EFFECT OF PROCESS PARAMETERS ON THE PHYSICAL PROPERTIES OF WIRES PRODUCED BY FRICTION EXTRUSION METHOD

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ABSTRACT
The aim of this experiment is the study of the process parameters on wires produced by a novel friction stir extrusion approach. Friction stir extrusion relies on the intrinsic frictional heating and extensive plastic deformation generated by process to stir, consolidate, and extrude the powders, chips directly into useable product forms in one-step. In this work it was attempted to find effects of process parameters such as traverse speed rate and die rotational speed on physical and micro structural properties. It has been observed that hot crack and cold crack defects were existed on wires produced using too high and too low die rotational speed, respectively. Furthermore, the dimension and amount of defects such as voids in the wires generally increases with the increase of die transverse speed.

KEYWORDS: *Aluminum Chips, Friction Stir Extrusion, Microstructure, Process Parameters*

I. INTRODUCTION

There have been immense advances in most aspects of material recycling specially in the field of Metallic chips that produced through various manufacturing processes; therefore in the last decade many studies have been carried out in developing an effective way to recycle metallic chips. During the manufacture of aluminum components, much of the original material is discarded as machine waste, e.g. swarf, metal chips, etc. Techniques that can compact waste products thereby allow more material to be stored. In addition, recycling and re-processing techniques that help recover some of the material costs are being encouraged. For aluminum and its alloys, the energy required to extract the metal from the primary ore is substantial. The recycling and re-processing of aluminum waste products is, therefore, becoming commercially more attractive. Processes utilized to recycle aluminum chips are divided into two main groups: Conventional method and the direct conversion method. The conventional method requires melting of the material to be recycled, casting of a billet, and then hot extrusion of the billet to form a consolidated product in wire or rod form. The direct conversion method utilizes conventional hot extrusion which may or may not be preceded by a static pressing stage. Among these methods direct conversion is much under attention because it may result in great reduction in consumed material, energy and labor costs [1-3].

In recent works for recycling aluminum chips, it was stated that the difficulty of recycling the selected aluminum scrap depends on scrap type, scrap size distribution, contaminant, and the ratio of surface area to body volume and also influence of chips preparation in the aluminum alloy recovery rate and dross production had been investigated [4-6]. In some other works additional tasks utilized to make improvements in recycling processes. These works include cold press pressure prior to melting process, additional sintering process before the final extrusion of aluminum chips, addition of aluminum powder as a soft matrix in the 7075 aluminum chips in direct conversion process [6-8].

Friction stir welding (FSW) and friction stir processing (FSP) are new welding and processing methods which were developed by TWI (1991) and Mishra et al (2003), respectively. These are solid state processes for joining and microstructure modification, respectively. Both methods rely on plastic dissipation for heat generation and may be considered severe plastic deformation processes. In both technologies, welding and processing, a rotating, non-consumable tool, is used to produce a plasticized layer which undergoes severe plastic deformation and heating. Another advantage of application of FSP to metals is that this process results fine grains in the processed zone due to substantial deformation at hot working temperatures.

A novel process that is developed from FSP and FSW is friction extrusion (also named friction stir extrusion). Friction extrusion was developed at TWI in the early 1990s, and employs frictional heat to generate the necessary heat required for extrusion. It has been demonstrated successfully with several aluminum alloys**.** The required temperature is generated and maintained by frictional contact between the material to be extruded and the extrusion die. A high shear strain rate is developed at the boundary between the die and the extruded material, and within the plastic zones of the extruded material. However, there are some attractive aspects of the friction extrusion process and it may yet prove to be an industrially useful technique for the achievement of several purposes, e.g. recycling of machining waste, consolidation of powder product and, potentially, as a method of mechanical alloying [3]. The friction extrusion process may be considered a variant of the direct conversion method of recycling since a consolidated product is produced without melting and casting. In present study, it was attempted to produce AA2025 aluminum wires by friction stir extrusion of machining chips. Also, effects of process parameters such as traverse speed of rotating die and die rotational speed on physical and micro structural properties had been investigated.

II. EXPERIMENTAL WORKS

The aluminium chips used as extruded material are AA2025-T8 aluminium which was fabricated through milling of AA2025-T8 shaft. Relatively uniform and clean chips were milled from aluminium shaft without any lubricant or cutting fluid. Then, these chips were dried and cleaned. Schematic illustration of designed setup can be seen in Fig.1. Furthermore, the experimental setup of process is demonstrated in Fig.2. Production of wire from machined aluminium chips includes four main steps: As it can be seen in Fig.1a, stationary billet chamber was located in stationary side of conventional turning machine. It should be mentioned that a conventional turning machine had been utilized in this study to supply required movements for friction stir extrusion die. In second step aluminium chips filled in stationary side of extrusion die and compressed into it (Fig.1b). The third stage is directing rotating die with a load into the stationary billet chamber. At last produced aluminium wire was pushed out through rotating die. Both stationary billet chamber and rotating die were fabricated from H13 hot worked steel. Inner diameter of stationary billet chamber and outer diameter of rotating die are same and 30 mm. The rotating die has a scrolled face and a central through hole. The scroll is similar to patterns machined into friction stir welding tool shoulders designed for operation at a 0◦ tilt angle. The central hole has a diameter of 2.5mm which defines the resulting wire diameter.

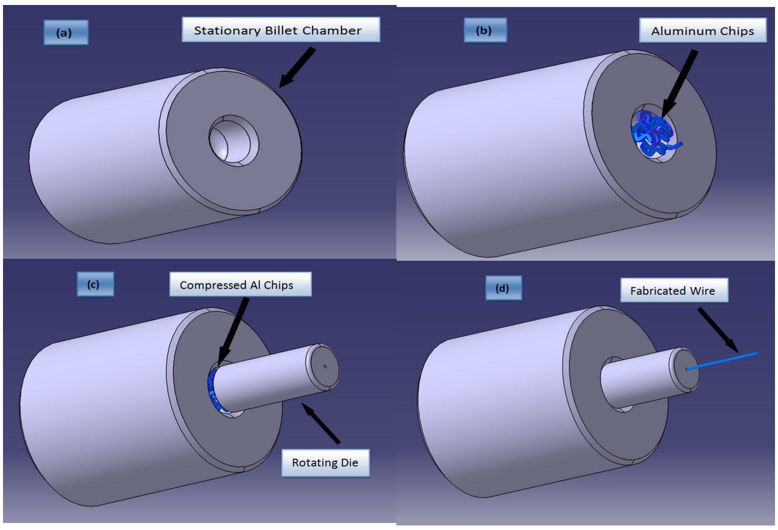

Figure 1. Schematic of friction stir extrusion process to produce aluminum wires from chips

A post-extrusion heat treatment (PEHT) of 15 h at 160◦C was applied to the extruded wires. The PEHT is similar to the artificial aging step used to produce T8 tempers in the alloy plates. However, in normal industrial practice the aging step is typically preceded by a solution heat treatment, water quenching, and stretching to several percent plastic deformations.

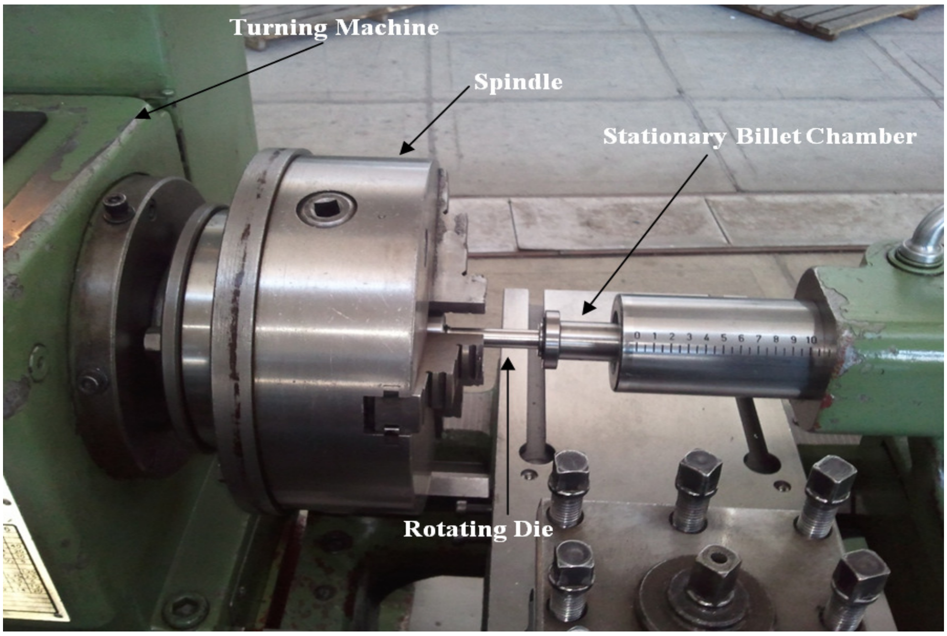

Figure 2. Experimental setup of friction stir extrusion process

In order to study the effects of process parameters to properties of fabricated wires various die rotational and traverse speeds had been selected which can be seen in table 1.

Table 1. Samples produced under various process parameters

Sample Number	Die Rotational Speed (rpm)	Traverse Speed (mm/min)
1	200	20
2	400	20
3	600	20
4	400	10
5	400	30

III. RESULTS AND DISCUSSION

Macroscopic photograph of produced wires in different process parameters can be seen in Fig.3. There are three common imperfection encountered in friction stir extrusion: twist, tear (or cold tear) and cracks [3]. The presence of cold cracks easily can be seen in Fig.3a. This can be attributed to low rotational speed of extrusion die. If the rotational speed is selected with lower amounts, generated heat will not be sufficient to reach the softening temperature of aluminum. Therefore cold cracks will be present on the surface of fabricated wires (see Fig.3a). As it can be seen in Fig.3b with increasing rotational speed from 200 to 400 rpm, this imperfection has been eliminated from surface of wire. It is clear that in samples produced with this rotating speed enough heat generated and conducted to chips to reach them to softening temperature of AA2025-T8 aluminum. In the other words, the required temperature is generated and maintained by frictional contact between the material to be extruded (or chips) and the extrusion die. In high rotational speeds, a high shear strain rate is developed at the boundary between the die and the extruded material (or chips), and within the plastic zones of the extruded material. The ensuing temperature rise can lead to deformation at localized regions. Since the material softens locally, further deformation is concentrated within the region and under an axial load it is continuously extruded through the open ended die without this imperfection. From Fig.3b, it is obvious that the entire surface is quite smooth but a slight twist can be seen. This imperfection can be eliminated by increasing rotational speed to 600 rpm (see Fig3.c), but in this one produced wires surface suffers from big cracks which was named as hot crack. In general, the twist is not obvious on any of the wires made at die rotation rates greater than 400 rpm but becomes more apparent with decreasing rpm below 400 rpm. The wires extruded 600rpm exhibited closely spaced, circumferential, surface, cracks as shown in Fig. 3c. It is worth to mention that in extruded wires with 600 rpm, the cracks appeared after 130mm of extrusion.

a) Sample 1 with 200 Rpm

b) Sample 2 with 400 Rpm

c) Sample 3 with 600 Rpm

Figure 3. Macroscopic photograph of produced wires with different process condition

Fig.4 shows microscopic observation of samples taken by scanning electron microscopy. As it can be seen in this figure, in samples produced with traverse speed of 20 mm/min there are large voids that may reduce mechanical properties. With increasing traverse speed of die to 30 mm/min, these voids change into channel and can exist through all length of wire (see Fig4.c). However in wires fabricated with low transverse speed there is not any imperfection such as voids formation or channeling effect (see Fig4.a). So the optimum traverse speed for rotating die is 10 mm/min or lower.

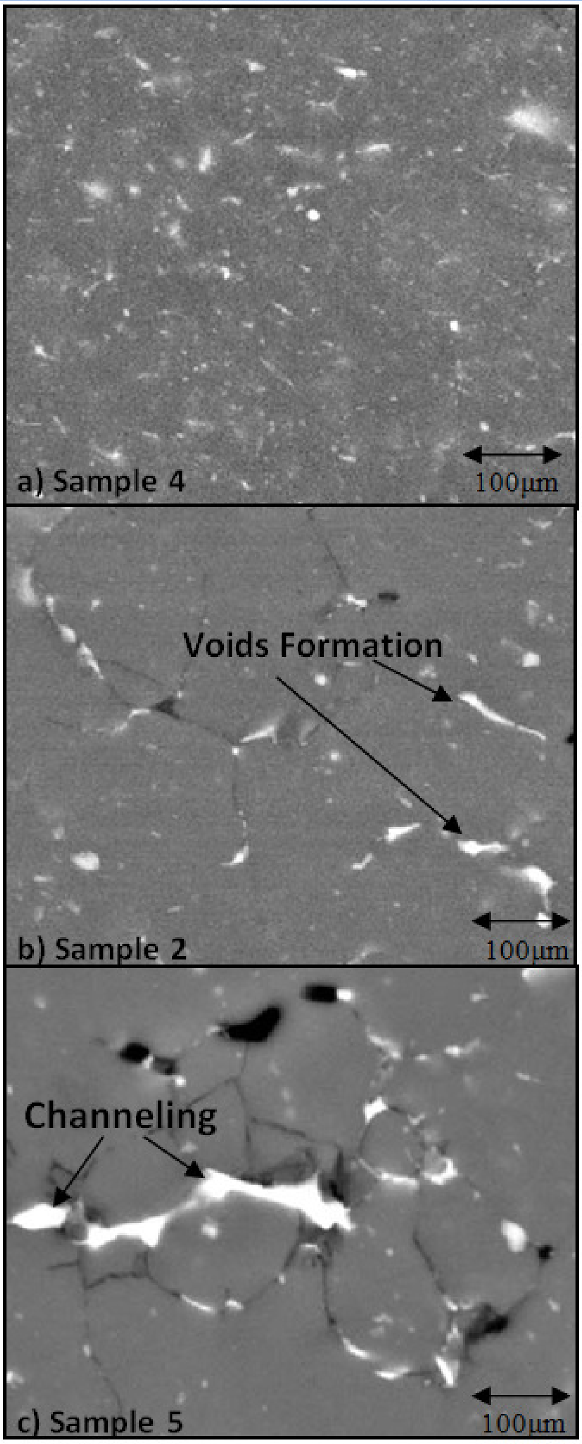

Figure 4. 4 microscopic observation of samples taken by scanning electron microscopy

IV. CONCLUSIONS

Taking all above-mentioned discussion into consideration the following conclusion can be drawn about issue:

1) By friction stir extrusion processing method defect free aluminum wires can be fabricated from aluminum chips that had been produced through other manufacturing processes.

2) Limits on the process appear to be related to the extrusion temperature which, if too low, results in cold tearing and, if too high, causes what appears to be a form of hot cracking.

3) From macroscopic and microscopic evaluations it can be inferred that the optimum condition for

processing is 400 rpm rotational speed and 10 mm/min traverse speed for rotating die.

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