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Analysis of the Pressure Distribution for Press Shoe considering Partially Changed Curvature of Bearing Surface

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A press shoe is an element of a machine for squeezing water from wood pulp in the field of manufacturing paper. This is used to compress the pulp enveloped by felt sheet with a large roller. The squeezing force is made by hydraulic pressure. The press shoe has a mechanism similar to a partial hydrostatic bearing. The pressure profile between press shoe and roller affects their squeezing ability, and partial peak pressure can tear the wet pulp. The curvature of the surface of press shoe varies to reduce the peak pressure and increase the mean pressure simultaneously. Therefore, the prediction of pressure distribution considering partially changed curvature of hydrostatic bearing is very important for designing the press shoe. In this study, the difference formulation of Reynolds' equation for partial hydrostatic bearing is derived by direct numerical method and a computer program to calculate the pressure distribution is developed. We investigate the effect of partially changed curvature of bearing surface on the pressure distribution. Other design parameter for hydrostatic bearing such as depth of pocket and relative velocity are also studied.

Keywords : Press shoe partially changed curvature, Hydrostatic bearing, direct numerical method

1. INTRODUCTION

In recent years, shoe presses, composed of roller and hydrostatic bearing, have been used to wring out wet paper. The squeezing ability of these machines depends highly upon their pressure profile between roller and bearing because the amount of remained water can be predicted by the pressure profile. At shoe press, the pressure is formed by tilting two pads, which make higher average pressure. But these mechanisms have some defect that has sudden rising pressure at the end part of bearing(see figure 2, tilting 1). This kind of peak pressure may cut off the paper. If we can reduce sudden rising pressure(see figure 2, tilting 2), these machines operate at a higher average pressure and have more efficiency. Therefore, the calculation of pressure profile in the shoe press is very important in order to design shoe press.

For these goals, we develop a computer program, which can calculate the pressure profile at the press shoe. This program can consider the curvature of bearing surface. We study the pressure profile according to variable pocket height and variable front or rear land shape. We know that land shape plays an import role in making pressure profile.

2. GOVERNING EQUATION

2.1 Governing equation

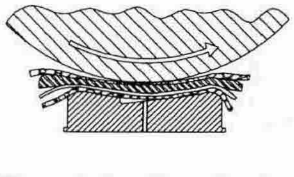


Figure 1. An object of study

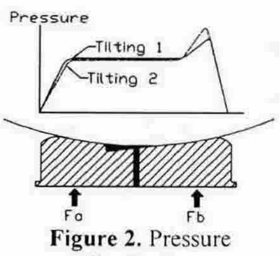


Figure 2. Pressure distribution of object

The bearing configuration used in the analysis is shown in Figure 1. The generalized dimensionless Reynolds' equation for incompressible fluid can be written as follows.[1]

$$\frac{\partial}{\partial\theta}\left(H^3\frac{\partial P}{\partial\theta}\right)+\frac{\partial}{\partial Z}\left(H^3\frac{\partial P}{\partial Z}\right)=\Lambda\frac{\partial H}{\partial\theta}+2\Lambda\frac{\partial H}{\partial\tau} \quad (1)$$

This equation is transform to the vector form and then finite difference equation is derived by direct numerical method using the mesh in Figure 3.[2]

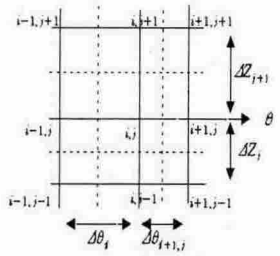


Figure 3. Mesh for analysis

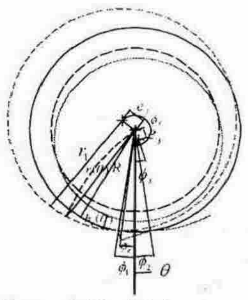


Figure 4. The lubricant film thickness

2.2 Flux to flow out pocket

The dimensionless flux from pocket is defined as follows. [3]

$$Q_{out}=Q_{ax}+Q_E-Q_W \quad (2)$$

The dimensionless flux to flow in through orifice is defined as follows.

$$Q_{in}=\frac{12\mu}{\sqrt{P_a C^3}}K_B\sqrt{P_s-P_r} \quad (3)$$

2.3 Lubricant film thickness

The dimensionless film thickness is written as [4]

$$H(\theta)=\frac{1}{C}\left[r(\theta)+h_e(\theta)-R\right] \quad (4)$$

3. NUMERICAL APPROXIMATION METHOD

3.1 Numerical procedure

If all pressure of pocket, eccentricity and attribute angle are given as input value, cost function is defined as follows:

$$\begin{aligned} &F_1(P_{r1},P_{r2},\ldots,P_{r11},\phi_s,e_s)=Q_{in,1}-Q_{out,1} \\ &\ldots \\ &F_{11}(P_{r1},P_{r2},\ldots,P_{r11},\phi_s,e_s)=Q_{in,11}-Q_{out,11} \\ &F_{12}(P_{r1},P_{r2},\ldots,P_{r11},\phi_s,e_s)=F_{ext,x}-F_x \\ &F_{12}(P_{r1},P_{r2},\ldots,P_{r11},\phi_s,e_s)=F_{ext,y}-F_y \end{aligned} \tag{5}$$

By multidimensional Newton-Raphson method, all pressure of pocket, eccentricity and attribute angle to satisfy cost function is obtained. [5]

4. RESULT

4.1 In case of changing the land shape

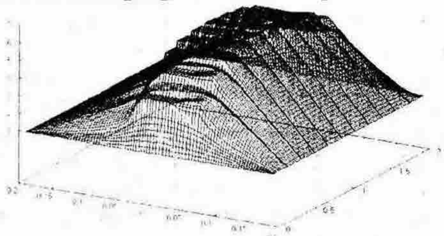


Figure 6. Three-dimensional pressure profile

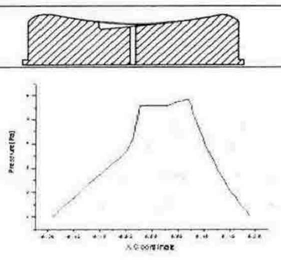
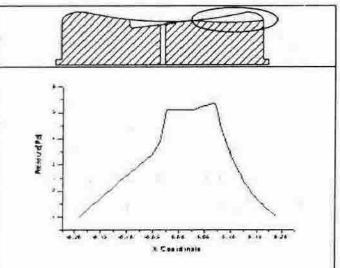
	
P_r =5.543409 P_{max} =5.813057 Difference=0.269648	P_r =5.543405 P_{max}=5.795923 Difference=0.252518

Figure 7. Modified rear land (**Case 1**. Modified rear land)

If the curvature of rear land is modified and the pressure of nozzle at rear land to be modified is equal to that at normal rear land, maximum pressure has a tendency to decrease. Also, as clearance at land end is larger than that at pocket end the peak pressure goes down. But the gradient of pressure at rear land is higher than that of normal rear land. As clearance at the end of rear land is the higher, average pressure at rear land becomes the smaller.

Case 2. Modified front land

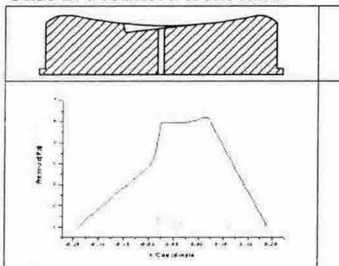
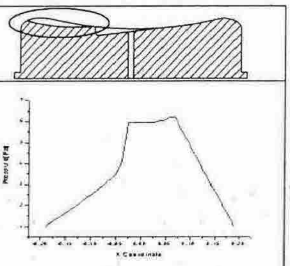
	
P_r =5.91607 P_{max} =6.174515 Difference = 0.258445	P_r =5.91607 P_{max} =6.182475 Difference =0.266405

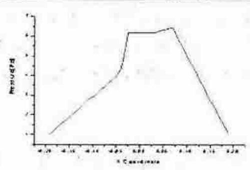
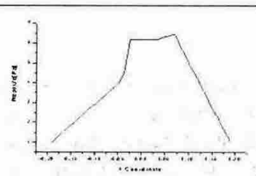
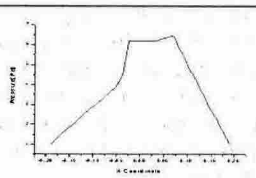
Figure 8. Modified front land

If the curvature of front land is modified and the pressure of nozzle at front land to be modified is equal to that at normal front land, maximum pressure has a tendency to **increase**. Also, as clearance at land end is larger than that at pocket end, the peak pressure go up. And clearance at the end of front land is the higher, average pressure at front land becomes the higher.

The before-mentioned result shows the follows.

1. As Q_{in} which is the flux to go through the pocket enter the pocket easer and more, peak value increase.
2. As Q_{out} which is the flux to go out the pocket enter the pocket easer and more, peak value decrease.

4.2 In case of changing the pocket depth

	**Pocket depth=10mm** P_r =6.137625 P_{max} =6.40211 Difference = 0.264485
	**Pocket depth=15mm** P_r =6.137724 P_{max} =6.402237 Difference = 0.264513
	**Pocket depth=20mm** P_r =6.137835 P_{max} =6.402376 Difference = 0.264541

In proportion to increasing the pocket depth, pressure is increased. But this increase rate is smaller than that of changing pocket curvature.

5. CONCLUSION

The pressure to be performed at shoe press is influenced by angular velocity of roller, radius of roller, supply pressure, orifice diameter, and so on. By this study, we investigate the effect of partially changed curvature of bearing surface on the pressure distribution. It shows that the curvature of land influence fluid motion. By controlling the fluid to go out the pocket easily, the peak pressure can be reduced.

6. REFERENCES

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