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Investigation into Advanced Aluminum Hybrid Composite Obtained by Powder Metallurgy

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Abstract:
The present invention proposed a new aluminum metal matrix hybrid composite (AMMHC) using a powder metallurgy method. In particular, the invention relates to recently developed hybrid compounds containing aluminum powders mixed with silicon, magnesium, copper and silicon carbide and graphite ceramic powders in precisely controlled quantities, which improve mechanical and/or physical properties. Composites have attractive properties, including strength, lightness, corrosion resistance, significant density, and low production costs. Aluminum hybrid composite containing aluminum as the main matrix metal and various intermetallic particles distributed in the metal matrix from 0.5 wt% to about 10 wt%, while this matrix material is combined with reinforced materials. silicon, magnesium, copper, silicon carbide and graphite as intermetallic particles
Keywords: AMMHC; Powder Metallurgy; Dies; Wear; Reinforcement; Corrosion

1. Introduction:

The world of modern materials requires serious research to create composite materials that are strong, light and have excellent mechanical properties. Typically, metal matrix hybrid composites have superior properties such as strength, stiffness, and wear resistance compared to metal matrix monolithic molds. However, to some extent this quality can be achieved depending on the specific metal powders, their weight, volume or weight fraction and the way the alloy is made. Behera et al. [1-7] The proposed aluminum matrix hybrid compounds (AMMHC) are made of ceramic powders such as silicon carbide and graphite in the form of particles, flakes or whiskey, increasing their rigidity, wear resistance and high temperature resistance.any attempts have been made in the field to form metal matrix hybrid composites in various ways. Several metallurgical processes are described in the art for producing aluminum hybrid compounds in solid or liquid form. In powder metallurgy (P/M) processes using a solid root, the metal matrix powders are mixed with some form of reinforcement powders, followed by cold pressing and sintering. The aluminum matrix composite obtained by the P/M process has a maximum volume or weight fraction of solidified ceramic powders such as silicon carbide and graphite of about 25% by weight or volume and less than 0% by weight or volume. of powder particles Radhika and Surappa [8-9] reported that the most commonly used composite system using a metal matrix of silicon-reinforced silicon carbide (SiC), magnesium, copper, and aluminum gives an aluminum matrix composite.

Powder metallurgy (P/M) metal is a new type of composite material with desirable properties such as low density, high hardness and strength, good coefficient of thermal expansion, good corrosion and fatigue resistance, and good dimensional stability at high temperatures. Mazakeri and Shabani [10] stated that aluminum alloy has excellent mechanical properties with low density, high thermal conductivity, good strength-to-weight ratio, durability and good corrosion resistance. Rohatgi et al. [11]

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invented a composite body with different properties that formed a molten slurry of the solid metal and matrix and placed the molten slurry in the mold cavity. This study sought to produce an attractive hybrid composite with increased strength, weight, corrosion resistance, significant density and low production cost. These compounds can be used to make various components in the automotive, aerospace, defense, window, irrigation, water, petrochemical and special machinery industries. The new AMMHC can also be used in various applications such as electronic enclosures and temperature control, while aluminum-based hybrid compounds are in high demand in the automotive and aerospace industries due to their high thermal conductivity. . They are used in sports and leisure products such as cycling, baseball, skiing, golf, etc. due to its performance and low cost. AMMHCs are considered to be widely used in robotics, medicine, biomedicine, and nuclear defense industries, because their combination of mechanical properties makes them particularly suitable.

2. Methods and Material:

2.1 Fabrication of AMMHCs

The present experiment has developed the production of new composites (Al-0.5Si-0.5Mg-2.5Cu-10SiC-2.5Gr) using a special die design for the production of products using traditional powder metallurgy processes. The weight fraction of reinforced ceramic particles (SiC) and graphite powders (Gr) in the composite material is 10 and 2.5%, respectively. The invention of the aluminium metal matrix hybrid composite has recently improved performance and properties over commercially available materials. The flowchart (seeFigure 1) for production of hybrid aluminium metal matrix composite (HAMMC) using powder metallurgy method has been shown in Figure 2.

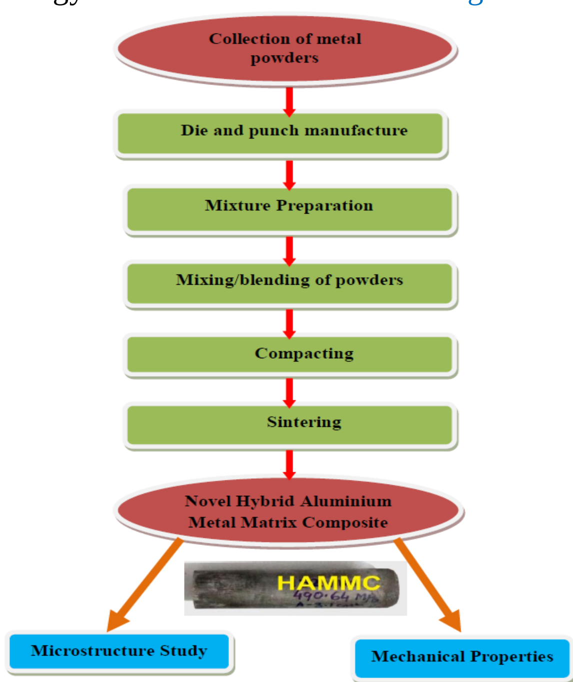

Figure 1: Flowchart for production of hybrid aluminum metal matrix composite (HAMMC) using powder metallurgy method

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Figure 2: Metal powders with its reinforcing effects

3. Methodology

To scale up the technical use of the AMMHC, several challenges must be overcome (see Figure 3). Solving these challenges requires effort in product design, research and development, as well as business development skills. A deeper understanding of the engineering of primary treatment, in particular of factors affecting micro-structural integrity, including AMMHC agglomerates. Other problems are:

- It is necessary to improve the properties of hardness and toughness of the AMMHC.
- The production of quality and inexpensive materials is required to avoid industrial wastes.

It needs to develop easy, more economical and non-destructive products for quantifying unwanted defects of AMMHC with recycling technology.

- It must be easy for composite cutting and machining operations.

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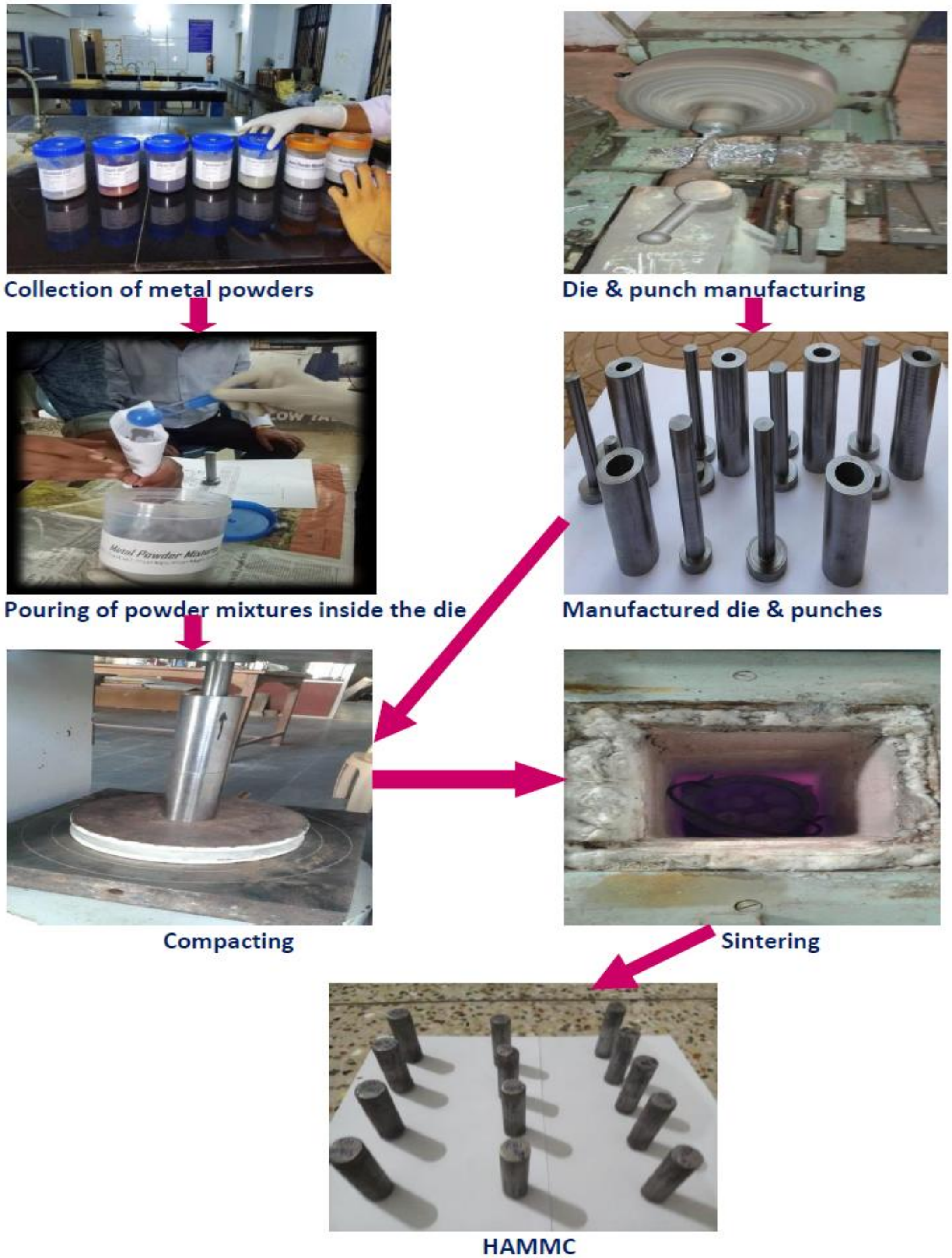

Figure 3: Pictorial representation for production of aluminium metal matrix hybrid composite

The available experiment associates with a novel product for fabricating a hybrid metal-matrix composite product. Figure 4 represents aluminium powders with a purity of 99.55% and 44 micron particles size are mixed with powders of metal alloys such as silicon, magnesium, copper, and reinforced with ceramic powders of silicon carbide and graphite in precisely controlled amounts.

Figure 4: Metal powders and their mixtures

Therefore, as described herein, there is an aluminum metal matrix reinforced hybrid composite consisting essentially of aluminum as the parent matrix metal; and many other inter-metallic particles. Inter-metallic particles having a size of 149 microns to about 44 microns and reinforced in a metal matrix in an amount of from 0.5 percent by weight to about 10 percent by weight, said ceramic materials (SiC + Gr) are reinforced with a matrix metal along with silicon, magnesium, copper in the form of inter-metallic particles.

AMMHCs product manufacture cannot be possible without the help of appropriate die-sets in solid-state of powder-metallurgy process. Therefore, the designing of dies are the most important considerations to manufacture it before machining because each parameters of die is directly affects the final products. The designing considerations such as stress-concentration and crack-propagation were taken into account for production of die. The schematic diagram of die sets and its final product are shown in Figure 5 and 6 respectively.

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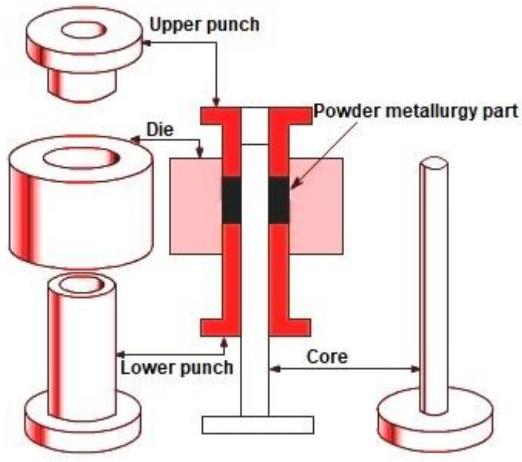

Figure 5: Schematic diagram for manufacturing of die sets

Figure 6: Die sets manufactured

Additionally, the production of hybrid-composite with a reinforced aluminum metal matrix, of the steps consisting of: a) mixing powders of metal aluminum and a plurality of inter-metallic particles, in particular silicon, magnesium, copper and ceramics of SiC and Gr; b) filling and compaction of the specified powder mixture under pressure with loading-rate of 0.3 kilo-Newton per second and a pressure of about 521.87 MPa to form the required shape and sintering the specified shape at a temperature of about 620^0 C and then annealing for 24 hours; wherein said reinforced powders are uniformly distributed among said alloying metal to form a hybrid composite having a uniform metal matrix hybrid composite.

The particle sizes of the particulate in binary inter-metallic reinforcing metal powders are considered about 44 microns. Preferably, the inter-metallic reinforcing powder particles are attending in the said composite about 0.5% to 10% by weight. The base-metal of the matrix aluminium combines with ceramics and other metals, including Si, Mg, Cu, SiC and Gr to form a reinforced hybrid composite. In the present invention where powder metallurgy process is used for AMMHCs manufacturing with the reinforcing powders and the matrix aluminium powders. The hybrid composite product was prepared with a process starting from the selection of metal powders, weighing, mixing / mixing, cold compacting and sintering.

AMMHCs were reinforced by 10% of SiC along with 2.5% Gr by weight. Silicon powders of 44 microns with purity 99.87%, Magnesium powders of 149 microns with purity 99.80%, Copper powders of 44 microns with purity 99.77%, Silicon carbide powders of 44 micron with purity 99.55% and graphite powders of 44 micron with 99.87% purity are mixed with aluminium powder of 44 micron particle size of 99.55% purity. SiC powder particles with a weight fraction of 10% and Gr powder particles with a weight fraction of 2.5% are blended properly with a mixture of Al-Si-Mg-Cu in weight-fractions of 84-0.5-0.5-2.5 percent. The mixed / blended powder mixtures were compressed in a digital compression tester using a C-45 steel die having loading-rate, 0.3 kilo-Newton / second and a

compaction pressure of up to 521.87 MPa. The green compacted AMMHCs products have been ejected from the die cavity and are ready for sintering.
The green compacted AMMHCs products sintered inside a muffle type furnace. The temperature maintaining at sintering was taken about to 620^0C and annealed for 24 hours at ambient environment as stated in Figure 7.

Figure 7: Novel Aluminium hybrid metal matrix composites (AMMHCs)

The new aluminium metal matrix hybrid composite made from these specified metal powder compositions with better distribution of reinforcements were obtained by powder metallurgy method as given in Fig. 10 and showed better outcomes if Silicon-carbide was reinforced 10% by weight and Gr with 2.5% by weight. Also the novel product found that its hardness was maximum 84 VHN measured on a Vicker hardness testing machine. The density of AMMHC was calculated as 2.83 gm / cm3 which are better than the currently available aluminum composites. Hardness in hybrid-composite increases with increasing silicon-carbide and graphite, but decreases in decrease in silicon carbide and graphite reinforcements. In order to achieve maximum hardness, a suitable proportion of the reinforced material is used.

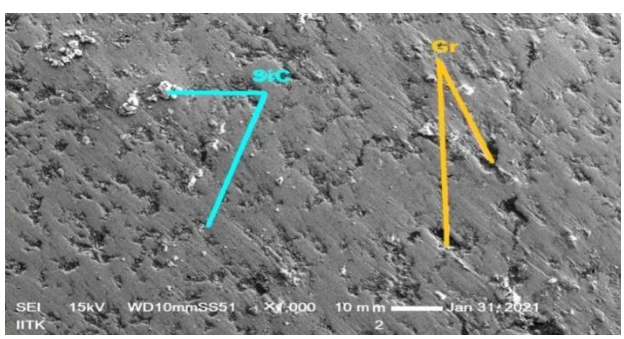

Figure 8: Al- 0.5Si- 0.5Mg- 2.5Cu- 10SiC- 2.5Gr SEM micrograph

Reinforcement of silicon carbide and graphite in the matrix element shows, the pores are very small when properly mixed in the powder mixture. The SEM micrograph shows in Figure 8 indicates the porosity of the hybrid-composites decreased with mixing of SiC and Gr. Increasing the SiC particle size reduces the porosity, volumetric-loss and friction co-efficient of the composite. In addition, hybrid composites showed very less wear-rate and co-efficient of friction. During sintering, the introduction of SiC particles as well as Gr particles inhibits a growth of α-aluminium grains which forms a site nucleation. The increase percentage of SiC and Gr powders, the greater in number of centre nucleation and the maximum number of grains of aluminium solidify into it. The distribution of intragranular SiC-Gr powder particles may be seen in micrographs of hybrid aluminum composites, which apparently have the best mechanical, physical and tribo-logical behaviours based upon the compaction and sintering processes. As the densities of both matrix particle and the reinforcing powder particles are different but in the semi solid states of P / M product gives uniform scattering of the particles especially SiC-Gr particles are almost uniformly reinforced throughout the aluminium-matrix represented in the micrograph.

4. Conclusion:

AMMHCs represent a great opportunity and many opportunities for design and materials engineers. There are now many opportunities to replace this new hybrid composite material with a conventional material, ensuring that certain mechanical properties are met for increased strength and stability. The experimental development indicates that AMMHC will be used in current and near-future industries. From the previous research, it is clear that the application of AMMHC products for any commercial and industrial use is very promising in the coming period. Various researchers have suggested that aluminium metal matrix hybrid composites are the best cost-reducing process compared to conventional materials such as iron alloys and aluminium alloys. The hybrid composite contains Cu which improves the hardness, ultimate tensile strength and minimizes the impact resistance in the composite. AMMHCs provide wear resistance by adding silicon. Wettability and lightness were found through the addition of magnesium to metal matrix composites.

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