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Analyses of various viscosity effects to hydrodynamic lubrication in tube spinning process

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ABSTRACT – Four kind of lubricants with different viscosity were applied to the tube spinning process. A theoretical analysis based on the two dimensional isothermal Reynolds equation was developed for the hydrodynamic lubrication. Experimental was done on a lathe machine where the metal spinning was done. The results show that linear velocity of the forming tool and rotational velocity of the mandrel both influence the establishment of a hydrodynamic lubricant film thickness at the inlet zone. Formation of a hydrodynamic lubricant film thickness at the inside of the tube is ruled by the eccentricity of the mandrel and tube. Theoretical and experimental estimate the values film thickness. The comparison illustrates that they are related on lubricant viscosity, but not for spray lubricant type.

1. INTRODUCTION

Metal spinning is a kind of forming process which is used to form pre-formed blanks either to be stretched further or modify shapes. The pre-formed tube shape product is placed over the mandrel and held firmly to the mandrel. In forming process, the mandrel with the pre-formed tube rotates and the forming tool, with one or two small rollers used to apply localized pressure, and moves forward over the mandrel length with steady velocity. This movement stretches the tube in axial direction and decreases its thickness. The presence of an effective lubricant film between contact surfaces in tube spinning process will increase the reduction in thickness, reduce tool wear, prevent cracking and wave forming build-up, and effect the surface roughness of the product.

Researches and studies in metal forming with hydrodynamic lubrication have been conducted by many researcher. Scaraggi, M. (2013), studied the friction properties of lubricant and analyzed the texture surfaces, where an experimental based on hydrodynamic lubrication. Alshamma, F. (2011) performed a research of a combined effect of hydrodynamic lubrication in cold rolling.

Previously, the results and analyses of plasto-hydrodynamic lubrication in other metal forming processes such as in extrusion process by Wilson(1971), wire drawing given by Dowson, Parson and Lidgitt (1972), and deep drawing by Mahdavian and Shao (1993). However, they have not be either to implement or modified for the spinning process to estimate the lubricant film thickness. The major difficulty in using these models is the additional relative movement between the tool and work-piece in the spinning process which makes it different from the other processes.

In this paper, researcher concerned with the development, using the two dimensional Reynolds equation, of a realistic steady hydrodynamic lubrication model for the metal tube spinning process. This analysis includes both the tool and mandrel velocities. The analysis produces an estimate of the lubricant film thicknesses between the inside and outside surfaces of the work-piece, mandrel, and forming tool.

2. PROCESS ANALYSIS

Process of tube spinning with lubrication of work-piece and tooling surfaces is shown in Fig.1. The tube is clamped to the mandrel and is rotating with the same speed with the mandrel. The forming roller, while free to rotate, is also advancing forward, parallel to the mandrel axis towards the trailing edge of the tube. The lubricant is drawn between the outside surface of the tube and the roller into the converging wedge spaces between these surfaces. The following table is the type of lubricant applied during the experiments.

Table 1 Type of Lubricants application.

Type of Lubricant	Viscosity at Room Temperature (Pa.s)	Remark
Castor Oil	0.082	-
Drawing Oil	0.164	-
DK 1172 Oil	1.472	-
PTFE Spray Oil	-	Colloidal dispersed type

The lubricant film between the mandrel and the inside tube surface, is formed due to both stretching of the tube wall in the feed direction over the surface of mandrel and also by squeezing the lubricant between the inside tube and mandrel surfaces. It is essential to notice that the spinning action, which is caused by continuous changes in the clearance between the tube and mandrel, is due to the eccentricity of the mandrel while rotating against the roller.

Theoretical analyses are carried out to estimate the lubricant film thickness at the inside and outside surfaces of the tube. The steady Reynolds equation for the inlet zone is:

$$\partial/\partial x(h^3 \, \partial p/\partial x) = 6\eta \, (U\partial h/\partial x \;+\; V \, \partial h/\partial y) \qquad (1)$$

Derivation of several equations generates the film thickness h_i is,

$$h_i = 3\eta \; U/ \sigma_y R \tan\alpha \qquad (2)$$

Where,

η : viscosity
U : Forming tool linear speed
σ_y : Yield stress of material
R : Radius resultant
α : Angle of attack

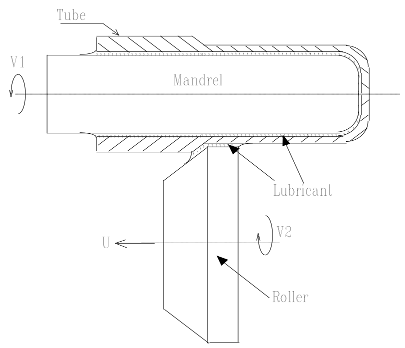

Figure 1 Lubricated tube spinning.

Comparison between theory and the experimental results is shown in Fig.2. Lubricant film thickness between the work-piece - mandrel theoretically and practically produce similar trend as indicated significantly The experimental results are higher than the theoretical results beyond the viscosity of drawing oil which is 0.164 Pa s. This is because of the factors or variables that have not been considered in the formulation of the equation such as the influence of temperature and pressure changes in viscosity. Another factor that can be influenced to this phenomena is the estimation of the eccentricity between the mandrel and the tube. Since the eccentricity can affect the speed of the lubricant on Z direction, the eccentricity has to be estimated accurately.

3. CONCLUSIONS

In this research the theoretical analysis for the film thickness in tube spinning was derived by using the Reynolds equation (1). Theoretical models was developed for the inlet zone of the work-piece. The film thickness at the inside of the wall, between the work-piece and mandrel, was analyzed. The result of the theoretical model for the inlet zone film thickness was obtained in a closed form equation (2). The variation of film thickness was plotted for the various viscosities and it was concluded that the formation of high lubricant thickness is only achieved under certain conditions. It was also shown that the angle of attack α influences the magnitude of the film thickness. Increasing the feed rate and mandrel rotation results in a higher film thickness. The comparison between theoretical and experimental film thickness indicated that the inside film thickness from theory was higher than the experimental measurement especially but beyond the viscosity of 0.164 Pascal second.

4. REFERENCES

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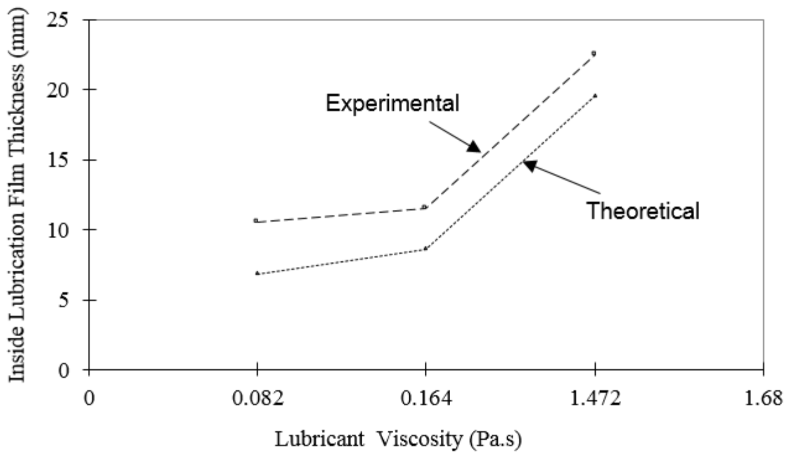

Figure 2 Comparison of the film thickness between experimental and theoretical results.