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The Effect of Geometrical Profile of Direct Extrusion Die on the Process Efficiency Using Visio Plasticity Method

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Abstract: In the current study, the effect of the geometrical profile of direct extrusion on metal flow was investigated. Pure aluminum (30 mm diameter, 60 mm length) was used. The 6 types of dies profile were used. The first die was with 36° while two dies were designed as convex on a theoretical basis (CCRHS and ACRHS), three dies were designed as concave on a theoretical basis (DCRHS, UCRHS and CMSR). The experimental results showed, the higher value of the efficiency of the metal flow was given by the die CCRHS which was 84% while the lower value was 50% for the die UCRHS.

Key words: Extrusion process, efficiency, types of dies, pure aluminum, value, metal

INTRODUCTION

The research metal in which forced forward a die opening to shape desired cross section is called direct extrusion process (Li *et al*., 2015). The extrusion die is the important part in the process, i.e., structure, propertied, shape and dimension, likewise the profile of the die is the same effect of the importance (Mahdi *et al*., 2015). The extrusion die tool is open forming cavity as shown in Fig. 1.

The metal flows due to the applied load or different forming operations are led to plastic deformation phenomena (Shkatulyak, 2014). The friction force between the metal and the wall of the die is affected on the efficiency of the current process, therefore, the metal flow in the center is faster than that in circumference (Ramnath *et al*., 2014). Many of factors is affected on the metal flow such as temperature interface friction and extrusion ratio. Figure 2 illustrates the patterns of metal flow.

Deformation zone is formed at metal extrusion process (De Barros Mesquita; *et al*., 2013). Dislocation intensity is relative lower amount in the metal before the process (homogeneous case). Therefore, dislocation intensity is higher amount in the metal after extrusion process (nonhomogeneous case) (Fang *et al*., 2009). Geometrical profile design is significantly affected upon the mechanical and physical properties of the extruded metal. In contrast, it can be classified the forming process to two parts (homogeneous and nonhomogeneous) (Khan *et al*., 2014). The following equations present about homogeneous strain:

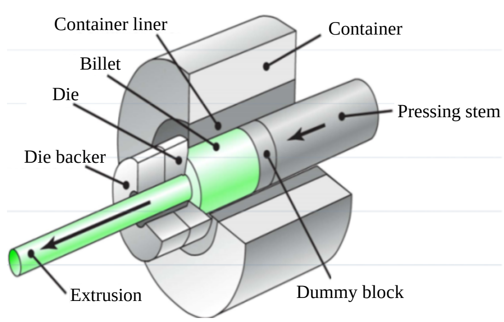

Fig. 1: Extrusion die parts

$$d\in H = \sqrt{\frac{}{3}}\; d\in \; - d\in \quad + \; d\in \; - d\in \quad + \tag{1}$$

$$d\in \; - d\in$$

$$d\in \; + d\in \; + d\in \; = 0$$

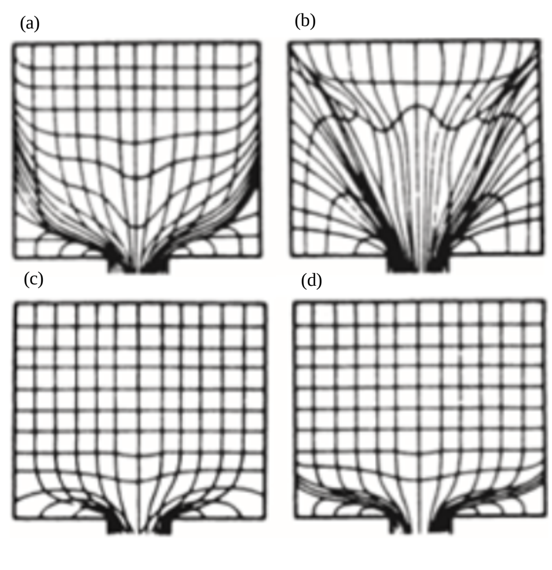

Fig. 2: a-d) Patterns of metal flow

$$\in_x + \in_y + \in_z = 0 \quad (2)$$

Then, the final equation for homogeneous strain as following:

$$\in H = \sqrt{\frac{2}{3}}\left(\in_x{}^2 + \in_y{}^2 + \in_Z{}^2\right)^{\frac{1}{2}} \quad (3)$$

The forming process is adopted on volume constant concept, therefore, the length strain is significantly affected with assuming constant volume (Ab Rahim *et al*., 2016). The following equations present about nonhomogeneous strain:

$$D\in_1 = \frac{dA}{A} \quad (3)$$

$$\in_1 = 2\text{In}\frac{r_o}{r_i} \quad (4)$$

$$\in_r = \in_c = \text{In}\frac{r_o}{r_i} \quad (5)$$

It can be concluded the total strain as shown in Eq. 6:

$$\in_T = \sqrt{\frac{2}{3}}\left[\frac{3}{2}\in H^2 + \frac{1}{2}\left(\in_1{}^2 + \in_r{}^2 + \in_C{}^2\right)\right]^{\frac{1}{2}} \quad (6)$$

Redundancy strain factor ϕ can be resulted by divide total strain over homogeneous strain as following:

$$\varnothing = \frac{\in_T}{\in_H} \quad (7)$$

The efficiency of the extrusion process η can be gotten as following:

$$\eta = \frac{1}{\varnothing} \quad (8)$$

MATERIALS AND METHODS

Material: Pure aluminum generally has good machinability, low density and high corrosion resistance. Strength to weight ratio is significantly high. Therefore, it has been used in aircraft parts, automobile (Gharde and Inamdar, 2015). Pure aluminum has specific gravity 2.71 g/cm^3, hardness 28 HB. The chemical composition of pure aluminum is shown in Table 1.

Extrusion process: There are many of extrusion process types according to direction or temperature (Bingo and Keskin, 2007). In the current research, direct extrusion process was done at room temperature. The 30 cm was the outside diameter for container and 30 mm was the inside diameter. The height for the container was 20 cm. The extrusion process was performed by hydraulic press with 100 tons maximum load. The height and diameter of the die were 50 and 60 mm, respectively. The 6 types of specimens were used. The first was 36° as die angle. Two types of the dies were convex on the theoretical basis (CCRHS, ACRHS). Three types of the dies were concave on the theoretical basis (DCRHS, UCRHS and CMSR). Figure 3 shows the profile for each die. Figure 4 illustrates the specimen dimensions.

Table 1: Chemical composition of the used metal (pure Al)

Elements	Experimental values
Si	0.280
Fe	0.380
Cu	0.060
Mn	0.065
Mg	0.060
Zn	0.055
Ti	0.035
Al	Rem

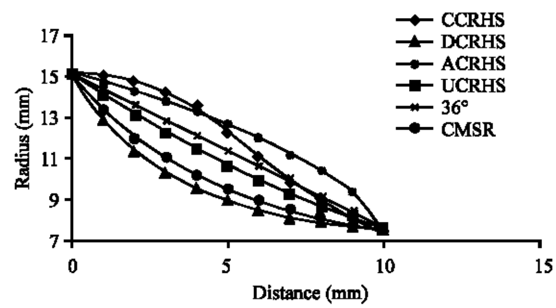

Fig. 3: Profile for the dies

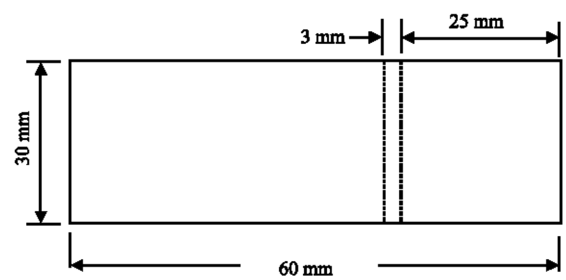

Fig. 4: Specimen dimensions

The 6 specimens were tested with a different die shape. All specimens were machined to appear the inside wire, the inside wire was given the details of the metal flow. Figure 5 shows metal flow patterns of the used dies. Table 2 illustrates the results of the dies.

Figure 6 illustrates the values of process efficiency and the load for the used dies. It can be seen, the maximum efficiency of the process was gotten of the die

Table 2: Results of the dies

Variables	A = 36°	CCRHS	ACRHS	DCRHS	UCRHS	CMSR
Spe. dimensions before extrusion	30*60	30*60	30*60	30*60	30*60	30*60
Spe. dimensions (D.)	30	30	30	30	30	30
after extrusion	15	15	15	15	15	15
Reduction (%) (Di)	75	75	75	75	75	75
Max.load KN	26.5	29.5	22	40	30	30
α	16.7	33	20.5	14	13.7	26
ϵ_L	3.33	1.538	2.667	4.001	4.083	2
ϵ_H	1.385	1.385	1.385	1.385	1.385	1.385
ϵ_L	2.369	1.644	2.07	2.692	2.733	1.802
$\varnothing$	1.71	1.187	1.494	1.843	1.972	1.301
η (%)	58	84	66	51	50	76

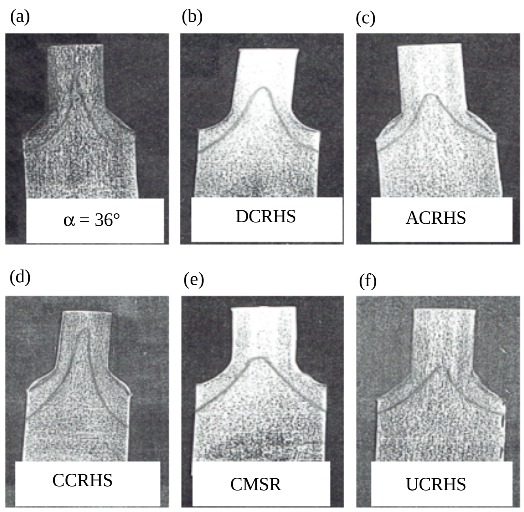

Fig. 5: Metal flow patterns; a) α = 36°; b) DCRHS; c) ACRHS; d) CCRHS; e) CMSR and f) UCRHS

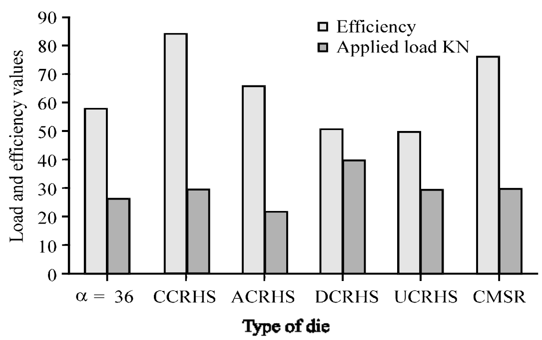

Fig. 6: Load and efficiency values of the dies

CCRHS which was 84% while the minimum value of the efficiency was 50% of the die UCRHS. The load is related factor with the efficiency. Therefore, it can be seen that the load value is reasonable value compare with the others. The ratio between the efficiency to the load is the highest, therefore, the die CCRHS is the best. Figure 7 explains the relation between the angle α and the metal flow efficiency. It can be seen, the efficiency increased with increasing shear strain angle. On the other hand while the metal flow increasing, the angle was increased.

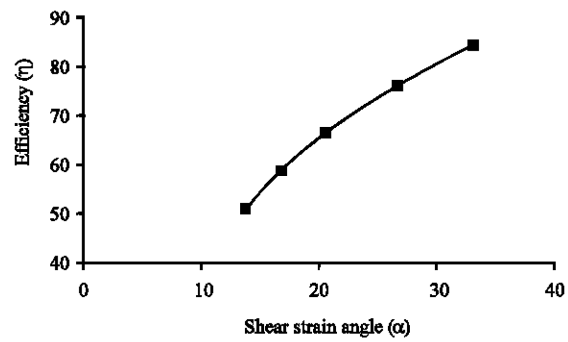

Fig. 7: Relation between the angle α and the metal flow efficiency

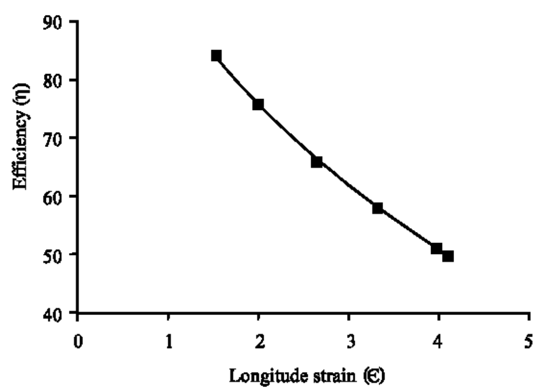

Fig. 8: Relation between longitude strain and the metal flow efficiency

Figure 8 appears the relation between nonhomogeneous longitude strain and the metal flow efficiency. When nonhomogeneous longitude strain increased, the metal flow efficiency decreased. These results attributed to the relation between the angle and strain ($\epsilon_l = \cot\alpha$). Figure 9 shows the relation between redundant strain factor and metal flow efficiency. When the redundant strain factor increased, the metal flow efficiency decreased. These results attributed to the type of die and the contact surfaces of the die.

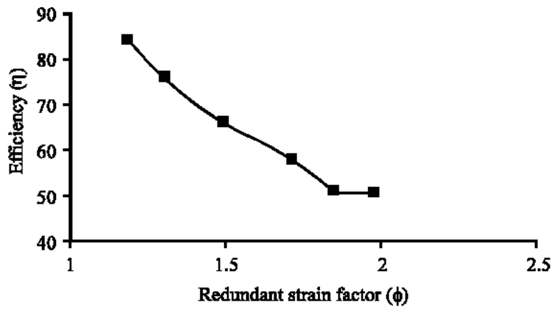

Fig. 9: Relation between redundant strain factor and metal flow efficiency

CONCLUSION

The current research reveals the relation between the type of extrusion die and the efficiency of the process. By the results, CCRHS die was given higher value of metal flow efficiency. Also, applied load was less value of the same die. Therefore, CCRHS was the best die. On the other hand when shear strain angle α was increased, the metal flow efficiency increased. Finally, when the total strain decreased, the metal flow efficiency increased.

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