Investigation into the Effect of Die Angle in Extrusion on Properties of Nano Sic Reinforced 6061 Aluminum Alloy

Ambati Vijay Kumar,[1] Chalamalasetti Srinivasa Rao[2] and Damera Nageswara Rao[3]

1. Associate Professor, Department of Mechanical Engineering, Raghu Engineering College, Visakhapatnam, India
2. Professor, Department of Mechanical Engineering, Andhra University, Visakhapatnam, India
3. Vice Chancellor, Centurion University, India

Abstract*; An experimental investigation was made to determine the effect of die angle on the properties of the extruded product, i.e. surface finish and hardness on cold extruded Nano Sic reinforced aluminum alloy. These results are compared with cold extruded 6060 aluminum alloy. The die angles considered are 12^o,15^o and 25^o. The extrusion load found to decrease with the increase in die angle, 25^o die angle has shown least resistance against extrusion compared with other two die angles in both experiments. Higher hardness values were observed and surface roughness also increased with the increase in die angles. Nano Sic Aluminum alloy has shown better properties in comparison with 6061 Aluminum alloy.*

Keywords-Forward extrusion, surface finish, hardness, AA6061, Nano Sic.

1. Introduction

1.1 Extrusion:

Extrusion process is one of the most important metal forming process due to its high productivity, low cost and increased physical properties. In recent years extrusion process is widely used in manufacture of components which are used in the aviation and machine areas in the area of aeronautics, astronautics and mechanical manufacture [1,2]. If the product can't be shaped in a single operation it may be performed in several stages [3]. The punches and dies used in cold extrusion are subjected to severe working conditions and are made of wear resistant tool steel e.g. high chromium steels. Extrusion produces compressive and shear forces in the stock. No tensile force is produced, which make high deformation possible without tearing the metal.

On examination of the extrusion load as a function of die land length, it is evident that the extrusion force required increased as the die land increased [4].

Geometrical characteristics of the extrusion die influence both the extrusion process and the mechanical properties of the extruded product. Experimental investigations have made to achieve the effect of die reduction ratio, die angle & loading rate on the quality of cold extruded parts, extrusion pressures & flow patterns for both lead and aluminum [5]. Previous research has shown that extrusion die design, frictional conditions at the die billet interface and thermal gradients within the billet greatly influence metal flow in cold extrusion [6].

The ability of crystalline material, particularly metals, to change plastic deformation rather than fracture is an invaluable property. Extruded and deformed products have undergone plastic deformation & this deformation increases their mechanical properties can only be relieved by an appropriate heat treatment process [7].

1.2 Nano composites:

Metal matrix composites (MMCs) are engineering materials in which a hard ceramic component is dispersed in a ductile metal matrix in order to obtain characteristics that are superior to those of conventional monolithic metallic alloys [8-12]. Among these materials, aluminum based metal matrix composites (MMCs) are appropriate materials for structural applications in the aircraft and automotive industries because they are lightweight and have a high strength-to weight ratio [13-19]. Uniform dispersion of the fine reinforcements and a fine-grained matrix improve the mechanical properties of the composite. Incorporation of ceramic particulates into the metallic matrix can be accomplished by several techniques, such as molten-metal routes or solid-state processing [20, 21]. Factors such as density, wettability and chemical reactivity of a matrix at high temperatures are considered for the selection of reinforcement particles. The best combination of reinforcement with the alloy matrix is critical for obtaining better properties. The different particles for reinforcement include alumina, Boron Graphite, Boron carbide, Boron nitride, The billet for second experiment which is a metal matrix nano composite(MMNC) was fabricated with an equipment consisting of melting furnace, ultrasonic transducer probe, temperature controller and inert gas protection nozzles for uniform distribution of nano composite. Nano SiC of 0.1% by wt is reinforced to the AA6061 and cast in a Silicon carbide, Carbon nano tubes, etc.,Silicon carbide is a popular reinforcement because of its relatively good wettability to Aluminum alloys and nearly identical to aluminum alloys.

2. Present Investigation:

An experimental investigation was undertaken to determine experimentally the effect of die angles on the surface finish and hardness of cold extrusion of aluminum AA 6061 and SiC reinforced AA6061. Experiments were conducted on the 100 Ton computerized compression testing machine using three different die with 12^o,15^o and 25^o die angles. The lubricant used for the experiment is graphite suspensions in grease

3. Experimental Research:

3.1. Billet Preparation

The billets considered for the experimentation are of initial diameter 25 & height 37.5 mm respectively In order to eliminate the problem of buckling of the billet, the height to diameter ratio is kept at 1.5 for all the cases. AA 6061 billet has a chemical composition as presented in table1.

die. The billets were subjected to annealing treatment to eliminate any residual stresses present prior to extrusion. This consists of heating the billets to 300^o in a muffle furnace soaking at this temperature for 15 min. followed by gradually cooling in air to room temperature

Table 1. Chemical composition of AA6061 by wt%-Base material

Alloy	Al	Mg	Si	Fe	Cu	Mn	Cr	Ti
AA6061	97.768	0.825	0.711	0.342	0.152	0.023	0.017	0.083

3.2 Extrusion Tool Design:

An extrusion tool designed for the analysis consists of mainly three parts the punch, container and die. The dies are designed in accordance with K.Geethalakshmi [22]. Container and die are made integral as in Figure 1. Three dies are made with included angles of 12^o,15^o and 25^o . The die is made of high carbon high chromium steel. The die is heat treated to increase hardness and finished.

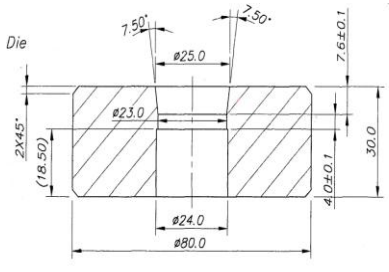

Figure 1

4. Experimentation:

4.1 Experimental Description and Procedure:

Extrusion tests were conducted on a 100 Ton computerized compression testing machine. at a loading rate of 2.6 mm/min [23] with constant extrusion strain of 0.28 for all the considered die angles. Loads were taken at every 1mm movement of ram.

4.2 Surface Finish and Quality Of The Products:

The dimensional accuracy of the products were checked with vernier caliper so as to compare with the dimensions of the die. The surface roughness was measured along the longitudinal direction at four different places of the extrude using a Talysurf.

4.3 Hardness:

Hardness measurement of extruded products were carried out on a Brinell hardness tester at a gap of 2 mm at four locations on the surface in extruded direction.

5. Results and Discussion:

5.1 Extrusion Load Versus Dispalcement Curve:

Figure 2 shows the load versus displacement curve for aluminum alloy 6061 with graphite suspended grease as lubricant

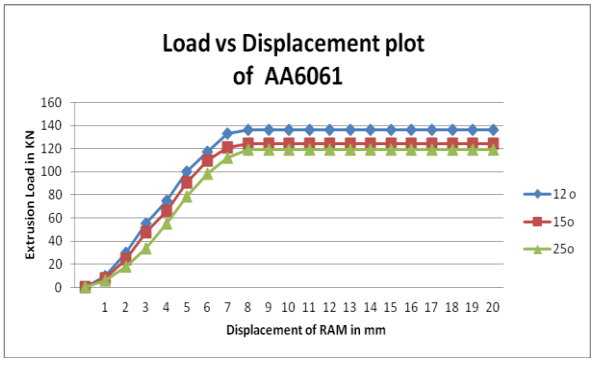

Figure 2

Figure 3 shows the load versus displacement curve for 0.1% SiC reinforced aluminum alloy 6061 with graphite as lubricant

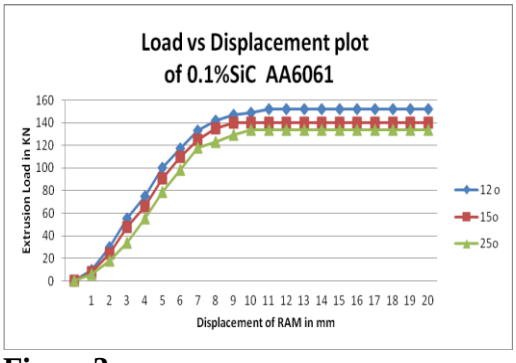

Figure3

The average load at steady stage is considered as extrusion load. Table 2 consisting of consolidated load vs dispalcement data. Results show that for both materials as the die angle dicreases from 25^o to 12^o the load required for extrusion increases. This is due the increase in contact area between the die and the billet, this the reason for higher frictional power loss.

The inclusion of nano Sic increases supeior property the sterngth of the material requiring more load for extrusion.

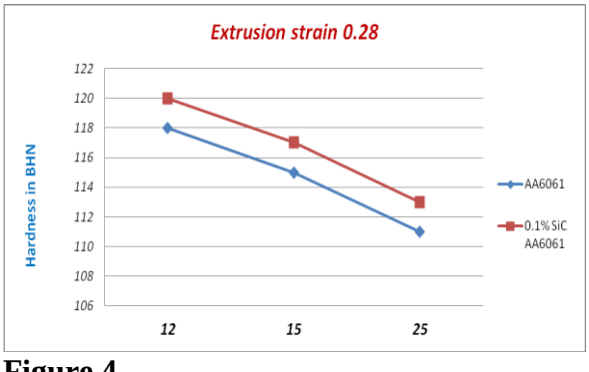

Figure 4

Table 2

Material	Die angle in Degrees	Extrusion Load in KN
Aluminum AA6061	12	136
	15	124
	25	119
0.1%SiC reinforced AA6061	12	152
	15	140
	25	134

5.2 Hardness Of The Extruded Product:

Figure 4 shows the change in hardness of both materials with the change in die angles. The results show that as the die angle is dicreasing there is an increase in hardness of the materials. This is due to more strain hardening. Considering the fact that Nano Sic impregnated Alloys increase the mechanical strength of the matrix by more effectively promoting particle hardening mechanism than micron size particles requires much higher extrusion load which inturn increses th strain hardening of the material finally the hardness.

5.3 Surface Finish Of The Extrude:

Figure 5 shows the change in Surface roughness with increase in die angle of two materials. It has shown that the surface smoothness has increased moderately for the extrusion of MMNC when compared with Aluminum as they provide better bonding of th material .The surface finish has not much effect on the die angle variation as coefficient of firction remains constant for a particular lubricant.

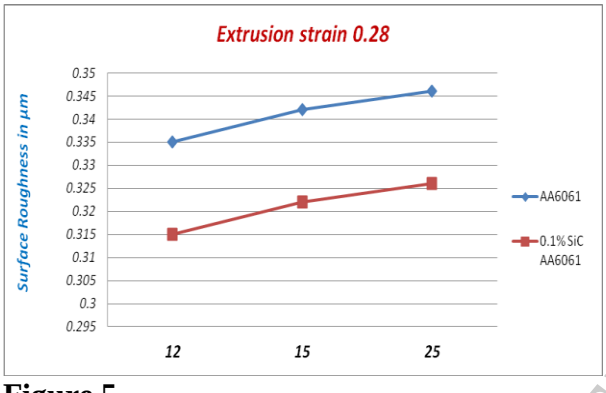

Figure 5

6. Conclusion:

During the experiment effect of die angle on surface finish, Hardness and Load of extrusion on AA6061 and Nano SiC reinforced AA6061 have been studied

- It is found that load required to deform billet in extrusion at 12^o is higher when compared to 15^o and 25^o die angles
- The extrusion load required to deform SiC AA 6061 is higher than the AA6061
- It shows no considerable variation in surface finish with variation in die angle.
- There is a moderate increase in surface finish of a Nano SiC in comparison to Aluminum alloy
- The average hardness values at 12^o die angle is higher than that at 15^o and 25^o die angles
- The Hardness of Nano SiC AA6061 is much higher than AA6061.

7. Future Scope:

There is further scope to get more precise results by considering more die angles with different lubricants and with different MMNCs reinforced aluminum. This work can be extended by using different Extrusion strains as well as varying loading rate, to some ferrous extrudable material.

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