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Comparative Study of the Lubrication Properties of Chemically Modified Neem Oil in Cold Extrusion of Aluminium

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ABSTRACT

This study investigates the effect of epoxidized neem oil as lubricant on cold extrusion of aluminium. Extrusion of aluminium using four different lubricants (neem oil, esterified biolubricant, epoxidized biolubricant and graphite dissolved in ethanol) was carried out. The four lubricants were used separately. After lubricating the billets, die, extrusion container and the ram, the whole assembly was placed on the universal tensile testing machine and the load was then applied. The extrusion was conducted under three different cross head speeds (2, 4 and 6 cm/min). Afterwards, surface finish and hardness of the extrudes were analyzed and measured. The results obtained show that large punch displacement is needed for easy extrusion of aluminium. The 6 cm/min proved the best. In addition, epoxidized biolubricant was the superior lubricant out of the four lubricants tested since it gave extrudes with good surface finish and higher hardness value. However, cross head speed of 2 cm/min produces extrude with finer surface finish.

1. INTRODUCTION

Extrusion is a process by which a block of metal either in the solid state or semi molten state is converted into the same metal which is of different surface orientation of a different cross-sectional area of continuous length (Raj, 2000). This process involves plastic deformation in which a work piece is reduced by the application of compressive forces to it, causing it to flow through a hole in a shaped die. The reduced section thus acquires the shape of the die orifice. This may be carried out hot or cold.

Lubricants are important because of the role they play in extrusion operation. This is because operation cannot be carried out efficiently without the application of the appropriate lubricant onto the work piece and die (Samuel and Victor, 2016). Conventional lubricating fluids are usually petroleum based, and since they are not bio-degradable, they pollute and contaminate water and soil when discharged as waste to the ground thereby having detrimental effect on health and environment. In consideration of the health hazards associated with the petroleum-based lubricants and the need to make the extrusion process more ecologically friendly, there is the need to develop an alternative safe and environmentally friendly lubricant (Samuel and Victor, 2016). Vegetable oils are perceived to be one of the options in developing new lubricants with high efficiency. This perception could be attributed to their properties which include; high viscosity index, high lubricity, higher flash point, very low volatility due to high molecular weight of the triacylglycerols (Borugaddaa *et al.,* 2014). However, they possess low thermal, oxidative stabilities and poor low temperature characteristics, which are mainly due to the presence of unsaturation in their fatty acid composition (Borugaddaa *et al.,* 2014). Transformation of unsaturated double bonds (C=C) into oxirane ring via epoxidation has received special attention as a bio-lubricant base stock, because it addresses the aforementioned limitations of the vegetable oils when used as lubricants (Campanella *et al.,* 2008; Salimon and Salih, 2010). Thus, the present study aims at investigating the potential use of epoxidized neem oil as lubricant during the cold extrusion of aluminium.

2. MATERIALS AND METHODS

2.1. Materials and Equipment

In conducting the experiment, the following materials and equipment were used: Denison testing machine, die, punch, container, neem oil, esterified biolubricant (esterified neem oil), epoxidized biolubricant (epoxidized neem oil), graphite dissolved in ethanol, 12 billets of diameter 27 cm and height 30 cm, manual surface analyzer, identic universal hardness testing machine (vickers). The esterified and epoxidized neem oils used were obtained from National Research Institute for Chemical Technology (NARICT) Zaria, Kaduna state, Nigeria.

2.2. Extrusion Procedure

The lubricants (neem oil, esterified biolubricant, epoxidized biolubricant and graphite dissolved in ethanol) were kept in separate bowls and the billets (semi-finished casting products that need further processing before being a finished good) were then lubricated by dipping into the lubricants. Following this, the extrusion container and the die were lubricated by swabbing. Next, immersion method was used in lubricating the punch head. A die angle and billets tapered at 45° were used. Subsequently, the die was coupled onto the die-holder which was in contact with the extrusion container. Afterwards, the lubricated billet was placed in the container which was properly aligned with the die cavity. The whole assembly was placed on the platen of the universal testing machine and the punch was kept fixed on top of the billet at an initial load of zero. Finally, the load was applied on the punch to achieve extrusion of the billet at the selected speed and under various lubrication conditions. The values of the load were taken at 4 mm intervals of punch travel and the results were recorded. After the extrusion, the extruded billet was kept aside and tools disassembled and cleaned properly before being reassembled back to carry out the next test. The procedure was repeated for each billet and for each lubricant. The extrusion was carried out at different speeds of 2 cm/min, 4 cm/min and 6 cm/min.

2.3. Surface Finish

The surface finish of the extrudes was analyzed using the manual surface analyzer. The analysis was carried out by swabbing using finger on the extruded billets and doing the same on the surface analyzer scale to record the value.

2.4. Hardness Test

The hardness measurement of the extrudes was taken across the diameter length of the extruded billets using identic universal hardness testing machine (Vickers), machine model MV1- PC.

3. RESULTS AND DISCUSSION

Figure 1 shows the variation of extrusion load with increasing punch displacement for different lubricants at 2 cm/min cross head speed. It's interesting to note that as the ram travel increased, the extrusion load increases due strain hardening effect. Additionally, it's observed that extrusion load using neem oil had the highest value whereas graphite (dissolved in ethanol) had the lowest value. At lower ram displacement, higher extrusion load is applied using epoxidized biolubricant as compared to other lubricants. Accordingly, epoxidized biolubricant is the second best lubricant after graphite (dissolved in ethanol). This might be linked to the lower evaporative loss of epoxidized biolubricant at higher displacement. Similar observation has been reported (Erinosho *et al.,* 2015).

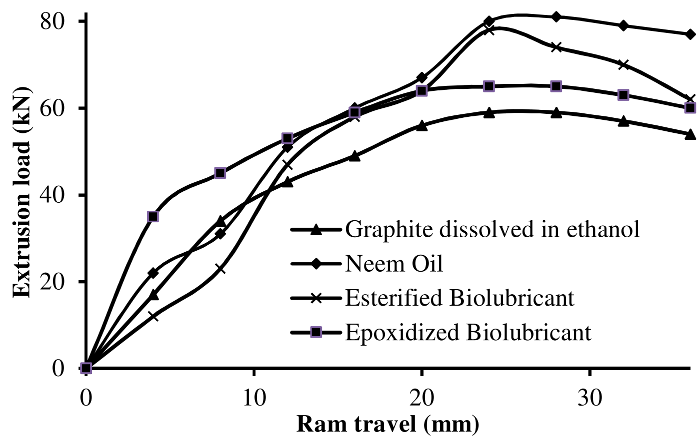

Figure 1: Variation of extrusion load and ram travel for different lubricants at 2 cm/min cross head speed

Figure 2 indicates the variation of extrusion load with increasing punch displacement for different lubricants at 4 cm/min cross head speed. It is noted that larger extrusion load using neem oil is observed at higher ram displacement. On the other hand, epoxidized biolubricant requires smaller extrusion load. This could be attributed to the higher thermal stability of the epoxidized biolubricant. This result agrees with what is obtainable in literature (Mohapatra and Nayak, 2015).

Figure 3 shows variation of extrusion load with increasing punch displacement for different lubricants at 6 cm/min cross head speed. The increase in the ram displacement led to a sharp and then a gradual increase in the extrusion load. Similarly, due to higher thermal oxidative stability of the epoxidized biolubricant, the epoxidized biolubricant reduces the friction and pressure generated between the billets and the walls of the container more compared to other lubricants (Salih *et al.,* 2017). This brings about low extrusion load requirement for the epoxidized biolubricant. This is in agreement with the report of Ojo *et al.* (2015). Relating this result to that obtained at 2, 4 cm/min cross head speed in Figures 1-2 respectively, it can be deduced that lower extrusion load is required at higher speed this is due to the fact that the deformation spreads towards the rear end and the periphery of the billet and the flow becomes more significant leading to a quick expansion of the deformation zone (Zhou *et al.,* 2003; Erinosho *et al.,* 2015).

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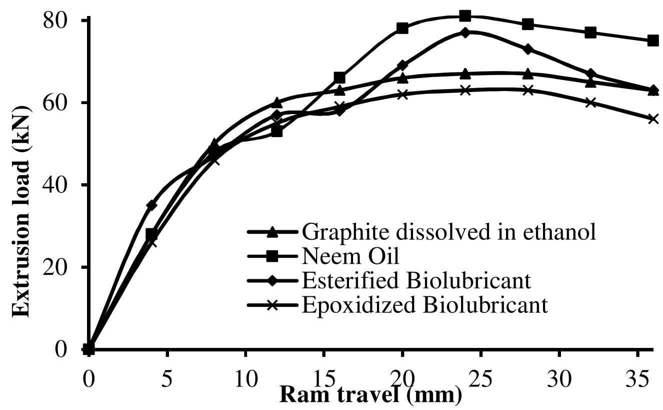

Figure 2: Variation of extrusion load and ram travel for 4 cm/min cross head speed

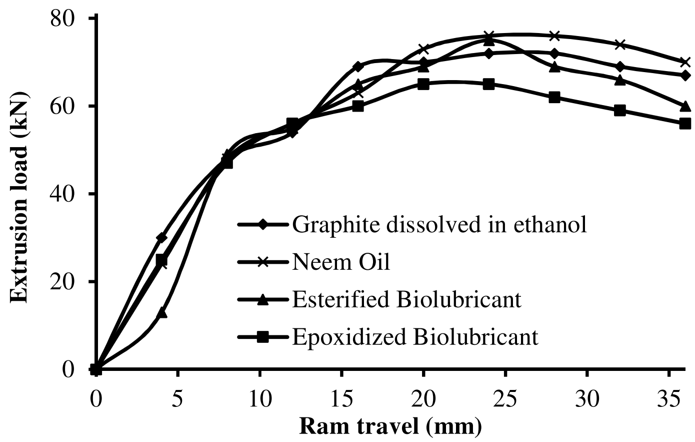

Figure 3: Variation of extrusion load and ram travel for 6 cm/min cross head speed

It is clear from Figure 4, that roughness values of extrudes obtained using graphite (dissolve in ethanol), neem oil and esterified biolubricant were significantly higher than that of extrude produced using epoxidized biolubricant. Thus, a more uniform material flow is achieved with epoxidized biolubricant. Furthermore, epoxidized biolubricant produced extrude with finer surface. This could be attributed to higher heat extraction ability which is linked to the high thermal stability of the epoxidized biolubricant. This result matches the report of the previous research (Ragab et al., 2017). Similarly, the surface roughness increases with speed and that makes the speed of 6 cm/min to be the one with the coarse surfaces (worst surface finish).

As shown in Figure 5, the hardness of extrudes produced using neem oil and esterified biolubricant increases as the cross head speed increases. However, both graphite (dissolve in ethanol) and epoxidized biolubricant gave extrudes with lower hardness at 4 cm/min speed and higher hardness at 2 and 6 cm/min speed. Notably, extrude produced using epoxidized biolubricant show substantial higher hardness at 2 and 6 cm/min speed. This proves the effectiveness of epoxidized biolubricant in producing defect free extrudes. This is in line with the previous findings (Adeosun et al., 2014).

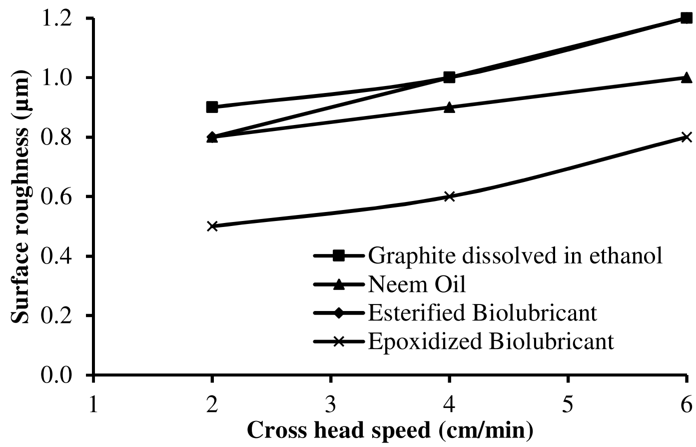

Figure 4: Variation of surface roughness with cross head speed

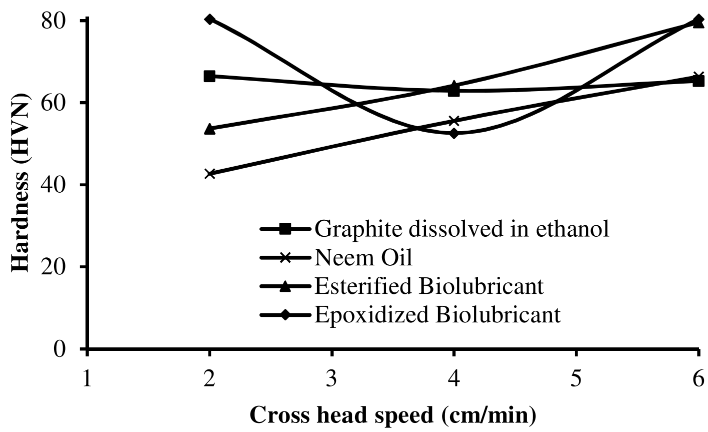

Figure 5: Variation of hardness with cross head speed

4. CONCLUSION

A comparative study on the chemically modified neem oil as biolubricant during cold extrusion of aluminium has been conducted. This has been achieved by varying the cross head speed at 2, 4 and 6 cm/min utilizing four different lubricants. The results indicate that higher ram displacement is most suitable for cold extrusion of aluminium. This is because at higher displacement, it requires lower deformation load to extrude the aluminium. In terms of the effect of lubricants on deformation load, surface roughness and hardness; epoxidized biolubricant is the best. In addition, 6 cm/min cross head speed produced extrudes with high quality then followed by 2 cm/min. Therefore, it is concluded that epoxidized neem oil and 6 cm/min cross head speed give the best process conditions for the extrusion of aluminium.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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