Effect of Punch Diameters on Shear Extrusion of 6063 Aluminium Alloy

Mutiu F Erinosho[1], Saheed O Ojo[2], Joseph S Ajiboye[3], Esther T Akinlabi[4]

Abstract—This paper reports the effect of punch diameters on the shear extrusion of 6063 Aluminium alloy. During the shear extrusion process, Aluminium billets of considerable diameter 30 mm and height 25 mm were inserted in a die hole and different punches of diameter 12 mm, 14 mm, 16 mm and 18 mm respectively were allowed to come in contact to perform the shear operation. The setup took place under a hydraulic press with maximum capacity of 600 kN. This work is aimed at studying the selection of the optimum punch diameter for shear extrusion using local groundnut oil as the lubricant. Different extrusion pressures were measured and the punch with a diameter of 18 mm gives the highest load of 77.7 kN while the punch with a diameter of 12 mm gives the lowest load of 51.2 kN. An indication shows that, an increase in the punch diameters led to an increase in the height of the extrudates and this in turn reduces the stress induced.

Keywords— 6063Aluminium alloy, die, extrudates, press, punch

I. Introduction

6063 ALUMINIUM alloy is a solid solution strengthened material and its alloying elements may reduce the rate of recovery by impeding dislocations glide and retarding their movement to achieve a relatively homogeneous ultra-fine microstructure [1]. Basically, the shear extrusion theory was derived from the combination of backward cup and forward rod extrusion theory. The extrusion force in shear extrusion method of severe plastic deformation for fabrication of metal shapes with ultra-fine structures is far lower than that of simple forward rod extrusion or backward cup extrusion. This severe plastic deformation has been used to improve a unique combination of high strength and ductility [2]. The process involves a shearing deformation during the metal forming process. Further works on continuous deformation process have revealed that the process can also be used as a novel texture control and microstructure control method for long coiled strips by introducing shear textures in addition to its capacity of being highly productive [3]. The mechanics of plastic deformation provide the means for determining how the metal flows in different forming operations and to obtain the desired geometry through plastic deformation; and also the means for determining the expected mechanical and physical properties of the metal produced [4]. The principal magnitude of the maximum load is required to give 6063 Aluminium alloy a maximum displacement during extrusion which made it possible for paramount plastic deformation. The travel of a punch during deformation by extrusion process also depends on the magnitude of the maximum pressure and the geometry of the die coupled with the intergral properties of the billet [5]. The extrusion load increases with the shape ratio of a billet; and the forward and backward extruded lengths can be predicted from the diameter, height and flow stress of a billet [6]. The pressure forces applied during extrusion process are smaller in the case of combined extrusion than the forming extrusion products in two technological operations which are the cylindrical part of the product (forward-extruded) and the sleeve part (backward-extruded) [7]. It is important to streamline the flow of material from the inlet to the exit, and as a practical measure to fine tune the flow balance and product dimensions, flow adjustment devices could be included in the die design [8]. Extrusion is used for the processing of Al alloy for shape forming, consolidation, and rearrangement of reinforcements. It was reported that extrusion speed does not change the hardness of aged and non-aged samples in a greater way and the hardness values obtained for the samples increased with the aging effect due to the precipitation hardening [9]. The heat treatment of 6063 cold-drawn Aluminium tubes were characterized for yield strength, ultimate tensile strength, and fracture elongation during aging. It was revealed that the result shows an increase in the properties; and at maximum the properties decreased due to over-aging [10].

This research work is aimed at unveiling the potentials in shear extrusion process in terms of reduction in the extrusion pressure and the production cost, improved structure refinement of the product and high productivity.

Mutiu F. Erinosho is a doctorate candidate in the Department of Mechanical Engineering Science, University of Johannesburg, Auckland Park Kingsway Campus, Johannesburg, South Africa, 2006. (Phone- +27747425924; E-mail: mferinosho@uj.ac.za).

Saheed O Ojo is a doctorate fellow in the Department of Structural, Geotechnical and Building Engineering, Politecnico di Torino, 3.so Duca degli Abruzzi 24, 10129 Torino, Italy. (E-mail: d031290@polito.it).

Joseph S Ajiboye is a Senior Lecturer in the Department of Mechanical Engineering Science, University of Lagos, Akoka, Nigeria. (E-mail: joeajiboye@hotmail.com).

Esther T. Akinlabi is an Associate Professor in the Department of Mechanical Engineering Science, University of Johannesburg, Auckland Park Kingsway Campus, Johannesburg, South Africa, 2006. (E-mail: etakinlabi@uj.ac.za).

II. Materials and Method

A. Equipment Design

This relates to the considerations in the choice of equipment and tooling needed for the experiment to be conducted successfully. It involves the design of the extrusion die, punch design, selection of the press, and the design of the fixture and other accessories. The material used for the extrusion is an Aluminium-6063 alloys which was obtained at the Tower Aluminium Industry, Sango Ota, Nigeria. Table I depicts the chemical composition of the Aluminium-6063 alloys. Local groundnut oil was used as the lubricant due to its availability and low cost effective.

TABLE I
Chemical composition of 6063 aluminium alloy

Alloying Element	Composition (%)	Alloying Element	Composition (%)
Si	0.518	Sn	0.007
Fe	0.251	Pb	0.000
Cu	0.007	Zn	0.100
Mn	0.006	Ti	0.013
Mg	0.521	Al	98.62

B. Die Design

The dies and tooling used in this research work was designed to withstand considerable amount of high stresses. This assembly was designed for easy replacement of punches of varying sizes. The die stack consists of the die body, die shoe and the punch plate. The die was constructed as a flat faced die in order to allow metal upon entering the die to shear internally to form its own die angle. A parallel land on the exit side of the die helps to strengthen the die and allows for reworking of the flat face on the entrance side of the die without increasing the exit diameter.

C. Punch Design

The maximum allowable punch length, L_m is calculated using the formula

$$L_m = \frac{\pi D}{8}\left[\frac{ED}{f_s t}\right]^{\frac{1}{2}} \quad (1)$$

Where D = diameter of punch, *mm,* f_s = shear stress, *MPa*, t = material thickness, *mm*, E= modulus of elasticity of punch material, *N/mm^2* and D/t= 1.1 or higher

Using the formula in equation (1) for a punch made of high carbon steel material,
f_s= 758.3 MPa, E= 203.4 $\times 10^9$ N/mm^2, D = 12 mm, 14 mm, 16 mm, and 18 mm respectively.
The maximum punch length, L_m for the various punch diameters is obtained thus, L_m (12 mm) = 81 mm; L_m (14 mm) = 94 mm; L_m (16 mm) = 107 mm; and L_m (18 mm) =120 mm.

Therefore, in order to ensure that the punch is of proper strength that can withstand deflection forces, a punch length of 60 mm was selected for the design.
Fig. 1 shows the punches of different diameters (12 mm, 14 mm, 16 mm, and 18 mm) with a punch land of 3.0 mm.

Fig. 1 Punches with different diameters

The extrusions were conducted with a vertical hydraulic press of 600 kN capacity. A constant extrusion speed was maintained for all the punches. The vertical press was selected due to its advantages of easier alignment between the press ram and the tools.

III. Result and Discussion

A. Extrudates

Figs. 2 a-d show the extrudates of the 6063 Aluminium alloy billet after undergoing the extrusion process with the punch diameters of 12 mm, 14 mm, 16 mm, and 18 mm respectively.

From Fig. 2, there is an indication that an increase in punch diameters lead to an increase in the height of the extrudates. The heights of the extrudates are 2.5 mm, 4.8 mm, 7.4 mm and 10.2 mm respectively. The depth initiated by the punches was also observed. The smaller the punch diameter, the deeper the depth formed on the extrudate and this can be attributed to the small surface area in contact with the specimen. The removal of the punch within the aluminium billet is assisted with the lubricant used. The deformation spreads towards the rear end and the periphery of the billet and the flow becomes more significant leading to an expansion of the deformation zone [11].

.

ISBN: 978-988-14047-0-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

(a) (b)

(c) (d)

Fig. 2 Extrudates formed with different punch diameters (a) 12 mm punch diameter; (b) 14 mm punch diameter; (c) 16 mm punch diameter; (d) 18 mm punch diameter

Fig. 3 shows the graphical representation of the load (kN) applied against the travel of ram or the ram displacement (mm) for the punch diameters of 12 mm, 14 mm, 16 mm and 18 mm respectively.

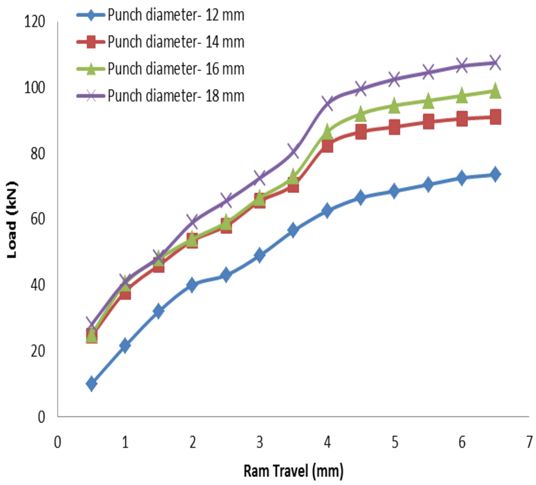

Fig. 3 Graphical representation of extrusion load versus ram displacement during shear extrusion of AA 6063 at different punch diameters

The graph shows an increasing load with increasing ram displacement. That is, the higher the load applied, the higher the displacement of the ram. The load obtained for the punch diameter of 18 mm was the highest as compared to other punch diameters. Relating this phenomenon to the Fig. 2d with the height of the extrudate formed, it can be deduced that the force applied on the billet was high.

IV. Conclusion

Shear extrusion process has been one of the approaches for plastic deformation. The mechanics of plastic deformation determine the flow behavior of materials with the desired geometry.

Based on the results obtained, an indication shows that the largest diameter punch (18 mm) gives the lowest stress level due to the large contact area spread on the surface of the billet. This punch gives the lowest yield stress, thus causing the material to deform easily and can be referred to as the optimum since it was able to withstand a high load without deflection while the small punch of 12 mm was considered not appropriate for the operation since it deflected on high load.

References

[1] H. Zendehdel and A. Hassani, Influence of twist extrusion process on microstructure and mechanical properties of 6063 aluminum alloy, Materials and Design, vol. 37, pp 13-18 (2012).

[2] S. A. A Akbari Mousavi, A. R Shahab and M. Mastoori, Computational study of Ti–6Al–4V flow behaviors during the twist extrusion process, Material and Design, vol. 29, pp 1316-1329 (2008).

[3] H. Utsunomiya, Y. Saito, and H. Suzuki Sakai, Development of the continous shear deformation process, Department of Materials Science and Engineering, Graduate School of Engineering, Osaka University, Japan, (2001).

[4] P.K Saha , Aluminium extrusion technology, ASM International, Ohio, (2000).

[5] O.P. Gbenebor , O.S.I. Fayomi , A.P.I. Popoola , A.O. Inegbenebor and F. Oyawale, Extrusion die geometry effects on the energy absorbing properties and deformation response of 6063-type Al–Mg–Si aluminum alloy, Results in Physics vol. 3, pp 1–6 (2013).

[6] E. Murai, M. Ono, Y. Tozawa, Y. Sawai , T. Kojima and S. Hamaya, Effect of shape ratio of billet on extruded length and extrusion load in forward can-backward can combined extrusion forging, Japan Society for Technology of Plasticity, vol. 50 No 584, (2009).

[7] P. Thomas and J. Chalupczak, Experimental research into forward and backward combined extrusion pressure forces for sleeve cylindrical aluminium products, University of Technology Kielce, (2006).

[8] M. Kostic and L. Reifschneider, Design of extrusion dies, Department of Mechanical Engineering, Northern Illinois University, Delkab, Illinois, USA, Department of Technology, Illinois State University, Illinois, USA, (2007).

[9] A. Aytac, B. Dascılar and M. Usta, The effect of extrusion speed on the structure and corrosion properties of aged and non-aged 6063 aluminum alloy, Materials Chemistry and Physics, vol. 130 pp 1357–1360 (2011).

[10] J.-P. Bourget , M. Fafard, H.R. Shakeri and T. Côté, Optimization of heat treatment in cold-drawn 6063 aluminium tubes, Journal of Materials Processing Technology vol. 209, pp 5035–5041 (2009).

[11] J. Zhou, L. Li and J. Duszczyk, 3D FEM simulation of the whole cycle of Aluminium extrusion throughout the transient state and the steady state using the updated Lagrangian approach, Journal of Materials processing Technology vol. 134, pp 383-397 (2003).

ISBN: 978-988-14047-0-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)