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CFD ANALYSIS OF THE HYDRODYNAMIC LUBRICATION IN PRESSURE DIE: APPLICATION TO WIRE DRAWING

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ABSTRACT

The modern wire drawing machines facilitated with pressure die to draw wire at high speed. Pressure die, These dies are basically combination of two nibs, first of pressure nib and second draw nib. Pressure nib is the one which build pressure at the entry of wire drawing nib in pressure die. There are no standards available for this pressure nib design. The Tattersall equation provides guide line to design the pressure nib. In this work analysis of wire drawing process under hydrodynamic lubrication has been done and effort made to validate the Tattersall equation using Computational Fluid Dynamics (CFD).

KEYWORDS: Wire Drawing Die, Hydrodynamic Lubrication, CFD, Pressure Die

NOMENCLATURE

SYMBOLS	ABBREVIATIONS
R_i	Initial radius of the wire
Q	Flow rate
Δp	Pressure at die entry
L	Length of nozzle
h_0	Flowing thickness
h_p	Radial gap between the wire and nozzle
u	Lubricant velocity
η	Viscosity

INTRODUCTION

In any wire drawing process the surface of the die and wire never be perfectly smooth when there is no lubrication provided the direct contact of surfaces occurs and there will be significant increase in friction and temperature. The contact between two surface cause the wire deformation and high load can be expected at the interface. When the lubrication provided due to wire speed the lubricant dragged inside the irregular surface and avoids direct contact of surfaces and the load required for the plastic deformation is transferred through lubricant partially (Figure 1). Increase in lubrication pressure will reduce the friction and maximum load carried through lubricant. The current die design is simple and the entry angle or the bell mouth region helps in develop the lubricant pressure at die entry [1]. The hydrodynamic concept used to study the behavior or lubricant during wire drawing process.

The current dies available in the market are conventional die. The die geometry influences the pressure build at interface. But the hydrodynamic study illustrate that for perfect lubrication the load required to deform wire should be completely transferred through lubricant and there will be no contact between wire and die surface. To achieve the hydrodynamic lubrication the pressure of lubricant must be equal to the yield stress of the wire. The concept of pressure nib is introduced to build the pressure at die entry. There are no standards available for this pressure nib. The analytical and computational method is used to define the pressure nib geometry [2]. The analytical work is done using basic fluid dynamics laws and Tattersall equation. The Tattersall equation helps to derive the basic pressure nib geometry and variable influence the pressure build. The analytical results are validated using CFD tool.

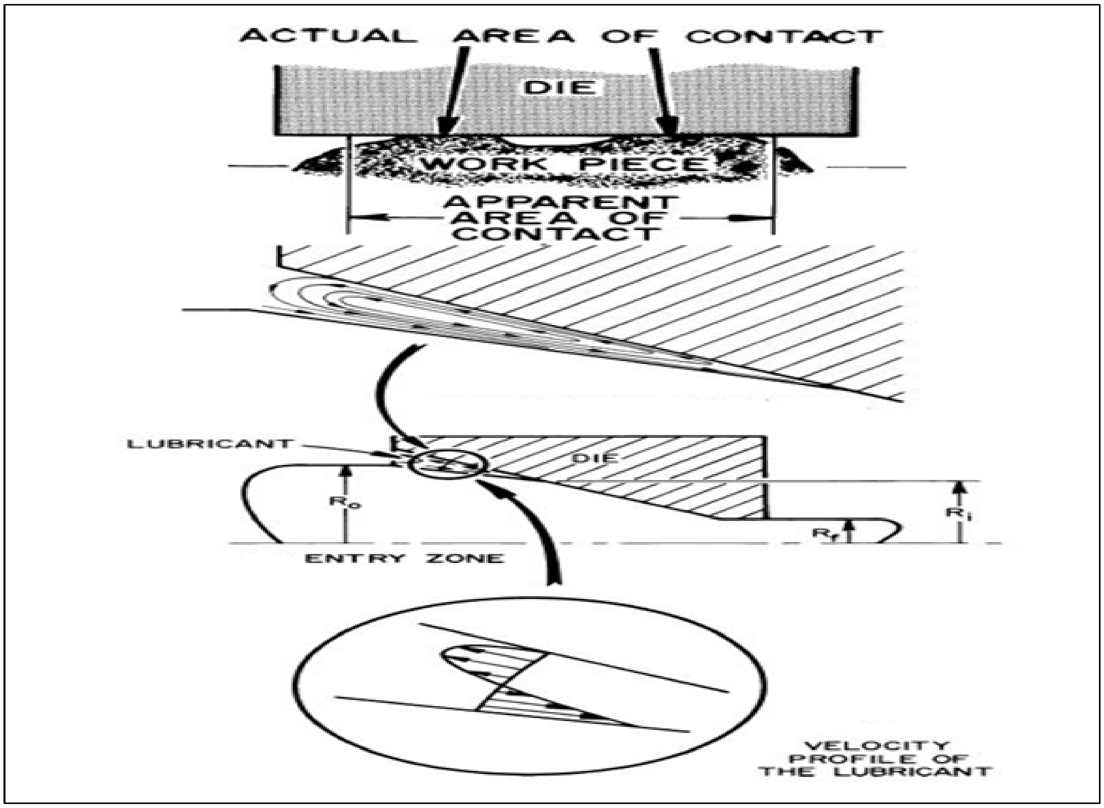

Figure 1: Lubricant Film

TATTERSALL EQUATION

The wire drawing allows to reduce by clod plastic deformation the diameter 2Ri of a wire by drawing it through an axisymmetric die (Figure 2). The wire/die friction must be minimized by the lubricant: drawing load increases with the friction and too high friction can induce wire surface defect, the wire rupture and high wear rate [3]. Therefore various experimental and theoretical works of wire drawing lubrication have been performed. Christopherson and Naylor [4] have demonstrated by experiments that a cylindrical nozzle, with a length L and leaving a radical gap hp. around the wire, placed before the die (Figure 1) can increase greatly the pressure of an oil at the die entry and therefore promotes the hydrodynamic lubrication in wire drawing.With soap as lubricant Tattersall [5] observed that a nozzle increases the soap pressure at the die entry Δp and the flow rate Q lubricating the die. By assuming that soap has viscosity η and by application of Reynolds equation to the soap flow in the nozzle, he obtained the relations(Eqn.1)

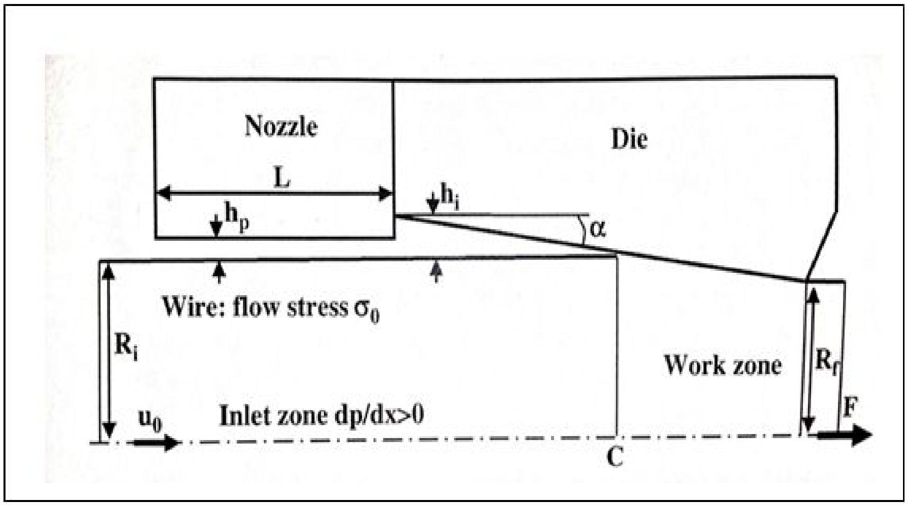

Figure 2: The Wire Drawing Process with Nozzle for Promotion of the Hydrodynamic Lubrication and Conical Die

Viscosity of RENOFORM ETA lubricant $\eta = 1.645$ N s m^{-2}, h_0= 10µm, h_p= 380µm, u_0= 20m s^{-1}, L= 14mm. These data will be used in order to compare Tattersall's experiment results.

$$\Delta p = \frac{6\eta u_0 L}{h_p^2}\left(1 - \frac{h_0}{h_p}\right) \tag{1}$$

$$\Delta p = \frac{6 \times 1.645 \times 17.5 \times 14 \times 10^{-3}}{(380 \times 10^{-6})^2}\left(1 - \frac{10 \times 10^{-6}}{380 \times 10^{-6}}\right)$$

$$\Delta p = 1.63 \times 10^7 \text{Pa}$$

COMPUTATIONAL FLUID DYNAMICS (CFD) ANALYSIS

Computational fluid dynamics (CFD) study of the system starts with the construction of desired geometry and mesh for modeling the dominion. Generally, geometry is simplified for the CFD studies. Meshing is the discretization of the domain into small volumes where the equations are solved by the help of iterative methods. Modeling starts with the describing of the boundary and initial conditions for the dominion and leads to modeling of the entire system. Finally, it is followed by the analysis of the results, conclusions and discussions.

Process Modeling and Data Input

- ANSYS FLUENT V15 is used for CFD analysis.
- The surface modeling of Pressure nozzle and Pellet built in the CATIA. It is a convergent divergent type nozzle. First, the fluid flow (fluent) module from the workbench is selected and geometry is imported from CATIA file.
- Initially a relatively coarser mesh is generated. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries. Care is taken to use structured quadrilateral cells as much as possible. It is meant to reduce numerical diffusion as much as possible by structuring the mesh in a well manner, particularly near the die entry region. The regions are named as per required inlet and outlet to define the boundary conditions the outer surface named as wall.

- Energy is set to OFF position. Viscous model is selected as “k-ε model (2 equation).
- The fluid- Renofrom ETA and solid- Tungsten Carbide is created in fluent data base.
- The parts are assigned as ETA and Tungsten Carbide as per fluid/solid parts.
- Boundary conditions are used according to the need of the model. The inlet and outlet conditions are defined as velocity inlet and pressure outlet.
- Boundary Condition

Table 1: Boundary Condition

	Boundary Condition Type	Magnitude
Inlet	Velocity	17.5 m/s
outlet	Pressure	1.2 bar

- The number of iteration is set to 500 and the solution is calculated and various contours, vectors and plots are obtained

RESULT

The pressure developed at the entry of pellet is 1.7x107Pa (Figure 3.)

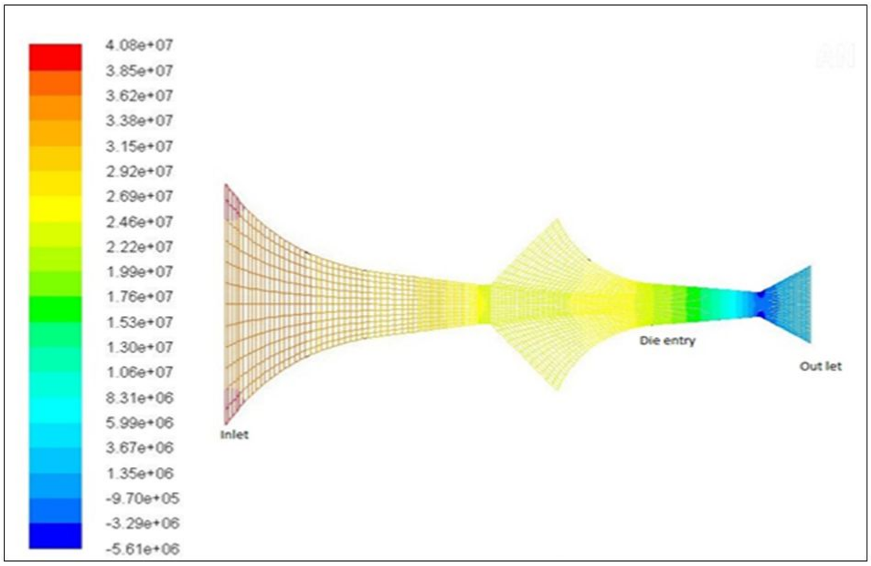

Figure 3: ANSYS Fluent Contours Pressure in Pascal

CONCLUSIONS

The results of the CFD model have been compared with the Tatterall’s experiment results. The results are comparable and the minor changes in the numerical values is due to the Tatterall’s equation ignores the change in viscosity with increase in pressure and temperature effect. In pressure nib design phase Tatterall’s equation can be used as reference to define geometry.

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