RECENT TRENDS IN THE MANUFACTURING PROCESSING OF METAL MATRIX COMPOSITES: PRIMARY PROCESSING

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ABSTRACT

The growing steel prices have significantly affected the manufacturing expenditure in automobile and house hold industries, thus making a strong case for substituting steels with other light weight and high strength to weight ratio materials. The aluminium and its alloy have outstanding properties like light weight, wear resistance andcorrosion resistance that make them suitable in numerous industrial applications. These materials, comprehensively used in automobile and aerospace industries have nearlytouched their limit of practicality. Therefore, substantial investigations in the area of materials science and engineering have been focused towards the growth of newfangled materials like composites. The research in the field of materials science has established that composites cansubstitute conventional materials because of their light weight as well as better mechanical and chemical properties.The present research paper explore the status of primary processing of metal matrix composites in the various domains of applications in Industry.

Keywords: Metal Matrix Composites; Stir Casting, Primary processing; Aluminium

I INTRODUCTION

The composites can be developed from metals and their alloys, ceramics, plastics or polymers through casting, powder metallurgy, metal alloying, injection molding, hand lay-up technique etc., to obtain the desired properties. MMCs were developed in early seventies and the primary support for their development was from aerospace industry. At present, as per the survey, more than eighty percent of MMCs are used for ground transportation **(Figure 1).** Therefore, the primary support for the development of MMCs is from transportation industry. The transportation industry is looking for efficient and cost effective methods for the processing and assembly of the MMCs.

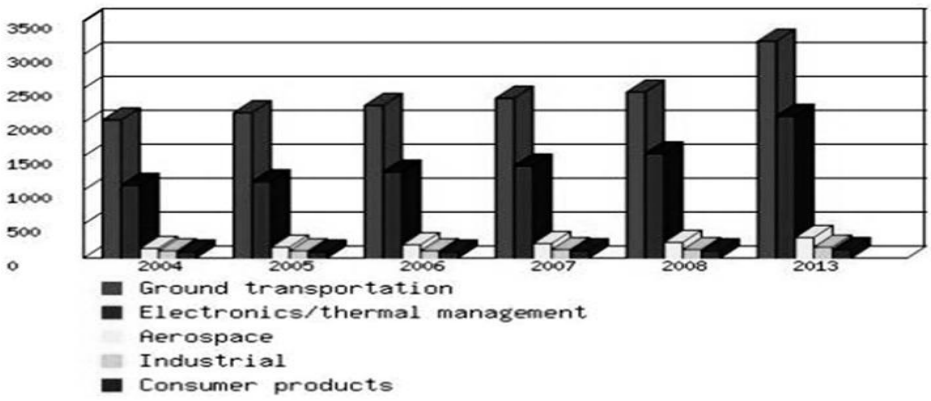

Figure 1Application of MMCs[1]

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The synthesis of metal matrix composites (MMCs) has been taken place from last four decades with the help of different casting routes. The commercial use of MMCs with improved physical and mechanical properties as compared to monolithic materials started after 1990. MMCs fundamentally comprise of two different materials. The main constituent is called matrix, and another constituent known as reinforcement is added in different volume fractions to the matrix material in the form of particles, whiskers and fibers. These composites are mainly classified as continuous and discontinuous MMCs, depending upon whether the reinforcement is fiber/whisker or particle. Properties of MMCs can be customized for numerous industrial applications through appropriate combination of matrix material, reinforcement and manufacturing techniques. The particle reinforced metal matrix compositeshave proved tobe economical due to less expensive reinforcement particles and use of low cost production methods such as casting or liquid metallurgy route [2].

II PRESENT STATE OF RESEARCH IN MANUFACTURING

The state of research in manufacturing can be classified in four categories as following:

- Existing technologies applied to existing materials.
- Existing technologies applied to new materials.
- New technologies applied to existing materials.
- New technologies applied to new materials.

Here, existing technologies denotes to those which are effectively being used in the industries, whereas new technologies are those which are either at laboratory stage or relatively new and not frequently practiced. Conventional stir casting, powder metallurgy, squeeze casting etc., have been considered in the former while vacuum infiltration, hybrid casting etc., have been considered in the later. On the other hand, new materials cover super alloy composites which are still in the research stage or in the stage of infancy.

III CURRENT DIRECTION IN THE PRIMARY PROCESSING OF METAL MATRIX COMPOSITES

The production of MMCs by casting route has been investigated and published nearly 1200 research articles over past 10 years. The number of articles published had been nearly constant per year. This fact can be visualized from the **Figure2.** The figure displays the year wise number of research articles dealing with processing of MMCs, available in several journals and conference proceedings. The data for year wise distribution has been collected through SCOPUS [3]. It may be noted that this distribution is demonstrative rather than real, as it may not cover all of the published as well as unpublished articles. However, the data collection is so large that it can be used to understand the present direction of research.

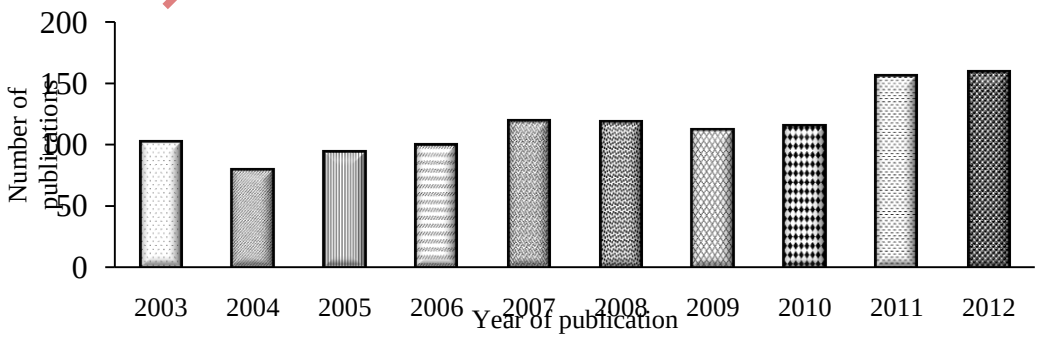

Figure 2 Research Publications Related to the Production of MMCs

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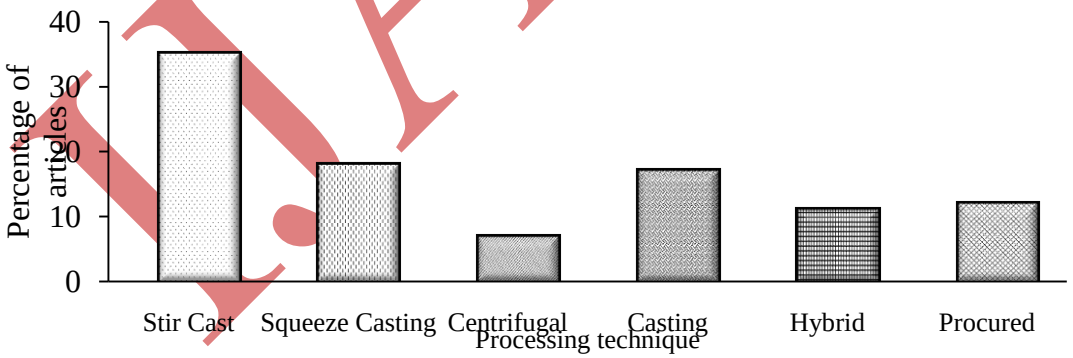
In order to analyze the worldwide research efforts in the broad area of manufacturing of MMCs, a study has been made undertaken. The articles available in international journals and conference proceedings in the year 2012 have been analyzed (on the basis of data accessible with SCOPUS [3]). Above 170 articles were reported for the year 2012. From study point of view, these articles have been categorized into three groups as following:

- Manufacturing process for the production of MMCs
- Analysis of process/ procedure
- Application/objective

The following inferences can be drawn from the exhaustive study of research articles**(Figure 3 (a, b and c)):**

1. A number of methods have been developed by the researchers for the production of MMCs. The most commonly used method for MMCsproduction is stir casting**(Figure 3 (a)).**
2. Mostly experimental work has been carried out to study the behavior of processing parameters **(Figure 3 (b)).**
3. Improvement in the mechanical and wear properties are the main research objectives by attaining uniform distribution of the reinforcement**(Figure 3 (c)).**
4. Machinability of the developed/procured MMCs has been investigated for optimum quality characteristics such as; tool wear, cutting forces, surface finish etc., **(Figure 3 (c)).**
5. Aluminium alloy matrix materials are extensively used by the research community.
6. The MMCs reinforced with abrasive particles are extensively developed as compared to whisker reinforced or long fiber reinforced composites.
7. Average grain size of the reinforcing abrasive particles (SiC, Al_2O_3)used for the production of MMCs is more than 25 microns. Very little information is available for the production of composites with smaller size of reinforcement particles. Among the particulates used as reinforcement, silicon carbide (SiC) has achieved aprimary position for production of MMCs.

(a)



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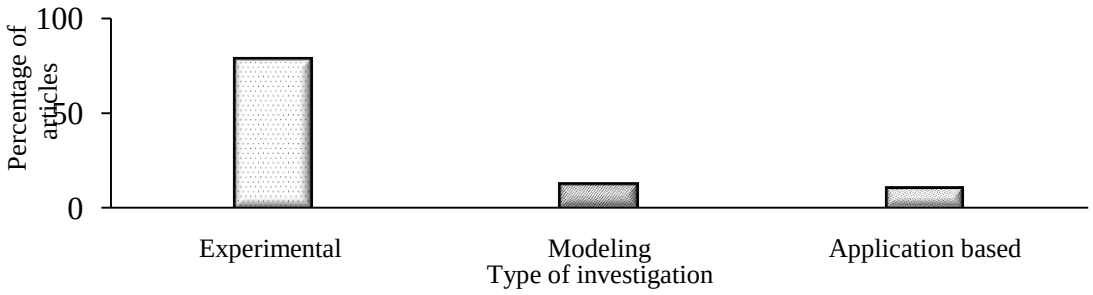

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(c)

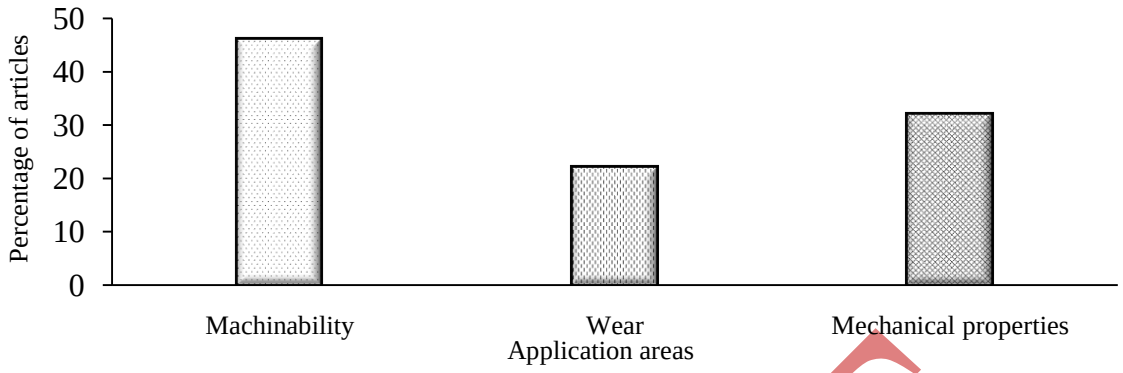

Figure 3(a, b and c) Classification of Research Articles in the Area of Processing of MMCs

IV PRODUCTION OF METAL MATRIX COMPOSITES (MMCS)

Solid, liquid and vapor state processing methods are used for the production of MMCs.The solid state processing methods are powder metallurgy, diffusion bonding etc. The liquid processing methodsare liquid infiltration, stir-casting, squeeze casting, spray deposition, reactive processing, compo-casting etc. The vapor phase processing methods are physical vapor deposition (PVD), chemical vapor deposition (CVD) etc. Further the production of the MMCs are categorized as ex-situ or in-situ processes. In ex-situ process, reinforcingparticles are added externally in the liquid matrixin form of whiskers or powder, and in the case of in-situprocess chemical reaction between the constituents of matrix causes the formation of reinforcements under controlled environment.

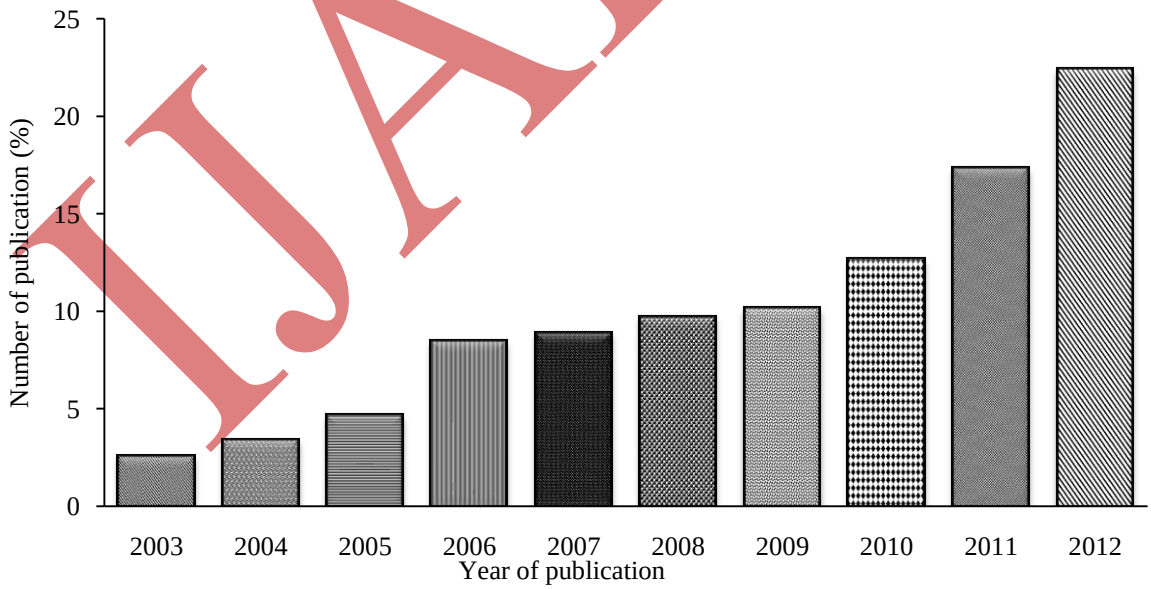

Figure 4Year Wise Distribution of Published Articles in the Area of Stir Casting

Stir casting route has been prominently used as a production technique as shown in **Figure 4** but it faces technical challenges as well. The main research challenge is to get a uniform distribution of the reinforcement in the matrix with minimum porosity [4-6]. Theconventional foundry technology with a little modification in the design of furnace and stirring method can be used for the production of MMCs by ex-situ process. Stir-casting

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route employs distribution of ceramic reinforcement such as SiC or Al_2O_3 into the liquid matrix and stirring the mixture at designed velocity for a period of time to create vortex formation for uniform distribution of reinforcement.The poor wettability of the reinforcement with the molten matrix is the major problem for the stir casting route. It causes weak interfacial bonding and deterioration in mechanical properties. The problem becomes more complex when fine reinforcement particles are used. Continuous improvement has beenmade to produce sound castingswith comparatively improved dispersion and appropriate wetting ofparticles by governing and optimizing the casting process parameters.

The matrix material used for the production of MMCs are aluminium and its alloys, magnesium and its alloy, copper and its alloys and other low melting point metallic materials. Amongst them, aluminium and its alloys are extensively used as matrix because of their outstanding physical andmechanical properties and comparatively low cost as compared to other matrix materials.Further, the addition of reinforcement in aluminium and its alloy is easy as compared to other matrix materials.

The appropriate combination of matrix, reinforcement, reinforcement size, and processing methods lead to improved physical, mechanical and corrosion properties required for a specific applications. The elastic-plastic behavior of MMCs is observed during stress strain analysis. The elastic-plastic behavior is based upon the ductility and fracture toughness of the MMCs. The MMCs behave like conventional monolithic materials, but their ductility and fracture toughness is reduced due to the presence of brittle reinforcement phase [7]. Improved mechanical properties of MMCs can be attained through proper selection ofmatrix and reinforcementcombination and standardization of processing methods. Stir-castingmethod is extensively used for the production of metal matrix composites to obtain near net shape withenhanced mechanical and chemical properties. The properties of stir cast components can be further improved with the help of squeeze casting, which promotes the forced wettability of the reinforcement with matrix and results in reduced porosity [7-8].

V CONCLUSIONS

From this review article onrecent trends in processing of metal matrix composites: primary processing, the following conclusions can be drawn:-

1. The most commonly used method for MMCs production is stir casting
2. The main research objectives of the researchers are improvement in mechanical and wear propertiesby attaining uniform distribution of the reinforcement.
3. The researchers extensively investigated for optimum quality characteristics such as; tool wear, cutting forces, surface finish etc.
4. The MMCs reinforced with abrasive particles are extensively developed as compared to whisker reinforced or long fiber reinforced composites.
5. Average grain size of the reinforcing abrasive particles (SiC, Al_2O_3)used for the production of MMCs is more than 25 microns. Very little information is available for the production of composites with smaller size of reinforcement particles. Among the particulates used as reinforcement, silicon carbide (SiC) has achieved aprimary position for production of MMCs.

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REFERENCES

1. http://www.bccresearch.com/report/metal-matrix-composites-market-avm012d.html
2. Huda D., El Baradie M.A., Hashmi M.S.J., 1993, "Metal-matrix composites: Manufacturing aspects. Part I", *Journal of Materials Processing Technology, Vol. 37, Issues 1-4, pp.513-528.*
3. SCOUPS DOCUMENTS, Available at: *http://www.scopus.com.citation,* (Accessed 05 April 2013).
4. Hashim J., Looney L., Hashmi M. S. J., 2001, "The wettability of SiC particles by molten aluminium alloy", *Journal of Materials Processing Technology, Vol.119, Issues 1-3, pp.324-328.*
5. Hashim J., Looney L., Hashmi M. S. J., 2002, "Particle distribution in cast metal matrix composites-Part I*", Journal of Materials Processing Technology, Vol. 123, Issue 2, pp.251-257.*
6. Mahmut D., and Kemal Aldas., 2006, "Experimental and numerical investigation of effect of particle size on particle distribution in particulate metal matrix composites", *Journal of Materials Processing Technology, Vol. 177, pp.300-307.*
7. Suresh S., Mortensen A., Needleman A. (1993) Fundamentals of metal-matrixComposites.*Butterworth-Heinemann, Stoneham, MA.*
8. DvivediAkshay., 2008, "Electric discharge machining of Al6063-SiC MMC produced by stir casting process", *Ph.D. thesis, Indian Institute of Technology Roorkee, India.*

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