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Comparison of Enhanced Mechanical Properties and Texture of Pure Aluminium & Its Composite Processed by Powder Metallurgy and Equal Channel Angular Pressing

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ABSTRACT

This research paper describes the synthesis of two solid billets processed by pure aluminium powder & zinc oxide powder, which was passed through parallel channel Pressing die to enhance mechanical properties and texture. Initially a die was designed for compaction, which consist of two die half and two plungers for top and bottom. Die parts were tightening together by using nut and bolts. After compaction, sintering was done using furnace. After that billets were passed first through parallel channel pressing die. Vickers Hardness, density, compressive strength and texture were evaluated before and after passing through parallel channel pressing die. Grain refinement and improvement in mechanical properties were observed by multiple passes of commercial billets of aluminium alloys. The research paper concludes the improvement in properties of billets prepared by PM (Powder Metallurgy) technique. Meanwhile there is lack of literature about PM techniques for aluminium alloys. In future PM will be a significant topic for research and samples made by (PM) Powder Metallurgy Technique will be easier to synthesize.

Key words: Powder metallurgy, compaction, sintering, ECAP, mechanical properties

INTRODUCTION

Powder metallurgy is a science used for producing powder and products by mixing with alloys[1]. The major steps in powder metallurgy are powder production, compaction, sintering and secondary operations. Excellence of any product is highly dependent on process quality. Product quality suggest many changes in powder description[2]. This awareness estimated the significance of producing homogeneous powders by high transparency. The problems like handling are due to its smaller in size and quantity, increased low quality powder & high scrap production. So it is necessary to analyse the quality of product during production. The concept of powder properties, handling and processing must be tied with powder production [2-3]. Various techniques can be implemented for producing fine powders like alloying, plasma, chemical precipitation etc. Plasma technique is one of the exciting techniques for producing ultra-fine powder. The cheapest method for powder producing is mechanical alloying. It is used for producing alloys required high strength and other mechanical properties. Mechanical forces are generally required to convert bulk material into fine powder or size reduction [4-5].

Compaction is most important process in powder metallurgy. This action helps in converting free powders into desired shape and size and provides initial strength to the product before heating. A die can be designed for completion of compaction process. A die can be of single piece or two pieces die. Two plungers are required to press the powder in the die which can be done by hydraulic press or universal testing machine [6-8].

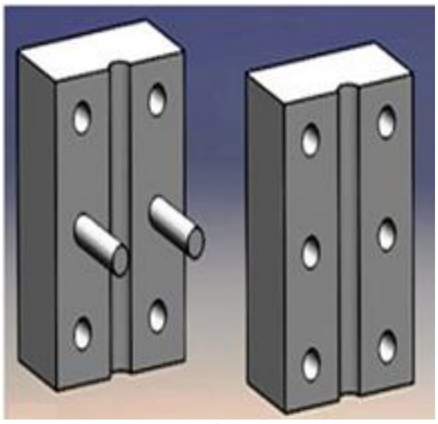
The process of heating a product after compaction without melting is known as sintering. In this process the material atoms diffused and particles fused together and form solid piece. During sintering the material temperature is always less than its melting temperature. The properties of the FCC alloys produced by PM are totally different from the metals made by other conventional methods. A layer of oxide is formed on aluminium surface during sintering which stops growth of grain and dislocation movement at boundaries and make creep resistance, high strength, and high temperature resistant material. Compaction and sintering by die are used for producing products of high accuracy dimensions with excellent surface finishing. Further operation used for close tolerance and higher accuracy are known as secondary operations[9-11].

Equal channel angular pressing and HPT (High Pressing Torsion) are most important methods come under SPD (Severe Plastic Deformation). These methods used for producing ultra-fine grains for better understanding of mechanical properties and texture study. Equal channel angular pressing (ECAP) is more significant technique for grain refinement because of high strain produced without changing the initial dimensions of the material. The grain refinement under ECAP is done from macro grained material to submicron or may be up to nano scale by using pressing die[12-13].

EXPERIMENT

A die was designed for compaction. D3 die steel material was taken for making two die halves & top and bottom plunger. UTM (Universal testing machine) used for applying pressureduring compaction. Fig. 1 shows the complete die assembly and Fig. 2 shows the furnace. Parallel channel of 13mm was cut in the centre of die parts. Diameter of plunger was taken 12.7mm. Hot furnace was used for further heating of compressed billet up to nearly 80% of their melting temperature. Two types of billets using aluminum 99.999% purity powder were formed. One was formed from the fine aluminum powder and the other from aluminum powder mixed with Zinc oxide powder in 10:1 wt/wt ratio as an additive. The fine aluminum powder and zinc oxide were of 325 meshes. Volume and density relation was used for calculating amount of power required for compaction.We compressed 10gm pure aluminum powder for first sample and for the second sample mixed 10gm of aluminum powder and 1gm of zinc oxide together to form a homogenous mixture by ultrasonication in the dispersion agent. A load of 50KN to 100KN was applied during compaction.

Fig. 1 a) Actual die for compaction



b) Die design for compaction

Fig. 2 Furnace

Many devices for mixing powders like rotating double cone, screw mixer, rotating drum and blade mixer can be used. In present work mixing was done with the help of blade mixer. Ball milling can also be used for mixing and reducing grain size at high precision level. Powder was poured in the die cavity at slow pace because if we increase the intensity rate of pouring it will adversely affect the density of billet. Immediately after pouring the powder into the die cavity, the "house of cards" situation arises. In this case powder is pressed manually by the upper plunger. After that, situation reached at a state from where the capacity of rearrange the powder is exhausted. The particles are locked in between their neighbours in more stable manner. When the pressure is applied by the upper or top plunger the gasses escape from very narrow gaps between die parts. The pressure applied was done with the help of UTM. Lower/bottom plunger act as a stationery obstacle in the exit of powder in the bottom of die, which was taken away for removal of solid billet in the end of compaction. The reduction in the bulk volume of a material as a result of the removal of the gaseous phase (air) by applied pressure. This was done by Universal Testing Machine until the displacement of the UTM arm became constant. Initial compaction was done for providing shape to the powder. Sintering was required to improve the strength of the material/billet. After that aluminium's billet were heated inside furnace which is shown in Fig. 2.

The purpose of sintering was to increase the strength and toughness of billets as well as grain reformation by heating. Furnace was set at 300˚ C which is the nearby temperature of sintering temperature of aluminium. Billet was placed inside the furnace in a ceramic utensil and allowed to be heated for 30 minutes. The heated billet was put again in the dies and compressive load was applied till the displacement of UTM arm became constant. This was done for further refinement in mechanical properties of billet. The compression after heating ensures the proper compaction of molecules for a long period of time. After the compaction and sintering the prepared samples as shown in Fig 3 were passed through the ECAP die for further grain refinement.

Fig. 3 Billets of a) Pure Al powder

b) Zinc oxide powder

Fig. 4 ECAP Die

Fig. 5 Vickers's Hardness Tester

D3 die steel was used for ECAP. Die geometry was a key factor for introducing strain in bulk materials. ECAP die was having 110˚ die channel angle and 35˚ back angle. Various route can be adopted for further processing after PM [14]. Only two passes through the ECAP die were possible, after that the crack starts to appear. Route BC (Sample rotated 90˚ in the same direction) was adopted for second pass. Fig 4 shows the die geometry. During every pass through ECAP die, the strain produced and grains started to elongate. After 5 to 10 passes the grains started to break and size of grains reduced markedly. The effect of ECAP was observed by optical microscopic images and Vickers hardness values.

RESULTS AND DISCUSSION

Vickers hardness was obtained in central workshop of mechanical engineering department of DCRUST University Murthal. HV-1000 model was used for hardness measurement had diamond pyramid indenter at an angle of 136˚ as shown in Fig. 5. Dense samples of pure aluminium powder and zinc oxide powder were formed by compaction and sintering. Vickers hardness, density and compressive strength tests were examined before and after ECAP passes as shown in Table -1. The values of Vickers hardness and density of Al with zinc oxide powder sample found higher as compare to pure Al powder sample. But the value of compressive strength of pure Al powder sample was more than other Al with zinc oxide powder sample. These properties can be improved by processing through ECAP. Therefore, samples were passed two times through ECAP die for grain refinement and improvement in properties. The results after ECAP passes are shown in Table -2. Samples started to crack after second pass.

Table-1 Test Results of Pure Al Sample V/s Zinc Oxide Sample Before ECAP

Test	Al With Zinc oxide powder	Pure Al powder
Vickers Hardness(HV)	53	37.1
Compressive strength(N/mm2)	47.20	54.60
Density(g/cc)	2.89	2.44

Table-2 Test Results of Pure Al Sample V/s Zinc Oxide Sample AfterECAP

Test	Al With Zinc oxide powder	Pure Al powder
Vickers Hardness(HV)	59.2	48.5
Compressive strength(N/mm2)	50.25	58.70
Density(g/cc)	2.97	2.64

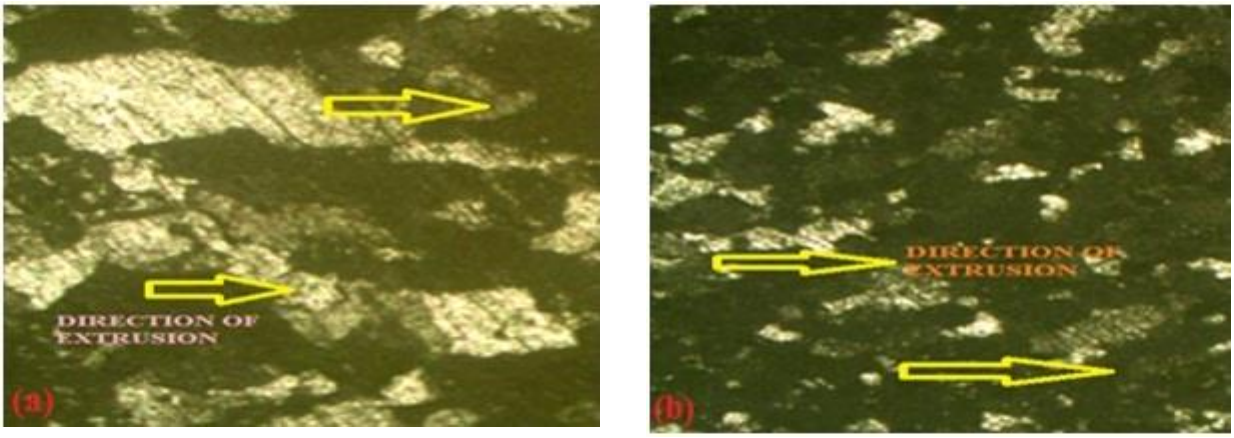


Fig. 6 optical microscopic images of elongated grains after ECAP (Magnification 100X)
a) Pure aluminum, b) Aluminum with zinc oxide)

Sample of pure aluminium powder become nearly 100% dense after ECAP. Therefore, it justifies that as the sample passed through die the strain produced and material become dense with every pass. After sample preparation optical microscopic images were observed. Sample preparation was a long and time consuming process. Sample preparation was a set of processes which include sample selection, mounting, grinding, polishing and etching. After mirror polishing etching was done for revealing grain structure. Pure aluminium sample was etched with Keller's for 10 second and modified Keller's was used for 8 seconds for grains development of Al with zinc oxide sample. Fig 6 shows the elongated grains of pure aluminium sample and Al with zinc oxide sample by optical microscope at magnification 100X. Grains were refined and elongated after every pass. Amount of strain produced can be calculated by the equation derived by Iwahashi[15].

CONCLUSION

ECAP die having 110˚ die channel angle and 35˚ back angle was used for two passes after compaction and sintering. Route B_C (Sample rotated 90˚ in the same direction) was selected for passing in ϕ 13mm die for further refinement of grains and better densification. Samples were prepared for revealing grains through optical microscopy. It was observed that the grain size reduced from 45µm to 35µm during sintering. The grains started to elongate in the direction of flow or extrusion after first and second passes as seen in Fig. 6. A major change in grain size observed after ECAP. After second pass the grain size reduced up to 10µm. Successive passes through ECAP can provide ultra-fine grains of sub microns or may be up to nano grains. Homogeneity can be observed in optical images but fully justification can be provided by Electron backscatter diffraction and orientation density function. Present work proves the effectiveness of Equal channel angular pressing for producing refined grains after samples produced by powder metallurgy technique.

REFERENCES

[1] M Balog, P Yu, M Qian, M Behulova, P Svec and R Cicka, Nanoscaled Al-AlN Composites Consolidated by Equal Channel Angular Pressing (ECAP) of Partially in Situ Nitrided Al Powder, *Material Science Engineering A*, **2013**, 562, 190–195.

[2] AS Rogachev, DO Moskovskikh, AA Nepapushev, TA Sviridova, SG Vadchenko, SA Rogachev, AS Mukasyan, Experimental Investigation of Milling Regimes in Planetary Ball Mill and their Influence on Structure and Reactivity of Gasless Powder Exothermic Mixtures, *Powder Technology*, **2015**,274, 44–52.

[3] M Snajdar-Musa and Z Schauperl, ECAP - New Consolidation Method for Production of Aluminium Matrix Composites with Ceramic Reinforcement, *Process Applied Ceramics*, **2013**, 7 (2), 63–68.

[4] M Yadollahpour, H Hosseini-Toudeshky and F Karimzadeh, The Use of Response Surface Methodology in Cryrolling of Ultrafine Grained Al6061 to Improve the Mechanical Properties, *Journal of Materials: Design and Applications*, **2016**, 230(2), 400–417.

[5] M Kubota, X Wu, W Xu and K Xia, Mechanical Properties of Bulk Aluminium Consolidated from Mechanically Milled Particles by Back Pressure Equal Channel Angular Pressing, *Materials Science Engineering A*, **2010**, 527, (24–25), 6533–6536.

[6] A Michrafy, S Haas, MS Kadiri, K Sommer and JA Dodds, The Effects of Ambient Temperature on the Compaction of Pharmaceutical Powders, *Journal of Process Mechanical Engineering*, **2006**, 220 (1), 1–6.

[7] G Majzoobi, H Bakhtiari, A Atrian, M Pipelzadeh and S Hardy, Warm Dynamic Compaction of Al6061/SiC Nanocomposite Powders, *Journal of Materials: Design and Applications*, **2016**, 230 (2), 375–387.

[8] H Dutta, SK Pradhan and M De, Microstructural Evolution on Ball-Milling Elemental Blends of Ni, Al and Ti by Rietveld' s method, Materials Chemistry and Physics, **2002**, 74, 167–176.

[9] M Gurbuz, M Can Senel and E Koc, The Effect of Sintering Time, Temperature and Graphene Addition on the Hardness and Microstructure of Aluminum Composites, *Journal of Composite Materials*, doi: 10.1177/0021998317740200 (in Press).

[10] C Haase, HP Ng, R Lapovok and Y Estrin, Ti-6Al-4V Billet Produced by Compaction of BE Powders Using Equal-Channel Angular Pressing, Powder Metallurgy of Titanium: Powder Processing, *Consolidation and Metallurgy of Titanium*, **2012**, 520, 301–308.

[11] EA El-Danaf, Mechanical Properties, Microstructure and Micro-Texture Evolution for 1050AA Deformed by Equal Channel Angular Pressing (ECAP) and Post ECAP Plane Strain Compression using Two Loading Schemes, *Materials and Design*, **2012**, 34, 793–807.

[12] E Avcu, The Influences of ECAP on the Dry Sliding Wear Behaviour of AA7075 Aluminium Alloy, *Tribology International*, **2017**, 110, 173–184.

[13] YT Zhu and TC Lowe, Observations and Issues on Mechanisms of Grain Refinement During ECAP Process, *Materials Science and Engineering A*, **2000**, 291(1), 46–53.

[14] S Ferrasse, VM Segal and F Alford, Effect of Additional Processing on Texture Evolution of Al0.5Cu Alloy Processed by Equal Channel Angular Extrusion (ECAE), *Materials Science and Engineering A*, **2004**, 372 (1–2), 44–55.

[15] Y Iwahashi, J Wang, Z Horita, M Nemoto and TG Langdon, Principle of Equal-Channel Angular Processing for the Processing of Ultra-Fine Grained Materials, *Scripta Materialia*, **1996**, 35 (2), 143–146.