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Plasto- Hydrodynamic Pressure Analysis in Converging Parabolic, Simple Tapered and Exponential Unit

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ABSTRACT

This study involves drawing of wire by hydrodynamic pressure, technique Hydrodynamic pressure technique is a relatively new where the wire is pulled through a pressure unit of certain internal geometry a polymer melt that gives rise to the hydrodynamic pressure inside the unit. The hydrodynamic pressure distribution may change during the process due to various factors such as the pulling speed, fluid viscosity, and geometrical shape of the unit. Main objective of this study is to compare the performance of converging parabolic, simple tapered and exponential unit in terms of pressure distribution, maximum pressure and axial stress and how the geometrical configuration of the unit affects the results with fluid has been assumed to possess Newtonian characteristics during the passage through the unit.

Keywords: Hydrodynamic, Analysis, Viscosity, Tapered, Exponential, Parabolic

1. Introduction

In the plasto-hydrodynamic wire drawing process, when a solid continuum is pulled through an orifice filled with a viscous fluid, the hydrodynamic action generates very high pressure in the converging gap. This action is caused by existence of viscous fluid (like polymer melt) between two surfaces. The pressure generated depend upon are dependent on various parameters, such as the viscosity of the fluid, the geometrical shape of the surfaces as well as the relative speed between the moving and fixed surfaces [1,2].In general, the developed pressure is not so high if the fluid used is oil, but it Grows to be many times greater if the fluid is polymer solution Accordingly, Studying the growth o f the hydrodynamic pressure in manufacturing operations Pressure may be sufficient to initiate plastic yielding and produce permanent deformation of the continuum[5, 6]. The application of the concept to die-less drawing was introduced in using a polymer melt as the fluid number of studies has been carried out applying this phenomenon to plastically reduce the diameter of wires and tubes by drawing through pressure units.

2. Theoretical Analysis

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In this study is plasto-hydrodynamic pressure models have been developed for converging parabolic, exponential units and tapered unit show Figures (1, 2) and (3).

2.1 Analysis for wire drawing in tapered unit

In order to establish a mathematical formulation of the process the following assumptions are made.
1-The thickness of the fluid layer is small compared to the bore of the orifice.
2-the pressure in the fluid is uniform in the thickness direction at any point along the length
3-The flow is in steady state.
4-The pressure gradient (dP/dx) independent of y.
The analysis is based can the geometrical configuration show in Fig.1 (a) of the orifice and the continuum, the gap at any point is given by:

$h = h_1 - BX$ Where, $B = (h_1 - h_2)/L$

The relationship between the pressure and shear stress gradient for a Newtonian fluid medium is given by

$$\left(\frac{dP}{dx}\right) = \left(\frac{d\tau}{dy}\right) \quad (1)$$

And the shear stress as

$$\tau = \mu\left(\frac{du}{dy}\right)^n \quad (2)$$

This equation is applicable for any type of fluid. Here, n is the power law index which equals to (1) for Newtonian fluid, greater than 1 for dilatants fluid and less than 1 for a pseudo plastic fluid. In this equation, (dU/dy) is the shear rate.
Hence the velocity distribution in the gap is given by

$$u = \frac{p'y^2}{2\mu} - \frac{p'h\,y}{2\mu} - \frac{Vy}{h} + V$$

The flow of the polymer melt in the unit is,

$$Q = \int_0^h u \; dy$$

The boundary conditions are

(a) at y = 0 , U = V at the wire surface

(b) at y =h , U = 0 at the surface of the unit

$$Q = -\frac{p'h^3}{12\mu} - \frac{k\,\tau^2\,p'h^3}{4\mu} + \frac{Vh}{2}$$

For steady state conditions

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$$Q = -\frac{p'h^3}{12\mu} + \frac{Vh}{2}$$

Now integrating it again and noting that (dQ/dx) =0 it gives

$$\frac{p'h^3}{6\mu} = Vh + C_3$$

The optimum pressure condition is at {dp/dx} = 0 ،where $h = \bar{h}$

$$C_3 = -V\,\bar{h}$$

Substitute into the above equation and rearrange gives

$$p' = 6\mu V\left(\frac{1}{h^2} - \frac{\bar{h}}{h^3}\right) \qquad (3)$$

The pressure at any point (x) within the orifice may be expressed by:

$$P = \frac{6\mu V}{B}\left(\frac{1}{(h_1 - BX)} - \frac{\bar{h}}{2(h_1 - BX)^2} - \frac{1}{h_1} + \frac{\bar{h}}{2{h_1}^2}\right) \qquad (4)$$

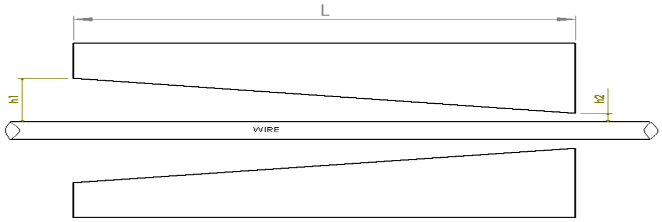

Fig (1) tapered hydrodynamic pressure unit

2.2 Analysis for wire drawing in parabolic unit

The researchers had first presented analytical and numerical solutions for a solid continuum pulled through a parabolic bore unit filled with a viscous [7].The geometry defined for Parabolic bore part unit is $h(x) = -a^2(x+b)^2 + C$

$$H(x) = \int_0^h \frac{1}{h^2}\,dx \quad , \quad G(x) = \int_0^h \frac{1}{h^3}\,dx$$

The boundary conditions are

(a) At x=0, P=0, and (b) at x -L, P= 0

Therefore, with the boundary condition (a) the pressure expression becomes

$$P(x) = 6\mu v\left[\,H(X) - \frac{H(L)G(X)}{G(L)}\right] \qquad (5)$$

The expressions for H(x) and G(x) in terms of h(x) is:

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$$H(x) = \int_0^x \frac{1}{[-a^2(x+b)^2 + C^2]^2} dx$$

$$G(x) = \int_0^x \frac{1}{[-a^2(x+b)^2 + C^2]^3} dx$$

After integration it get,

$$H(x) = \frac{1}{4aC^3}[\ln[\frac{x+b+d}{x+b-d}] - \ln[\frac{b+d}{b-d}] - d[\frac{1}{x+b+d} + \frac{1}{x+b-d} - \frac{1}{b+d} - \frac{1}{b-d}]] \quad (6)$$

And

$$G(x) = \frac{1}{16d^5a^6}\left[3\ln[\frac{x+b+d}{x+b-d}] - 3\ln[\frac{b+d}{b-d}] - 3d\left[\frac{1}{x+b+d} + \frac{1}{x+b-d} - \frac{1}{b+d} - \frac{1}{b-d}\right] - d^2\left[\frac{1}{(x+b+d)^2} - \frac{1}{(x+b-d)^2} - \frac{1}{(b+d)^2} + \frac{1}{(b-d)^2}\right]\right] \quad (7)$$

Where, d=c/a

To obtain the optimum position for pressure it is necessary to calculate G (L) and H (L) for hydrodynamic converging parabolic unit the die geometry can be expressed as

$$h(x) = -(h_1 - h_2/L)\,x^2 + h_1$$

$$a = ((h_1 - h_2)^{0.5}/L), \quad b = 0 \quad \text{and} \quad c = (h_1)^{0.5}$$

Substituting the values for a, b and c at x=L, the expressions for G(L) and H(L) becomes,

$$H(L) = \frac{L}{4h_1\sqrt{h_1}\sqrt{h_1-h_2}}\left[\ln\frac{\sqrt{h_1-h_2}+\sqrt{h_1}}{\sqrt{h_1-h_2}-\sqrt{h_1}}\right] + \frac{L}{2h_1h_2} \quad (8)$$

$$G(L) = \frac{L}{16h_1^2\sqrt{h_1}\sqrt{h_1-h_2}}\left[3\ln\frac{\sqrt{h_1-h_2}+\sqrt{h_1}}{\sqrt{h_1-h_2}-\sqrt{h_1}}\right] + \frac{1}{16h_1}\left[\frac{6L}{h_1h_2} + \frac{4L}{h_2^2}\right] \quad (9)$$

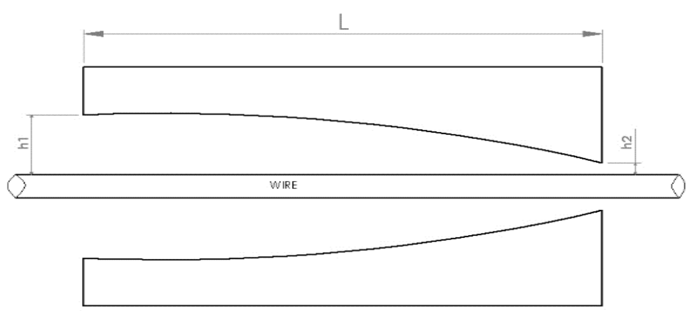

Fig (2) parabolic hydrodynamic pressure unit

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2.3 Analysis for wire drawing in exponential unit

The geometry defined for exponential unit is $h(x) = a^2(x+b)^2 + c^2$.

The expressions for H(x) and G(x) in terms of h(x) becomes,

$$H(x) = \int_0^x \frac{1}{(a^2(x+b)^2+c^2)^2}dx$$

$$G(x) = \int_0^x \frac{1}{(a^2(x+b)^2+c^2)^3}dx$$

After integration it get,

$$H(x) = \frac{1}{2c^2}\left[\frac{1}{ac}\left(\arctan\left((b+x)\frac{a}{c}\right) - \arctan\left(\frac{ab}{c}\right)\right) + \left(\frac{b+x}{a^2(b+x)^2+c^2} - \frac{b}{a^2b^2+c^2}\right)\right] \quad (10)$$

And

$$G(x) = \frac{1}{4c^2}\left[\frac{b+x}{(a^2(b+x)^2+c^2)^2} - \frac{b}{(a^2b^2+c^2)^2}\right] + \frac{3}{4c^2}H(x) \quad (11)$$

For plasto-hydrodynamic converging exponential unit, the geometry can be presented as

$h(x) = ((h1-h2)/L^2)(x-L)^2 + h2$, therefore in this case the terms

$a = (h1-h2)1/2 / L$, $b = -L$ and $c = (h2)1/2$.
Substituting the values for a, b and c at x = L, the expressions for H (L) and G (L)

$$H(L) = \frac{L}{2h_2}\left[\frac{1}{(\sqrt{h_2})(\sqrt{h_1-h_2})}\arctan\frac{\sqrt{h_1-h_2}}{\sqrt{h_2}} + \frac{1}{h_1}\right] \quad (12)$$

$$G(L) = \frac{1}{4h_2}\left[\frac{L}{(h_1)^2} + 3H(L)\right] \quad (13)$$

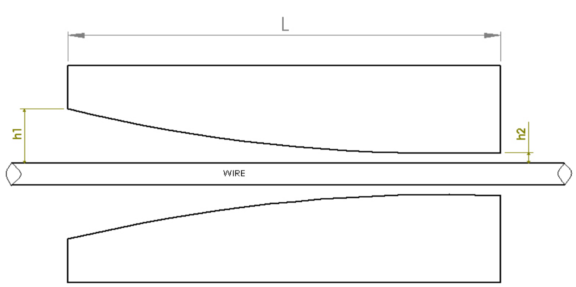

Fig (3) exponential hydrodynamic pressure unit

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3. Results and discussion:

Fig (4) shows the pressure distribution of three different gap ratios for tapered unit it is evident from Fig that for the range of gap ratio considered, the peak pressure occurs in the tapered zone of the unit and that this peak changes with the gap ratio combinations. it could be observed that as (h2) becomes smaller pressure generated for the same drawing speed is higher. That is, the maximum pressure increases as the gap ratio is decreased, and at gap ratio h1/h2 =10, the maximum pressure 750bar, bar was obtained, whereas for gap ratio h1/h2 =5, a lower pressure of 288 bar was observed, a further reduced magnitude of pressure of 98 bar being obtained with a gap ratio combination of h1/h2 =2.5. This is also true for the pressure distribution obtained for the exponential unit, as shown in Fig (5), except that the magnitudes of the peak pressure are generally much. It is considered the lowest pressure distribution that can be obtained in parabolic unit as shown in Fig (6).

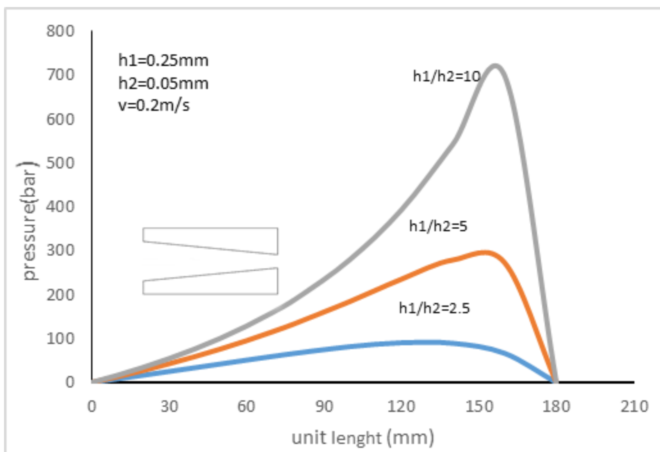

Fig (4) Showing the pressure distribution for tapered unit

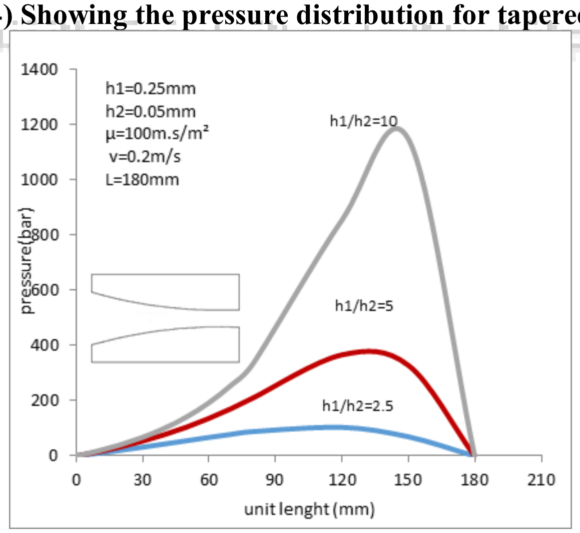

Fig (5) Showing the pressure distribution for exponential unit

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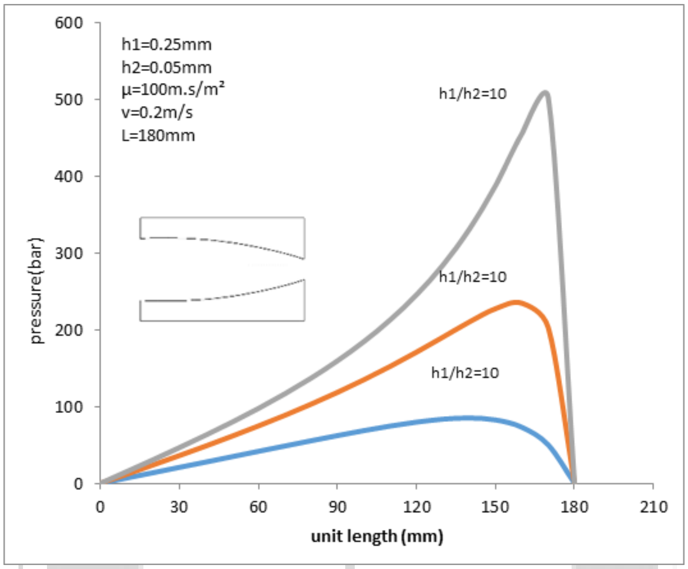

Fig (6) Showing the pressure distribution for parabolic unit

Fig (7) shows the parabolic, simple tapered and exponential unit on the maximum pressure. Ically calculated such pressure distributions for a number of drawing speeds ranging from 0.1 m/s to 0.6 m/s. This figure show that the maximum pressure values increase, when the drawing speed values are increased and maximum pressure values are the largest in the exponential unit.

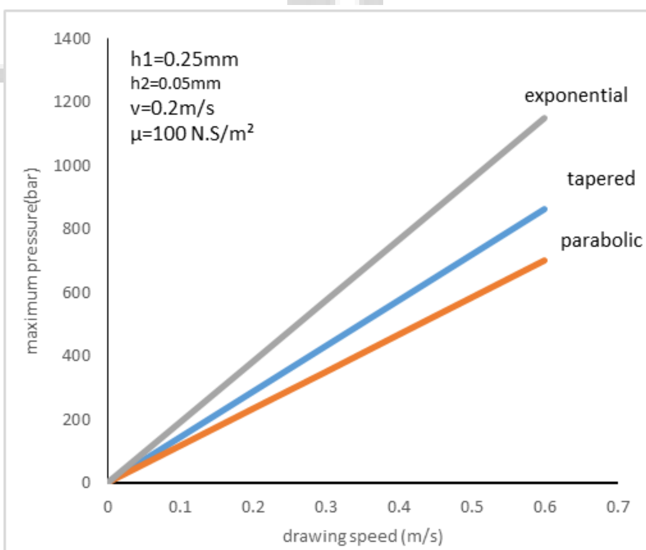

Fig (7) Showing the maximum pressure for units

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Fig (8) illustrates the effect of viscosity on the pressure distribution. Shows the pressure distribution at (μ= 50) this figure indicates that when the viscosity of polymer increases the pressure increased for a given drawing speeds

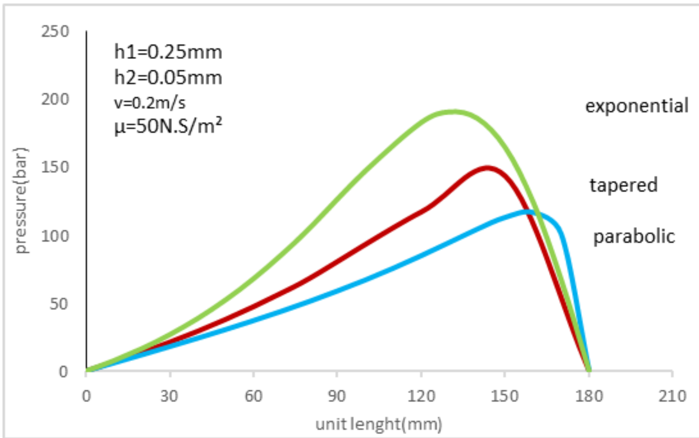

Fig (8) Showing the effect of viscosity on for units

4. CONCLUSIONS

Experimental results for the pressure distribution, the maximum pressure and the drawing force for parabolic, simple tapered and exponential unit pressure units have been presented. It is evident that for a given overall gap ratio, there exists a particular gap exponential unit that produces considerably greater magnitudes of pressure when compared with the pressure obtained using the parabolic, simple tapered. Also the maximum pressure for the exponential unit is greater than the maximum pressure for the parabolic and simple tapered .and for drawing and / or coating processes, this higher pressure is very useful. Other parameter has been considered studying the maximum pressure in the units such as the viscosity value, the maximum pressure raises when the drawing speed increases for a given value of viscosity.

Nomenclature

X is any distance (point) in the die.(mm)

μ viscosity of the fluid .(Ns/m²)

V velocity of the wire (m/s)

L length of the orifice (mm)

P hydrodynamic pressure. (N/m²)

h gap at any point in the orifice .(mm)

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h1 gap at the Inlet of the orifice (mm)

h2 gap at the exit of the orifice (mm)

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