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Evaluation of RBD Palm Stearin as an Extrusion Lubricant of Aluminum Alloy 5083

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Malaysia is one of the world's largest producers and exporters of palm oil. Palm oil, included palm kernel oil were contributed the highest percentage (27%) of global production of oils and fats in year 2006. Palm oil also is the most efficient oil-bearing crop in term of land utilization and productivity. Palm oil could produces an average 3.74 tonnes of oil per hectare every year, compared to 0.38 and 0.48 tonnes of oil per hectare per year for soybean and sunflower respectively. Today, development of the bio-lubricant which is biodegradability becomes one of the most urgent research projects in modern society. In Malaysia, palm oil has high possibility to be produce as bio-lubricant. Palm oil is eco-friendly and has high produce rate which could fulfills the demand of vegetable base lubricating oil. In the present research, RBD palm stearin, a refined palm oil product was evaluated on their performances as metal forming lubricating oil in cold work plane strain extrusion process. The workpiece material is Aluminum Alloy 5083. The analytical results were done by Visioplasticity method. The evaluations are focused on forming load, surface roughness and final product quality. The results show that RBD palm stearin could be applied as metal forming lubricating oil. The fatty acid in RBD palm olein helps to reduce the extrusion load and give slightly different in sliding velocity and effective strain.

Keywords: *Extrusion, paraffinic mineral oil, palm stearin, velocity.*

1. Introduction

The use of vegetable oils in industrial sector is not a new idea. Vegetable oil and animal fats were used in construction of monuments in Ancient Egypt [1]. In early 16th century, European sailors make soap from palm oil. In 19th century, people of France and England used palm oil to make candle. They also used palm oil as oil gas to light. Before the development of petroleum, palm oil was used for greasing the axle boxes of railway carriages. In the tin plate industry, palm oil was initially used to prevent oxidation of the iron and as flux before tinning [2].

Today, vegetable oil is much concerned for its application to a metal forming process as a lubricant because vegetable oil is renewable source and has high biodegradability compared to mineral oil. According to the OECD301C testing method, the biodegradability levels of the vegetable oils are more than 60% in 28 days. While, the biodegradability level of the mineral oil is less than 30% in the same period of time [3]. Palm produces 3.66 ton oil for every hectare, which is 7 and 2.5 times more than soybean and rapeseed respectively [4]. Then, palm oil has potential to fulfill the supply volume in demand of the vegetable based lubricants. We investigated the performance of RBD palm stearin as a lubricant in a cold metal forming process by carrying out the plane strain extrusion experiments and Visioplasticity analyses [5]. The plastic flow velocities, strain rate and strain conditions in a deformation zone in steady state extrusion were revealed quantitatively by the Visioplasticity analyses referring to the flow lines observed by the experiments.

Billet material was Aluminum (AA5083). RBD palm olein is refined, bleached and deodorized palm olein. A series of experiments were carried out by applying Paraffinic mineral oil and RBD palm olein as test lubricant at room temperature, around 30ºC. The whole experimental and analytical results were compared mutually. Surface roughness of billet was also measured after each extrusion experiment. We confirmed that the lubrication performance of RBD palm stearin is as effective as paraffinic mineral oil in its ability to reduce frictional constraint in a cold metal forming.

2. Experimental Procedure

2.1 Experimental apparatus

Figure 1(a) shows the schematic sketch of plane strain extrusion apparatus used in the experiments. The main components are container wall and taper die, and workpiece (billet). The taper die has 45-degree die half angle. The taper die is made from tool steel SKD11 and necessary heat treatment were done before the experiments. The experimental surface of taper dies (surface which contact the billet) were polished with abrasive paper and have surface roughness Ra less than 0.1 μm. The amount of test lubricant is 5 mg, and it was applied on this surface before the experiments. The other surfaces of experimental apparatus were applied with same type of test lubricant.

Figure 1(b) shows the schematic sketch of billets used in the experiments. The material of billet is aluminum alloy 5083. The billets' shape was made by the NC wire cut electric discharge machining device. Two similar billets were stacked and used as one unit of billet. One side of the contact surface of the combined billets was the observation plane of plastic flow in plane strain extrusion. The observation plane is not affected with the frictional constraint by the parallel side walls. A square grid pattern measuring the material flow in extrusion process was scribed by NC milling machine on the observation plane of billet. The lines were V-shaped grooves with 0.5 mm deep, 0.2 mm wide and 1.0 mm interval length. The billets were annealed before the experiments.

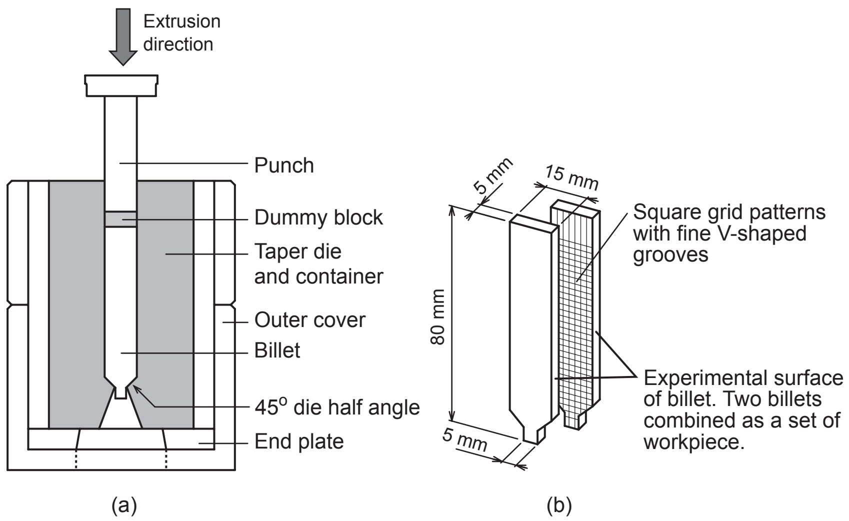


Fig. 1: (a) Experimental apparatus and (b) combination of billets.

2.2 Test lubricant

The testing lubricant is RBD palm stearin. RBD is an abbreviation for Refined, Bleached and Deodorized. Palm stearin is the solid fraction obtained by fractionation of palm oil after crystallization at controlled temperature. In this experiments, a standard grade of palm stearin which incorporated in Malaysian Standard MS 815:1991 was used [6]. The results obtained from the experiments used RBD palm stearin (written as PS) were compared with additive free paraffinic mineral oil VG460, written as P3. The amount of test lubricant used in the experiment is 5 mg, and applied on the taper die surface that contact the billet.

2.3 Experimental procedure

The plane strain extrusion apparatus was assemble and placed on the press machine. The forming load and displacement data were recorded by computer. The experiments were carried out at room temperature. Extrusion was stopped at piston stroke of 40 mm. After the experiment, the partially extruded billets were taken out from the plane strain extrusion apparatus and the combined billets were separated for the surface roughness measurement and metal flow analysis.

Metal flow analysis consist of the plastic flow velocity, strain rate components, effective strain rate, and effective strain in the deformation zone were calculated by using the Visioplasticity equations, since the analytical calculation procedure was explained in earlier publications [5, 7], it is omitted here.

3. Results and Discussion

3.1 Extrusion load

Figure 2 shows the extrusion load – piston stroke curves. Extrusion temperatures were around 30ºC. The notation P3 represents that those results were obtained when Paraffinic mineral oil VG460 was applied as test lubricant on the experimental surface of plane plate tool. While, PS represents that those results were obtained when RBD palm stearin was applied as test lubricant on that surface. The steady state extrusion condition starts at around the punch stroke, Y = 20 mm, in the extrusion applying above two lubricants. The experimental result shows that steady state extrusion load in extrusion applying RBD palm stearin as test lubricant is lower than that in extrusion applying paraffin mineral oil VG460 as test lubricant. The reason is that the fatty acids in the palm oil reduce the frictional constraint [8, 9].

Figure 3 shows the ram speed for each experimental condition. RBD palm stearin shows high ram speed at the steady state condition compare to paraffinic mineral oil VG460. The value of ram speed of billet extruded with RBD palm stearin and paraffinic mineral oil VG460 as lubricant are 11.60 mm/s and 9.38 mm/s respectively. This result shows that RBD palm stearin could reduce the sliding friction between the taper die and billets.

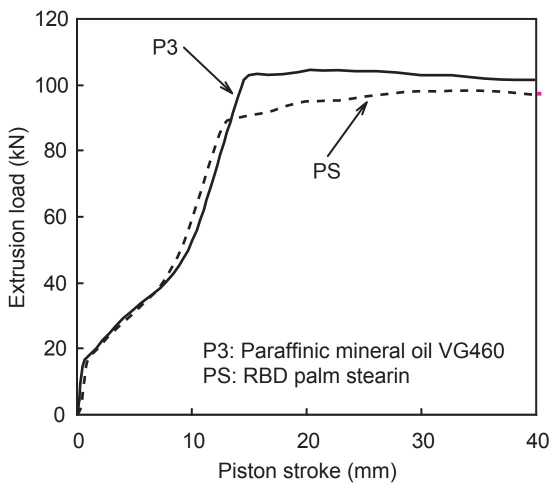


Fig. 2: Extrusion load – piston stroke curves

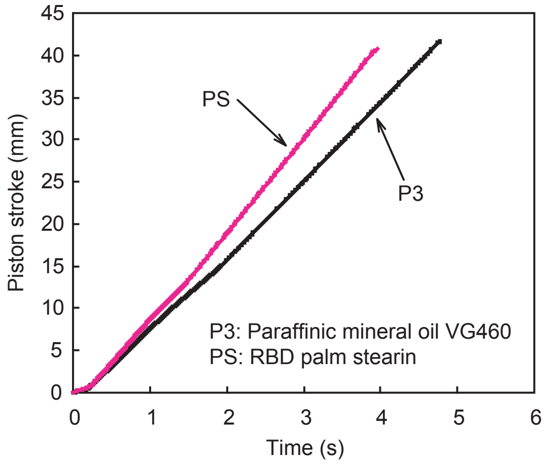


Fig. 3: Piston stroke – time.

3.2 Surface roughness

Figure 4 shows the CCD pictures of the extruded part of billet at Y=-4 mm. From the observation, there are no severe wear were found. The average value for the arithmetic mean surface roughness, Ra, at the extruded area for RBD palm stearin is almost similar with the paraffinic mineral oil VG460.

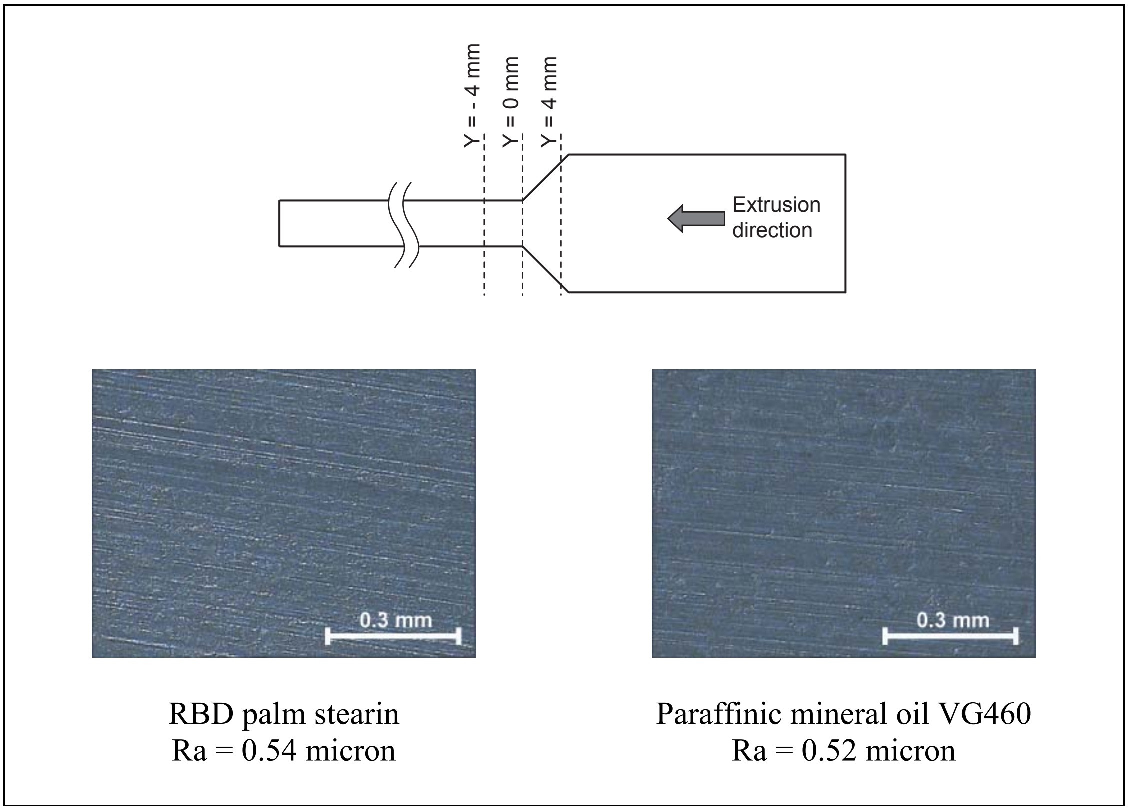
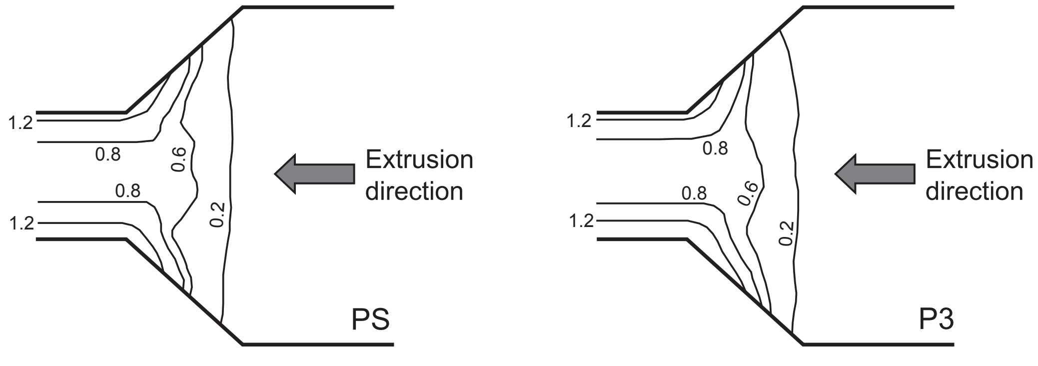
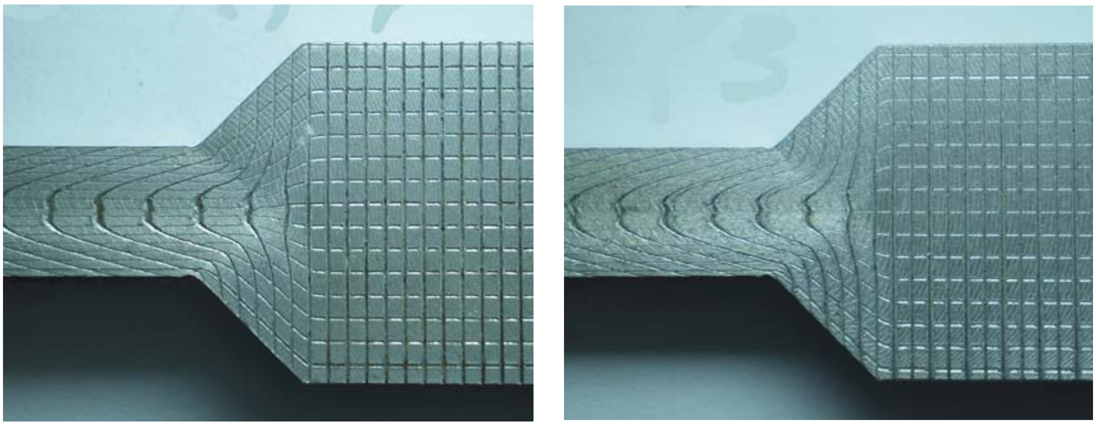


Fig. 4: CCD pictures of billet at Y = -4 mm.



RBD palm stearin
Paraffinic mineral oil VG460

Fig. 5: Distribution of effective strain in deformation area for billet extruded with RBD palm stearin and paraffinic mineral oil VG460.



RBD palm stearin
Paraffinic mineral oil VG460

Fig. 6: Metal flow pattern billet extruded with RBD palm stearin and paraffinic mineral oil VG460.

3.3 Effective strain distribution

Figure 5 shows the effective strain distribution in deformation zone for billet extruded with RBD palm stearin and paraffinic mineral oil VG460. From the figure, the effective strain distribution in the deformation zone is almost the same regardless of any difference of the experimental conditions. Figure 6 shows the metal flow pattern for both experimental conditions.

4. Conclusion

The performances of RBD palm stearin as cold metal working lubricant were investigated by plane strain extrusion test with Aluminum alloy AA5083 as workpiece. We could confirm from the experimental and analytical results that RBD palm stearin could be applied as cold metal forming lubricant. The existence of stearic acid (fatty acid) could help RBD palm stearin reduce the extrusion load.

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