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A Review on Improvement in Alumunium Alloy (AA1100) Hybrid Composite

[1]Gourav Kalra, [2]Dr. Bikram Jit Singh
[1] Assistant Professor, Mechanical Engineering, Maharishi Markaneshwar University, Ambala, Haryana, India
[2] Professor and Head, Mechanical Engineering, Maharishi Markaneshwar University, Ambala, Haryana, India

Abstract:

Aluminium 1100 Metal-Metal Composites (AA1100 MMHCs) are reported to be the materials of 21st century in the view of their unusual properties and unique design possibilities that are not exhibited by conventional composites. Aim of this study is to optimize AA1100 MMHCs for improved Micro-structural and Mechanical Properties, so that it may be used to fabricate high strength and light weight automotive chassis and body cabins of hatchback cars. AA1100 MMHC will be synthesized with Stir Casting Technique. Compositional Parameters and Process Parameters will also have been pre-decided from available literature. Optimization technique like Mixture Design of Experiment (DoE) would be used to design the experiments through MINITAB statistical software. Designed experiments will be executed and corresponding responses will be found. Then Mixture DoE statistics will demonstrate the main and interactional impact of various compositional and process parameters as far as optimization of Micro-structural and Mechanical Responses (Properties) are concerned.

Keywords: Automotive Body Material, Stir casting, MMHCs, AA1100 Alloys, SEM, Compressive Strength, UTM, Vicker Hardness Tester, Orthogonal Matrix, Mixture DoE

I. INTRODUCTION

Al and Al alloys became attractive material for the application in aerospace, defence and automotive industries owing to their versatile properties. Basically it is found wide range of applications for rail coaches, aircraft industry, bearing materials, piston material, transmission lines etc. A major requirement for such applications is the high strength along with reasonable ductility. But due to their low melting point and low hardness they will wear and deformed easily [1]. The metal Aluminium cannot meet all the required properties suitable for various engineering applications. So it is important to produce the Aluminium based materials that should have all satisfying engineering requirements. Nowadays the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating the fabrication of secondary components. The particulate composites can be prepared by injecting the reinforcing particles into liquid matrix through liquid metallurgy route by stir casting. Casting route is preferred as it is less expensive and amenable to mass production. Among the variety of manufacturing processes available for discontinuous MMHC production, stir casting is generally accepted, and currently practiced commercially. The advantages of this process are in its simplicity, flexibility and applicability to large scale production Si, Cu and Mg can be considered as reinforcements, due to their high strength, high aspect ratio and thermo-mechanic properties [2-4]. However, until now the main obstacle is to obtain a homogenous dispersion of the Reinforcement in the desired matrix [2, 3]. The objective of this work is to reinforce light Aluminium (AA) 1100 alloy with Si-Cu-Mg by melt stirring method. Different weight percentages of reinforcements are to be added separately to make Aluminium metal-metal composites and it's Mechanical Properties (like; Compressive Strength & Hardness) and Micro-structural Properties (like; Grain Size, Micro-structure & Morphology etc.) have been investigated. Necessary analysis and optimization has been performed for improved properties with the help of 'Mixture Design of Experiment' technique. At end, the shortlisted properties of AA1100 MMHC have been compared with corresponding properties of raw AA1100 alloy. The increasing demand of fuels and rapidly increasing of fuel prices. Which result there is a need to develop more fuel efficient and environmentally cleaner means of automobile. Automotive manufactures in collaboration with other industries are developing new technologies in order to meet customer demand for fuel efficiency, improved safety, comfort and strict environmental legislation. Which can be possible either PMC (Polymer matrix composite) or MMHC (Metal matrix hybrid composite) The most common MMHC in which particulate composite system is an aluminium alloy (AA) reinforced with Si, Mg, Zn, Cu and SiC in powder forms. So far, most of the alloys that have been chosen as matrices are; A356, 2000, 5000 and 6000 series alloys. Few studies have been reported on the AA1100 series alloys reinforced with silicon, copper and Magnesium particulates. These alloys show the highest strength of commercially available Al alloys and are widely used for structural applications. AA1100 alloy and its composites have a high tensile strength, electrical conductivity, corrosion resistance and workability [5-6].

II. CURRENT PROBLEM

The issue of CO_2 emission has become more and more critical during the last decades. One of the main sources of CO_2 emission is transportation. One litre of petrol consumption induces 2.34 kg CO_2 and the petrol consumption is directly connected to the average weight of a car. European Commission has proposed to reduce the average CO_2 emission from new cars to 130g/km by 2018. To fulfil these regulations, the grass root solution is to reduce the weight of a car. An average weight for a hatchback car should be less than 800kg to meet above regulations. Therefore, the use of light metals or its composites for car-bodies or chassis are erupting as a logical way for the present nuisance. Currently lightweight metal alloys are used in relatively small quantities in automotive applications due to their relatively low strength, which limits their potential applications. During 'Crushing Test' of automobiles, Compressive Strength and Hardness of the body material along with Micro-structural Properties related with Grain Size and Micro-structure are very critical (i.e. Compressive Strength should atleast be 170 MPa to 310MPa and the corresponding Hardness must lie in the range of 150BHN to 190BHN) [7]. To achieve these targets, research has been done on light metal matrix hybrid composites to improve the mechanical properties by adding different reinforcements. Metal matrix hybrid composite (MMHC) is engineered on combination of the metal/alloy (as a Matrix) and hard particles/ceramics (as reinforcements) to tailored desired properties. In present case, rarely used AA1100 alloy reinforced with different percentages of Si, Cu and Mg particles has been decided to make an AA1100 MMHC, having Mechanical and Micro-structural Properties (or Responses) within the desired specification limits.

Metal-Matrix Hybrid Composites (MMHC): The matrix in these composite is a ductile metal or an alloy. These composites can be used at higher service temperature than their base metal counterparts. The reinforcements in these materials may improve specific stuffiness, specific strength, abrasion resistance, creep resistance and dimensional stability. The MMHCs are light weight and resist wear and thermal distortion, so it mainly used in automobile and aerospace industry. Metal matrix hybrid composites are much more expensive than PMCs and therefore their use is somewhat restricted. This fact will further provide a sufficient 'Research Scope' that effort should be done to fabricate economical Aluminium alloy based MMHC with Stir-casting Techniques.

Stir Casting: In given study, we will prepare MMHC with Stir Casting Method. This is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies. Stir Casting is the simplest and the most cost effective method of liquid state fabrication [4,8].

Distribution of dispersed phase may be improved if the matrix is in semi-solid condition. The method using stirring metal composite materials in semi-solid state is called Recasting. High viscosity of the semi-solid matrix material enables better mixing of the dispersed phase. The high cost of production of even minimally complex shape components hinders the widespread adoption of particulate metal matrix hybrid composites. Casting technology is the solution to this problem. But there are several technical challenges as mentioned below that need considerable attention before going for this technique.

- The difficulty of achieving a uniform distribution of particles.
- Wettability between the matrix and the particles.
- Porosity in the cast metal matrix hybrid composites.
- Chemical reactions between the reinforcement material and the matrix alloy.

In stir casting technique (look at figure 4 for demonstration) of production of metal matrix hybrid composites, a melt of the selected matrix material is produced by heating the material in a furnace. In the molten matrix material, the reinforcing particles are then added followed by stirring of the melt to make the reinforcement particles homogenous to the melt. After stirring, solidification of the melt containing suspended particles takes place to obtain the desired product.

Figure: 2 Stir casting Setup

The settling time should be as minimum as possible during solidification of melt. The reinforcement particles in general, occupy interdendritic or between secondary dendrite arm spacing, therefore the matrix grain size or the spacing must be finer for better distribution of particles. In this study we will do experimental runs by varying Stirring Speed, Stirring Time and Working Temperature for achieving effective optimization, as these process factors may put impact on grain structure, morphology, compressive strength and hardness of MMHC at end.

Mixture Design of Experiment: Designed experimental techniques are finding increasing use in manufacturing to optimize the given production process. Specifically, the goal of these methods is to identify the optimum settings for the different factors that affect the production process. Mixture experiments are a special class of response surface experiments in which the product under investigation is made up of several components or ingredients. Designs for these experiments are useful because many product design and development activities in industrial situations involve formulations or mixtures. In these situations, the response is a function of the proportions of the different ingredients in the mixture. In the simplest mixture experiment, the response (the property or performance of the product based on some criterion) depends on the relative proportions of the components (ingredients). DOE offers industrial physicists and their engineering colleagues the opportunity to design better parts at lower cost and in less time. Its cost-effectiveness, greater speed, and ability to reveal design solutions not apparent with the traditional experimental method make the DOE approach increasingly vital in maintaining American industry's competitive edge.

III. REVIEW OF LITRATURE

Thorough literature review has been initiated as far as MMCs are concerned and briefed as under. Henri et al. (2014) had given an idea that Si, Cu, & Mg in the powder form can be mixed for better improvement in aluminium alloys up to 1% to 14%, 2% to 5% to 10% respectively [1]. Jokhio et al. (2011) investigated the effect of elemental metal such as Cu-Zn-Mg in aluminium matrix on mechanical properties of stir casting of aluminium composite materials reinforced with alpha "Al2O3" particles using simple foundry melting alloying and casting route. "Al2O3" particles up to 10% increase the tensile strength 297 MPa and elongation 17% in aluminium alloy matrix containing Cu-Zn -Mg in aluminium [9]. Singhla et al (2009)Porosity generally found in stir casting of aluminium composites increases with increase in"Al2O3" particles contents in aluminium matrix especially containing high %age of alloy addition. Mg has pronounced effect on aluminium cast composites up to 2.77% Mg contents which increases Wettability, reduces porosity and develops very good bonding with "Al2O3"particles, The results also suggest that Cu contents in small quantity less than 2.7% Cu increases the strength and ductility along with Mg and Zn contents in aluminium matrix as in case of alloy [10].

Dwivedi et al. (2014) prepared an AA6082/SiC metal matrix composite with different size of reinforcements (75μm, 50μm and 25 μm) by mechanical stir casting. Macro-structural analysis, tensile test, hardness test, impact test were performed to find out microstructure and mechanical properties of the metal matrix composites. Minimum porosity was observed for the 25μm of silicon carbide. The mechanical properties showed that the reduction of the size of SiC particles led to the improvement in tensile strength, hardness and toughness. It indicates that size of reinforcement is the effective factor influencing the mechanical properties [11].

Alizadeh et al. (2011) studied that aluminium alloy (Al–2 wt% Cu) matrix composites reinforced with 1, 2 and 4 wt% boron carbide nano-particles fabricated through mechanical milling with average size of 100nm were fabricated via stir casting method at 850^{o}C. Cast ingots of the matrix alloy and the composites were extruded at 500^{o}C at an extrusion ratio of 10:1 to investigate the effects of hot extrusion on the mechanical properties of the composites [12]. Sharma et al.(2013) described that stir casting for production of Aluminium-matrix composite and various process parameter of stir casting and Difficulties encountered in successful manufacturing of AMC by stir casting. Processing variables such as holding temperature, stirring speed, size of the impeller, and the position of the impeller in the melt are among the important factors to be considered in the production of cast metal matrix composites as these have an impact on mechanical properties [13].

Sekar et al. (2013) studied that Design of a stir casting machine. In this machine the nano-particle pre heater attached in the top of the furnace, because of red hot condition with constant temperature of nano-particle injected by push rod into the molten metal. The stirrer rod designed by variation of speed (0-2000 rpm) for mixing purpose, so that non-Wettability of particles, floating or settling of particles would be avoided. After mixed molten metal transfer into the mould with constant temp through taper pathway heater pipe into the die .From this cast part improves all the mechanical properties without casting defects [14]. Bhandare et al. (2013) prepared Aluminium Matrix Composite by Using Stir Casting Method For uniform dispersion of material blade angle should be 45° or 60 ° & no of blade should be 4. For good wet ability we need to keep operating temperature at semisolid stage i.e. 630 for Al (6061). At full liquid condition it is difficult uniform distribution of the reinforcement in the molten metal. And Preheating of mould helps in reducing porosity as well as increases mechanical properties.[15] Mathur et al. (2013) studied Effect of Process Parameter of Stir Casting on Metal Matrix Composites with Sic and Cu. Hardness of the composites found increased with increased grit size of SiC. Impact (Izod), tensile strength of the composites found increased with increased grit size of SiC. The pouring temperature of 725°C gave the best optimum value of hardness, impact strength and ultimate tensile strength [16].

Prabu et al. (2006) fabricated high silicon content aluminium alloy–silicon carbide metal matrix composite material by using different stirring speeds and stirring times. The micro-structure of the produced composites was examined by optical microscope and scanning electron microscope. The Brinell hardness test was performed. Increase in stirring speed and stirring time resulted in better distribution of particles. The hardness test results also revealed that stirring speed and stirring time have their effect on the hardness of the composite. The uniform hardness values were achieved at 600 rpm with 10 min stirring. But beyond certain stir speed the properties degraded again [17].

Mostly researcher used the 2000, 5000, 6000 and 7000 series of alloys and less work has been contributed on AA1100 for fabricating MMCs. Literature Survey reveals that researchers rarely include the process parameter of Stir Casting along with fabrication of MMC simultaneously. Critical Parameters (like; Grain Size, Stirring Speed, Holding Time, Preheating Temperature, Material Composition and Cooling Medium etc.) were rarely considered all together, as far as optimization for enhanced Mechanical and Micro-structural properties of Aluminium MMCs were concerned.

IV. CONCLUSION

Parameters such as Process parameter Stirring speed, stirring temperature and stirring time and Compositional parameter such as Si, Cu and Mg all have major effect in casting of composite through stir casting process. Therefore by varying this parameters compositions we can achive a wide range of mechanical properties. It is suggested that through this review study for abating optimum value of mechanical properties that Stirring speed should be in between 200 rpm to 300 rpm. Stirring time 5 minutes to 10 minutes and temperature should be approximately 700^0C. Whereas Compositional parameters Si and Cu should be 8% to 10 % and 7% to 9%.

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