stir casting technique the micrographs revealed formation of clusters in the matrix as shown in Figure 3 (a).

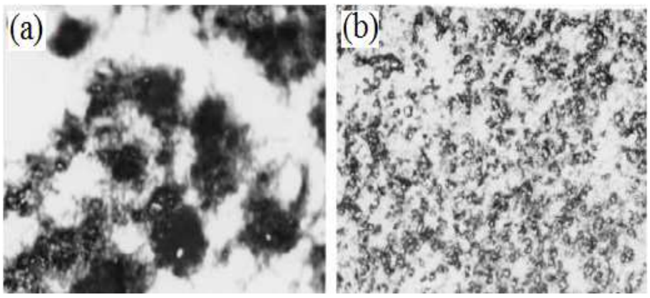

Figure 2: Microstructures of a Flat Billet Al6063/20%SiCp Composite Material (a) Mechanical Stirring without UST (b) Electromagnetic Stirring with UST [6]

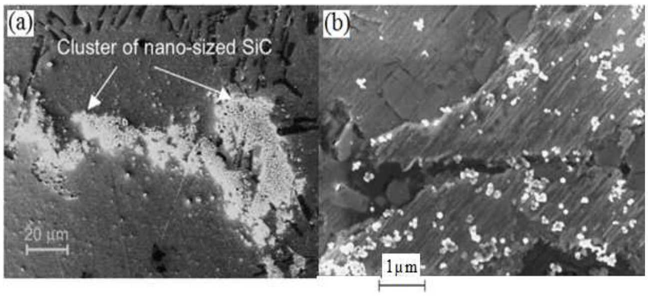

Figure 3: SEM Micrographs of A356/SiCp
(a) Without Ultrasonic Assisted Casting
(b) With Ultrasonic Assisted Casting [7]

Zhiwu et al. (2005) investigated the interactions between a Zn-Al alloy and an Al_2O_{3p}/Al6061 composite with and without aid of ultrasonic vibration. Penetrating and undermining phenomena were observed in Fig 4 (a), but the oxide layer was still continuous at most places between the undermining zone and the Zn-Al alloy during interaction without ultrasonic vibration. As shown in Fig 4 (b) the oxide film disappeared, and the Zn-Al alloy turned into composite materials after ultrasonic aided interaction and the reinforcements distributed uniformly and had metallurgical bonds with the matrix [8].

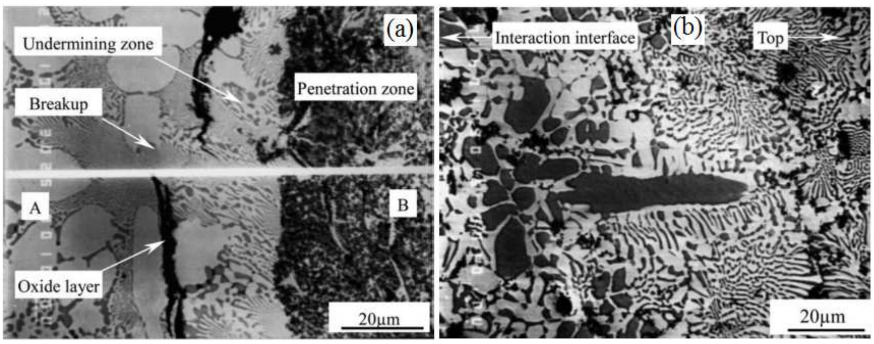

Figure 4: Micro Structural and Elemental Distribution of
Zn-Al Alloy and Al_2O_3/Al6061 Composites
(a) Without Ultrasonic Vibrations (b) With Ultrasonic Vibrations [8]

Zhiwei Liu et al. (2011) synthesized composite of Al/Ti/C materials were made through ultrasonic vibration and compared between non ultrasonic and ultrasonic methods. The micro structural characterization indicated that in situ formed Al_3Ti and TiCp particles were distributed uniformly in the matrix and a homogeneous microstructure with a low porosity was got when degassing and ultrasonic vibrations are used [9].

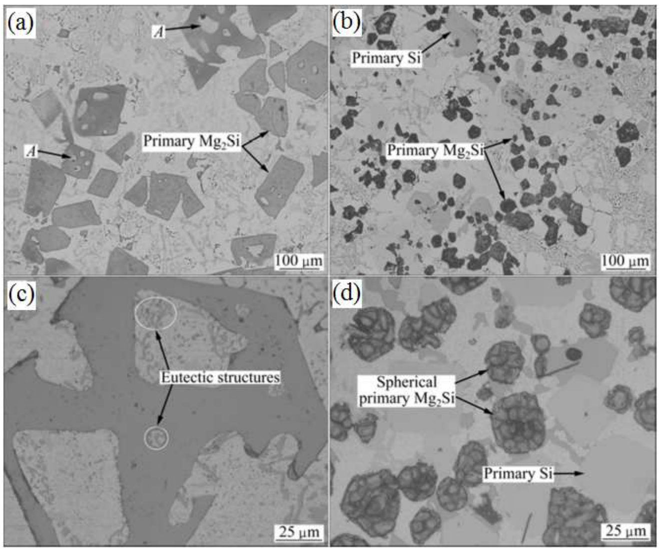

Figure 5: Morphologies of primary Mg_2Si in Al/Mg_2Si composites without (a) and with (b) Ultrasonic Vibration, High Resolution Planar Characters of Primary Mg_2Si Without (c) and with (d) Ultrasonic Vibration [11]

Narasimha Murthy et al. (2012) fabricated Al2024/flyash nanocomposites by ultrasonic cavitation route. SEM study results shown that nano flyash particles were distributed homogeneously in the Al 2024 matrix [10]. Jia tao et al. (2013) produced of Al/Mg_2Si composite by ultrasonic cavitation route. The prepared composites were investigated by metallographic microscopy and field emission scanning microscopy. The results show in Figure 5 (a), (b), (c) & (d) that the mean grain size of primary Mg_2Si crystals is refined from 150µm to 20µm by high intensity ultrasonic, and the morphologies of primary Mg_2Si crystals are changed as well. With out ultrasonic the morphologies display octahedron and tetrakaidecahedron with hopper like hole in the crystals. After ultrasonic vibration, primary Mg_2Si particles become solid crystals with rounded corners and edges [11]. Poovazhagan L et al. (2013) were fabricated hybrid nanocomposites based on Al6061/(0.5, 1.0, 1.5 vol. %) and 0.5 vol. % B_4C by using ultrasonic cavtation based solidification process. The results shown that the ultrasonic cavitation effects transient cavitation and acoustic streaming, the nano reinforcements were successfully incorporated uniformly in the Al6061 matrix [12]. M R Dehnavi et al. (2014) investigated the effect of mechanical stirring, continuous and discontinuous ultrasonic treatments on Al413/SiC_p nanocomposites. The results showed that the reinforcement particles were distributed uniformly in the matrix and gas layers removed on the particle surfaces and good wettability [13]. Adam Hehr et al. (2015) fabricated composites Al/NiTi by ultrasonic vibrating method. This method is usful for to improve the interfacial shear strength of metal matrix composites [14].

MECHANICAL PROPERTIES

The mechanical properties of composite materials mainly depend on type of reinforcement, shape, quantity of reinforcement and size etc. The researchers investigated mechanical properties of Aluminium based composite materials last two decades. They were identified superior properties with nano ceramic particle dispersion in aluminium alloy metal matrix material. Sreekumar et al. (2015) investigated mechanical properties on Al/3.5wt% $MgAl_2O_4$ metal matrix composites produced through ultrasonic assisted casting method showed that 10% increase in yield stress and 15% increase in ultimate tensile strength while maintaining the ductility similar to base alloy [15]. Rana et al. (2014) were tested mechanical properties of Al5083/micro and nano SiCp metal matrix composites produced through ultrasonic assisted casting technique. The elastic modulus Al5083/10wt% micro SiCp composite increased 8.6% compared to base alloy, in case of Al5083/3wt% nano SiCp composite increased. For the same 3 weight percentage of micron and nano size the elastic modulus are 71.2 GPa and 75.4 GPa respectively. The tensile strength of Al5083 alloy with the addition of 10% micron SiCp is 10.58% increment. For the 3 wt. % of SiCp particles the tensile strength of micron and nano SiCp composites are 236.5 MPa and 260.9 MPa respectively. Al5083/4wt. % SiCp have the maximum tensile strength of 270.2 MPa. The elongation of Al5083/SiCp composites decrease with increasing wt. % of micron SiCp. In case of Al5083/nano SiCp composites, the elongation remains constant with increasing wt. % of nano SiCp particles. composites with 10 wt. % micron SiCp have higher hardness 77 BHN in all micron SiCp composites. Al5083/4 wt. % nano SiCp shown highest value of hardness 79.2 BHN among all the samples. The compressive strength increases in wt. % of SiCp particles. Al5083/ 4 wt. % nano SiCp composites have the maximum compressive strength of 361 MPa among all the samples tested [16]. Dehnavi et al. (2014) were tested properties of Al413/SiCnp composites fabricated by ultrasonic assisted casting technique. The improvement in the yield strength and ultimate strength were increased about 126% and 100% compared to those of the monolithic sample [17]. Govind et al. (2013) investigated ultimate tensile strength on AA2024/B_4C composites were produced through ultrasonic assisted casting method. The ultimate tensile strength has been increased by 6% and leads to 442 MPa and yield strength 312 MPa [18]. Narasimha et al. (2012) tested properties on AA 2024/fly ash nano composites fabricated by ultrasonic assisted casting technique. The 1wt. % nano fly ash addition to AA 2024 metal matrix showed in Fig 6 highest tensile strength 345 MPa [19].

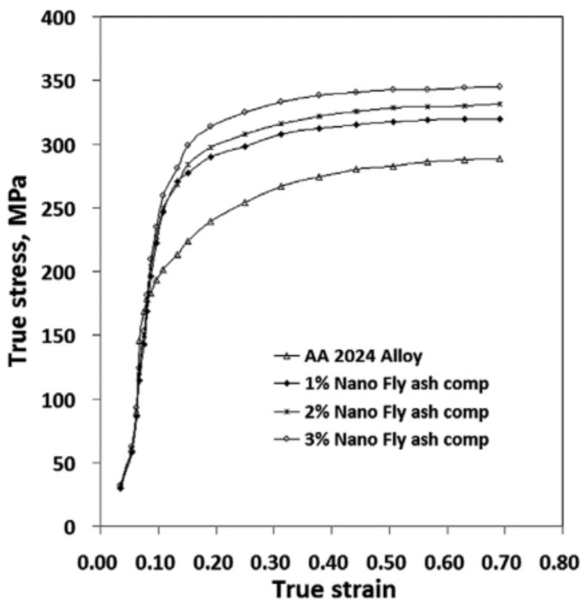

Figure 6: True Stress-True Strain Curves for Alloy and Nano Fly Ash Composites [19]

The compresive strength of the AA 2024/ 3wt. % fly ash composite was increased from 289 MPa to 345 MPa. The strength of the fly ash nano composites increased because of addition of solid nano ceramic particles due to the strengthening effects occurred in nano particulate reinforced composites [19].

CONCLUSIONS

A few authors have been reported ultrasonic assisted casting fabrication method for improving the distribution of the micro and nano reinforcements in the aluminium alloy matrix composites. The reinforcement particles were distributed uniformly in the matrix material and do not found the formation of Al_4C_3 phase. There are advantages such as matrix-reinforcement bonding, low cost processing and nearer net shape can get form ultrasonic assisted casting method.

REFERENCES

1. *Jain P.K, "Ultrasonic Cavitation Assisted Fabrication and Characterization of A356 Metal Matrix Nano composite Reinforced with SiCp, B4C, CNT" AIJSTPME, 2(2), 27-34 (2009).*
2. *G. J. Eskin, D. G. Eskin, "Ultrasonic Treatment of Light Alloy Melts" Second edition, Advances in Metallic Alloys, CRC Press, Boca Raton, (2014).*
3. *S Donthamsetty, N R Darmera, P K Jain, Asian Int.J. Sci. Technology. Prod. Manuf. Eng. 2, 27-34 (2009).*
4. *M R Dehnavi, B.Niroumand, F Ashrafizadeh, P K Rohatgi, "Effects of continuous and discontinuous ultrasonic treatments on mechanical properties and micro structural characteristics of cast Al413-SiCp nano composite" materials Science & Engineering A 617, 73-83 (2014).*
5. *L C Martinez, "Ultrasound in chemistry" Analytical Applications, Wiley-VCH, New York, (2009).*
6. *G I Eskin, D G Eskin, "Production of natural and synthesized aluminum based composite materials with the aid of ultrasonic (cavitation) treatment of the melt" Ultrasonics Sonochemistry, 10, 297-301, (2003).*
7. *Yong Yang, Jie Lan, Xiaochun Li, "Study on bulk aluminum matrix nano composite fabricated by ultrasonic dispersion of nano sized SiC particles in molten aluminum alloy" Materials Science and Engineering A 380, 378-383, (2004).*
8. *Zhiwu Xu, Jiuchun Yan, Gaohui Wu, Xiangli Kong, Shiqin Yang, "Interface structure of ultrasonic vibration aided interaction between Zn-Al alloy and Al 6061/Al_2O_{3p} composite" Composites Science and Technology, 65, 1959-1963, (2005).*
9. *Zhiwei Liu, Qingyou Han, Jianguo Li, "Ultrasound assisted in situ technique for the synthesis of particulate reinforced aluminum matrix composites" Composites: Part B 42, 2080-2084, (2011).*
10. *I Narasimha Murthy, D Venkata Rao, J Babu Rao, "Microstructure and mechanical properties of aluminum fly ash nano composites made by ultrasonic method" Materials and Design 35, 55-65, (2012).*
11. *Jia tao Zhang, Yu guang Zhao, Xiao feng XU, Xiao bo Liu, "Effect of ultrasonic on morphology of primary Mg_2Si in in situ Al/Mg_2Si composite" Trans. Nonferrous Met. Soc. China, 23, 2852-2856, (2013).*
12. *Poovazhagan L, Kalaichelvan K, Rajadurai A, Senthilvelan V, "Characterization of Hybrid Silicon Carbide and Boron Carbide Nanoparticles Reinforced Aluminum Alloy Composites" Procesdia Engineering 64, 681-689, (2013).*
13. *M R Dehnavi, B Niroumand, F Ashrafizadeh, P K Rohatgi, "Effects of continuous and discontinous ultrasonic treatments on mechanical properties and microstructural characteristics of cast Al413/SiCp nanocomposite" Materials Science & Engineering A, 617, 73-83, (2014).*
14. *Adam Hehr, Marcelo J, Dapino, "Interfacial shear strength estimates of Al/NiTi matrix composites fabricated via ultrasonic additive manufacturing" Composites Part B 77, 199-208, (2015).*
15. *V. M. Sreekumar, N. Hari Babu, D. G. Eskin, Z. Fan, "Structure-property analysis of in situ Al-MgAl2O4 metal matrix*

composites synthesized using ultrasonic cavitation" Materials Science & Engineering A 628, 30-40, (2015).

16. *R S Rana, Rajesh Purohit, Sanjay Soni, S. Das, "Comparision of Mechanical Properties and Microstructure of Aluminum alloy Micron and Nano SiC Composites fabricated by ultrasonic vibration" International Journal Of Advance Engineering and Research Development, Volume 1, Issue 12, Page 2348-6406 (2014)*
17. *M. R. Dehnavi, B. Niroumand, F. Ashrafizadeh, P. K. Rohatgi, "Effects of continuous and discontinuous ultrasonic treatments on mechanical properties and microstructural characteristics of cast Al413/SiCnp nano composites" Materials Science & Engineering A 617, 73-83, (2014).*
18. *Dr Govind Nandipati, Dr. Ravindra Kommineni, Dr. Nageswara Rao Damera, Dr Ramanaiah Nallu, "Fabrication and Study of the Mechanical Properties of AA2024 Alloy Reinforced with B4C Nano particles using Ultrasonic cavitation method" IOSR Journal of Mechanical and Civil Engineering, pp01-07, Volume 7, Issue 4, (2013).*
19. *I. Narasimha Murthy, D. Venkata Rao, J. Babu Rao, "Microstructure and mechanical properties of aluminum fly ash nano composites made by ultrasonic method" Materials and Design 35, 55-65, (2012).*