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RESEARCH ARTICLE

INFLUENCE OF AREA REDUCTION ON FRICTION BY EXTRUSION PROCESS

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ABSTRACT

The goal of the present paper is to find friction between die and work piece. In this work, aluminum 6061 alloy with 5% volume fraction of Sic particle used. Al/SiC composites were produced by stir casting process. Extrusion die were used in three reduction ratios as (Inlet diameter: Outlet diameter) of 12:2, 8:4 and 4:2. Specimens were extruded at 300^{0}C and constant strain rate of 0.002/Sec. Friction values to be determined in three dies and size effect to be studied. Extruded specimens Hardness, surface roughness and microstructure were compared with as cast specimens.

INTRODUCTION

The friction phenomena are considered to be one of the most essential topics for the metal forming process [1]. The evaluation of friction is a complex matter, which depends on both material and interface local conditions, such as temperature, strain, strain rate, flow stress, normal pressure and surface roughness [2]. Reliable data of forming force and deformation work can be obtained only if the frictional Conditions on the active surfaces of the subsystem "component surface/tool surface" are determined by experimentally obtained values of frictional forces and by the partial coefficients of friction of the metal forming process [3]. The recent trend towards miniaturization of products and technology has produced a strong demand, when scaling down a component from conventional to micro level the grain size of the microstructure changes and also the friction factor value will change [4]. When a forming process is scaled down to micro dimensions, the microstructure of the work piece, the surface topology of the work piece and that of the tooling remain unchanged. The material of the work piece cannot be considered as a continuum due to the large share of volume occupied by an individual grain. Thus, the micro forming process imitations are largely influenced by the work piece dimensions and this is commonly referred to as the size effect [5]. In this paper Al/SiC 5% Composites were extruded at 300^{0}C and constant strain rate of 1 (Sec^{-1}). Hardness, surface roughness of the specimens was compared with as machined components and friction factor to be calculated.

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Experimental work

Experimental Procedure & Materials used

Composites were prepared by Stir Casting process, SiC 5 % Volume fraction with Aluminum 6061 alloy. Specimens were machined into the required size of 12, 8 and 4 mm diameters and 10, 15 mm lengths. Die and punch was made of Oil Hardened Non-shrinking Steel (OHNS). Dimensions of three extrusion die as shown in figures (1-3). Graphite used as lubricant and applied inside the die and outside the punch. Extrusion was performed at 300^{0}C Temperature and Strain rate of 0.002/sec. For every 0.5 mm billet movement corresponding load was noted and maximum load noted for each specimens. Once the die was filled that was the maximum load, further pressing load has been decreases.

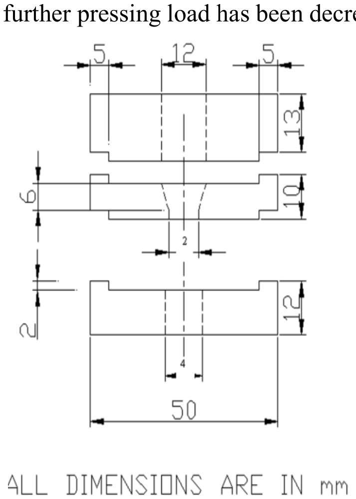

Figure 1. Extrusion Die (12:2)

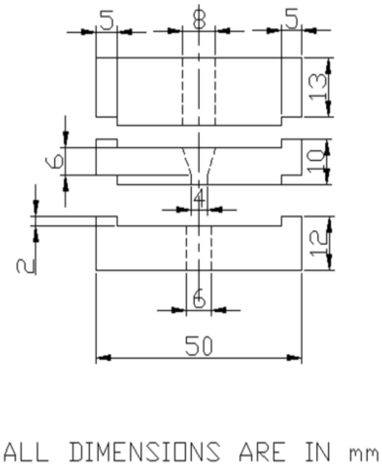

Figure 2. Extrusion Die (8:4)

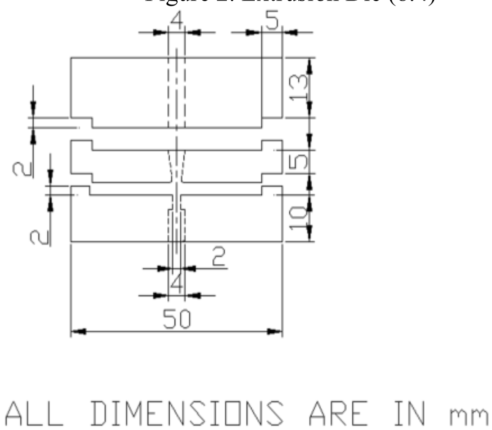

Figure 3. Extrusion Die (4:2)

Theoretical Analysis of Friction Factor

Figures (1-3) shows the schematic illustration of forward extrusion. The total extrusion force required to produce deformation is as follows [3]:

$F_T=F_d+F_c+F_e$ (1)

Where,
F_T – Total extrusion force in Newton,
F_c – Friction force between billet and container in Newton,
F_d – Force required to fill the die in Newton
F_e – Force required to form extruded pin in Newton
The total extrusion force can be written as

$F_{T1}=F_{d1}+F_{c1}+F_{e1}$ (2)

$F_{T2}=F_{d2}+F_{c2}+F_{e2}$ (3)

Equation 2 is for first sample and equation 3 is for second sample.

In forward extrusion the maximum load is reached as soon as the die is filled completely with the work piece material, so F_{d1} and F_{d2} are same. As the punch was moved by ΔL, then change in the punch load would be ΔF. Equation (2) subtracted with equation (3)

$$(F_{T1}- F_{T2}) = (F_{c1}- F_{c2}) + (F_{e1}- F_{e2}) \quad (4)$$
$$\Delta F = \tau\,[\pi d_c L_{c1}- \pi d_c L_{c2}] + \tau\,[\pi d_e L_{e1}- \pi d_e L_{e2}] \quad (5)$$

Where $F_{c1} = \tau\,[\pi d_c L_c]$ and $F_{e1} = \tau\,[\pi d_e L_e]$

$$\Delta F = m\,\frac{\sigma_o}{\sqrt{3}}\,[\pi d_c[\Delta L_c] + m\,\frac{\sigma_o}{\sqrt{3}}\,[\pi d_e[\Delta L_e] \quad (6)$$

Where $\tau = m\,\frac{\sigma_o}{\sqrt{3}}$

$$\Delta F = m\,\pi\,\frac{\sigma_o}{\sqrt{3}}\,[d_c\Delta L_c + d_e\Delta L_e] \quad (7)$$

Or

$$m= \frac{\sqrt{3}\Delta F}{(d_c\Delta L_c + d_e\Delta L_e)\sigma_o\pi} \quad (8)$$

The friction factor m can obtain by evaluating all parameters in this Equation (8).

m = Friction factor
ΔF = Difference in the punch load - N
σ_o = Flow stress – N/mm^2

RESULTS AND DISCUSSION

Friction factor

The maximum load corresponding to the billets of lengths 15 mm and 10 mm were 24 KN and 10.4 KN respectively. Difference between maximum load corresponding to billets of length of 33 and 25 mm is 24-10.4=13.6 KN (4:2). Similarly for 8:4 and 12:2 die were the change in load are 42 KN and 150 KN. The same was used to find out the friction factor for the corresponding die. For each die Lc, Le, ΔF and friction factor values tabulated in table 1.

Table 1. Load, Displacement Values and Friction Factor

Die (I:O) mm	Lc (mm)		Le (mm)		ΔF (KN)	Friction factor (m)
	L_{c1}	L_{c2}	L_{e1}	L_{e2}		
4:2	3.5	2.1	4.2	6.3	13.6	0.384
8:4	2.8	0.4	1.5	5.8	42	0.318
12:2	5.6	12	7.9	13	150	0.475

From table 1, friction factor of 4:2 die was 0.384, friction factor of 8:4 die was 0.318 and friction factor of 12:2 die was 0.475. Area reduction was more, friction factor value increased for 12:2 die. In 8:4 die friction factor value was 0.318 and in 4:2 die friction factor values was 0.384. 8:4 and 4:2 die has same 75 % area reduction but 4:2 die has more friction, Due to Size effect friction factor has more in 4:2 die compare with 8:4 die and also surface area to volume ratio has maximum for 4:2 die. From this for maximum reduction ratio die has high friction values.

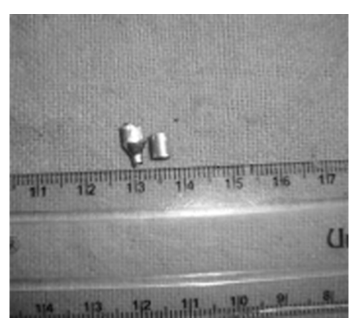

Figure 4. Extruded specimen (4:2)

Figure 5. Extruded specimen (8:4)

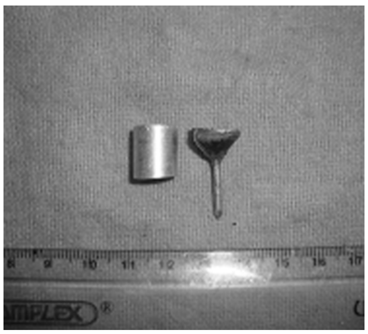

Figure 6. Extruded specimen (12:2)

Figure 4, figure 5 and figure 6 shows as machined specimen and extruded specimen of 4:2, 8:4 and 12:2 die. Biovis material software was used to capture microstructure. Extruded specimen has more uniform particle distribution as shown in Figure 9 as compared with Figure 7 (Micro structure of billet) and Figure 8 (Micro structure of die part).

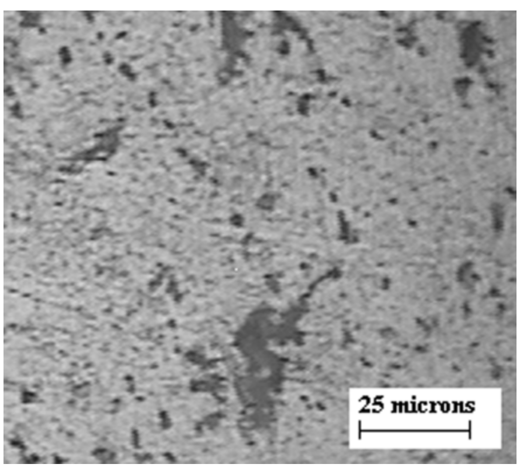

Figure 7: Micro structure of Billet

Hardness and Surface roughness

Hardness value of the extruded billet has less compare to as cast specimen and also die part has less hardness compare with container part. Extruded pin has less value compare to die part and container part, this value reduced due to blow holes are cured and material has soften due to thermal softening. Hardness was measured in micro vicar's hardness testing machine and the average hardness values of container, die part and extruded are 98, 91 and 84 VHN. Average surface rough of extruded specimen has 48 µm and machined specimen has 61 µm, from this extruded specimen has good surface finish.

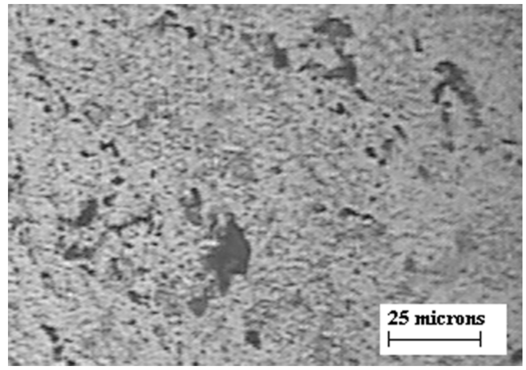

Figure 8: Micro Structure of Billet in Die Part

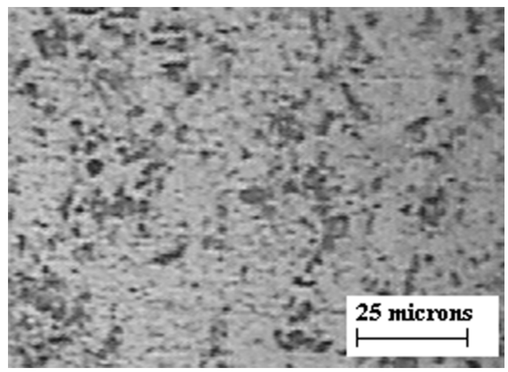

Figure 9: Micro Structure of Extruded Material

Conclusion

Al/SiC composites were extruded in three reductions Die 4:2, 8:4 and 12:2. Heating the billets flow stress of materials reduced and load required to deform was minimum. In 12:2 die has maximum friction factor, because of it has high reduction ratio, 4:2 die has 0.384 friction factor value and 8:4 die has 0.318 friction factor value. For high reduction area specimen has friction value high this is due to surface area to volume ratio of specimen has maximum for 12:2 die. From this friction values of size effects clearly understood. Extruded specimen has good surface roughness compared to stir casting specimens and improvements in particle distribution.

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