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Estimating the Effect of Fluid in Pressing Process

A. Movaghar, R. A. Mahdavinejad

***Abstract*—To analyze the effect of various parameters of fluid on the material properties such as surface and depth defects and/or cracks, it is possible to determine the affection of pressure field on these specifications. Stress tensor analysis is also able to determine the points in which the probability of defection creation is more. Besides, from pressure field, it is possible to analyze the affection of various fluid specifications such as viscosity and density on defect created in the material. In this research, the concerned boundary conditions are analyzed first. Then the solution network and stencil used are mentioned. With the determination of relevant equation on the fluid flow between notch and matrix and their discretion according to the governed boundary conditions, these equations can be solved. Finally, with the variation creations on fluid parameters such as density and viscosity, the affection of these variations can be determined on pressure field. In this direction, the flowchart and solution algorithm with their results as vortex and current function contours for two conditions with most applications in pressing process are introduced and discussed.

***Keywords*—Pressing, notch, matrix, flow function, vortex.

I. Introduction

THE knowledge of specifications affection of fluids used in metal forming trends and their surface and depth defects in pressing process is the subject which has growing application in industries [1]. Various kinds of oils with a wide range of industrial applications are used in press forming process. The function of these oils is lubrication to friction reduction and surface coolant of the metal sheets [2]. The obvious friction results are due to the long time operations for almost all forming processes. According to the increase of this friction, the bigger force is needed for an especial deformation [3]. Therefore, there should be more attention to friction reduction on this subject. This is not usually the main factor in the selection of a metal forming lubricant of course. Since the damaging effects of the metal particles on the surface of electrodes are the most major mode [4]. Tool life can be improved with the friction reduction and the preventing of the deburies from the contact surface of tool and workpiece via flushing [5]. These deburies are; the pollutions in pressing and the coolant oils as cutting fluids, oxidation layers, dust and micro particles of metal and so on which are on the contact surfaces in various processes [6]. What is under consideration in this research is the analysis of a layer of fluid sprayed on the surface of metal sheet. Although the oil layer thickness is very small but, it cannot be ignored under pressing when punch and matrix are going to be attached [7]. The kind of this oil layer and/or its tensional or flushing usages does not have any effect on the procedure of analyzing. In other words, from codes written, it is possible to predict both the behavior of tensile and/or flushing oils on the surface of the material. To determine the pressure field, a sample geometric model is used first, and then with a little change, it is possible to predict the behavior of the fluid at somewhere else as the points of corner's matrix. The whole work is carried out via discrete the Navy-Stokes equations which are in the form of vortex-current function. Some fluid's parameters like density and viscosity are used directly in these equations. Therefore, any variations in these parameters change the flow numerical solution method and pressure field. The later, in its order, will effect on various parameters such as the defects and cracks in the surface of materials. From this point of view, the final product properties can be analyzed regarding the affection of various parameters of the fluid forming process.

A. Movaghar is with the Information Technology Engineering Department, Sharif University, Kish Campus, Iran (e-mail: a.movaghar@gmail.com).
R.A.Mahdavinejad is with the School of Mechanical Engineering, College of Engineering, University of Tehran, Tehran, Iran.

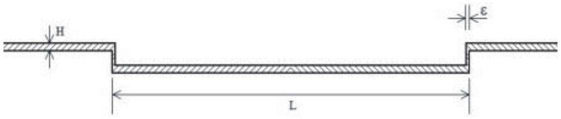
II. Modeling Procedures

The model of the problem is a pressing system with a special load and geometrical characterizations. To solve the problem, the model of the figure is analyzed first. It can be shown that more complicated geometrical shapes can be converted to this simple one, so that, according to the numerical solution of this problem, the results of more complicated shapes can be determined via this solution with little more calculations.

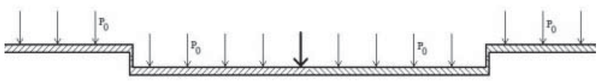
In modeling, it is considered that non-slip condition is satisfied and the rigid and solid surfaces are not under deformation. Rigidity and not the flexibility of the punch surface cause the similarity motion of matrix and oil together at the same direction. Consequently, with the reduction in the gap between punch and matrix and according to the incompressible fluid condition, the oil will flow upward from this gap at the end of the pressing duration. The speed of oil is V_1 which is the function of pressing span (L) and the gap between matrix and punch at the end section (ε) (as shown in Fig. 1).

III. Physical-Cinematic Condition

The motion of the liquid with the speed of V is the first cinematic condition. In order to determine the pressure field, some specified pressure points as reference are needed to calculate the pressure in the whole field. Since the pressing load is known, it is possible to consider the whole points on the upper surface of punch with the same pressure P_0 which is the equivalent pressing load and using them as reference pressure points. Cinematic-physical conditions of the problem which are the velocity and pressure values are shown in Fig. 2.

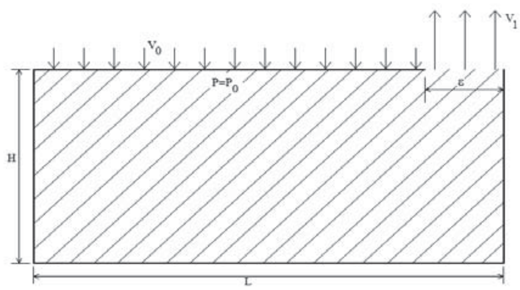


(a)

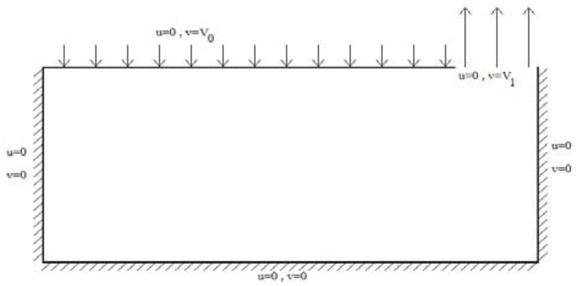


(b)

Fig. 1 (a) Geometrical model of the press and (b) its physical-cinematic conditions



(a)



(b)

Fig. 2 (a) The model used in numerical solution (b) with its boundary conditions

IV. Symmetric Point of View

The downward speed of punch is V_0 and the upward speed of fluid between punch and matrix is considered to be V_1. This means that the fluid goes throw a gap with the width of ε and the speed of V_1 which depends on the speed V_0. Due to the application of continuum equation, the relationship between these two velocities will be determined. In brief, it is possible to show that the ratio between these two velocities is in the same order. In other words:

$$O\left(\frac{V_0}{V_1}\right) = O\left(\frac{\varepsilon}{L}\right)$$

Since ε/L ratio is very small, V_1 will be very big in comparison with V_0 with the application of Bernoulli equation as a simple and qualified form in the region between punch and matrix where the fluid moves with the speed of V_1. It can be calculated that the pressure values in such area are very small in comparison with the other areas. Therefore, in pressure field determination, this section is no considerable.

According to the physical and geometrical symmetric in this problem, the model is converted to the form of Fig. 2 (a). All calculations in the next steps will be based on the geometric conditions of this model, and the boundary conditions are also argued on it.

V. Governing Equations

Basic and well-known Navy-Stokes equations which are usually solved by various numerical methods due to the complexity of their theoretical solution are used to model and predict the behavior of the fluid. The formulation of flow vorticity function is one of the most usual methods for these equations. Fluid flow vorticity is defined as follows:

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = -\omega \tag{1}$$

where ψ and ω are flow function and vorticity, respectively. The displacement equation for vorticity is:

$$u\frac{\partial \omega}{\partial x} + v\frac{\partial \omega}{\partial y} = v\left(\frac{\partial^2 \omega}{\partial x^2} + \frac{\partial^2 \omega}{\partial y^2}\right) \tag{2}$$

where the velocity components u and v are defined as:

$$u = \frac{\partial^2 \psi}{\partial y^2}, \qquad v = \frac{\partial^2 \psi}{\partial x^2} \tag{3}$$

VI. Boundary Conditions

Non-slip condition necessitates the following boundary conditions for velocities (as shown in Fig. 2 (b)):

$$u = 0, v = 0 \text{ at } x = 0, L \text{ and } y = 0 \tag{4}$$

$$u = 0, v = V_0 \text{ at } 0 \le x \le L - \varepsilon \text{ and } y = H \tag{5}$$

$$u = 0, v = V_1 \text{ at } L - \varepsilon \le x \le L \text{ and } y = H \tag{6}$$

The velocity boundary condition versus the flow and vorticity function can be written as follows:

$$u = \frac{\partial \psi}{\partial y} = 0 \quad at\, x = 0, L \tag{7}$$

The value of flow function on each boundary stream line except the upper wall is to be zero; therefore, the boundary conditions will be as follows:

$$\psi = 0 \quad at\ x = 0\ , L \quad 0 \le y \le H \tag{8}$$

$$\psi = 0 \quad at\ y = 0\ , \quad 0 \le x \le L \tag{9}$$

The vorticity function can be simplified as:

$$\omega = -\frac{\partial^2 \psi}{\partial x^2} \text{ (on } x, L \text{) and } \omega = -\frac{\partial^2 \psi}{\partial y^2} \text{ (on y=0)} \qquad (10)$$

These equations are obtained in vertically zero velocity condition. The vorticity boundary conditions should also be found from tangential speed conditions which are not used before. The boundary condition for this function is as follows:

$$\omega = -\frac{\partial^2 \psi}{\partial x^2} \text{ and } \frac{\partial^2 \psi}{\partial x^2} = -V_0 \text{ at } 0 \le x \le L - \varepsilon \qquad (11)$$

$$\omega = -\frac{\partial^2 \psi}{\partial x^2} \text{ and } \frac{\partial^2 \psi}{\partial x^2} = -V_1 \text{ at } L - \varepsilon \le x \le L \qquad (12)$$

VII. Discrete of Velocity Equations

According to the definition of vorticity function the discrete of longitudinal and vertical components of velocity is as follows:

$$u_{i,j} = \frac{\psi_{i,j+1} - \psi_{i,j-1}}{2\Delta y} \qquad (13)$$

$$v_{i,j} = -\frac{\psi_{i+1,j} - \psi_{i-1,j}}{2\Delta x} \qquad (14)$$

VIII. Discrete of Vortex Equations

The discrete of vortex equation according to its definition, is as follows:

$$\frac{\psi_{i+1,j} - 2\psi_{i,j} + \psi_{i-1,j}}{\Delta x^2} + \frac{\psi_{i,j+1} - 2\psi_{i,j} + \psi_{i,j+1}}{\Delta y^2} = -\omega \qquad (15)$$

A. Discrete of Displacement-Distribution Equation

The discrete of displacement distribution equation according to its differential form, is as follows:

$$u_{i,j}\frac{\omega_{i+1,j} - \omega_{i-1,j}}{2\Delta x} + u_{i,j}\frac{\omega_{i,j+1} - \omega_{i,j-1}}{2\Delta y} = \nu\left\{\frac{\omega_{i+1,j} - 2\omega_{i,j} + \omega_{i-1,j}}{\Delta x^2} + \frac{\omega_{i,j+1} - 2\omega_{i,j} + \omega_{i,j-1}}{\Delta y^2}\right\} \qquad (16)$$

where Δx and Δy are the sizes of positioning steps and i and j are point indexes in x and y directions, respectively. The discrete forms of (15) and (16) can be arranged as follows:

$$\psi_{i+1,j} + \psi_{i-1,j} - 2\left(1+\beta^2\right)\psi + \beta^2\left(\psi_{i,j+1} + \psi_{i,j-1}\right) = -\Delta x^2 \omega \qquad (17)$$

$$\omega_{i+1,j} + \omega_{i-1,j} - 2\left(1+\beta^2\right)\omega_{i,j} + \beta^2\left(\omega_{i,j+1} + \omega_{i,j-1}\right) - \frac{u_{i,j}\Delta x}{2\nu}\left(\omega_{i+1,j} - \omega_{i-1,j}\right) - \frac{\beta v_{i,j}\Delta x}{2\nu}\left(\omega_{i,j+1} - \omega_{i,j-1}\right) = 0 \qquad (18)$$

where $\beta = \Delta x / \Delta y$. As it is mentioned before, the calculation of ψ at the upper bound is not possible via central difference method, therefore; the rebound difference method of the discrete form is used in this case:

$$\psi_{i,j} = \frac{1}{2\left(\beta^2 - 1\right)}\left\{\beta^2\left(\psi_{i,j-3} - 4\psi_{i,j-2} + 5\psi_{i,j-1}\right) - \left(\Delta x^2 \omega_{i,j} + \psi_{i+1,j} + \psi_{i-1,j}\right)\right\} \qquad (19)$$

Each of (17)-(19) determines a five-diagonal matrix. Totally, these equations can be solved via the inversing matrix, line by line and point to point methods. Since these equation systems are non-linear and their solution method is repeatable, the line by line method is preferred to inverse them.

IX. Results and Discussion

A program is written in Fortran 90. The code of this program is run for two different cases. In the first case (as shown in Fig. 3), the Reynolds number is 100.

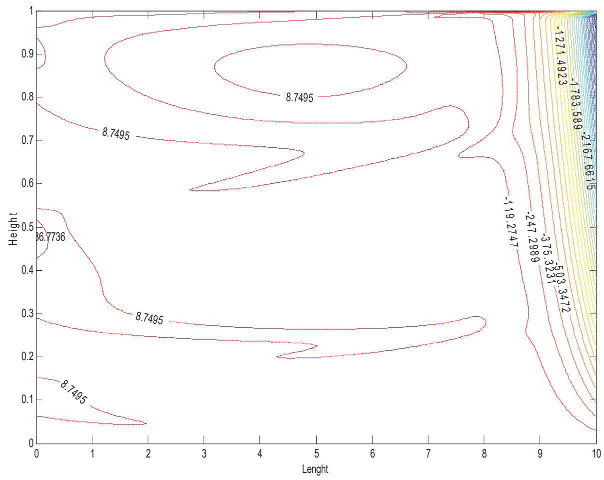


Fig. 3 Vorticity function contour for the first case

On the other case, it is 1000. The flow function contour for this case is shown in Fig. 4.

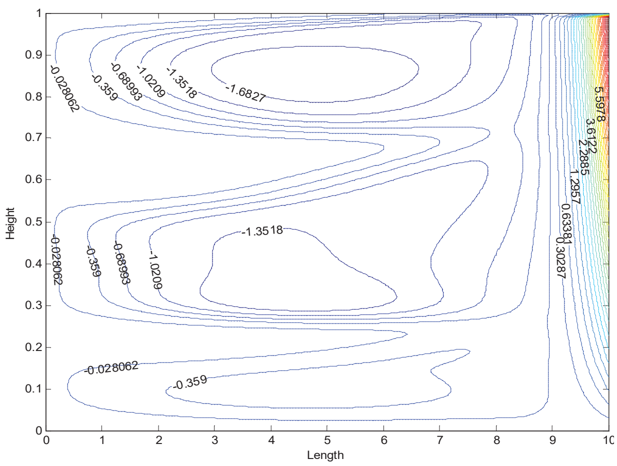


Fig. 4 Flow function contour for the first case

Geometric forms and cinematic conditions of these two cases such as the speed of notch, pressing load and the specifications of the fluid are different. The latter is more realistic. The typical Reynolds numbers are chosen according to the specifications of fluid normally used in the pressing process. For example, the least value of Reynolds number is related to the viscous oils with the high value of viscosity. In a second manner with the lower Reynolds number, since the viscosity of the oil is more, there is more vorticity going to be expected in comparison with the other case (as shown in Fig. 3). This subject is also confirmed by the contour of flow function in this case (as shown in Fig. 4). In the second case, the input parameters for cinematic and geometric conditions are closed to the real operational values. Since the ratio of fluid film height to the weight of press system (H/L) is very small in this case, it is expected that the fluid flow lines to be converged at the exhaust position (as shown in Figs. 5 and 6).

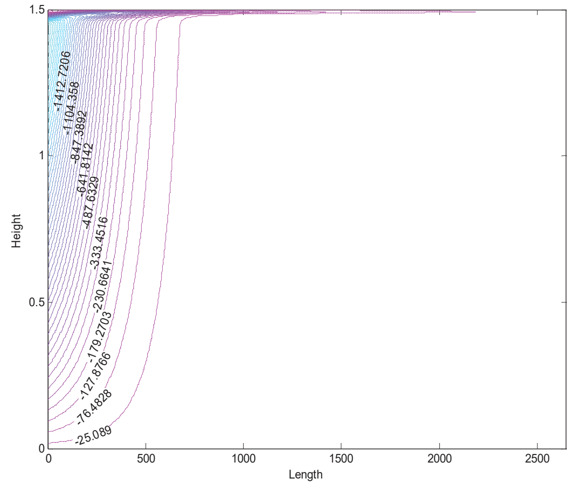


Fig. 5 Vorticity function contour for case Π

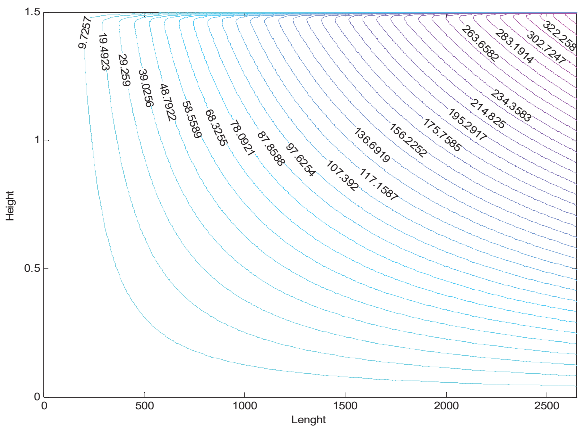


Fig. 6 Flow function contour for case Π

On the other case (case Π) vorticity function contour is 1000. Geometric forms and cinematic conditions of these two cases such as the speed of notch, pressing load and the specifications of the fluid are different. The latter is more realistic.

This subject is also confirmed by the contour of stream function in this manner. It is noteworthy that in the cases with very low H/L values, it is possible to use the obtained results in simulation of some special areas such as corners.

References

[1] K. Mijanovic, J. Kopac, “Environment management inside production systems,” Proceeding of the 13th International Scientific Conference, Gliwice, Poland,2005, pp. 429–433.

[2] E. Laitinen, J. Picska, V. Toivonen, "On 3D Daynamic Control of Secondary Cooling in Continuous Slab Casting Process," 8'th International Conference on Advanced Computational Methods in Heat Transfer ,Lisbon, Portugal, 2004, pp. 161–170.

[3] J. Jedrzejewski, Z. Kowal, "High Speed Precise Machine Tools Spindle Unit Improving,"13th International Scientific Conference, Gliwice, Poland,2005, pp.275–279.

[4] J. Okrajini, K. Mulvil, “Chemical Pipelines Material Fatigue,” 13th International Scientific Conference, Gliwice, Poland,2005, pp. 497-503.

[5] N.R. Dhar, S. Paul, A.B. Chattopadhyay, “The influence of cryogenic cooling on tool wear, dimensional of accuracy and surface finish in turning AISI 1040 and E4340C steels,” Int. J. Machine Tools & Manufacture,2001, pp. 932-942.

[6] R. Pantic, P. Ivanovic, “New Technologies in the Manufacturing of Vital Assemblies of Hydraulic Systems,” 5th International Conference on Research and Development in Mechanical Engineering(RaDMI),2003, Serbia & Montenegro, pp. 394-400.

[7] S.N. Chobal, A.R. Aher, R.R. Nadkarni," Design and Development of Hydraulic Multiside Pressworking Centre" Proceeding of the 16th all India Manufacturing Technology Design and Research Conference," Bangalore, India, 1994, pp.42-50.