MICROSTRUCTURE EVOLUTION ANALYSIS OF RECYCLING ALUMINUM AA6061 CHIPS USING HOT EXTRUSION PROCESS

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ABSTRACT

In the present research, AA6061 chip metals were produced by hot extrusion and the effect of extrusion parameters on mechanical properties and surface integrity were investigated. The objective of the present study it to analyze mechanical and structural features of 6061 after plastic consolidation by hot extrusion with different preheat temperature and preheat time on constant ram speed. The findings of the study highlight the potential of combining the process extrusion parameter as an efficient processing route for production of high-performance extrude quality. Tensile test results showed that material extruded using temperature 550°C exhibit higher mechanical properties with comparison to temperature 400°C. The surface integrity shown that microstructure at 550°C much more consolidate and fine grain rather than microstructure at 400°C. Fracture surface shown that ductile fracture mode occurred at condition 500°C and 2 hours and brittle fracture occurred at condition 400°C. Summarize revealed that ultimate tensile strength and elongation of fine chips extrudates exhibit properties to the as-received billet.

Key words: Aluminum chip; Recycling; Sustainability; Hot Extrusion

INTRODUCTION

Greater urbanization, higher living standards, climate change and increasing energy needs call for efficient and a sustainable aluminum solutions. Aluminum solutions can reduce environmental impact. Manufacturing of aluminum products is connected with environmental point of view. A large amount of waste in the form of chips and discards is produced in the machining process of castings and sheets. Extrusion is defined as the process of shaping material, such as aluminum, by forcing it to flow through a shaped opening in a die. Aluminum extrusion is a technique used to transform aluminum alloy into objects with a definitive cross-sectional profile for a wide range of uses. The extrusion process makes the most of aluminum's unique combination of physical characteristics. Extrusion is done by squeezing the metal in a closed cavity through a tool, known as a die using either a mechanical or hydraulic press. Extrusion performance can be affected by three major factors, mainly, the number of billets used scrap, the die life and the extrusion speed. According to Tekkaya A.E. et.al., (2009), that due to the occurring strains, pressure and temperature at high quality longitudinal seam weld within the profile was assumed during conventional extrusion. According to Misiolek W.Z. et. al. (2012) and current research by Güley V. et.al., (2013) found that recycling aluminum 6061 chips by the hot extrusion process as a potential secondary resource. The extrusion process capitalizes on the built-in advantages in aluminum and increase on their use and applications. Repeating the experiment to achieve desired optimized extrusion process condition will be expensive and time consuming. For improving recyclability of aluminum there are some areas should be focused for instance ram speed (Vr), preheat temperature (Tph) and preheat time (tph) in the recycling of aluminum (Rahim S.N. et.al., 2017). On the other hand, research for modeling of hot extrusion parameter process not really established. Aluminum recycling has a number of key environmental and economic benefits. With these energy and cost savings in mind, many producers now have targets of increasing their usage of secondary materials.

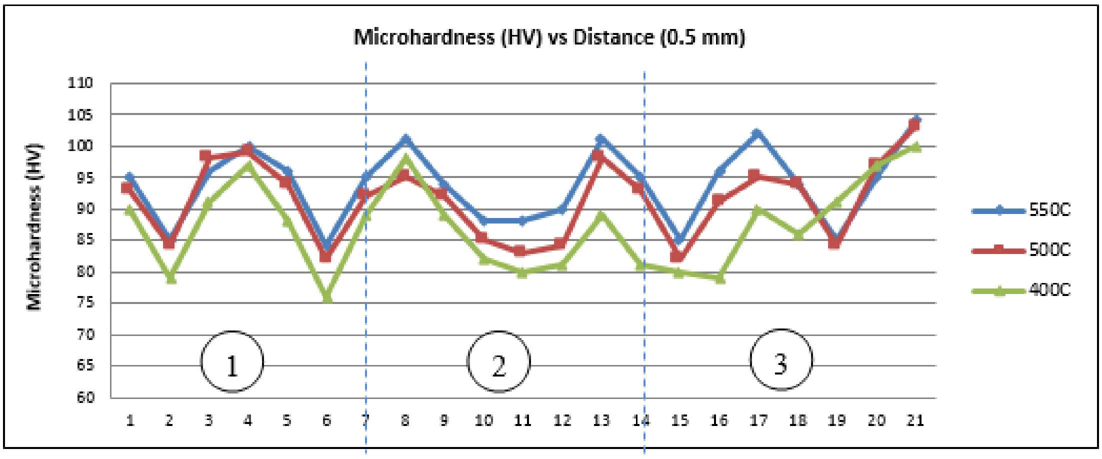

Figure 1 : Microhardness as the function of temperature for parameter speed recycled specimen

MICROHARDNESS ANALYSIS

The result of the experiment shows that microhardness has a stacked line trend with an increment of temperature. The theoretical hardness value for aluminum alloy 6061-T6 is 95 HV. This value is used to compare with the sample that has undergone extruded. On the other hand, the absolute minimum microhardness of 95 HV is observed at preheat temperature of 550°C. The maximum microhardness of 88 HV is achieved at maximum temperature 550°C. Figure 1 shows the trend microhardness test analysis had be done by 3 difference preheat temperature. The experiment was followed to DIN EN ISO 6507-1:2005. On the region 1 the microhardness gives a better result and same with region 3, nevertheless on region 2 the microhardness show a low hardness result. The hardness values showed that a gradual increment of 0.02 mm on preheat 3 hours 10 mm where it began to decrease. It can be concluded that peak extruded was achieved at 3 hours, preheat at 350°C however, it decreased over middle region. The high value exists at along the die extruded wall. The highest strength was generally achieved when a large amount of closely spaced, small and round precipitates is coherently dispersed throughout an alloy (Chiba R et. al., 2015). The homogenous distribution of the fine precipitate of copper, in aluminum matrix is largely responsible for the hardness of the extruded aluminum alloy. Thus, there is a very high possibility that the maximum hardness can be obtained by further preheat time. The precipitate particles continued as consolidate progress caused the particle size to increase and thus decreased the degree of complication for the dislocations to break the magnesium-silicon bonds when they pass through the precipitates (Schikorra M. et.al., 2008). Thus, it was concluded that the higher the preheat temperature, the softer the sample became which then caused its loss of good mechanical properties such as hardness and tensile strength. Therefore, the structure was becoming brittle at cross section surface fracture.

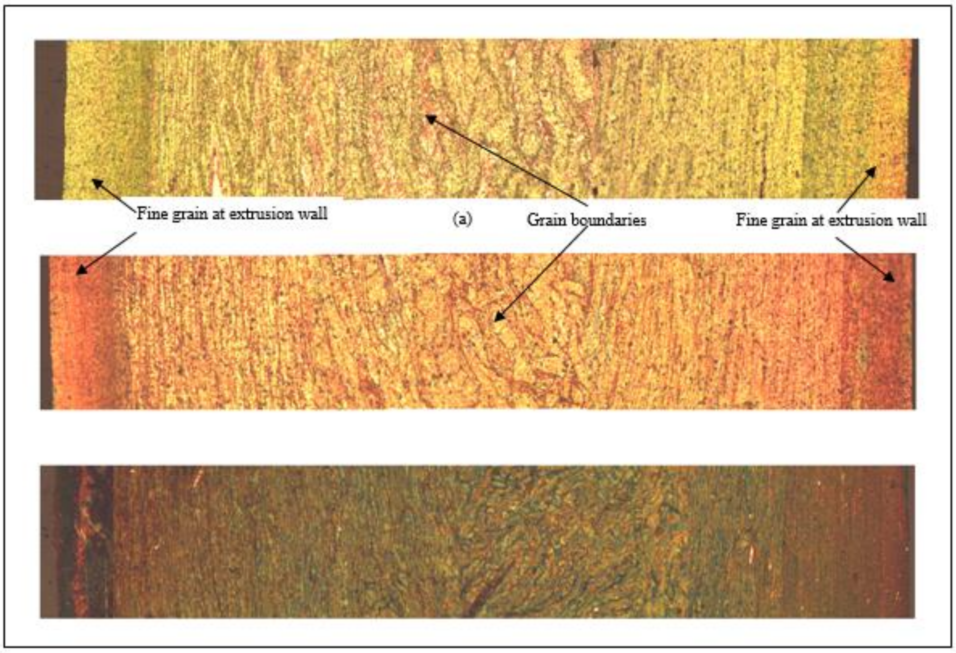

Figure 2 : The images of profile extruded through the flat-face dies in the cross-section direction (a) temperature 550°C, (b) temperature 500°C and (c) temperature 400°C.

The images are presented using the light microscopy representing the whole cross-section of 10 x 6 mm. The highest temperature in the welding zone of the flat-face die led to fully crystallize grains. Figure 2 (a) show at temperature 550°C the grain more consolidate rather compare with Figure 2 (b) using temperature 500°C and also Figure 2 (c) using temperature 400°C. Small chip boundaries and grain size exhibited relatively on the samples extruded using billet temperature at 400°C. Hence, the materials hot extruded using high billet temperature (500°C and 550°C) with different preheating time from the same chips as illustrate in Fig. 2a & 2b had shown no observable cracks on selected area and the grain size is slightly bigger within the grain boundary regions compared to temperature 400°C. The results show that in case of extrusions through the flat-face die present a dynamic recrystallization without any post deformation microstructure response mechanisms is observed. Higher shear forces show that result in the more efficient breaking of the oxide layers into small particles and more homogeneous distribution of the oxide particles. The chips billets showed a fine grained microstructure after homogenization. When the chips were extrude through the flat-face die, those small grains were also elongated in extrusion direction. It can also be seen that the autistic Si phases were refined, when compared with those in the original ingot and machining chips (Lajis M.A. et.al., 2015). Additionally, figure 2 shown the fine grain occurred along the extrusion wall foe each parameter cause of shear force and normal force along the extrusion process.

MICROSTRUCTURE EVOLUTION

The microstructure images were taken using the Light Optical Microscopy under polarized light from the extrusion through the flat-face die.

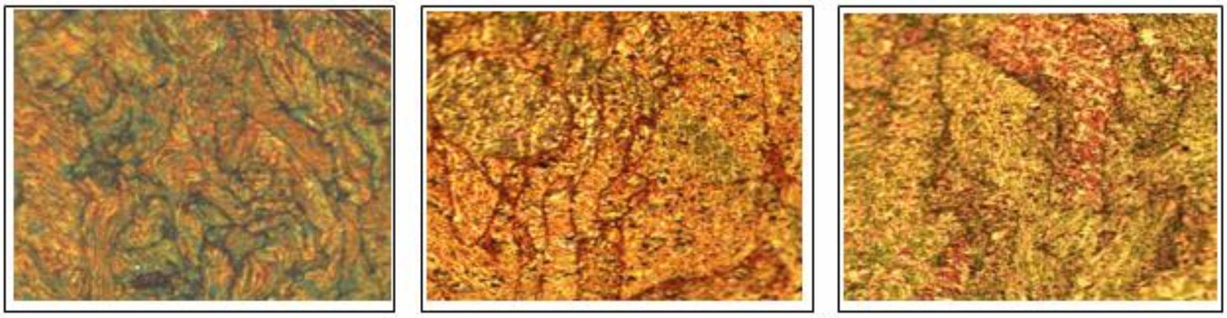

Figure 3 : Microstructure of aluminum alloy AA6061 chips. (a) chip billets at 400°C. (b) chip billets at 500°C. (c) chip billets at 550°C.

Figure 3 shows the microstructure of the extruded specimens AA6061 chips in the center of the cross section of the infant side using Optical Microscope. The well developed microstructure will produce the quality of the extruded and the success of the recycling by hot extrusion. The sample was prepared cross section directions following the typical metallographies techniques. The mounting specimen was etched with a Weck's reagent for 120 seconds to reveal the grain boundary and get color contrasts under polarized light. The poor consolidation structure had on parameter temperature 400°C as Figure 3 (a) but some improvement consolidation microstructure was revealed at parameter condition 500°C as Figure 3 (b). On the other hand, fully recrystallized grains of the flat face die led by the higher temperatures 550°C in the welding zone as Figure 3(c). The temperature within the welding area was much higher rather than the maximum profile temperature. Hence, the severe shear deformation of the material, including the residual voids near the surfaces, causes obvious crack along the chip interfaces.

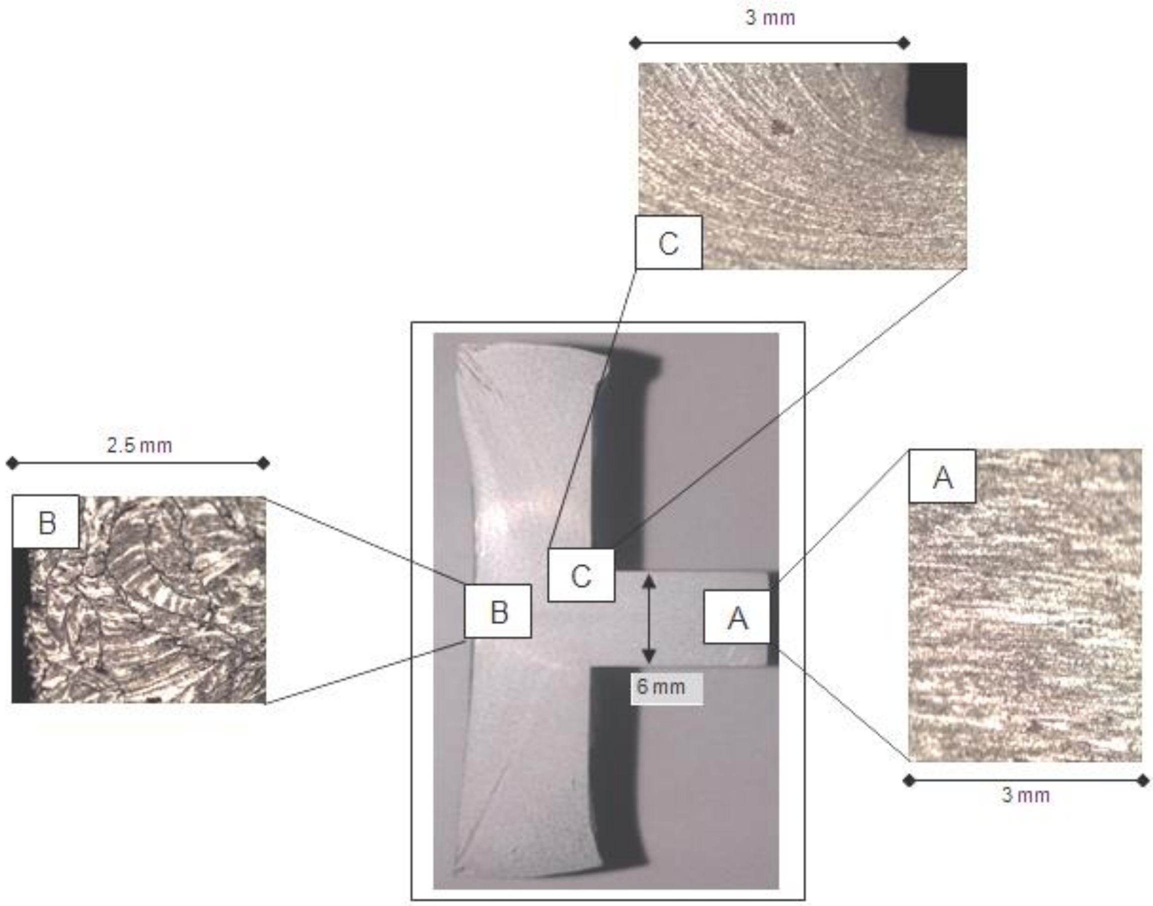

Figure 4 : Images from the different location of the billet chips extrude billet 500°C & 3 hours extruded through the flat-face die.

The consolidation between among chips occurred from container into extrusion flat-face die will be referred on Figure 4 above, respectively extrude using billet temperature 550C and preheating time 3 hours . Compressed aluminum chips within the container and the boundaries between the chips can be easily seen can be described in Image B. The shear zone during hot extrusion is shown in Image C. The grain size evolution in the high shear zone revealed bigger grains at higher temperatures and fine grains at higher sliding speed. The broken oxide layers are distributed between the newly formed grain boundaries (Mohammed Iqbal, U. et. al., 2013). Image A shown the microstructure essential of chip welding during hot extrusion. This boundary represents the weld seam, formed when the aluminum chip streams rejoin in the weld chamber downstream of the obstruction in the die. The high plastic deformation could cause the multiplication of the dislocations and the increase of the grain boundary area, generating the grain refinement (Paraskevas, D. et.al, 2014).

CONCLUSION

Tensile test results showed that material extruded using temperature 550°C exhibit higher mechanical properties with comparison to temperature 400°C. The extrudate temperature is the most important because it determines the quality of the product and indicates the possibility of increasing extrusion speed. Ram speed affects the amount of heat generated and also the amount of the heat loss to the extrusion tooling. The achieved tensile strength and elongation of aluminum chips 6061 produced by forward hot extrusion is at least approximately the same than as-received 6061. At high temperature the chips bonding improve through the inter-particle diffusion under the high strain in extrusion process, the diffusivity between virgin chips also increases. Preheating duration times were influence a better homogeneity of the billet structure made a better consolidation during extrusion processes.

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