PERFORMANCE OF MAGNETIC FIELD ON SECANT CURVED CIRCULAR ANNULAR PLATES WITH COUPLE-STRESS FLUID

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Abstract

The theoretical study of magnetic field effect on secant curved circular annular plates with couple-stress fluid is presented in this study. Gap between the plates is filled with conducting non-Newtonian fluid having film thickness. The modified Reynolds equation is derived from the stoke theory the closed form of solution is obtained for pressure, load carrying capacity and squeezing time to study the influence of transverse magnetic field and couple stress lubricant on secant curved circular annular plates. The Non-dimensional pressure, load and squeeze time is obtained analytically and presented graphically. The results revealed that the use of magnetic field and couple stress lubricants show the significant increase in the pressure, load carrying capacity and squeeze time as compared to the non-magnetic and Newtonian case.

Keywords: MHD, Couple Stress, Reynolds Equation, Bearings.

1. Introduction

Now a days Magneto hydrodynamics plays an important role in physics that deals with dynamics of electrically conducting fluids. In present time much attention has been given to the various problems on the motion of electrically conducting liquid lubricants in magneto hydrodynamics theory of lubrications.

Hughes and Elco [1] studied the MHD lubrication flow between parallel rotating disks, they observed that the load carrying capacity is increased with external pressure or magnetic field strength and no flow with current. Maki E R [2] found the Magneto hydrodynamics lubrication flow between parallel plates based on the assumption that the bearing surfaces are perfectly smooth. Pinkus and Sternlicht [3] presented the lubricants found between the two surface acts as cushion ,which in deed prevents the surfaces making instantaneous contact. Cameron and Hamrock [4] found the bearing of squeeze film with Newtonian lubricants the study is focused on squeeze film phenomena of mechanism lubricated with the lubricants. Kuzma [5] analysed the magneto hydrodynamics journal bearing. The author found that the application of magnetic field by increasing the load carrying capacity. Malik & Singh [6] gave the conclusion on finite magneto hydrodynamics journal bearings. The magneto hydrodynamics squeeze film was investigated by Kuzma et.al [7] . MHD squeeze film bearing was investigated and found the result for various values of Hartmann number by

Dodge et.al [8]. Prakash and Vij [9] presented the effect of porosity which reduces the load carrying capacity for the slider bearing which is in the inclined form. Hazma [10] analysed the influence of MHD between parallel pates. Bujurke et.al [11] studied the effect of surface roughness on the squeeze film lubrication between curved annular plates. J.L. Gupta and K.H. Vora [12] presented the MHD squeeze film between curved circular plates. Deheri, et.al[13] gave the conclusion on based squeeze film behaviour between transversely rough curved annular plates.

To gain the knowledge of different physical problems, the concept of couple-stress fluid is important. Bujurke et.at [14] presented the influence of couple stresses in squeeze films. Ramanaiah [15] analyzed the Squeeze films between finite plates lubricated by couple stress fluid. Lin [16] analysed the squeeze film between a sphere and flat plate using couple stress fluid model. Lin [17] presented MHD squeeze film characteristics for finite rectangular plates. Effect of surface roughness on static and dynamic characteristic of MHD couple stress lubrication of parabolic slider bearing was studied by Naduvinamani et.al [18]. Naduvinamani et.al [19] present the Squeeze film lubrication of a short porous journal bearing with a couple stress fluid. Hanumagowda [20] studied results of the squeeze film performance with MHD and couple stress. Recently, Ayyappa et al [21-23] made the study on curved circular plate and flat plate with MHD couple stress, author reported that the existence of magnetic field and non-Newtonian lubricant will enhances the squeeze film performance.

From the literature no study has been done on the effect of MHD on secant curved annular plates with non-Newtonian fluid. Hence in the current study we made the theoretical analysis MHD on secant curved annular plates with non-Newtonian fluid.

2. Mathematical Solution

Figure-1 describes the geometry of secant curved annular circular plate with internal radius b and outer radius a. The upper plate approaches the lower plate with squeezing velocity V and external magnetic field B_0 is applied perpendicular the plates. The curvature parameters for upper and lower plates are β and γ.

The mathematical equations for MHD flow of incompressible couple stress lubricant within the film region are considered

$$\mu\frac{\partial^2 u}{\partial z^2}-\eta\frac{\partial^4 u}{\partial z^4}-\sigma B_0^2 u=\frac{\partial p}{\partial r} \tag{1}$$

$$\frac{\partial p}{\partial z}=0 \tag{2}$$

$$\frac{1}{r}\frac{\partial}{\partial r}(ru)+\frac{\partial w}{\partial z}=0 \tag{3}$$

Where, u, w are the velocity components at r, z directions, p be the pressure in the fluid film region, μ be the viscosity coefficient, σ is lubricant conductivity and η new material constant for the characteristics of couple stress.

Boundary Conditions are :

i)**At the upper surface z=h**

$$u = 0 \qquad \frac{\partial^2 u}{\partial z^2}=0, \tag{4a}$$

$$w = V = {-\partial h_0}/{\partial t} \tag{4b}$$

ii) **At the lower surface z=0**

$$u=0 \qquad \frac{\partial^2 u}{\partial z^2}=0, \tag{5a}$$

$$w=0 \tag{5b}$$

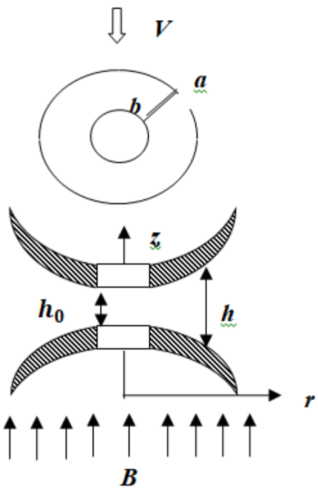

Fig. 1(a). Geometrical representation of the problem.

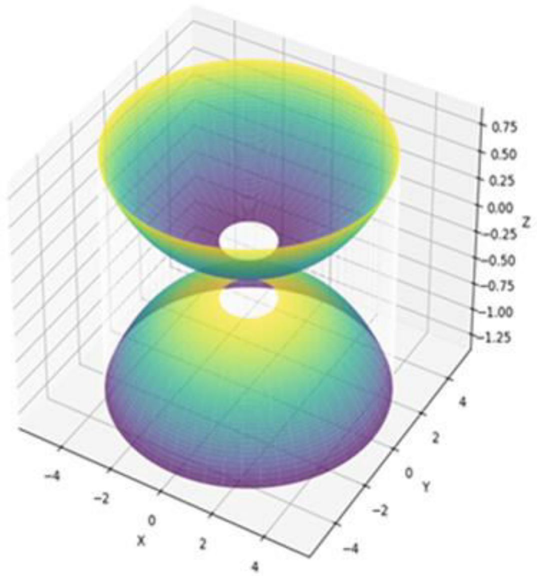

Fig. 1(b). 3D visualization of the problem.

Solving the equation (1) by reducing in the form ODE with help of boundary conditions (4a) and (5a) to get the velocity component

$$u=\frac{1}{\sigma B_0^2}\frac{\partial p}{\partial r}\left\{\left(-\frac{B^2}{(A^2-B^2)}\frac{Cosh\frac{A(2z-h)}{2l}}{Cosh\frac{Ah}{2l}}+\frac{A^2}{(A^2-B^2)}\frac{Cosh\frac{B(2z-h)}{2l}}{Cosh\frac{Bh}{2l}}\right)-1\right\} \qquad (6)$$

Using equation (6) in continuity equation (3) and integrating the across the film thickness using the relevant boundary conditions (4b) and (5b) we obtain a Reynolds equation which is mentioned below

$$\frac{1}{r}\frac{\partial}{\partial r}\left\{rS(h,l,M_0)\frac{\partial p}{\partial r}\right\}=-\mu V$$

(7)

Where, $S(h,l,M_0)=\frac{h_0^2}{M_0^2}\left\{\frac{2l}{(A^2-B^2)}\left(\frac{B^2}{A}Tanh\frac{Ah}{2l}-\frac{A^2}{B}Tanh\frac{Bh}{2l}\right)+h\right\}$

The film shape h is taken to be an exponential type

Upper plate lying along the surface determined by the relation

$$z_u=h_0\sec(\beta r^2)\,; \qquad b\le r\le a \qquad (8)$$

Lower plate lying along the surface determined by the relation

$$z_l=h_0\left\{\sec\left(\gamma r^2\right)-1\right\}\,;\; b\le r\le a \qquad (9)$$

Where β and γ are the curvature parameters of the corresponding plates and h_0 is the central film thickness. The film thickness $h(r)$ then,

$$h(r)=h_0\left\{\sec(\beta r^2)-\sec(\gamma r^2)+1\right\};\; b\le r\le a \qquad (10)$$

Introducing the following non-dimensional quantities in equation (7),

$$\bar r=\frac{r}{a},\bar h=\frac{h}{h_0}\,\bar l=\frac{2l}{h_0},\bar P=-\frac{h_m{}^3p}{\mu a^2V},K=\beta a^2,C=\gamma a^2,$$

$$\bar h=\sec(K\bar r^2)-\sec(C\bar r^2)+1$$

The Reynolds equation for film pressure is given by

$$\frac{1}{\bar{r}}\frac{\partial}{\partial \bar{r}}\left\{\bar{r}\bar{S}\left(\bar{h},\bar{l},M_0\right)\frac{\partial \bar{P}}{\partial \bar{r}}\right\}=-1 \tag{11}$$

The boundary conditions to present the squeeze problem is,

$$\bar{P}=0 \quad \text{at} \quad \bar{r}=\delta=b/a \tag{12a}$$

$$\bar{P}=0 \quad \text{at} \quad \bar{r}=1 \tag{12b}$$

The expression for $\bar{P}$ is obtained by integrating equation (11) with the help of above pressure boundary conditions

$$\bar{P}=\frac{f_2(\bar{r})\,f_1(1)-f_1(\bar{r})\,f_2(1)}{2f_2(1)}$$

(13)

Where, $f_1(1)=\int\limits_{\bar{r}=a}^{1}\frac{\bar{r}}{\bar{S}\left(\bar{h},\bar{l},M_0\right)}\,d\bar{r}$, $f_2(1)=\int\limits_{\bar{r}=a}^{1}\frac{1}{\bar{r}\bar{S}\left(\bar{h},\bar{l},M_0\right)}\,d\bar{r}$

The expression for load carrying capacity is obtained by integrating above equation between the limit 0 to 1.

$$\bar{W}=\frac{-1}{2}\int\limits_{\bar{r}=a}^{1}f_1(\bar{r})\bar{r}\,d\bar{r}+\frac{1}{2}\frac{f_1(1)}{f_2(1)}\int\limits_{\bar{r}=a}^{1}f_2(\bar{r})\bar{r}\,d\bar{r}$$

(14)

Integrating the above equation with respect to dimensionless minimum film thickness then we obtain the non-dimensional squeezing time

$$\bar{T}=\int\limits_{\bar{h}_0}^{1}\left(\frac{2f_2(1)}{f_2(1)\int\limits_{\bar{r}=a}^{1}f_1(\bar{r})\bar{r}\,d\bar{r}-f_1(1)\int\limits_{\bar{r}=a}^{1}f_2(\bar{r})\bar{r}\,d\bar{r}}\right)d\bar{h}_0$$

(15)

Where, $\bar{h}=\bar{h}_0\left\{\sec(K\bar{r}^2)-\sec(C\bar{r}^2)+1\right\}$

3. RESULT AND DISCUSSION

The effect of MHD on secant curved circular plates with couple stress lubricant is analysed and the squeeze film characteristics are examined regarding the non-dimensional parameters like Hartmann number M_0 and couple stress parameter l^*.

3.1 Dimensionless Pressure

Figure 2 & 3 depicts the non-dimensional pressure $\overline{P}$ with horizontal coordinates r^* for distinct values of Magnetization M_0 and couple stress l^* keeping held $K = 0.8$, $J = 0.8$ and b = 0.3. It shows that magnetization and couple stress lubricant effects on secant curved annular circular plates is bump up the pressure distribution at the centre with the rise of M_0 and l^* in comparison to in cases of magnetic field and Newtonian cases. The pressure distribution $\overline{P}$ along r^* as a function of lower curvature parameter J reported that there is a decrease of pressure distribution in the fluid region due to increase of lower curvature parameter J.

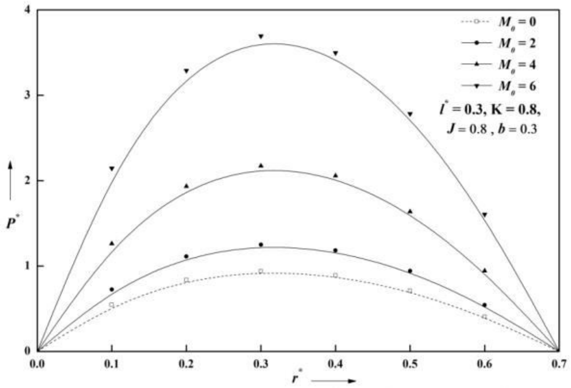

Figure 2. Variation of non-dimensional pressure P^* *verses* r^* distinct M_0 with $l^* = 0.3$, $K = 0.8$, J = 0.8 and $b = 0.3$

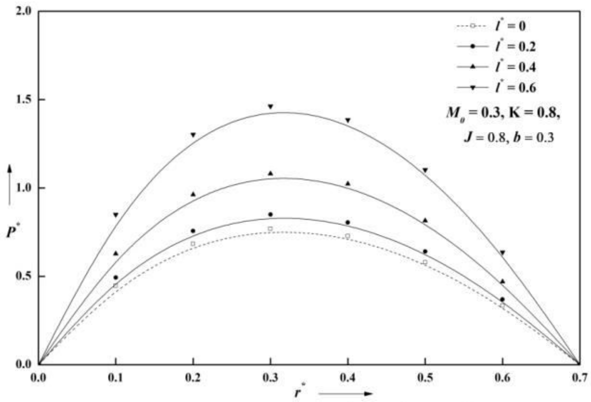

Figure 3. Variation of non-dimensional pressure P^* *verses* r^* distinct l^* with $M_0 = 0.3$, $K = 0.8$, J = 0.8 and $b = 0.3$

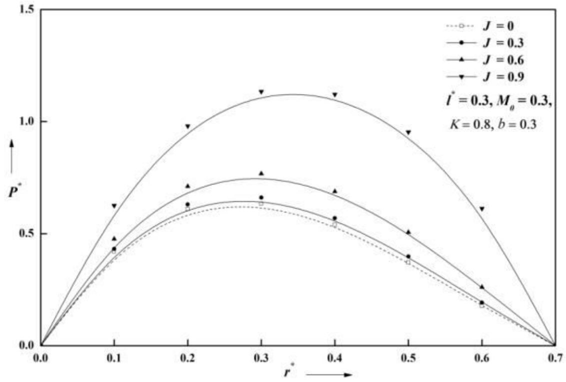

Figure 5. Variation of non-dimensional pressure P^* *verses* r^* distinct J with M_0=0.3, l^*= 0.3 , K= 0.8 and b=0.3

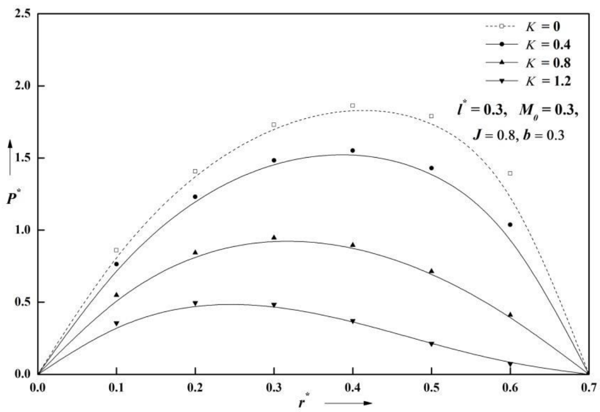

Figure 4. Variation of non-dimensional pressure P^* *verses* r^* distinct K with M_0=0.3,l^*= 0.3, J = 0.8 and b = 0.3

3.2 Dimensionless Load carrying capacity

Figure 6 and 7depicts the profile of non-dimensional load carrying W^* against curvature parameter J for distinct values M_0 and l^* with $K = 0.8$ and $b = 0.3$ the impact of magnetization is enhance the load carrying capacity compared to non-magnetic case and the effect of couple stress lubricant is creates the pressure distribution in the fluid film region this causes the rise of load support capacity. We found decrease of load carrying due to increase of upper curvature parameter K in figure 8.

Figure 9 and 10 declares the increase of load capacity due to the impact of magnetization and non-Newtonian lubricant as a function of curvature parameter K with $J = 0.8$ and $b = 0.3$. We found increase of load carrying due to increase of lower curvature parameter J in figure 11.

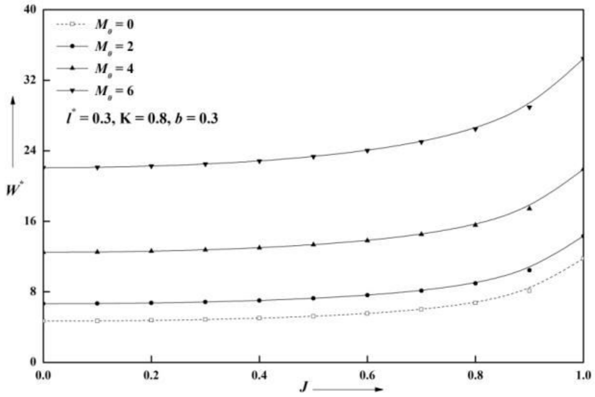

Figure 6. Variation of non-dimensional Load Carrying W^* *verses* J^* distinct M_0 with $l^* = 0.3$, $K = 0.8$ and $b = 0.3$.

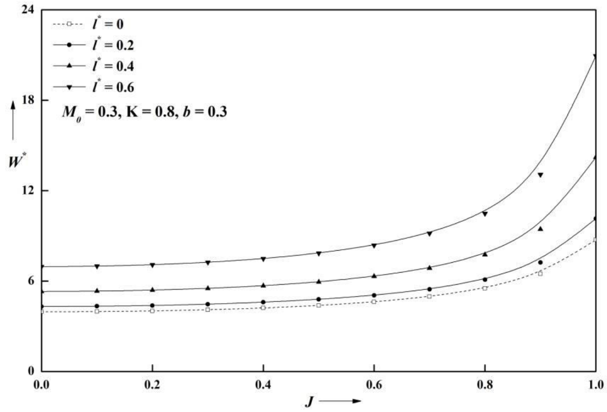

Figure 7. Variation of non-dimensional pressure W^* *verses* J^* distinct l^* with $M_0 = 0.3$, $K = 0.8$ and $b = 0.3$

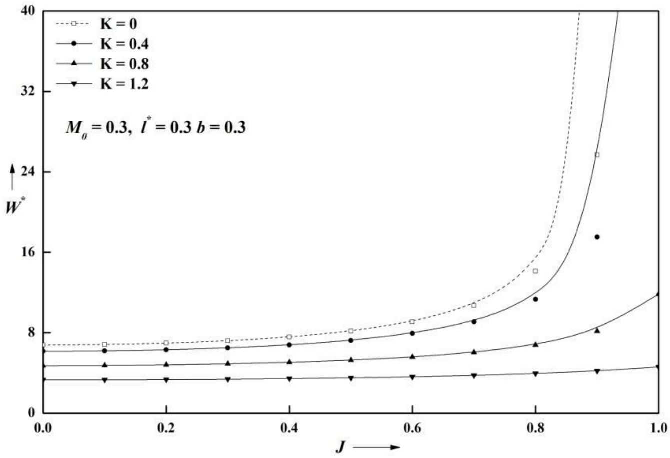

Figure 8. Variation of non-dimensional pressure W^* *verses* J^* distinct K with $M_0 = 0.3$, $l^* = 0.8$ and $b = 0.3$

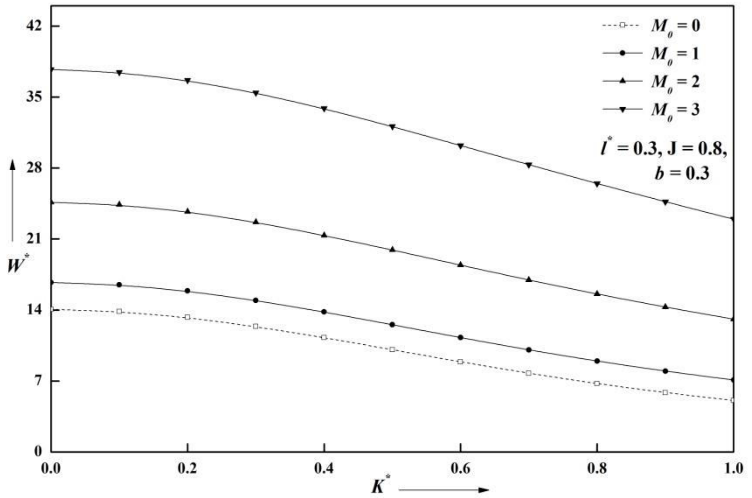

Figure 9. Variation of non-dimensional Load Carrying Capacity W^* *verses* K^* distinct M_0 with $l^* = 0.3$ $J = 0.8$ and $b = 0.3$

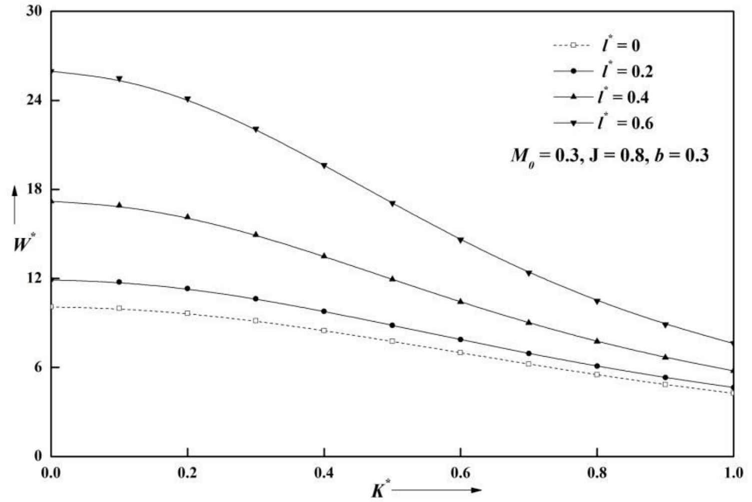

Figure 10. Variation of non-dimensional Load Carrying Capacity W^* *verses* K^* distinct l^* with $M_0 = 0.3$, $J = 0.8$ and $b = 0.3$.

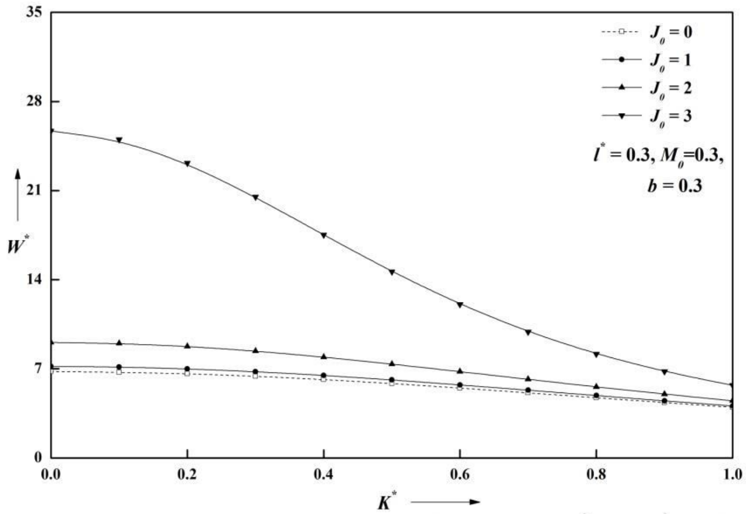

Figure 11. Variation of non-dimensional Load Carrying Capacity W^* *verses* K^* distinct J with M_0 =0.3, l^* = 0.3 and b = 0.3

3.2 Dimensionless Squeeze film

For distinct values of Hartmann number M_0 and couple stress l^* graphs of squeezing time $\overline{T}$ along minimum film thickness h_0^* plotted and keeping other physical parameters constant is displayed in figure 12 and 13 from these graphs we concludes there is an increase of squeezing time due to impacts of magnetization and couple stress. Further the squeezing time decreases as increase of film thickness h_0^*. More fluid preserve in the film region due to external magnetic field which actively persist the flow. Thus, the squeeze film time increases significantly leak the fact that the magnetic field offers the delayed squeeze film of the plates.

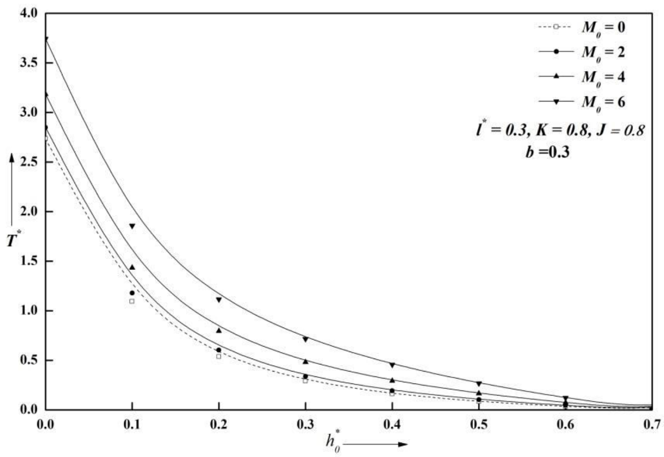

Figure 12. Variation of non-dimensional Squeeze film time T^* *verses* h_0^* distinct M_0 with l^* = 0.3 ,K = 0.8 J = 0.8 and b = 0.3

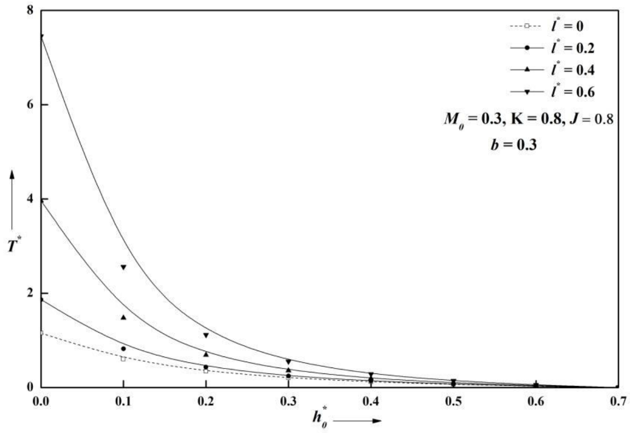

Figure 13. Variation of non-dimensional Squeezing Time T^* versesh_0^* distinct l^* with $M_0 = 0.3$, $K = 0.8$, J = 0.8 and $b = 0.3$.

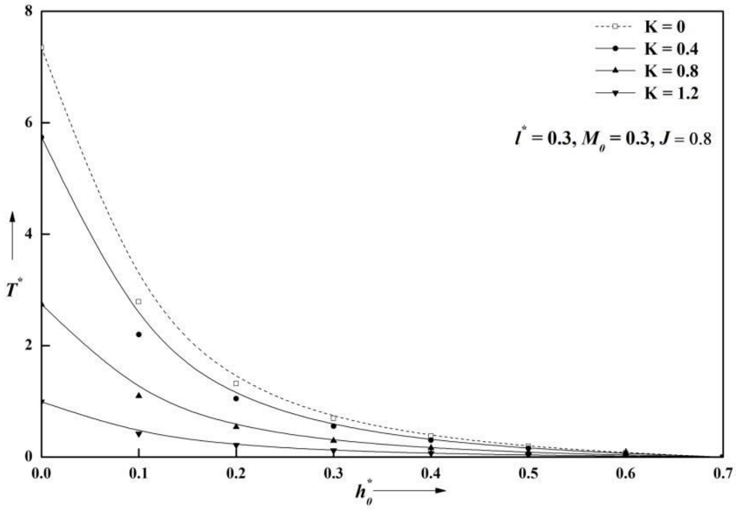

Figure 14. Variation of non-dimensional Squeeze film time T^* verses h_0^* distinct K with $l^* = 0.3$,$M_0 = 0.3$, J = 0.8 and $b = 0.3$.

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