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APPLICATIONS OF METAL MATRIX COMPOSITES- AN OVERALL ASSESSMENT

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Abstract: In today's world there are many challenges recognized in automotive industries such as improving fuel economy, enhancing performance, reducing vehicle emissions, maintaining safety, quality and profitability, increasing styling options, etc. Now to meet these challenges there is the need of developing new materials and new manufacturing processes. And thus Metal Matrix Composites are of those developed materials which give result as per the needs. Metal matrix composites today are extensively used in automobile and aerospace applications. In this article, the applications of metal matrix composite for aircraft have been identified and also an in-depth study has been made through previous articles and with the asset of the informations a novel metal matrix design was projected. Also it is focused that the review on the production and characterization of hybrid metal matrix with summarizing the recent developments covering aluminium used in manufacturing process.

Keywords: Mechanical Properties**,** Metal Matrix Composite, SEM, TEM, Production

Introduction

Necessity is the mother of Invention and today's most important demand of an automobile industry is to reduce energy consumption and pollution in an automobile. This could be done in one way by increasing the efficiency. For the properties like strength, toughness, stiffness to weight ratio, good formability, good corrosion resistance and high machinability must be improved. This challenge could be accomplished by Metal Matrix Composites (MMCs). Metal Matrix Composites are one of the recent advanced materials having the properties of light weight, high specific strength, good wear resistance and low thermal expansion coefficient. These composites materials are extensible used in structural, aerospace and automotive industries. MMCs are composed of metallic base material called matrix, which is reinforced with a hard ceramic or soft reinforcement. Now days for reduction of weight in the aeronautical for improved strength the composites are largely used apart from automotive and defense industries. In current aeronautical applications more than eighty percent of the structural materials are made up of composites. The

metal matrix composites are born by adding the matrix of more than two materials as it will improve the properties of MMCs. The MMCs are unique materials fabricated by reinforcement of at least two types of ceramic particles in a tough metal matrix. The widely used application in MMCs consisting of Al (SiC/B4C), Al (SiCp+Grp), (Al/Al2O3/Gr) and (Al6061/SiC/Al2O3). However MMCs have the advantages of high strength, stiffness, wear resistance and thermal resistance over fiber based composites, only a small number of researches were observed in investigating the applicability of MMC to aeronautical applications. This article focuses to study the applications in design and development of MMC for the necessities of aeronautical materials.

Literature Review

For applications involving aluminum and its alloys where surface contact is involved, the useful life of the components is mainly determined by their surface properties such as wear resistance and hardness. Therefore, it is highly desirable that surface layer of the component is reinforced by hard ceramic particles to achieve the desired hardness while the substrate still maintains the original structure with good ductility and thermal conductivity [1, 2]. Frictions stir processing (FSP), based on the principle of friction stir welding, is an emerging solid state metal working process and has proved to be a successful technique for production of hybrid Surface Metal Matrix Composites (SMMCs) in aluminum/aluminum alloy plates [3, 4]. This technique causes intense plastic deformation and high strain rates in the processed material resulting in precise control of the microstructure through material mixing and densification [5]. Miracle [6] observed that FSP densifies the microstructure, refines the grain size, results in closure of porosities and provides a convenient method to improve the surface properties of aluminum alloy by forming surface composites. Affordable Al MMCs, reinforced with SiC and Al_2O_3, that reduced the weight and increase the engine efficiency, and thereby reduced fuel consumption and vehicle emissions were developed [7]. Chen et al [8] investigated the effect of processing parameters on microstructure and mechanical properties of Al-Al11Ce3-Al_2O_3 in-situ composite produced by Ce3-Al_2O_3 FSP. The study indicates a significant difference between the compressive and tensile strength of the composite produced under different processing conditions. Dharmpal Deepak et al [9] presented a paper on “Preparation of 5083 Al-SiC surface composite by friction stir processing and its mechanical characterization in which they reveals that the doping of 5083Al with hard SiC particles through FSP leads to significant increase in hardness of the surface composite produced on FSPed sample layer. The base matrix and the reinforcing phase were AA 6061, AA 7075 and particles of Al_2O_3 and SiC of size 20 µm were examined [10, 11] . It is observed that the densities of composites are higher than that of their base matrix, further the density increases with increased percentage of filler content in the composites. It is observed that the tensile strength of the composites is higher than that of their base matrix. Dolatkhah et al [12] produced metal matrix composite (MMC) through FSP on the surface of 5052 aluminum sheets by using SiC of 5 µm and 50 nm sizes. The results showed that the reversal of tool rotation direction between FSP passes, increase in number of passes and decrease of SiC particles size enhance hardness and wear properties of the composites. The effect of alumina and Zircon sand particles of different size and amount have been incorporated in Al-4.5 wt% Cu alloy by stir casting route was observed [13-15]. Microstructures of the composites in as-cast condition show uniform distribution of particles and reveal better bonding in the case of zircon particles reinforced composite compared to that in alumina particles reinforced composite also studied

in this. Abrasive wear resistance of both the composites improves with the decrease in particle size. It is observed that the alumina particle reinforced composite shows relatively poor wear resistance property compared to zircon-reinforced composite. Vishal Sharma et al [16] investigated the effect of Al- 4.5wt%Cu/ zircon sand/ SiC hybrid composite by stir casting route by controlling various casting parameters. The as-cast samples were observed under optical and scanning electron microscope. Micro structural observations of the as-cast hybrid composite, shows uniform distribution of reinforcement particles and also good interfacial bonding between the particles and the matrix.

Data Collection: The data has been collected from different international journals as a part of this research with one hundred and six articles from the leading publishers. From these articles a highly significant datas based on huge experimental observations were collected and which was taken for the review and then analyzed carefully for recognizing a new possible MMC composition for improved qualities to be used in aeronautical applications. Articles are classified to study the various major issues with different journal resources are shown in the following figure 1.

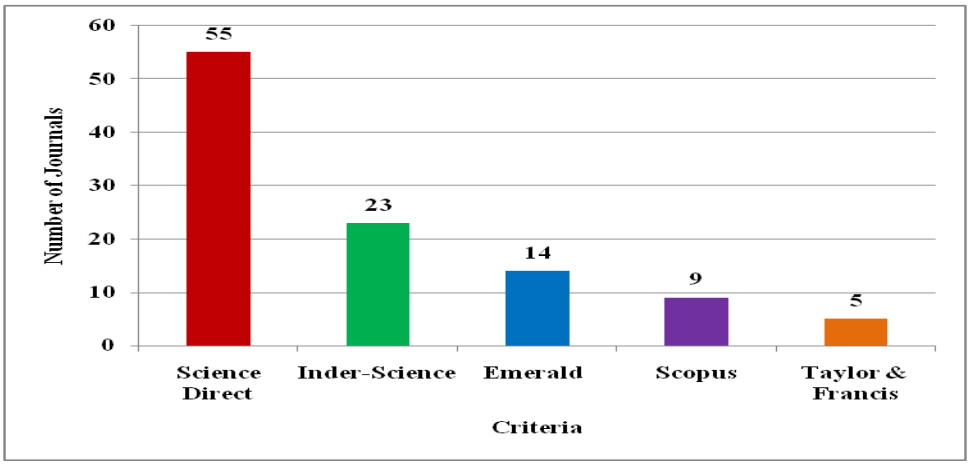

Fig. 1 Resources of Journal

The classification of journals was based on the composition and properties of MMC, production processes and methods of testing. Several research scholars were expanded various metal and reinforcement composites for dissimilar requirements and properties of the same were studied.

Methods of Production: Care must be taken when producing a metal matrix composite since the reinforcement material has to bond properly with the matrix material. The common techniques for producing a MMC are Solid state production, Liquid state production and In-Situ production. Solid state production is the method were MMC are formed as a result of bonding metal matrix and isolated stage due to mutual diffusion occurring between them in solid states at elevated temperatures under pressure. Liquid state production method involves amalgamation of isolated stage into molten matrix metal followed by its solidification. This liquid state production of MMC is disintegrated melt deposition, pressure less infiltration, pressure infiltration and stir casting. In-Situ production is the method were isolated stage is formed in the matrix as a result of precipitation from the melt during its cooling and solidification.

Methods of Testing: MMC it is subjected to broad range of tests which are to determine its physical and mechanical properties after production. Generally MMC is tested by means of physical, mechanical, optical observation and non destructive testing. Dimensional checks and weight of the composite are to be tested by physical test. The mechanical properties of the materials are to be tested by means of mechanical tests like Rockwell, Brien ell, Vickers test methods, Impact test like Izod, Charpy, Torsion test and Tensile test, Compression test. The recent technique of optical observation used powerful microscope to examine the property of the composite at micron level like Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM). Scanning electron microscope is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. Transmission electron microscopy is a microscopy technique in which a beam of electrons is transmitted through an ultra-thin specimen, interacting with the specimen as it passes through. An image is formed from the interaction of the electrons transmitted through the specimen; the image is magnified and focused onto an imaging device, such as a fluorescent screen, on a layer of photographic film, or to be detected by a sensor. Non destructive testing method is used to detect a flaw without causing any damage to the object like Dye Penetrator, Visible inspection, Ultrasonic testing, Eddy current Testing and Radiography.

Analysis of Properties*:* A desired properties of metal matrix composites was investigated like physical, mechanical and tribological properties by means of the study in the selected journal articles. The physical properties like weight, thickness of the material and dimensional stability of the material at varying loads and temperature were studied. Mechanical properties like hardness, stiffness, fatigue, yield strength, etc were also studied. Since the application of material includes wear and friction in aeronautical due to interaction of flows over the object the tribological properties for the materials were considered as most important. The survey from the previous articles was done carefully using the journals and each issue influencing the design of a new metal matrix composite were intensely examined.

Result and Discussion

Based on the above literature analysis the compositions of metal matrix composite projected for developing a new metal matrix composite for aeronautical applications are clarified. MMC of Al-SiC-Ni and matrix Al with reinforcement material of SiC/Ni improved the hardness properties. MMC of Al-Zn-SiC and matrix Al with reinforcement material of Zn, SiC with stands the shear load properties. MMC of Al-SiC-Ti and matrix Al-Ti with reinforcement material of SiC may improve the high thermal resistance. Similarly MMC of Al-Al_2O_3 and matrix Al with reinforcement material of Al_2O_3 having the properties higher stiffness. From the above declared compositions, we have been selected to develop Al-Al_2O_3 based MMC for aeronautical applications as they can give higher stiffness which is essential for structural components in aeronautical wings.

Proposed Production Method

Out of the academic achievements from the stated literature in this article, it is easy to make a comparative analysis on various production methods of metal matrix

composites. From the analysis of different production processes it was clearly found that the method of stir casting is the best suitable choice for the proposed composition, as this method blends the matrix and reinforcement in correct proportion and also improves the mechanical properties of the materials. The different manufacturing methods and its applications are explained.

Diffusion bonding process cost is high and normally it is used to make sheets, blades, vane shafts and structural component. Also this process handles foils or sheets of matrix and filaments of reinforcing element. Powder metallurgy process cost is medium and mainly used to produce small objects such as bolts, pistons, valves, high strength and heat resistant material. Both matrix and reinforcement used in powder form and best for particulate reinforcement, since no melting is involved. Liquid metal infiltration process is low/medium cost and used to produce structural shapes such as rods, tasks, beams with maximum property in a uni-axial direction. Filaments of reinforcement are also used for manufacturing. The cost of squeeze casting process is medium and widely used in automotive industry for producing different components such as pistons, connecting rods, rocker arms, cylinder heads and suitable for making complex object. Spray casting process cost is medium and used to produce friction materials, electrical brushes and contacts, cutting and grinding tools. The cost of compo casting process is low and commonly used in automotive, aerospace, industrial equipment and sporting goods industries.

Conclusions

Based on the survey result analysis the following conclusions were drawn to find out a new metal matrix composite for aeronautical applications.

1. The study was conducted to propose a method to produce a combination of metal matrix composite of Al-Al_2O_3.
2. The best base metal matrix material of aluminium was chosen for aeronautical applications hence it contains high strength to weight ratio of non-ferrous metals.
3. More over aluminium is the reinforcement material to improve the stiffness of metal matrix composite to be formed by reduction in weight and cost hence its suitable for aeronautical applications.
4. Diffusion bonding process is high cost method which is used to make sheets, blades, vane shafts and structural components. Handle foils or sheets of matrix and powder metallurgy
5. Powder metallurgy is an important processing technique for processing of these MMCs but requires a relatively long mixing time for obtaining a uniform distribution of graphite and SiC particles

Investigation of the proposed metal matrix composite will need to be conducted for its mechanical properties and to determine its viability especially in aeronautical applications, since it's a huge area in engineering.

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