Aluminium alloy Extrusion

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Abstract

Current studies mainly focus on high efficiency, short stage and low cost methods such as variable section extruder, mold optimum technique and equal channel angular extrusion(ECAE). What attracts more manufactures is to improve the present lines and develop various dies to satisfy the custom demands. So far, aluminium alloy nano-extrusion has attracted very few researchers to study.
Key words: aluminium alloy, consumption market, end-use market, extrusion technique, nanoextrusion

Backgrounds

Global primary aluminium consumption has been increasing at a compounded annual growth rate (CAGR) of about 5% over the last decade, despite two recessions and continuous market threat of substitutes[1], indirectly demonstrating the huge market demand of aluminium alloy.

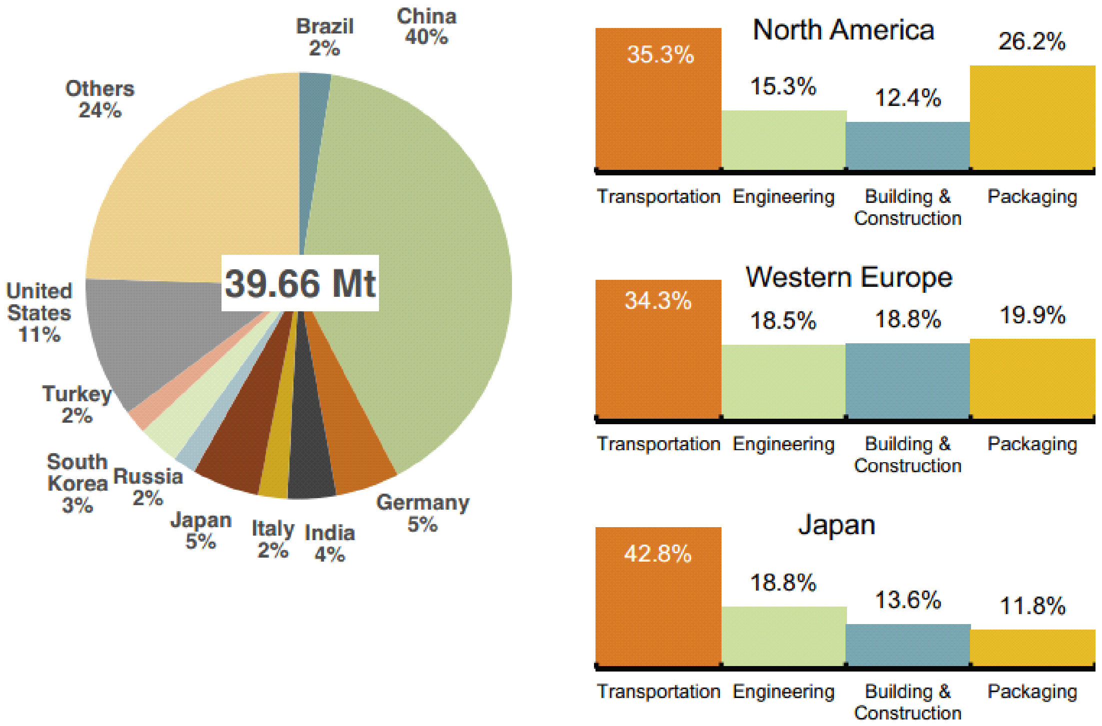

Fig. 1. Primary Aluminium Consumption (2010)

Source: WBMS, various years and Brook Hunt Long Term Outlook, July in 2011

Only inferior to rolling, aluminium alloy extrusion product output accounts for 42% in 2009, 85% of which are profiles. Extrusion product output also keeps the growth rate of about 5% similar to primary aluminium consumption, while industrial profiles has been rising at a rate of about 8%.

The leading aluminium consumption market has shifted to China (40% in 2010). As for end-use market, architecture structural profiles now still dominates in China[2]. As the construction demand weakens and stricter fuel economy regulations appears in the near future, the structure of end-use market in China will become similar to the developed countries such as North America, West Europe and Japan in which transportation is playing the most significant role (about 35-40%).

As for the other end-use markets, a number of circumstances favour aluminium: the copper to aluminium substitution in overhead cables, battery cables, wire harnesses and aluminium wiring in air conditioners and white goods; the wider use in consumer electronics for backing plates for flat screen TVs and mobile phones; green applications such as solar panelling (used in the frame) and wind farms[1].

Recent researches on aluminium alloy extrusion technique

Since extrusion technique could dramatically refine grains, improve mircostructure and enhance strength and toughness, the application of this technique to aluminium alloy product is always subjected to relatively higher production cost compared with Fe-based materials due to its limited application, rigid production line and electricity energy problem. Current studies mainly focus on high efficiency, short stage and low cost methods such as variable section extruder, mold optimum technique, finite element analysis in torsion extrusion and equal channel angular extrusion (ECAE).

CNC extruder for varied section extrusion

Variable section extrusion, as showed in fig.2, is to change the section of the extruded billet by moving molds along the direction perpendicular to the extrusion direction during the forming process, based on which H.J.Choi et al designed and fabricated a CNC variable section extruder as well as the dedicated mold with movable parts in 2008, realizing the variable section aluminium alloy extrusion process.

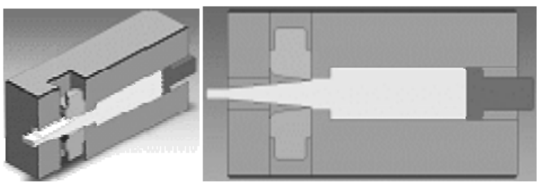

Fig. 2. Concept of variable section extruder

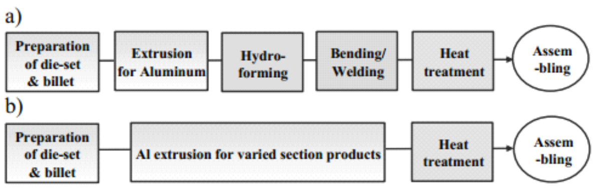

Fig. 3. Comparison of car sub frame fabricating process

(a) conventional extrusion (b) variable section extrusion

Fig.3 presents that variable section extrusion compared to conventional extrusion simplifys the whole process for car sub frames. Eliminating the successive processes benefits the integration of new processes, commercialization and cost reduction of aluminium alloy extrusion. However as an immature technique, fundamental works including heat transferring characteristics and lifetime of sliding molds should be further studied and new products applying to this process should be designed to support its development because of its limited applications[3].

Die parameters and materials

Optimum design of die for aluminium alloy extrusion has been attracting a number of researchers since its birth due to its key role in ensuring extrusion quality and reducing cost. Though dies increasingly become complex and flexible in commercial aluminium alloy extrusion production, the recent studies are mainly about fundamental work because of its significance in understanding basic optimum design methods.

In 2012 Gbenebor et al investigated the influence of die parameters and materials on the microstructural evaluation of AA6063 aluminium alloy extruded at room temperature. Mild and tool steel dies of entry angles of 15° , 30° , 45° , 60° , 75° and 90° were applied to the extrusion test. The results demonstrate that maximum extrusion pressure increases with increasing die entry angle and in the case of 45° , 75° and 90° the billet deforms better with mild steel die than tool steel die[4].

At the same year Ahmed et al studied the direct extrusion behavior of pure aluminium and aluminium alloy 2014 by using conical dies with entry angles of 15° , 30° ,90° and billets with length of 20, 28, 40 and 52 mm in this experiment. The conclusions are as follows: 1. As the billet length increases the extrusion load increases due to the increase in direct contact area. 2. With the increase in entry angle the extrusion pressure increases as the above study because that the larger entry angle will cause the bigger dead metal zone[5].

Torsion extrusion

This process, as one kind of severe plastic deformation (SPD), is characterized by rotation of a die or a container during an extrusion process for introducing a very large strain into the metal.

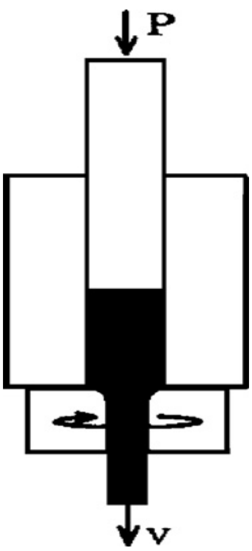

Fig.4. Torsion extrusion

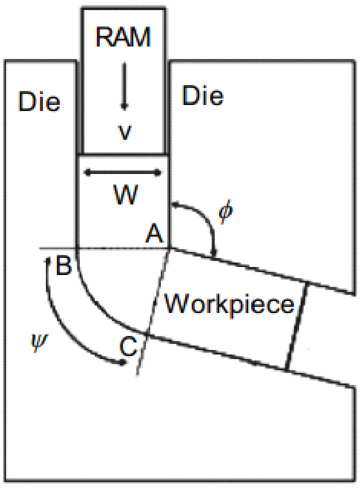

Fig.5. ECAE

Ali et al, in 2012, succeeded in performing torsion extrusion (TE) and forward extrusion (FE) processes on AA1050 alloy samples at room temperature. Finite element analysis was carried out by ABAQUS/Explicit to simulate the above experiment. The results show that the load requirement for TE process is lower than that for the FE process. The strain distribution for the TE sample at the final stage of extrusion shows smoother strain gradient in comparison with the one produced by FE process[6].

Equal channel angular extrusion

Equal channel angular extrusion (ECAE) or equal channel angular pressing (ECAP), as another kind of SPD method, is to impose pure shear deformation on materials so that an intense plastic strain is produced with the materials without any change in the section dimension of the workpiece.

In 2012 R Raj Mohan et al offered a brief summary of the effect of die geometry and processing route on aluminium alloys processed by ECAE. Various factors to influence the extrusion behavior are known as corner angle ψ and channel angle ϕ , as shown in fig.5. The study reveals that strain is more sensitive to the corner angle than the channel angle. The high strain of aluminium alloy billet is obtained with the channel angle close to 90° ,while the high reduction of grain size is achieved with the channel angle 60° . As the corner radius increases both the largest and uniform accumulative effective plastic strain decreases and the force required to press the workpiece also decreases[7].

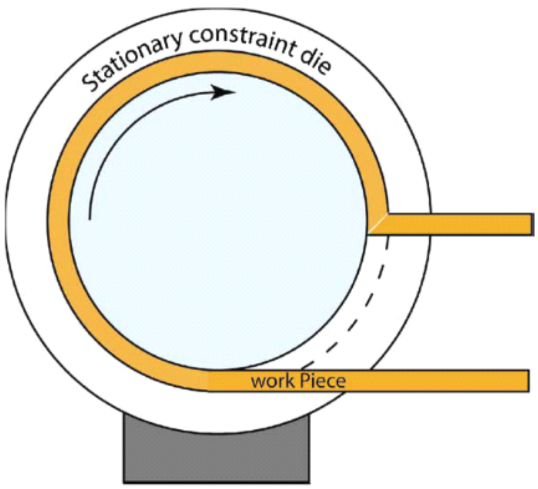

Fig. 6. Schematic illustration of ECAE-C

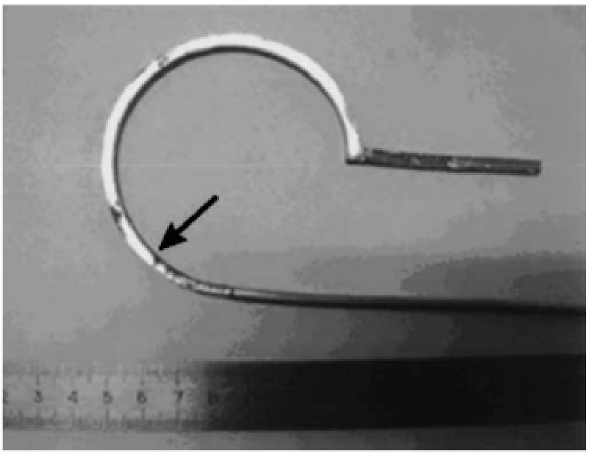

Fig. 7 Al workpiece produced by ECAE-C

To make ECAE more easier to commercialise Georgy J. Raab et al have developed equal channel angular extrusion conform (ECAE-C) to continuously produce ultra fine grained (UFG) materials. The preliminary experiments shows that ECAE-C could refine grains of coarse grained Al and improve its mechanical properties in a similar way to the conventional EACE. However the influence of the differences between ECAE-C and ECAE on the final product are still necessary to be further studied[8].

Conclusions and Outlook of aluminium alloy extrusion

In conventional aluminium alloy extrusion industry changing the production line seems impossible except substitutes can significantly reduce the production cost and lead time. So that companies and researchers rarely do the related work. What attracts more manufactures is to improve the present lines and develop various dies to satisfy the custom demands.

In our future research we should combine it with other new techniques to continuously inspire its energy. For example, nano-extrusion of aluminium alloy is more suitable due to its feasibility in laboratory and relatively low cost. So far, aluminium alloy nano-extrusion has attracted very few researchers to study because of its lower market profits and the weak support of fundamental techniques such as nano-battery and nano-dies. However when the aluminium alloy nano-extrusion succeeds, a large scale production of nano-parts will be realized to popularize the nano-products. What's more, the good deformability under room temperature of aluminium alloy makes nano-extrusion seem more feasible.

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