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ALUMINUM ALLOYS BY ECAP CONSOLIDATION FOR INDUSTRIAL APPLICATION

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ABSTRACT

Affecting factor of important in industrial applications of Powder Metallurgy is a process of consolidation, the fabrication process with the good parameters by increasing of the bond strength on surface to reduce the number of pores. In particular, methods of Severe Plastic Deformation (SPD) overcoming a number of difficulties associated with residual porosity in the sample which solidified. Ultrafine–Grained (UFG) materials processed by ECAP usually show unique mechanical properties such as; high yield stress at low strain hardening, good ductility on low temperatures and high strain-rate super-plasticity at high temperatures. Production of Al alloy growing rapidly, particularly in the automotive industry. Although high-strength aluminum alloys containing Mg and Si (6xxx series aluminum alloys) which are easily reached, but for formability processes is not sufficient to be applied. Therefore, much research has focused on increasing the formability of these alloys through heat treatment. High strength aluminum alloy, such as alloy AA7XXX, which combines the power of high-density ratio with excellent mechanical properties, is widely used for aviation applications, superplastic forming into high-volume fabrication of components in the automotive. Consumer products industry is currently limited because of the relatively low strain rate. AA6XXX are some of the alloys materials, mostly used currently covering the whole range of industry. Applications of AA6XXX easier to process than AA7XXX because of properties the material elasticity, AA7XXX tend to form internal cracks as a result of micro-segregation. That way heat treatment is required to improve the properties of the material when it is processed by ECAP.

Keywords: *Powder Metallurgy, ECAP, AA6XXX, AA7XXX and Consolidation.*

INTRODUCTION

Process of Powder Metallurgy (P/M) enables for fabrication of bulk materials of metal, composite or ceramic powders. One of the important factors affecting industrial applications of P/M is a process of consolidation, when the materials produced by P/M method, the pores are generally present inside on material. Initiator pores is micro-cracks during deformation. Thus, the fabrication process with the right parameters is increasing of the bond strength of surface to reduce the number of pores [DVOŘÁK, 2010]. In particular, methods of SPD overcoming a number of difficulties associated with residual porosity in the sample which solidified [R.Z. Valiev, 2000].

A significant increase in the strength of the aluminum-based alloy can be achieved through the establishment by ultrafine grained (UFG) using methods of equal channel angular pressing (ECAP) [A. A. Mogucheva, 2012]. UFG materials processed by ECAP usually show unique mechanical properties such as; high yield stress at low strain hardening, good ductility on low temperatures and high strain-rate super-plasticity at high temperatures [R.Z. Valiev, 1991 And R.Z. Valiev, 1997]. Processing of plastic deformation method quite good for grain refinement of metallic materials, processed materials SPD does not only show the physical and mechanical properties that uniquely inherent in various materials UFG but also a number of advantages over nanostructured materials produced by other methods through powder processing [Hyoung Seop Kim, 2004].

Production of Al alloy growing rapidly, particularly in the automotive industry. Although high-strength aluminum alloys containing Mg and Si (6xxx series aluminum alloys) which are easily reached, but for formability processes is not sufficient to be applied. Therefore, much research has focused on increasing the formability of these alloys through heat treatment [Jae-Yeol Jeon, 2012]. High strength aluminum alloy, such as alloy AA7XXX, which combines the power of high-density ratio with excellent mechanical properties, is widely used for aviation applications, superplastic forming into high-volume fabrication of components in the automotive. Consumer products industry is currently limited because of the relatively low strain rate [C.M. Cepeda-Jiménez, 2011]. AA6XXX are some of the alloys materials, mostly used currently covering the whole range of industry [Akhtar S. Khan, 2010]. This study aims to provide an overview to the engineers to apply heat treatment of AA6XXX and AA7XXX. The aluminum material for automotive component application needs requires suitables for mechanical properties, especially hardness and ductility, so that in doing the process stages can be done the selection of the appropriate temperature and pressure variables especially for Equal Channel Angular Pressing Consolidations (ECAP-Consolidations).

MATERIALS AND EXPERIMENTAL METHODS

Consolidated of metal powder through ECAP often segmented as they pass through the shear zone. To prevent this common problem, it has been suggested to use thin-wrapped cans for the consolidation of the metal powder through ECAP [R. Lapovok, 2008]. In this case, tinned copper used to come out from the hydraulic machine press and the heating of copper alloy rod annealed at 400-450°C for 1 hour. Starting AA6XXX/AA7XXX with average grain particle size of 70-100μm was received from Aluminum Powder Company Ltd, ALPOCO, list of material composition used are presented in Table 1. The samples were transported on hot pressing during 3–4 seconds and pressed at the rate of 5 mm/s through the angle of 90° for one pass. For each sample front stopper as back-pressure was used. The pressure for compacting 16×16 mm square specimens was in the range of 350-500 MPa.

Table 1. The chemical composition (wt.%) of aluminum alloys were used

Al Alloys	AA6061	AA7075
Al	97.13	89.76
Si	0.76	0.052
Fe	0.7	0.19
Cu	0.22	1.59
Ti	0.1	0.025
Cr	0.07	0.19
Zn	0.06	5.68
Mn	0.04	0.007
Mg	0.92	2.51

To improve the properties of the alloy, heat treatment was performed after ECAP as shown in fig 1 Heat treatment of AA6XXX:

a) Annealing was conducted by heating the sample up to 415°C and holding for 2. 5 hours. Then the temperature was lowered to 177°C and held for 8 hours.

b) Solution heat treatment is done by first solution heat treatment at 530oC for 1 hour, quenching and then holding at the temperature of 100°C for 24 hours [Pramono. A, 2015].

Figure 2. Heat treatment of AA7XXX for improve properties of materials:

a) Annealing was conducted by heating the sample up to a temperature of 415°C and holding for 2 hours. Then the temperature was lowered to 230°C and held for 4 hours.

b) Solution heat treatment is done by first solution heat treatment at 500°C for 1 hour, quenching and then holding at the temperature of 120°C [Pramono. A, 2014].

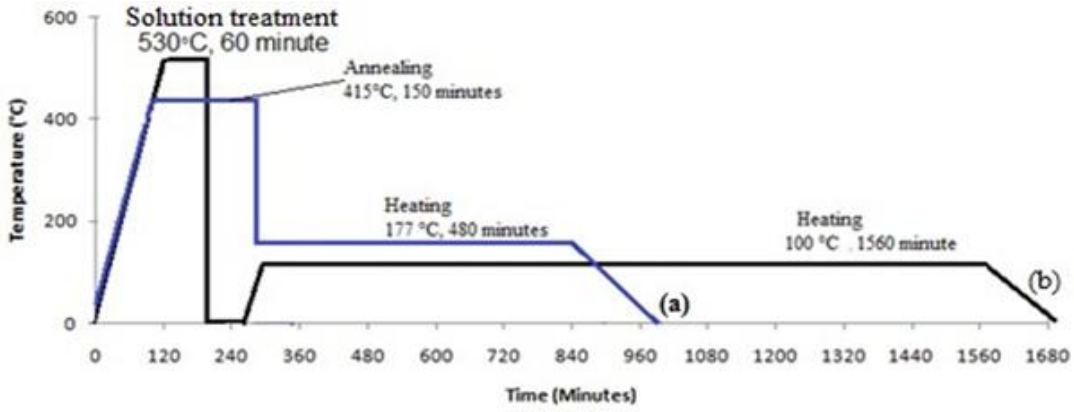

Fig 1. Diagrams heat treatment of AA6XXX: a) Annealing (O) b) Artificial aging (T6).

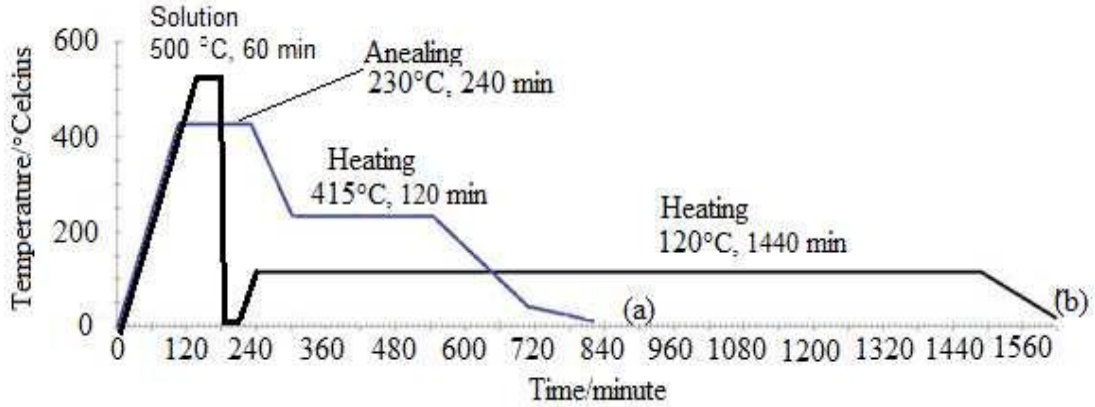

Fig 2. Diagrams heat treatment of AA7XXX: a) Annealing (O) b) Artificial aging (T6).

Aluminum alloy materials used as a material process of UFG specimens obtained by ECAP as described in Figure 3. ECAP machine can use the route A, Bc or C. It has stresses between 4 - 8 passed by a 90° for Al alloys. Compression tests performed to check the formability of conventional fine grained specimens, obtained from the material flow stress test compression with constant ram speed 0.1 mm/s at room temperature by applying material, lubrication function to reduce friction between the sample with a pressure rod, graphite for powder and MoS_2 as a lubricant for rod materials, constant friction sliding model is used to apply a frictional force at the interface between the specimens and die in order to obtain a good formability.

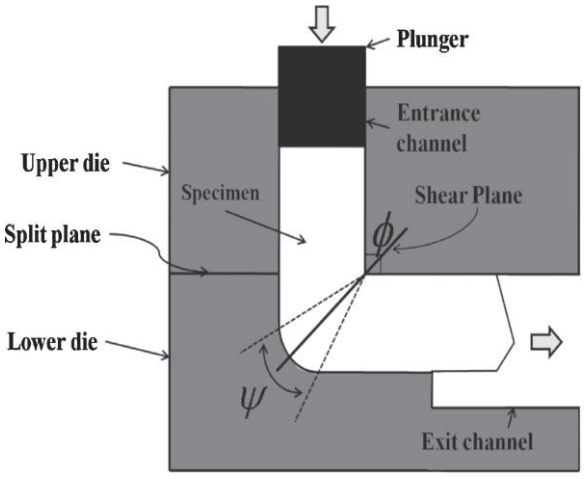

Fig 3. The schematic diagram process of ECAP

RESULT AND DISCUSSION

Application of AA6XXX for component spare parts: The ability of AA6XXX is determined by the application of formability, formability of ultra-fine-grained specimens processed by ECAP processes measured by a compression test. In this test, a specimen is made of conventional materials does not buckle when the aspect ratio of height to diameter of specimens. Given the limit of the aspect ratio of the value obtained from the compression test, to establish the order bolts developed into three stages. Load requirements and defect formation during the formation process may be estimated using rigid-viscoplastic. After the manufacture of high strength bolts using ultra-fine-grained specimens on 4-8 passed, increase strength and tensile test. Homogeneity increase strength also is assessed by measuring the distribution of local hardness. In addition, the components are manufactured with ultra-fine grained AA6061 [Jun-Seok Choi, 2011], component form presented in fig 4.

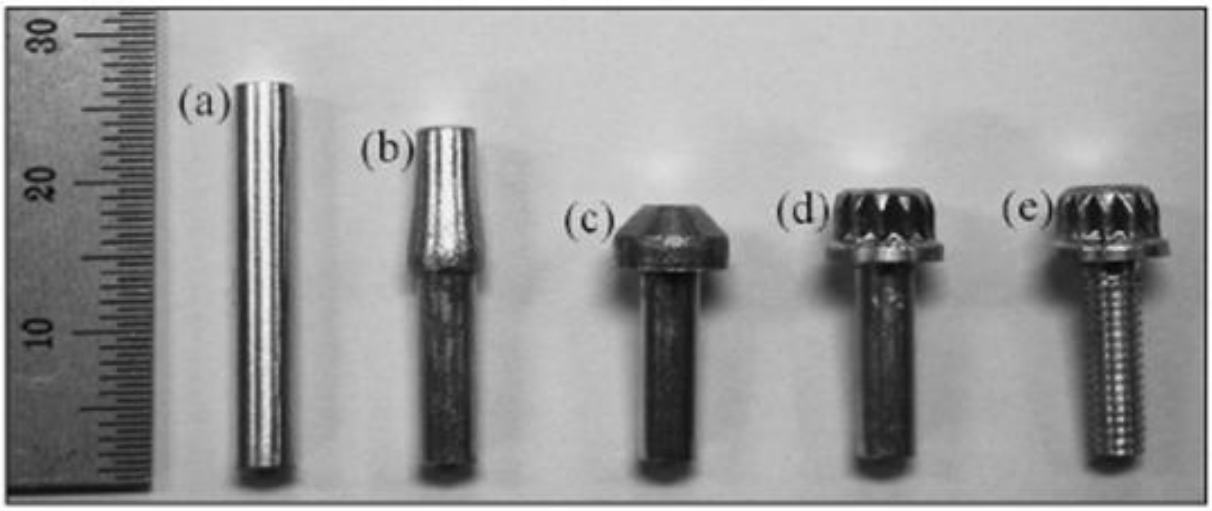

Fig 4. Three Basic of stages for forming bolts to ultra-fine-grained specimens: (a) as the engine, (b) first preform, (c) a second preform, (d) the final product, and (e) the bolt thread with the machine.

In other hand, another application was applied also on micro-gears, for the low rotation. Pressing of 8-12 passed on AA6XXX, resulted in a sharp decrease in strength due to the dynamic recovery accelerated in extremely fined structure (sub) grained. The process of making micro-gear components with ECAP process associated with the intensive plastic deformation and decrease in strength after the peak associated with a decrease in density of the material. Flow stress falls gradually to follow the material flow stress materials. The successful of the manufacture component depend on ductility of material, if the material is more ductile then the components are easy to set up, but if the ductility drops then the components will have cracks. When deformation suppression

then the strength will decrease fulfill the formation of the components. Power reduction occurred following the increased emphasis to 8 passed [W.J Kim, 2008], AA6061 micro gear components presented in figure 5.

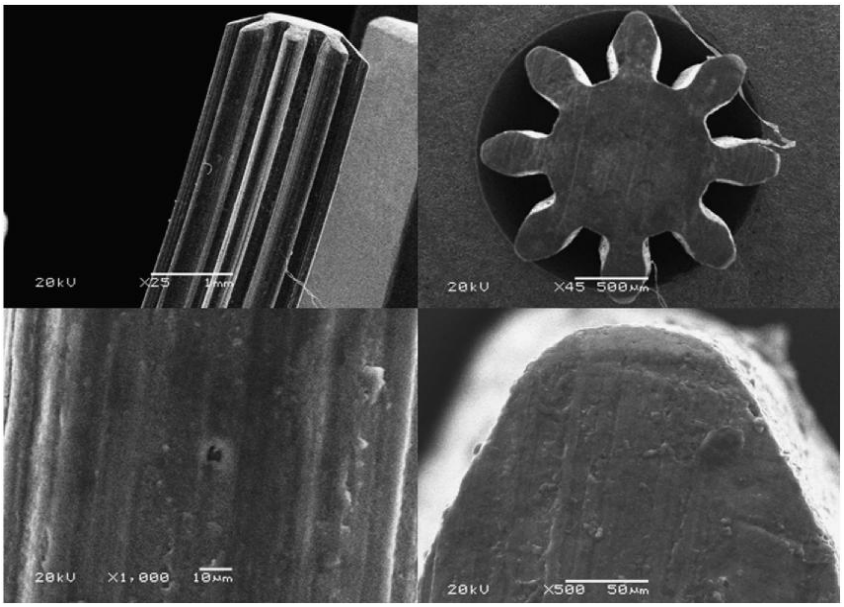

Fig 5. Micrographs of the micro-gear shafts extruded at AA6XXX.

AA7XXX of Manufacturing process: Working **p**rocess on AA7XXX material is usually constrained by the microstructure of the material, deposit of precipitates such as $Mg.Zn_2$ element typically forming a micro-segregation, which lead to cracking when processed materials [S. Fritsch, 2012]. Based on plastic strains of structure of the alloys was determined, Fig 5 represents the results of the failure of sample formation process due to limited ductility AA7XXX due to micro-segregation of produce cracks.

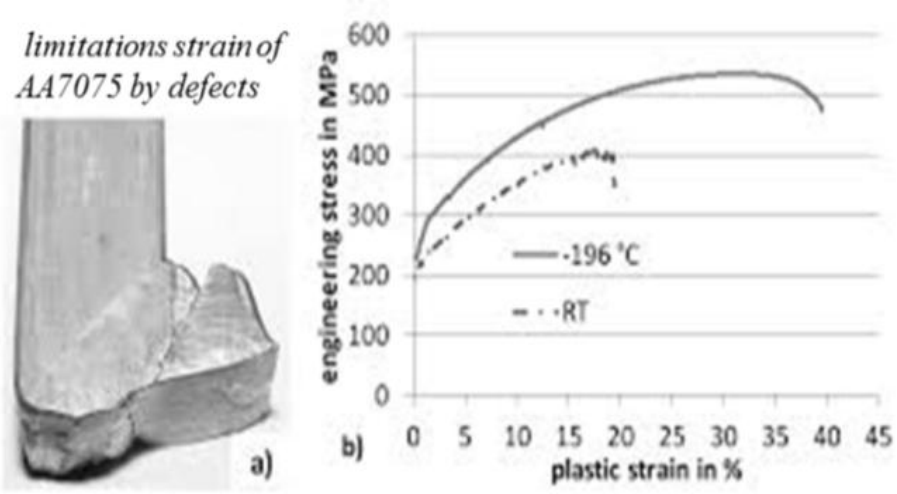

Fig 6. Limitations due to the formation of cracks AA7XXX by ECAP process.

AA7XXX has been widely used in commercial applications because it shows high strength and can be heated to a wide range of properties, but in practice constrained by microstructure [C.M Cepeda, 2010], therefore making the ECAP process components with AA7XXX material is constrained by factors internal cracks, so in this case takes precision the process of associated with some of the parameters used in ECAP [L. Kollo, 2012]. AA7XXX by ECAP at room temperature constraints exist, the heat treatment of plastic deformation severe leading to overaging of the sample through the formation of particles are relatively coarse and stable so AA7XXX-O alloy after treatment overaging shows large grains are elongated and flattened parallel to the direction of rolling, the coarsening of hardening precipitates during thermal treatment. Settlement of the problem of limited nature of the AA7XXX is the homogenization of additional improvements microstructure by plastic deformation severe (SPD) processing data to improve the mechanical properties at room temperature and to obtain superplastic quickly formed at relatively low temperatures, providing that the grains ultrafine developed stable at these temperatures [C.M Cepeda, 2012]. Micro-segregations formation of $MgZn_2$, during a gradual freezing was not present during rapid cooling. It was also found that the age hardening and annealing heat treatment operations are eliminated micro-segregations and improve the mechanical properties of the alloy Al 7XXX. It concluded that micro-segregation can be removed by rapid freezing and right heat treatment on process. Micro-segeregation of $MgZn_2$ in aluminum matrix while the as-cast (cooled quickly) it will show the fine grains of $MgZn_2$ phase uniformly distributed in the aluminum matrix, so microsegregation which can cause cracking can be avoided [A.D Isadarel, 2012].

CONCLUSION

1. The ability of AA6XXX is determined by the application of formability, formability of ultra-fine-grained specimens processed by ECAP processes measured by a compression test.
2. the manufacture of high strength bolts using ultra-fine-grained specimens on 4-8 passed, increase strength and tensile test.
3. ECAP process associated with the intensive plastic deformation and decrease in strength after the peak associated with a decrease in density of the material.
4. Based on plastic strains of structure of the alloys was determined, the failure of sample formation process due to limited ductility AA7XXX due to micro-segregation of produce cracks.
5. ECAP process components with AA7XXX material is constrained by factors internal cracks, so in this case takes precision the process of associated with some of the parameters used in ECAP.

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