Wear and Mechanical behavior of Aluminum matrix composites - A Review

Ashish Sharma[1], Sachin Mohal[1], Narender Panwar[2]

1*(Department of Mechanical Engineering, Chandigarh Engineering College,Landran(Mohali), India)*
2*(Department of Mechanical Engineering,NIT Srinagar, Srinagar, India)*

ABSTRACT

Lighter and energy efficient materials are requirement of current era. Aluminium and its composites are one of the possible answers to these requirements. In the present research, authors have critically reviewed the physical and mechanical properties of Al-based composites reinforced with hard ceramic reinforcements such as silicon carbide (SiC) and Alumina (Al_2O_3). The whole literature is categorized on the basis of mechanical behavior, wear behavior, design of experiment and modeling of composites. This paper will enhance the knowledge of researchers working in this field.

Keywords*:Aluminum matrix composite,fabrication processes, stir casting,Taguchi,wear resistance.*

1.INTRODUCTION

The aluminium matrix composites comprises of two or more physically and chemically distinct phases. One is termed matrix and other is reinforcement [1-3]. Composites have high strength, stiffness, resistance to corrosion, thermal properties etc. The matrix materials can be classified into various categories depending upon the type of material used. These are categorized into three types namely metal, ceramic and polymer matrix composites. Metal matrix composites comprises of two phases i.e. the matrix and the reinforcements. Matrix is the main metal having most of the composition whereas reinforcement is the material that is added to matrix material to improve its properties. MMCs consists of two constituent phases, out of which one necessarily is to be a metal and the other material might be another metal or any other matter such as organic compound or a ceramic. These two phases are chemically and physically different, and evenly distributed to provide the properties that are impossible to achieve with rather of the single phase. Basically,MMCs have two phases, a fibrous and particulate phase, [4-6]. MMCs have been provided designers and consumers to different newer possibilities that directs to new inventions with reliability at reasonable cost. It gave designer the freedom of workability at different extreme limits and better options for planning to obtain required results and products. The use of MMCs in now a day has been very common because the properties required for various applications can be achieved by using these types of materials with suitable reinforcements.Also,in the today's competitive world, the conventional materials are not able to fulfill the requirement of increased quality standards and reliability at low cost. The main advantage of the MMCs over the conventional materials has been that they are relatively cheaper with respect to the performance provided by them [7].

The only disadvantage we have with the use of MMCs is the cost of production which is very high.So, the focus of our work is to achieve the desired results at minimum cost. The cost of particles reinforcements such as SiC and Al_2O_3 has been comparably low, they have low density and are easily available in the local market. The aluminium and its alloys such as Al6063 grade of aluminium can be used because of its wide usability at Architectural applications and Extrusion properties etc. Aluminum based composites have reduced cost and might be used for automotive industries and various other applications.

In the present research work, authors have critically reviewed the physical and mechanical properties of Al-based composites reinforced with hard ceramic reinforcements such as silicon carbide (SiC) and Alumina (Al_2O_3). The whole literature is categorized on the basis of mechanical behavior, wear behavior, design of experiment and modeling of composites. This paper will enhance the knowledge of researchers working in this field.

2. FABRICATION PROCESSES

Fabrication process used for different metal matrix composite depends upon the matrix martial, type of reinforced used, required properties and production cost etc. Mostly used fabrication processes for metal matrix composite have been stir casting, composting, spray co-deposition and powder metallurgy etc. The properties obtained for fabricated composite depends upon the type of process used and how effectively and efficiently the process has been executed. According to the operational conditions the fabrication processes of Aluminum based composites have been categorized into three types that are liquid state fabrication, solid state fabrication and gaseous state fabrication.Table1 shows the fabrication process for the metal matrix composites. In Liquid state fabrication the reinforcement has been added into molten matrix which has been aluminium and its alloys in Aluminum based composites. Reinforcements used for Aluminium based composites have been SiC, Al_2O_3, B_4C, TiC, TiB_2, MgO, TiO_2 and BN etc [8]. The Gaseous state process for fabrication has been physical vapour deposition. Solid state of fabrication processes used are powder metallurgy, extrusion, forging, pressing and sintering, roll bonding etc. Out of all solid-state fabrication processes powder metallurgy has been most used process. In powder metallurgy firstly blending of powder of matrix material and reinforcement material has been used using ball mills. Then blended powders have been cold pressed followed by sintering [9-12]. Out of all fabrication processes stir casting has been used in majority. This method has been used because it is cost effective and can also be used for mass production. The stirring speed of the stirrer in stir casting influences the distribution of particles inside the matrix. Hasim studied the impact of speed of stirrer on the porosity and distribution of reinforcement particles in the matrix for the non-uniform SiC particles reinforced in aluminium alloy at staring speeds of 100, 200 and 500 RPM respectively. It has been concluded by the author that the sample produced at 100 and 200 RPM has less porosity [13]. Incorporation of reinforcement particles in the matrix melt at semisolid state improves the wettability between matrix and reinforcement and also improves the distribution of particles in the matrix with reduction in porosity [14]. To observe the distribution of reinforcement particle in the matrix and to investigate the grain morphology, microstructure optical microscopy and scanning electron microscopy have been used [15].

Table 1. METAL MATRIX FABRICATION PROCESS

Melting and Solidification	• Metal Infiltration • Laser deposition • Metal spinning • Casting
Electrochemical Deposition	• Electroless Deposition • Electro Deposition
Powder Metallurgy	• Deformation processing of powder compact • Spark Plasma Sintering • Mixing/ mechanical alloying and hot pressing • Mechanical alloying and Sintering
Thermal Spray	• Cold spraying • Plasma spraying and HVOF
Other Novel Techniques	• Vapor Deposition • Nano- scale dispersion • Mixing as paste • Sandwich processing • Molecular level mixing • Sputtering Technique • Torsion/ Friction welding

3.MECHANICAL BEHAVIOR

Herein, the mechanical behavior of aluminium based composites has been studied. Studies on the mechanical behavior of the aluminum composites reinforced with particles as reinforcement reveals considerable improvements in mechanical properties like stiffness, strength whereas the weight has been as compared with monolithic materials. Particle reinforced Aluminum based composites have been more attractive for designers and industries because they are cheaper than other types of composites and have uniform properties and also, they can be processed, manufactured similar to the metals and alloys [16]. Parshad et al. fabricated Aluminum 356 matrix composite reinforced with rice husk ash (RHA) and silicon carbide using double stir casting process and studied its mechanical properties.It has been observed by the authors that the hardness and porosity of the hybrid composite increased with increase in reinforcement and density found to be reduced with increase in particle volume. It has also been concluded that the ultimate tensile strength and yield strength increased with particle percentage whereas elongation decreased with reinforcement percentage [17]. Ozden et al. studied the impact strength of aluminium composite reinforced with silicon carbide (SiC) particles. The authors found that the impact strength of the studied composite has been increased with increase in particle size. It has also been observed that the artificial ageing reduces the impact strength of unreinforced alloy and the studied composite

[18]. Moses et al. investigated aluminium 6061 reinforced with 15% TiC and revealed that ultimate tensile strength (UTS) has been high when porosity in fabricated composite was low and the distribution of reinforcement particles has been homogenous in the matrix [19]. Karabulut et al. fabricated aluminium 6061/B_4C composite and found that the hardness of fabricated metal composite improved with increase in B_4C percentage and the impact strength reduces with increase in B_4C reinforcement content in the matrix [20].

4. WEAR BEHAVIOR

Few researchers have focused on wear behavior of aluminium based composites. For the determination of the wear behavior of reinforced particulate in MMC, pin on disc wear testing machine has mostly been used [21-23]. The study of effect of the size of particle on wear behavior of fly ash particles reinforced in aluminium Matrix composite of grade A-380 has beien studied. The dry sliding friction has also been studied. The fly ash particles of various size ranges and percentage by weight has been reinforced into aluminium composites. Pin on disc machine has been used in dry condition for the determination of wear behavior of composite. The varying loads for the specific time period have been used to determine the wear behavior. In automobile industries the study of wear in dry sliding condition is necessarily performed for the components like Piston, Piston rings, cylindrical blocks and liners. The adhesive wear is generally seen in these cases. The important parameters which are considered for these type of wear cases is adhesive wearing, surface adhesive wear, load applied, sliding speed, fracture toughness for the enforcement morphology etc. [24]. Larger particle size reinforced composite has more wear resistance than the smaller particles reinforced composite [25]. Ramesh and Ahamed found the developed aluminium 6063/TiB_2 composites have lower wear rates in comparison with Aluminium 6063 alloy. The better wear rate developed composites have been due to formation of fine TiB_2 particles uniformly distributed inside the aluminium 6063 matrix. Also, the wear resistance of both aluminium 6063 alloy and aluminium 6063/TiB_2 composites increases with increase in load and sliding velocity [26]. Dabral et al. studied the higher temperature wear behaviour of aluminium 6061 red-mud composite using Taguchi technique. The authors concluded that specific wear rate increases with increase in temperature [27].

5. DESIGN OF EXPERIMENTS AND MODELING

Design of experiments (DOE) has been important statistical techniques used in many disciplines such as engineering, medical, agriculture, management for design comparison, variable identification, design optimization, process control and product performance prediction. Taguchi method has been most commonly used DOE technique [28]. The number of experiments for determining the wear and mechanical behaviour of a composite can be designed using taguchi method. In Taguchi technique orthogonal arrays have been used to acquire the data in a controlled manner. This is followed by analyses of variance which investigate the influence of parameters like normal load, sliding speed and sliding distance on dry sliding wear of the aluminium composites. It evaluates the effect of individual parameter on wear rate and mechanical properties [29-30]. Mmathematical models like response surface regression analysis has been used by many researchers. In this context. A. Baradeswaran et al. develop AA6061and AA7075 based hybrid composites and found out wear loss [31].

6. CONCLUSIONS

From the outcome of the literature survey it has been concluded that the most commonly used fabrication processes for metal matrix composites are stir casting, compo casting, powder metallurgy, spray co-deposition etc. Mechanical properties and tribological properties of aluminium matrix composites after the use of reinforcement like fly ash, red-mud, silicon carbide (SiC), alumina (Al_2O_3) have been improved practically and theoretically. The mechanical and wear properties like hardness, tensile strength, wear resistance, toughness, porosity expected to be improved with the addition of reinforcements whereas the impact strength, elongation tends to decrease in the process. For the determination of the wear behaviour of reinforced particulate in MMC pin on disc wear testing machine has mostly been used. Moreover, it has been concluded that few researchers have focused on modelling and optimisation of composite. The future work may be in the direction of enhancing the mechanical properties of Aluminium based composites. Moreover, it has been concluded that few researchers have focused on wear testing of composites.

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