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MODELLING THE OPEN-CLOSED FORGING USING DIFFERENT TYPE OF PALM OIL DERIVATIVES.

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ABSTRACT

Due to rising demand for manufactured products in sectors including vehicles, electronics, construction, aerospace, and others, many researchers are trying to developing an environmentally friendly manufacturing process. Most metal forming lubricants are harmful to the environment and may release enormous amounts of pollutants into the environment. Bio-oil lubricants are being considered as mineral oil alternatives. This study aims to serve as a case study and demonstrate the use of palm oil derivatives as bio lubricants in a forging test (Open-closed forging). Computational modelling of the forging process using the finite element technique and other validation methods speeds up design validation. Using a Coulomb–Tresca friction model, a cold forging test was utilised to study the interaction between the Coulomb friction coefficient (CFC) and Tresca shear friction (TSF). From both test, palm stearin (PS) shows the lowest friction behaviour where at open forging (RCT) the friction is estimated at $m=0.10$ /$\mu=0.05$ and the closed forging (CFT) has a varied friction and the average friction is estimated at $m=0.352$ /$\mu=0.1626$. Commercial metal forming oil (CMFO) is the highest-lubricating sample in friction, with a value of $m=0.45$/$\mu=0.1875$ on RCT test $m=0.424$ / $\mu=0.1681$ on CFT.

KEYWORD

Modelling, friction, open-closed forging, palm oil; tribology

INTRODUCTION

A decent lubricant must not only have outstanding tribological properties, but it must also be environmentally friendly. The use of mineral-based lubricating oil raises environmental concerns since it is known to have a non-biodegradability property and is seldom spontaneously dissolved in the environment as shown in Figure 1 (Nowak et al., 2019). It's important to have lubrication on the die surface, particularly when doing cold work. Metal forming lubricants are provided to the tool work contact during numerous metals forming processes to minimize friction and wear, which would in turn affects life of the tool, metal flow, energy consumption, heat evolution, and surface finishing (Abdulquadir & Adeyemi, 2008).

Figure 1: Mineral oil based in industrial application.

Palm oil is one of the world's most widely used vegetable oils. It is most typically used as cooking oil, also known as palm olein. In terms of lubrication, palm oil has shown great potentials to be used in engineering applications as a lubricant due to their unique properties i.e longer hydrocarbon chain length and among the lowest degree of unsaturation levels (Zareh and Davoodi,

2016) in tribological testing. The length of the fatty acid chain as well as the degree of unsaturation fatty acid impact the viscosity of palm oil. Most commercial lubricants are based on mineral oils, which are not environmentally friendly due to their non-biodegradability and hazardous to the environment (Aiman *et al.*, 2022). Commercial metal forming oil also involve in open loop system where the lubricant will end up to the surrounding and can affect the health of industrial workers. Most of the used mineral oil lubricant will be refined as fuel that is very costly, which will then be employed in low-performance devices. This refined fuel usually undergoes incomplete combustion that pollute air to environment. FEM is one of the alternative approaches in order to reduce the number of times actual experimental sample are needed throughout the design process,

In this research, two forging processes will used in order to study friction relation (Coulomb-Tresca) in open forging process and to investigate the metal flow during the closed forging process. Geometrical validation and simulation of closed die forging process for aluminum with different derivatives of palm oil will help producing light products for industrial applications which will promote the use of renewable material that environmentally friendly as a metal forming lubricant.

MATERIAL AND METHODOLOGY

In order to evaluate the frictional behaviour with various derivatives of palm oil-based lubricants, two main tests were proposed, which were open forging and closed forging test. A hydraulic press machine, similar to the one seen in Figure 2, will be used to conduct an analysis on each and every test sample. The experimental materials and conditions are summarised in Table 3.

Table 1: Materials and conditions for experiments

Properties	Open forging test	Closed forging test
Workpiece	Pure aluminium (A1100)	
Workpiece Hardness (Hv)	Before annealing = 134.8	
After annealing = 52.6	After annealing = 52.6	
Tooling material	SKD-11	
Workpiece size (mm)	18:9:6	35x15x4.5
Reduction in height	~10%, ~20%, ~30%, ~40% and ~50%	
Lubricant quantity (mg)	~5mg	~10mg
Temp (ºC)	24-27 (Room temperature)	
Lubricant sample	PS, PMO PKO and CMFO	
Compression speed (mm/s)	1	

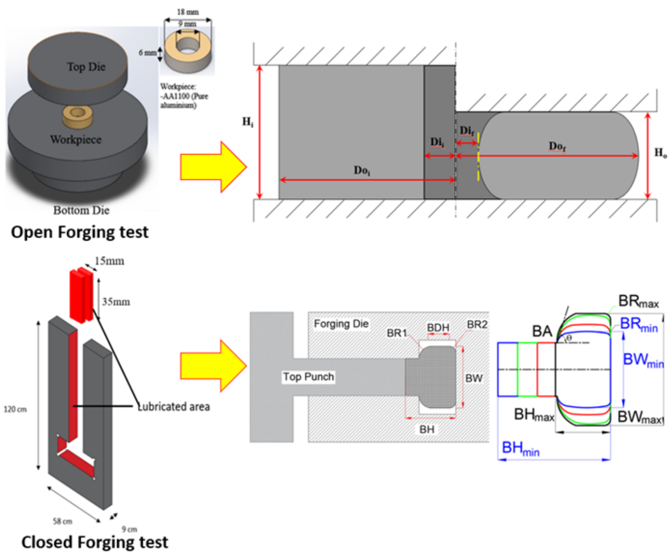

Figure 2: The open-closed forging test set up.

RESULT AND DISCUSSION

Figure 3 shows the calibration curve of all samples after calculating the *e* value compared to the finite element method. From the result obtained, we can see that as a benchmark of the test on the no lubricant sample (NA-O), the friction is best fitted at m = 0.45 and μ = 0.1875, which shows the highest value of friction when compared to the other sample. The CMFO result shows a tendency that is comparable to where the deformation of the NA-O sample. However, based on observations through the palm oil-based sample, the PS has the lowest amount of friction at m = 0.1 and μ = 0.05. The PMO shows a slightly higher value friction at m = 0.15 and μ = 0.075 when compared to the PS. PKO on the other hand, shows the highest friction in palm oil based at m = 0.20 and μ = 0.09375.

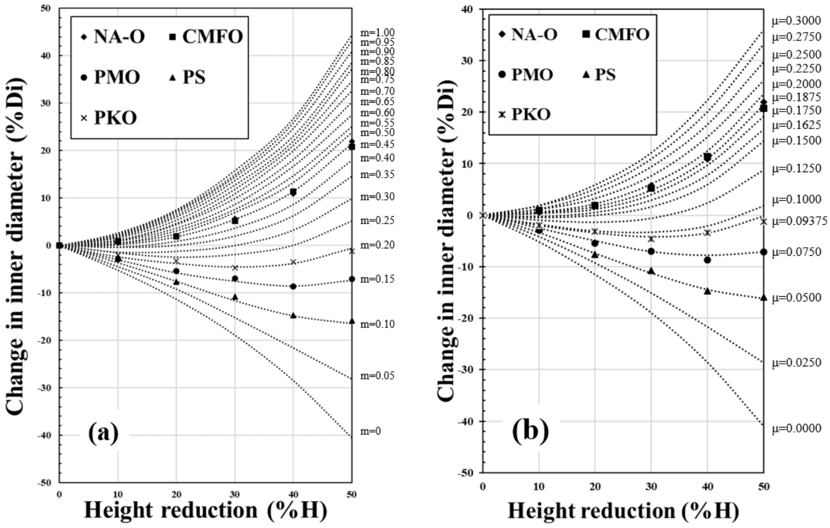

Figure 3: Validation of experimental result (a) TSF and (b) CFC

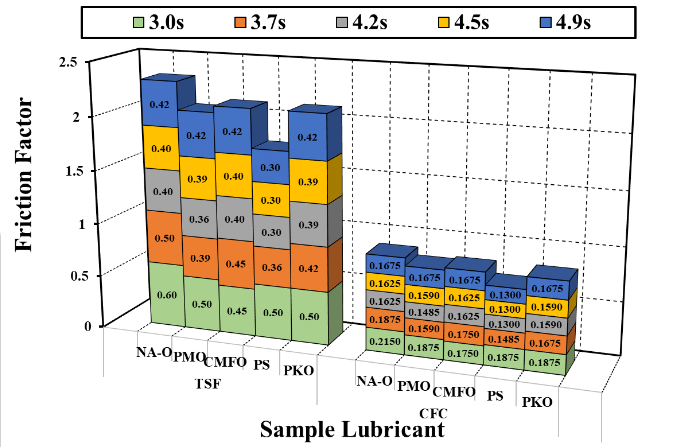

Figure 4: Summary of friction behaviour for each component of the sample test following FEM validation.

From the closed forging test, after going through the process of validation, we have come to the conclusion that the development of friction during a closed forging test may be summed up as shown in Figure 4. It appears that the friction behaves differently depending on the die stroke that is being compressed, which is in contrast to the ring compression test, in which the friction may be easily described as a single friction behaviour. The absence of lubricant resulting a very high friction that has average of $m=0.46/\mu=0.18$. According to the findings also, palm stearin (Average of $m=0.35/\mu=0.15$), when compared to palm kernel oil (Average of $m=0.42/\mu=0.17$), palm mid-olein

(Average of *m=0.41/μ=0.16*), and commercial metal forming oil (Average of *m=0.42/μ=0.17*), had the lowest amount of friction occur during the cold forging test. PS exhibited a decreasing trend from ~10% to ~30% as the die stroke compression increased, and this tendency persisted until the compression was complete. PS, PMO and PKO have a slightly different tendency, in which the friction increases when the compression reaches between ~40% and ~50 %. Another prospective palm oil-based lubricant that may be used as a metal forming lubricant is called PMO where in comparison to CMFO, the average total friction that occurs during the compression test is slightly lower. PKO, on the other hand, demonstrates practically the same performance as CMFO in terms of friction, which is the highest when compared to palm oil-based lubricants.

PS PMO and PKO with high contents of saturated fatty acids displayed effective molecular packing, which protected the metal surface and suggested a reduced friction coefficient. According to Zulhanafi et al. (2018), a higher degree of unsaturated fatty acid lowers the capacity of the molecules to be chemisorbed; as a consequence, the metal surfaces in the fourball test experience less protection. However, during the metal forming process, the lowest level of unsaturated fatty acid, which is PKO (17.7%), has no effect on lowering friction, when compared to PS (46.40%) and PMO (39.29%). This may be the result of very high compression on the surfaces, which reduces the strength of the intermolecular bonds and destroys the thin layer of soap film, resulting in higher friction.

CONCLUSION

The results of the open and closed forging tests were shown to have significantly different patterns of frictional behaviour. The interpretation of friction in open forging tests is acting as a single friction for each sample test. On the other hand, the behaviour of friction in closed forging tests is different at each die stroke, and the friction varies depending on how the stroke is changed. Both of the findings from the tribological performance of palm oil-based lubricants as metal forming lubricants demonstrate that palm oil-based lubricants exhibit a superior performance when compared to CMFO.

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