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Effect of addition of Fe-Si on Mechanical and Metallurgical Behaviuor of Al Powder Metallurgy (PM) Product

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Abstract

Powder metallurgy (PM) offers an alternative technology, capable of producing alloys having improved fatigue, corrosion, and stress-corrosion resistance, as well as improved strength and toughness at room or elevated temperatures. Now a day PM products are getting popularity in automobile industry, aerospace especially Aluminium based PM product because of their light weight and low cost of production. Many researchers are engaged in enhancement of mechanical properties of PM products. In the present study an attempted has been made experimentally for improving of mechanical properties of PM product of Aluminium by adding Fe, Si .The present invention provides an aluminum alloy consisting essentially of (a) 5 to 30% by weight of Si, (b) 0.5 to 10% by weight of at least one species selected from the group consisting of Fe, Ni, Cr and Mn with the proviso that the total amount of these species cannot exceed 20% by weight and (c) aluminum in a remaining amount. An aluminum alloy product produced by extruding said alloy is excellent in strength at high temperatures and resistance to creep.

INTRODUCTION

A much wider range of products can be obtained from powder processes than from direct alloying of fused materials. Recent developments have made it possible to use manufacturing techniques which use the metal powder for the products

A literature survey of aluminum powder metallurgy (PM) for high-strength applications was undertaken. Improvements in aluminum—base alloys made via ingot metallurgy (IM) are reaching the point of diminishing returns. PM offers an alternative technology, capable of producing alloys having improved fatigue, corrosion, and stress-corrosion resistance, as well as improved strength and toughness at room or elevated temperatures.

The properties of several new PM alloys are compared, with particular emphasis on high strength, corrosion-resistant alloys and alloys developed for use at elevated temperatures J.R Pickens(1981).Rapid solidification was used in modeling methods of achieving solidification at high cooling rates and its effects on alloy constitution and microstructure H Jones(1984). V.Chiavazza, M.Pijolat et al (1988) experiments performed on X7091 alloy by means of thermo-gravimeter and temperature-programmed desorption technique for determining the influence of degassing conditions (temperature, pressure, nature of the gaseous atmosphere) on the stability of the alloy composition. The mechanism of sub-microscopic precipitation in an Al-Zn-Mg alloy selected for its maximum response to ageing has been studied by a standardized oxide-replica technique in a 100 kV. K. Stiller, P.J. Warren et al (1998). The experimental results of the studies conducted regarding density, microstructure and wear resistance properties of Al6061-SiC. The experimental results showed that the Sic reinforcement in the Al6061 matrix material resulted in increasing the density of the composites. Messer and K. L.*Z.* Metallkunde (1999).High-strength products from atomized Al-Zn-Mg-Cu-Co alloy powders have good combinations of strength, ductility, resistance to stress-corrosion cracking and fracture toughness. Powder Metallurgy (PJM) methods produce fine metallurgical structures and compositions which cannot be produced by Ingot Metallurgy (IJM) methods. J. P. Lyle and W. S. Cebulakin(2000) evaluation the properties and to optimize the preparation of precursors by a powder-compacting process was done. Irena Paulin, Borivoj et al(2010) founds in their research that Aluminum foams, produced by the powder-metallurgy route, have a good potential for use in weight-sensitive structural parts.

EXPERIMENTAL SETUP

Metal Powder Used:

Basic experiments were conducted on Aluminium Alloys metal powder preforms. Atomized Aluminium powder of purity 99.5% and finer than 100 μm is used throughout the experiments. Fine Iron & Silicon powder is used with Aluminium.

Die preparation & compaction :

Aluminum Alloys powder is compacted in a closed circular die using a hydraulic press at various recorded pressures for the different composition of the Aluminum Alloys. The die wall is lubricated with fine graphite powder After that compaction is done as shown in next figure. Compaction is done by the help of universal testing machine (UTM), on which dies are placed and after then pressure is applied as our requirement.

Sintering of aluminium compacts was carried out at 2000C, 300℃ and 4000C for two hours in an endothermic sand atmosphere. All sintering operations were carried out in a muffle type silicon carbide furnace capable of providing sintering temperature of an accuracy of ± 50C.

Experimental Procedure and Measurements :

Experiments were conducted on a Universal Testing Machine and hydraulic press using appropriate dies. The Aluminium alloys powder preform of known relative density was placed between flat dies and was compressed at room temperature by applying the load. The compression was carried out in dry and lubricated conditions. Fine graphite powder was applied as lubricant. The following important measurements were made:

(i) Increase in relative density of the preform with increase in compressive load.

(ii) Increase in relative density of the preform with decrease in height.

In order to evaluate the formability (limit reduction) the sintered Aluminium and Copper powder preforms of known initial relative densities were deformed at room temperature between flat dies. The compressive load was gradually increased until cracks were observed on the equatorial free surface of the Aluminium and Copper powder preform. The percentage compression and the corresponding compressive load value just at the time of the appearance of cracks were recorded for all specimens. The experimental procedure was repeated for five compacts under the similar processing conditions and an average reading was recorded.

EXPERIMENTAL RESULT & DISCUSSION

Powder Particle Size :

Powder particle size has a remarkable effect on the relative density which in turn affects deformation characteristics and fracture mechanisms of the metal powder preforms. The influence of powder particle size on the relative density of the copper powder preforms compacted at 30 kg/mm^2 and sintered at 650^{0}C and the influence of powder particle size on the relative density of the aluminium powder preforms compacted at 10 kg/mm^2 and sintered at 450^{0}C and. The decrease in grain size of powder, however, results in more densification and improvement in formability of the powder preforms. Poor flow rate for finer particles are also observed.

Compacting Pressure:

Figure 1 shows the relative density variation with increase in compacting pressure. It is seen that the relative density of the Aluminium alloys powder preforms increases gradually with increase in compacting pressure. The formability of Aluminium alloys powder preforms improves at higher compacting pressure.

Combine figure and table for various compacting pressure and different temperature range (400˚C-450˚C) for aluminium.

Figure 1 (load Vs. relative density for various sintering temperature) shows a considerable pattern for increase in relative density. In Figure1 relative density increases with rapid rate from load 0 – 2 tone. After that rate of increase in relative density decrease in the range of load from 2 -2.5 tone. Further increase in load shows an increased rate of increase in relative density.

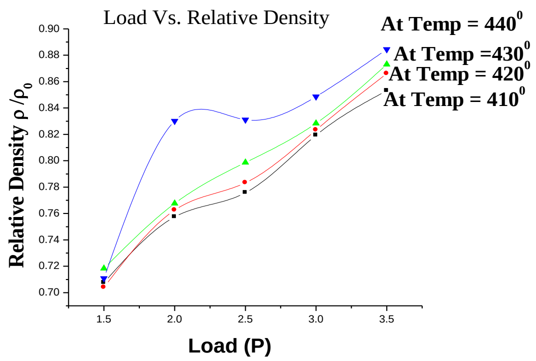
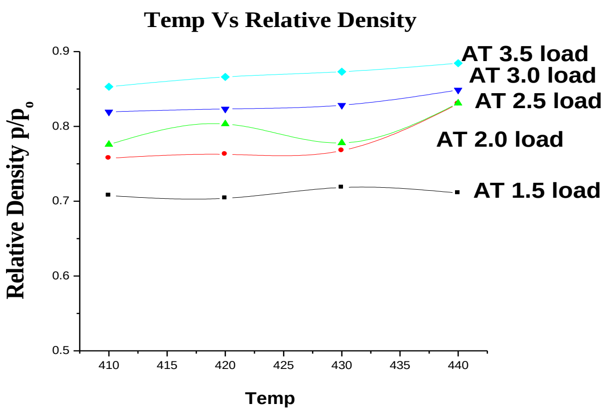


Figure1: Variation between load in tone and relative density

So we can conclude that compacting pressure range for aluminium components is 3 tones to 4 tons per inch square for better quality and for obtaining relative density near to 1. i.e. density of aluminium powder components approaches to the density of solid aluminium.



As shown in the Figure 2 relative density increases with the increase in sintering temperature. It is experimentally found that the pieces held at greater sintering temp.

have the high density as compared to the pieces held at relatively low sintering temp. This difference in the density occurs due to the bonding formation between the powder particles. At relatively high temp. Crystallization takes place and bonding starts between the particles as a result void reduced in the metal preform hence density increases. Crystallization Temp. for aluminium is 450˚C.

Effect of sintering temperature on microstructure of aluminium:

Grain size increases with increase in sintering temperature. At low temperature bonding between the particles does not take place. A densification of about 5% and relative density of approximately 84% to 89% of the pore-free value were obtained during the solid state sintering of Cu. From temp.400˚C to 450˚C. When there is increase in the sintering temp. , crystallization stage reached where bonding between particles takes place which result in the uniform micrograph as shown in above fig for sintering temp. 450˚C. The influence of compression is to increase the relative density of the metal powder preform.

Powder Metallurgy v/s Casting :

A comparative satudy has been done on Mechanical properties of Al alloy made from powder metallurgy and casting. It is found that there is improvement in properties in the case of powder process. Properties which has been tested, their comparative study are given below :

Particle Size :

Powder particle size has a remarkable effect on the behavior of alloy metal. It affects deformation characteristics and fracture mechanisms of the metal powder preforms. Aluminium alloy powder is compacted at the load of 3.5 tonne and 4.5 tonne and sintered at 200℃ and 300 ℃. It is found that the grain size of compacted billet is comparatively small than casting. Decrease in grain size of powder results in more densification and improvement in formability of the powder preforms. Poor flow rate for finer particles are also observed.

CONCLUSIONS

It should be clear from the literature survey that the P/M processing of aluminium alloys offers the possibility of obtaining alloys with better properties than with conventional ingot metallurgy. Many alloys are still under investigation and regularly new alloy compositions are proposed. Nevertheless an increasing number of P/M alloys are commercially available now. The reason that, compared to the classical alloys, only a small amount of these new alloys is being used for industrial applications is probably due to cost barriers and to the fact that a lot of customers hesitate to use new materials. Therefore, the Aluminum alloys which we have made by P/M process may be cost effective and better mechanical properties. The present invention provides an aluminum alloy consisting essentially of (a) 5 to 10 % by weight of Si, (b) 0.5 to 10% by weight of at least one species selected from the group consisting of Fe, Ni, Cr and Mn with the proviso that the total amount of these species cannot exceed 20% by weight, and (d) aluminum in a remaining amount. An aluminium alloy product produced by extruding said alloy is excellent in strength at high temperatures and resistance to creep.

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