Lubrication Effect on Friction Factor of AA6063 in Forward Extrusion Process

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Abstract

Friction is a kind of response occurring during relative motion in extrusion process. When friction occurs between tool and work piece fractionize with each other, surface expansion and high normal pressure occurs even at elevated contact temperature between work piece and die, which leads to adhesions(cold-weld), abrasion of die and work material. To reduce the friction, it requires a suitable lubricant. In the present work lubricant like Graphite, Molybdenum disulphide (MoS₂) and Zinc stearate were tested in the extrusion process of AA6063 against Hot die steel (H13). The frictional factor has been determined for both un-lubricated and lubricated conditions. Experimental predicted values were compared with simulation © 2014 The Authors. Published by Elsevier Ltd.

Keywords: Extrusion; Lubricants; Friction factor; Aluminum alloy.

1. Introduction

Lubrication plays an important role in cold extrusion process since good lubricants prevent direct metallic contact, with the reduction of extrusion load and the improvement of product quality and tool life [1]. One of the major quality requirements of the lubricant is that it should adhere firmly to the surface of the deforming materials [2]. Good lubricant for metal forming process should possesses self-repairing properties, that is, the ability of the molecules to reorganize themselves into the original state after being mechanically disrupted during deformation [3]. The effectiveness of lubricants in metal forming process depends on variables namely die–punch system, work materials and the lubricant also the process variables interface pressure, sliding velocity, interface temperature [4].
Liquid lubricants are proved to be ineffective at high interfacial pressures, in such circumstances solid lubricants may be more effective if they have low shear strength. Also lubricants should wet the work material surface during the injection of the work material [5]. Graphite is effective in reducing the frictional forces by reducing the tangential force there by reduces specific energy [6]. The low friction and easy cleavage of molybdenum disulfide is intrinsic to the material and a result of its crystal structure [7]. Graphite is the most widely used as solid lubricant followed by MoS\textsubscript{2} [8]. In this research paper, the friction factor of AA6063 determined with Graphite, MoS\textsubscript{2}, Zinc stearate lubricants are studied. Experimental predicted values were compared with simulation.

Nomenclature

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>ΔF</td>
<td>Difference in extrusion load (kN)</td>
</tr>
<tr>
<td>ΔL</td>
<td>Difference in work piece length (mm)</td>
</tr>
<tr>
<td>D</td>
<td>Inlet diameter of work piece (mm)</td>
</tr>
<tr>
<td>σ</td>
<td>Flow stress of material (N/mm\textsuperscript{2})</td>
</tr>
<tr>
<td>L</td>
<td>Work piece length in the container (mm)</td>
</tr>
<tr>
<td>m</td>
<td>Friction factor</td>
</tr>
</tbody>
</table>

2. Experimental procedure

2.1 Materials and method

Extrusion die used in this work having reduction factor of 12:8 (Inlet diameter: Outlet diameter). The punch, container and die were made from Hot die steel (H13) hardened and tempered to a hardness of 48-52 (RHN). In the present study, AA6063 ingots (0.2% Si, 0.35% Fe, 0.1% Cu, 0.1% Mn, 0.45% Mg, 0.1% Ch and balance is Al) were used as a work piece with the dimension of 15 mm, 10 mm in length and 12 mm diameter. Extrusion has been performed on the work pieces with Graphite, MoS\textsubscript{2}, Zinc stearate lubricants. Friction factor ‘m’ is determined using equation (1).

2.2 Determination of Friction Factor

Friction factor ‘m’ is determined by Bakhshi-jooybari [10], in this work friction factor determined by the same formula. Two different lengths of 15 mm and 10 mm billets were extruded for 5 mm length. Friction factor determined by equation (1) by using the load difference, the length difference and flow stress. The friction factor can be written as,

Friction factor \( m = \frac{\sqrt{3} \Delta F}{\pi D \Delta L \sigma} \)  

(1)

3. Results and discussions

3.1 Experimental determination of friction factor

AA6063 was extruded in un-lubricated condition in 12:8 die. Initially, during forward extrusion the load gets peaked up in the container part. As the process is continued, the work piece length decreases in the container part and gets filled in the die part and in the follower. During this process, the total load keeps increasing until the die part and follower part gets filled by the work piece. Further movement of the work piece will result only in the saturation of die load \( (F_d) \) and follower load i.e the load becomes constant. Any additional movement in this stage will result in the reduction of total load, due to the gradual decrease in contact between the work piece and container. The extruded billet is shown in Figure 1. In Figure 2 (a), the load-displacement curve corresponding to AA6063 work piece of 15 mm and 10 mm length are shown in forward extrusion. The 15 mm work piece has maximum load of 47
kN at 5 mm movement in the container and for the same condition, 10 mm work piece has maximum load of 36.56 kN. The difference between the curves is because of variation in the length of the work pieces which leads to decrease in the friction force in the container. Initially the extrusion load increases suddenly up to A. The region AB shows the gradual increase in load as the die part is filled. BC shows the increase in load while the follower parts get filled. After point C, as the contact between the work piece and container decreases hence load decreases.

In Figure 2 (b), the load-displacement curve corresponding to AA6063 work piece of 15 mm and 10 mm length are shown in forward extrusion with graphite lubricant. The 15 mm work piece has maximum load of 44 kN at 5 mm movement in the container and for the same condition, 10 mm work piece has maximum load of 34.33 kN. In Figure 2 (c), the load-displacement curve corresponding to AA6063 work piece of 15 mm and 10 mm length are shown in forward extrusion with MoS₂ lubricant. The 15 mm work piece has maximum load of 45.09 kN at 5 mm movement in the container and for the same condition, 10 mm work piece has maximum load of 35.16 kN. In Figure 2 (d), the load-displacement curve corresponding to AA6063 work piece of 15 mm and 10 mm length are shown in forward extrusion with Zinc stearate lubricant. The 15 mm work piece has maximum load of 46.08 kN at 5 mm movement in the container and for the same condition, 10 mm work piece has maximum load of 35.76 kN.
Table 1: Experimental friction factor of various lubricant

<table>
<thead>
<tr>
<th>S.No</th>
<th>Lubricant</th>
<th>Load for 15 mm work piece (kN)</th>
<th>Load for 10 mm work piece (kN)</th>
<th>∆F (kN)</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Un-lubricated</td>
<td>47.00</td>
<td>37.56</td>
<td>9.44</td>
<td>0.84</td>
</tr>
<tr>
<td>2</td>
<td>Graphite</td>
<td>44.00</td>
<td>34.33</td>
<td>9.68</td>
<td>0.76</td>
</tr>
<tr>
<td>3</td>
<td>MoS$_2$</td>
<td>45.09</td>
<td>35.16</td>
<td>9.93</td>
<td>0.78</td>
</tr>
<tr>
<td>4</td>
<td>Zinc stearate</td>
<td>46.08</td>
<td>35.76</td>
<td>10.32</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Fig. 2: (a) Extrusion load Vs Displacement of AA6063 under Un-lubricated condition. (b) Extrusion load Vs Displacement of AA6063 under graphite Lubricant. (c) Extrusion load Vs Displacement of AA6063 under MoS$_2$ Lubricant. (d) Extrusion load Vs Displacement of AA6063 under Zinc stearate Lubricant.
From Table 1, it is seen that the value of friction factor ‘m’ of graphite is minimum (0.76) when compared to other lubricants. Hence extrusion load is minimised. This can be understood by the following literatures, Graphite possesses self-lubricating ability and that will reduce the friction factor [10]. Graphite will not lose its properties in the working temperature around 1000°C [11].

Figure 3 (a) – (d) shows the loading under the unlubricated, Graphite, MoS₂, zinc stearate condition. The peak value of 50.49 kN is obtained at 5 mm movement of the billet in the container, similarly the peak value for graphite, MoS₂ and zinc stearate are 47.59 kN, 48.53 and 49.1 kN respectively. It is observed that all the conditions the peak value at 5 mm billet movement in the container. The obtained experimental friction factor is given as input to the interaction module and material properties are given in the property module: the simulations values are obtained. Finally, the simulated peak values are compared with experimental conditions, error percentage is within 10 percentage.

4. Conclusion

The forward extrusion process was carried out on AA6063 with un-lubricated and lubricated with Graphite, MoS₂ and Zinc stearate. The performance of the lubricant was investigated and conclusions were made.
- The influence of lubricant on friction factor has been found, the value of the friction factor ‘m’ for graphite is minimum (0.76) when compared with MoS₂ (0.78) and Zinc stearate (0.81), hence extrusion load is minimized by the use of graphite.
- Comparisons were made for the experimental extrusion load with simulated extrusion load. It is found that for all conditions, experimental extrusion load is minimum, simulated extrusion load is maximum. The average error between the experimental with simulation is 8.4%.
- The close agreement between the simulation results confirms the validity of the extrusion for evaluating conditions.
References


