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Bio-lubricant for metal forming

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ABSTRACT
The present paper review a lubrication condition metal forming process like forging, extrusion, deep drawing and rolling. The lubricant film at tool-workpiece interface must able to sustain inconsistencies of temperature, pressure and velocity, so that a product with desired surface finish could be deformed. Meanwhile, vegetable oil has a great potential to replace the current used of petroleum-based lubricant. However, limitations of vegetable oil need to overcome first before could find application at industrial scale.

1. Introduction

The process of metal forming encompasses of forging, extrusion, deep drawing, rolling and sheet metal forming, are performed under either hot environment or cold environment. During the forming work, lubricant plays a vital role in reducing friction at the tool-workpiece interface because of it directly affects tool wear rate, surface quality of the product, metal flow and energy consumption. Generally, low friction coefficient is beneficial to the manufacturer in term of reduction in forming load, power consumption and energy loss. From the environmental point of view, friction reduction would be possible to save fuel energy that has been used to overcome friction and emission of carbon dioxide. According to Holmberg and Erdemir [1], about 15-25% of total energy consumption worldwide was used to reduce friction in mechanical system and about 7000 tonnes of carbon dioxide has been emitted to the environment.

2. Lubrication condition in metal forming

In forging process, metal is forged or pressed under great pressure and temperature. For this condition, the lubrication used must able to sustain continuous changing of pressure-temperature-velocity combination along the process. Temperature is very critical issue as in even cold forging work, the working temperature can reach 100°C-200°C. If lubrication failed to reduce friction and serve as thermal barrier at interface, disproportionate metal flow and heat distribution may trigger defects like exterior or internal cracking and cavitation failure especially at sharp corner and deep cavity.

In extrusion, a bulk metal of workpiece is forced to flow through a die of small cross section area, forming an extruded part. Extrusion process involved high level of working pressure, resulting from the summation of pressure required for the deformation of metal and hydrostatic pressure due to friction of sliding contact. And the variation of pressure occurred along the contact surface. If lubrication film breaks down during extrusion work, high friction condition may induce the formation of dead zone, an area where deformation does not occurred, which led to severe distortion at the corner. Besides that, addition of lubricant on the billet's surface is to avoid sticking to the surface of die and assist in removing of deformed metal from die [2].

Deep drawing process is performed to produce a part with light weight, low density and high strength properties. These requirement led to the high occurrence of wrinkling, a wave formation on the surface of drawn metal. Development of a right film thickness is a critical task need to be achieve because it directly affects strain distribution, thickness distribution and eventually surface quality of drawn metal. The lubrication condition must be effectively separated the surfaces of punch and sheet metal throughout the process. This is

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because a uniform strain distribution and reduction in value are obtained in the full film lubrication regime [3, 4]. Friction increments would instantaneously induced wrinkling and fracture.

Lastly, the process of reducing thickness of metal sheet is called rolling. Viscosity of lubricant has a significant effect on the efficiency of rolling process. A thick lubrication film as a result of high viscous fluid in not desired in this metal work because it generates poor surface roughness. Meanwhile, a low viscous lubricant does not help in rolling process and provoke large coefficient of friction and power consumption. However, viscosity of lubricant is always changing during rolling process due to the uncontrollable of temperature variation at each rolling mills [5]. Thus, optimum viscosity of the lubricant must be choose properly to avoid material defects like internal crack, edge crack, centre crack and wavy edges. In the worst case, the sheet metal is split into two during rolling work and moving in the opposite direction relative to the mill. This phenomenon is called as an alligatoring.

3. Vegetable oil as forming lubricant

For a certain deformed metal, the used lubricant is desired to adhere on the metal surface in order to avoid rusting taking place before handling to the user. Thus, the lubricant must be non-toxic, non-hazardous and environmental friendly to humans. And vegetable oil seems to meet those requirement because of (i) vegetable oil is from a natural source (ii) vegetable oil has strong adhesion to the metal surface attributed to the uniqueness of fatty acid structure. In another requirement of removing lubricant from the metal surface, vegetable oils is easy to clean and disposal and also does not need any special chemical or treatment for the process in comparison with mineral-based oil. Therefore, vegetable oil is highly potential to be used as a forming lubricant.

Besides that, due to the increasing awareness towards declining of the Earth's finite resources and environment's health, a development of vegetable oil as biolubricant become a favourable approach when implementing a clean forming process. In fact, the application of vegetable oil as lubricant at industrial application is not relatively new. Back then, vegetable oil such as coconut oil, rapeseed oil, olive oil and palm oil have been extensively used during Industrial Revolution, between 1750 and 1850 [6]. However, the used of vegetable oils started to gradually dwindle after first publicizing of distillation process of mineral oil in 1812, in Parague. Since that, the industrial lubricant is mostly produced from mineral oil-based.

The extensive use of vegetable oils is restricted due to the inefficient performance at low temperature, low hydrolytic and poor oxidation stability. To overcome these limitations, chemist and tribologist are keen to modify chemical structure of the vegetable oil, by introducing a more stable functional group at the carbon chain of fatty acid [7]. This could be accomplished by chemical modification of natural vegetable oil or addition of additive. The example of chemical modification process are esterification / transesterification, epoxidation, hydrogenation or oligomerisation. Meanwhile, viscosity modifier or viscosity index improver, antioxidant, dispersant, pour point depressant, antiwear, extreme pressure additive and corrosion inhibitors are example of chemical additives blended with vegetable oils.

4. Conclusion

Form the discussion, it can be conclude that different metal forming process require different lubrication condition. And physical properties of lubricant used in are different according to the lubrication condition of forming process and their environment. These properties are need to be determined first before modifying chemical structure of the vegetable oil.

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