Correlation between contact load and surface roughness in plane strain extrusion

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Abstract

Effect of contact load and surface roughness on friction behavior in plane strain extrusion is one of the biggest phenomena in improving the sliding performance of cold forward extrusion. Wear resistance that commonly occurs on the plane requires an appropriate method to obtain the finest product surfaces. This paper highlighted is the correlation between contact load and surface roughness on the friction behavior and wear resistance of the sliding plane in the extrusion process. The analysis described in this paper involved the experiments to assess the contact load in the extrusion and the surface roughness. The experiments were set up by using pure aluminium A1100 as billet extruded between dies made of hot work tool steel (SKD11). Extrusion ratio of the process is three (3) and the billets were pressed by a hydraulic press machine. The contact load for each experiment was taken at a 20 mm length of the extrusion, and the average surface roughness of the aluminium was plotted on a graph. Three types of lubricants were used in this study: Refined Bleached Deodorized (RBD) palm stearin and two types of paraffinic mineral oil, 95 and 460. These two types of paraffinic mineral oil differed in viscosity. These three types of lubricants were run with four different quantities: 0.1 mg, 1 mg, 5 mg, and 20 mg. The results showed that an increased amount of lubricant reduced the surface roughness. The correlation between contact load and surface roughness showed significant differences for each lubricant while at 5 mg of RBD palm stearin and paraffinic mineral oil 460, the results showed the same contact load but different surface roughness.

Keywords: Surface Roughness; Contact Load; Extrusion; Lubricants

Nomenclature

\begin{tabular}{|l|l|}
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\textit{\mu}\textsubscript{s} & Friction coefficient \\
RBD & Refined Bleached Deodorized \\
Paraffinic 460 & Paraffinic mineral oil with high viscosity: 460 cSt \\
Paraffinic 95 & Paraffinic mineral oil with low viscosity: 95 cSt \\
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1. Introduction

Among the many criteria imparted on extrusion in the industry, surface roughness has risen to be one of the most important requirements in recent years. This is especially true in the metal forming industry where the particular types of lubricants are selected for making the smooth sliding between two components. As consumers and manufacturers alike have the common goal of achieving and maintaining the highest surface quality possible, it is important to know the factors that could potentially compromise wear resistance.

Metal forming frequently perform at heavy loads and low speeds. The understanding of fluid film lubrication and wear occurs in heavily loaded sliding contact has been developing considerably. Sufficiently high pressures can produce plastic deformation of the same order of magnitude as the film thickness [1].

Traditionally, the friction coefficient ($\mu_s$) is given two designations; static and sliding. The static $\mu_s$ between a pair of surfaces is defined as the ratio of tangential force required to exert movement divided by the normal force. The sliding $\mu_s$ is expressed using the same formula as the static $\mu_s$, while the tangential force is given as the force required maintaining sliding motion, which is normally smaller than static $\mu_s$. The frictional force can be divided into two components: the adhesion component and the deformation component, both of which are related by the presence of surface asperity [2]. A finite element analysis proved that the contact load, which is caused by the rate of change in normal and tangential forces on the die sliding surface, is increased by friction [3].

Shunpei Kamitani et al. [8] developed the model of friction measurement using plane strain extrusion apparatus with different viscosity of lubricant. The result shows that the higher viscosity could be reduced the load and the plastic flow condition in whole deformation of a workpiece affected with lubrication condition on the plane. The thin lubricant layer was formed by using low viscosity of lubricant.

In previous work, the finite element analysis was done shown the influence of the lubricant quantity on the stress distribution in extruded workpiece was large at the exit region of the deformed zone, and the higher the friction coefficient, the greater the load needed [9]. Through the previous experimental work, the result was shown 5 mg of RBD palm stearin is the minimum quantity lubricants which are produce the lowest extrusion load, surface roughness, velocity and effective strain [10].

Therefore this paper would be present the correlation between contact load and surface roughness by different lubricants and quantity.

2. Procedure

2.1 Billet

Pure aluminium A1100 was used as workpiece (billet) in this experiment. The aluminium is 5 mm in thickness with 15 mm in width and 80 mm in length. The property of pure aluminium A1100 mainly contains almost 99% aluminium and also contains some other material such as magnesium and silicon. The pure aluminium A1100 has been chosen cause of their excellent forming characteristics, good ductility and heat treatable [4].

2.2 Taper Dies

Taper dies are main component in this experiment. The main function of the taper dies is used to deform the billet in the extrusion process. The taper dies were made from hot work tool steel (SKD 11). This material has been chosen based on their excellent wear resistance and good hardenability, which leads to reduced deformation.

2.3 Procedure

Several preparations need to be done before the test. The preparations process includes machining, heat treatment, surface and hardness test to the billet and taper dies. After all machining and finishing processes were completed; annealing process has been done on the billet. Annealing is use to induce ductility, soften material, relieve internal stresses, refine the structure by making it homogeneous and improves cold working properties. Then, hardening process has been done on the taper dies used to increase the hardness of a metal and provide higher...
resistance to plastic deformation [5]. The hardening step for this process is: heating the dies until 350°C, after that soaking the dies at 850°C until the temperature increased reach at 750°C, austenitizing process happens at temperature 1000°C, cooling the dies in air until the temperature of the dies same as room temperature (around 30°C).

Before the apparatus of the experiment was set up, all of the components were cleaned and ensured to be in good condition. The outer wall, container, dies, punch, and billet were cleaned first with acetone to remove any grease on them, and then they were oiled with lubricant for each test. Four different quantities of lubricant for RBD Palm Stearin were used: 20 mg, 5 mg, 1 mg and 0.1 mg. The weight of each lubricant was determined using a micro-analytical balance. The lubricant was applied evenly to the plane of each taper die.

The lubricated taper dies were then placed in the taper die holder. The billet was placed at the center between the taper dies to ensure symmetrical positioning without reducing the layer of lubricant. The extrusion rig was assembled and then centered on the hydraulic press machine as shown in Fig. 1. Load readings were taken at every 0.01 seconds during the punch travel, as indicated by the dial gauge indicator. The surface roughness was measured on the sliding plane of the extruded product surfaces which is at 20 mm of the extrusion length and the average surface roughness was obtained. These values were then plotted into the graph. From this graph, the correlation between load and surface roughness were determined. The entire procedure was repeated with the other stated quantities of lubricant in order to see the correlation between load and surface roughness. The test also was repeated by using paraffinic mineral oil with different viscosities which are 95 cSt and 460 cSt.

![Fig. 1. Schematic diagram of the plane strain extrusion process.](image)

3. Results and discussion

![Fig. 2: Correlation between the contact load and surface roughness](image)
Fig. 2 shows the correlation between contact load and surface roughness using different quantities and lubricants. The quantities differed by 20 mg, 5 mg, 1 mg and 0.1 mg had been chosen. Three lines of curve were plotted by different lubricants which are RBD palm stearin, paraffinic 460 and paraffinic 95.

As shown in the Fig., the contact load and surface roughness dropped when the quantity of RBD palm stearin was increased from 0.1 mg to 5 mg. It was shown the lowest quantity lubricant needs the highest contact load and surface roughness. When the highest quantity was applied which was 20 mg of RBD palm stearin, the contact load was increased suddenly while the surface roughness remaining to reduced. Thus, the highest amount of RBD palm stearin required more contact load and the lowest surface roughness. These results could be discussed with more lubricant was placed on the surfaces raise of the lubricant film thickness. Therefore to obtain the optimum film thickness it could be balance by the tolerance between interface of the billet and dies to found the correlation between contact load and surface roughness. These allow the lubricant to move actively at the interface between dies and billet. On the other hand, in this experiment, the tolerance on the interface of the billet and dies was fixed, and it caused the curve correlation suddenly changes with use of 20 mg of lubricant. The other factor that affects the correlation between the contact load and surface roughness was the viscosity level of the RBD palm stearin. Tasdelen et al. [6] stated that, when the workpiece starts to slide on the sliding region, the material starts to harden due to the high deformation ratio in the shear zone. The amount of lubricant is important because it reduces the friction and roughness of the surfaces by delivering fluid into the sliding area. This is caused by reduced heat conduction in the billet through lubrication and convective cooling [7].

On the same graph the results were shown by using paraffinic 460 and paraffinic 95 as lubricant. As general observation the surface roughness was reduced by increasing of quantities. Paraffinic 460 has lower contact load compared to paraffinic 95. This may occurs by viscosity differences between paraffinic 95 and paraffinic 460. However the optimum quantity for paraffinic 460 was found at 5 mg.

4. Conclusion

The correlation between the contact load and surface roughness by using RBD palm stearin, paraffinic 460, and paraffinic 95 used as a lubricant in a cold forward extrusion process was investigated. It was found that:

1. RBD palm stearin and paraffinic 460 were at the optimum contact load using 5 mg of lubricant, but they produced different surface roughness, which the surface roughness of RBD palm stearin was lower than paraffinic 460.
2. The Paraffinic 95 has consistent contact load by different quantities.
3. An increased amount of lubricant reduced the surface roughness for RBD palm stearin and paraffinic 460 up to the optimum quantity, which was 5 mg.
4. Generally, for the three lubricants used, the surface roughness can be reduced by the increasing the quantity.

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