ABSTRACT

Hydrodynamic squeeze films play an important role in engineering practice. The discovery of film lubrication had a profound effect on the design of bearings. It resulted in a complete reversal and understanding in the limitations of bearing design, operation and life expectancy of machinery.

The squeeze film behaviour arises from the phenomenon of two lubricated surfaces approach each other with a normal velocity. Because the viscous lubricant contained between these two surfaces cannot be instantaneously squeezed out, it takes a certain time for these surfaces to come into contact. Hence the viscous lubricant has a resistance to extrusion, a positive pressure is built up during that interval and the lubricant film then supports the load. No solid surface is perfectly smooth on atomic scale. In other words, all solid surfaces are rough to some extent. The effect of surface roughness plays a significant role in the development of science and technology of tribology.

In chapter 1, the main constituencies of Tribology, namely, Friction, Wear, Lubrication are discussed. Also, the theory of non-Newtonian fluid and its behaviour, fluid film lubrication and its application are accounted. The basic equations governing the flow of hydrodynamic lubrication are discussed.

In chapter 2, the basic equations and some basic concepts of squeeze film lubrication are discussed. The chapter also includes a literature review.

In chapter 3, the squeeze film lubrication theory between two isotropic porous elliptic plates has been analyzed to study the effects of couple stresses arising due to the presence of micro-structure additives in the
lubricant. The squeezing flow of couple-stress fluid between two elliptic plates is considered. The upper plate is approaching the lower, stationary porous plate. The gap between the plates is filled with a couple stress fluid. The most general form of the modified Reynolds equation is derived for the squeeze film lubrication of the porous elliptic plates and an expression for squeeze time is obtained. The important parameters for discussing the behaviour of bearing characteristics are the couple stress parameter $\tilde{l}$, the percolation parameter $\beta$ and the slip coefficients $s$, permeability parameter $\psi$ and viscosity coefficient $\lambda$. It is observed that there is significant increase in the load carrying capacity and hence delayed squeeze time for fluids with couple stress in comparison with Newtonian fluids. According to the results evaluated, the presence of micro structures in the fluid film cause an enhancement of squeeze film time compared with the Newtonian case. The couple stress effects are more prominent when either the molecular size of the polar additives is large or the minimum film thickness is small.

In chapter 4, the effect of surface roughness on the squeeze film behaviour between two elliptic plates, when one plate has a porous facing with isotropic permeability has been studied. The stochastic Reynolds equation accounting for the couple stress and randomized surface roughness structure is mathematically derived. Modified equations for the mean pressure, mean load carrying capacity and squeeze film time are obtained by using the Christensen stochastic theory for hydrodynamic lubrication of rough surfaces. It is observed that the effect of roughness and couple stress fluid is to provide a significant load carrying capacity and ensure a delayed squeezing time compared to the normal case. On the basis of Christensen stochastic model, the effect of surface roughness and couple stress as lubricant on the squeeze film between two parallel finite elliptic plates is presented. The Stochastic Reynolds equation for the mean film pressure and hence the load carrying
capacity are solved numerically. It is found that the effect of roughness along with couple stress lubricant is to increase the load carrying capacity.

In chapter 5, a theoretical analysis of hydrodynamic squeeze film behaviour for long partial porous journal bearing lubricated by fluid with couple stress is presented. To take into account the couple stress effects, the modified Reynolds equation governing the film pressure is obtained from Stokes equation of motion. The analysis takes into account the velocity slip at the surface of the porous medium by using Beaver-Joseph criterion. The dimensionless load carrying capacity $W$ is a function of the eccentricity ratio $e$. Results reveal that the load carrying capacity is higher for couple stress fluids than the Newtonian case. Since the couple stress accounts for the higher squeeze film pressure the load carrying capacity is also higher. Bearing characteristics are then calculated and compared with the Newtonian lubricant case. Moreover the quantitative effects are more significant for higher values of $\ell$. On the whole the squeeze film characteristics of the system are significantly improved.

In chapter 6, an attempt to study and analyze the performance of a couple stress fluid based squeeze film between infinitely long plane porous rectangular plates has been made. The associated Reynolds equation is solved with suitable boundary conditions to get the pressure distribution which is then used to obtain the expression for load carrying capacity leading to the calculation of response time. The results are presented graphically. The behaviour of bearing characteristics with respect to the couple stress parameter $\bar{\ell}$ and the percolation parameter $\beta$ and the slip coefficient $s$ and the permeability parameter $\psi$ are analyzed. The observations show that there is significant increase in the load carrying capacity and hence delayed squeeze time for fluids with couple stress compared to Newtonian fluids.
In chapter 7, the surface roughness effects on the hydrodynamic lubrication of squeeze film between infinitely long parallel plates are analyzed. The modified Reynolds equation which incorporates randomized roughness structure with Stoke’s couple stress fluid is solved with suitable boundary conditions to get the pressure distribution, which is then used to obtain the load carrying capacity. The results are presented graphically as well as in tabular form. It is observed that the effect of surface roughness on the bearing characteristics are more pronounced for couple stress fluids as compared to the Newtonian fluids. The observations show that the bearing system registers a slightly enhanced performance for higher values of couple stress parameter. Also the present study indicates that there is a negative influence in the bearing characteristic due to the parameters α (mean) σ (the standard deviation) and ε (a measure of symmetry of random variable h_s). It is observed that the effect of rough surface decreases the load carrying capacity whereas the squeeze film characteristics are more pronounced for a couple stress fluid. It is expected that the couple stress effects are prominent either when the chain – length of the polar additives is large or the film thickness is small.

Chapter 8, gives the conclusion and lists the various applications of squeeze films in our day to day life. This chapter also includes the recommendation for future work.