INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

OPEN ACCESS

Received: 16-10-2024

Accepted: 05-02-2025

Published: 28-02-2025

Citation: Naduvinamani NB, Koppa BK (2025) Impact of Viscosity Variation on The Static and Dynamic Characteristics of Squeeze Film Lubrication of Rough Short Journal Bearing With Micropolar Fluid. Indian Journal of Science and Technology 18(8): 595-607. https://doi.org/10.17485/IJST/v18i8.3402

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Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Impact of Viscosity Variation on The Static and Dynamic Characteristics of Squeeze Film Lubrication of Rough Short Journal Bearing With Micropolar Fluid

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Abstract

Objectives: The theoretical examination of the impact of variation in viscosity of micropolar fluid lubricant on dynamic and static characteristics of rough short journal bearings lubrication with squeezing effect and to compare it with the performance of non-viscosity variation. **Method:** The mathematical model for the physical problem considered, modified stochastic Reynolds type equation assessing for variation in viscosity of micropolar fluid and structure of roughness on bearing surface is inferences by exploiting a random variable having stochastic behavior with non–zero mean, skewness and variance. The analysis is done for both the scenarios of a stable and an alternating applied load. **Findings:** According to the result, the velocity of the journal center is reduced by the micropolar fluid when there is a cyclic load, and analysis is done on the impact of viscosity variation in micropolar fluid on the squeeze film behaviors of rough short journal bearing reviles that, the viscosity variation parameter is to diminish the pressure and load carrying capacity in squeeze film and increases the velocity of journal center. **Novelty:** The original research was conducted on the variation in viscosity of micropolar fluid lubricant on dynamic and static behaviors of squeeze film lubrication of rough short journal bearings and results are compared with non-viscosity variation parameter. This, according to the authors' knowledge of the literature, has not yet been investigated.

Keywords: Journal Bearings; Micropolar Fluids; Surface Roughness; Viscosity Variation; Dynamic Loading

1 Introduction

Journal bearings are the most fundamental kinds of bearings that allow the shaft to rotate freely within a sleeve. The section of the shaft that fits inside these bearings is referred to as a journal bearing. There are no rollers in these bearings to support radial loads, but the shafts' weight makes them capable of supporting these weights. In order to raise the overall level of machine reliability, journal bearings are important. The accomplishment of journal bearings, which function under a variety of specifications and lubrication circumstances is greatly impacted by advancements in lubrication methodology. Tipei [1] explained lubrication theory and its applications. The influence of lubricants on the performance of journal bearings was presented by Sunil.et al [2]. The majority of industrial operating conditions use lubricants that are either blended with additives or oils that have been thickened with polymer. Normally, these lubricants become laboriously stuffed with abandoned particles of metal or debris and they begin to manifest non-Newtonian character. One such non-Newtonian fluid is micropolar fluid which comes under the category of microfluid. These fluids have inertia and microrotational effects along with body couples and support surface and these are commonly represented the complex fluids with microstructure, for example, animal blood and liquid crystals. Several microcontinum theories have been suggested to consider the influence of additives. Eringen [3,4] studied the theory of micropolar fluids and the implications of simple micropolar fluids. Theoretical analysis of single-layered porous short journal bearing under the lubrication of micropolar fluid was analyzed by Bhattacharjee et.al [5]. Several investigators have used dimensionless forms of characteristic length. Nicolae Tipei [6] studied the implementation of micropolar fluids lubrication to short journal bearings. Squeeze film technology is extensively employed in numerous engineering applications for example disk clutches, gears, dampers, human body, machine tools industry and aircraft engines. Newtonian fluid lubricants are usually enforced in squeeze film bearing, with the evolution of contemporary machine tools, the expanding usage of lubricants with microstructures, including an accumulative suspension. Chaithra and Hanumagowda [7] discussed the effect of Micropolar Fluid to Study the Characteristics of Squeeze Film Between Porous Curved Annular Plates. During the past few years, a significant portion of tribology investigations have been committed to the examination of the impact of geometric imperfections or roughness on hydrodynamic lubrication, basically because, in realistically majority of the bearing surfaces are uneven. The definite height and aspect ratio of roughness asperities are influenced by the attributes of the material and also by the method used for surface consciousness. The influence of roughness asperities on hydrodynamic bearing lubrication has been examined by numerous investigators. The theory of stochastic for the study of hydrodynamic lubrication of rough surfaces was established by Christensen [8]. Yang and Lee [9] studied the concept of steady-state and dynamic performances of journal bearing based on rough surface reconstruction technology. Naduvinamani and Kashinath [10] study the concept of consequences of micropolar fluids and roughness impact on dynamic and static performance of short journal bearing lubrication with squeezing effect under fluctuating loads without journal rotation. The viscosity's temperature variation is significant in numerous experimental applications where lubricants must be able to function across a wide temperature range. The change in oil's viscosity with temperature cannot be reliably predicted by any basic mathematical relationship. For accurate calculations, the lubrication engineer requires experimental data, as the implied formulas for defining the viscosity-temperature are entirely empirical. The present article presumes that the relationship between viscosity and film thickness can take the place of the viscosity-temperature relationship. This makes sense because it has been experimentally confirmed that the areas with the lowest film thickness have the highest temperatures [1]. When viscosity μ_{iv} at $H = h_1$ is known, then

$$\mu = \mu_{iv}\left(\frac{H}{h_1}\right)^Q$$

In general, Qlies between 0 and 1 depending on lubricant behavior. The thermal calculations can be completed to determine unknown$Q$. However, with regard to deliberating about the influence of viscosity variation without performing in-depth thermal computations, different numerical values for Q are assumed in this paper. The effect of viscosity variation on non-Newtonian lubrication of squeeze film conical bearing having porous wall operating with Rabinowitsch fluid model was explained by Rao and Rahul [11]. The effect of surface texturing and variation of viscosity on the squeeze film lubrication of journal bearings in the presence of micropolar fluids was postulated by Naduvinamani. et.al. [12].

The aim of the present paper is to analyze the impact of viscosity variation on the squeeze film performance of micropolar fluid lubricated rough short journal bearings in both static and dynamic behavior which has not yet been investigated, according to the authors' knowledge of the literature. As a result, this study attempted to analyze the influence of viscosity variation on the squeeze film lubrication of rough short journal bearings lubricated with micropolar fluid using Eringen's [3] micropolar fluid theory.

2 Methodology

Figure 1 shows a schematic diagram of the problem being examined. The journal with zero rotation and radius R is an impending surface of bearing with known velocity $(\frac{\partial h}{\partial t})$at any circumferential section θ. To represent surface roughness mathematically, the thickness of film can be defined as

$$H = h(\theta) + h_s{}^* \tag{1}$$

Where h is the average film thickness and it is defined as $h(\theta) = c[1 + \varepsilon cos\theta]$, here c is radial clearance, ε is the eccentricity parameter factor, the bearing's roughness is described by $h_s{}^*$, a randomly fluctuating number that is measured from the mean level.

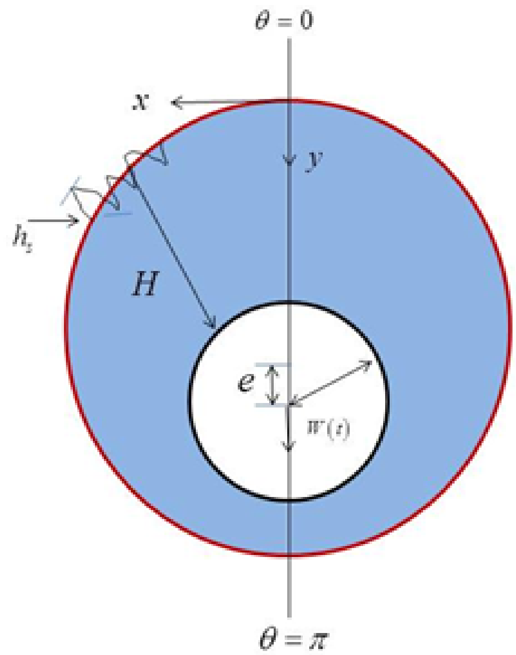

Fig 1. Geometrical configuration of the considered problem

The probability density function $f(h_s{}^*)$defined over the domain $-c^{'} \leq h_s{}^* \leq c^{'}$ where $c^{'}$ represents maximum deviation from the average thickness of film. $\alpha^{'}$, $\sigma^{'}$ and $\varepsilon^{'}$ are mean, standard deviation and parameter respectively, which is measure of the symmetry of the random variable $h_s{}^*$, are defined as[10].

$$\alpha^{'} = E[h_s^*] \tag{2}$$

$$\sigma^{'2} = E[\left(h_s^* - \alpha^{'}\right)^2] \tag{3}$$

$$\varepsilon^{'} = E[\left(h_s^* - \alpha^{'}\right)^3] \tag{4}$$

where E, the expectancy operator defined as follows

$$E(\bullet) = \int_{-\infty}^{\infty} (\bullet) f(h_s{}^*)\, dh_s{}^*$$

The parameters $\alpha^{'}$, $\sigma^{'}$ and $\varepsilon^{'}$ are not dependent on x. While $\sigma^{'}$ can always take on positive values, parameter $\varepsilon^{'}$ and mean $\alpha^{'}$ are acceptable on negative and positive values. The specific instance of $\varepsilon^{'} = 0$ related to symmetrical issuances. Negative and positive values of $\varepsilon^{'}$ assigns to negatively and positively skewed roughness respectively on surface bearing.

With normal supposition of lubrication theory, the governing equations for micropolar fluid suggested by Eringen[4] are given by

$$\left(\mu+\frac{\chi}{2}\right)\frac{\partial^2 u}{\partial y^2}+\chi\frac{\partial v_3}{\partial y}-\frac{\partial p}{\partial x}=0 \tag{6}$$

$$\frac{\partial p}{\partial y}=0 \tag{7}$$

$$\left(\mu+\frac{\chi}{2}\right)\frac{\partial^2 \omega}{\partial y^2}-\chi\frac{\partial v_1}{\partial y}-\frac{\partial p}{\partial z}=0 \tag{8}$$

Angular momentum conservation

$$\gamma\frac{\partial^2 v_1}{\partial y^2}-2\chi v_1+\chi\frac{\partial w}{\partial y}=0 \tag{9}$$

$$\gamma\frac{\partial^2 v_3}{\partial y^2}-2\chi v_3-\chi\frac{\partial u}{\partial y}=0 \tag{10}$$

Mass conservation

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \tag{11}$$

Where μ is the Newtonian viscosity and χ,γ are spin viscosity and viscosity coefficient for micropolar fluids u,v and w are velocity components in x,y and z directions, respectively, and v_1,v_2 and v_3 are components of microrotational velocity.

Admissible boundary circumstances are

i. At $y=0\ (bearing\ surface)$

$$u=0,\ v=0,\ w=0 \tag{12}$$

$$v_1=0,\ v_3=0 \tag{13}$$

ii. At $y=H$ (journal surface)

$$u=0,\ v=-V,\ w=0 \tag{14}$$

$$v_1=0,\ v_3=0 \tag{15}$$

Here, V =Squeezing velocity= $\frac{\partial H}{\partial t}$

Under the related boundary circumstances provided in Equations (12), (13), (14) and (15), the solutions of Equation (6) and Equations (8), (9) and (10) are,

$$u=\frac{1}{\mu}\left(\frac{y^2}{2}\frac{\partial p}{\partial x}+A_{11}y\right)-\frac{2N^2}{m}\times[A_{21}sinh(my)+A_{31}cosh(my)]+A_{41} \tag{16}$$

$$w=\frac{1}{\mu}\left(\frac{y^2}{2}\frac{\partial p}{\partial z}+A_{12}y\right)-\frac{2N^2}{m}\times[A_{22}sinh(my)+A_{32}cosh(my)]+A_{42} \tag{17}$$

$$v_1 = \frac{1}{2\mu}\left(y\frac{\partial p}{\partial z} + A_{12}\right) + A_{22}cosh(my) + A_{32}sinh(my) \tag{18}$$

$$v_3 = A_{21}cosh(my) + A_{31}sinh(my) - \frac{1}{2\mu}\left(y\frac{\partial p}{\partial x} + A_{11}\right) \tag{19}$$

Where

$$A_{11} = 2\mu A_{21}$$

$$A_{21} = \frac{A_{31}sinh\,(mH) - [\frac{(H)}{(2\mu)}]\,[\frac{(\partial p)}{(\partial x)}]}{1 - cosh\,(mH)}$$

$$A_{12} = -\frac{H}{2\mu}\frac{\partial p}{\partial z}\{Hsinh\,(mH) + \frac{2N^2}{m}[1 - cosh\,(mH)]\} \times \frac{1}{A_5}$$

$$A_{12} = -\frac{H}{2\mu}\frac{\partial p}{\partial z}\{Hsinh\,(mH) + \frac{2N^2}{m}[1 - cosh\,(mH)]\} \times \frac{1}{A_5}$$

$$A_{22} = \frac{A_{12}}{2\mu}$$

$$A_{31} = \frac{H}{2\mu}\frac{\partial p}{\partial x}\{\frac{H}{2}[cosh\,(mH) - 1] + H - \frac{N^2}{m}sinh\,(mH)\} \times \frac{1}{A_5}$$

$$A_{32} = \frac{1}{\mu}\frac{\partial p}{\partial z}\{\frac{H}{2}[cosh\,(mH) - 1] + H - \frac{N^2}{m}sinh\,(mH)\} \times \frac{1}{A_5}$$

$$A_{41} = \frac{2N^2}{m}A_{31}$$

$$A_{42} = \frac{2N^2}{m}A_{32}$$

$$A_5 = \frac{H}{\mu}\{sinh\,(mH) - \frac{2N^2}{mH}[cosh\,(mH) - 1]\}$$

in which $m = \frac{N}{l}$, $N = \left(\frac{\chi}{\chi + 2\mu}\right)^{\frac{1}{2}}$, $l = \left(\frac{\gamma}{4\mu}\right)^{\frac{1}{2}}$

where N is a coupling number that describes the coupling of angular and linear momentum equations. When $N = 0$, the equations of angular and linear momentum disassembled and linear momentum equations diminish to Navier-Stokes classical equation. Length dimension l is the parameter that represents lubricant molecular size. The influence of microstructure is negligible in limiting case $l \to 0$.

The influenced Reynolds equation is acquired during the integrating continuity Equation (11) with respect to y over film thickness and displacing u and w in equation by their related expressions gained in Equation (16) and Equation (17) and also utilizing boundary circumstances for v located in Equation (12) and Equation (13), we acquire

$$\frac{\partial}{\partial x}\left\{f(N,l,H)\frac{\partial p}{\partial x}\right\}+\frac{\partial}{\partial z}\left\{f(N,l,H)\frac{\partial p}{\partial z}\right\}=12\mu\frac{\partial H}{\partial t} \tag{20}$$

Where

$$f(N,l,H)=H^3+12l^2H-6NlH^2coth\left(\frac{NH}{2l}\right)$$

Multiplying Equation (20) by $f(h_s{}^*)$ on both sides and integrating with respect to $h_s{}^*$ from $-c^{'}$ to $c^{'}$ and utilizing Equations (2), (3) and (4) , averaged Reynolds equation is acquired in the form

$$\frac{\partial}{\partial x}\left\{f(N,l,h)\frac{\partial E(p)}{\partial x}\right\}+\frac{\partial}{\partial z}\left\{f(N,l,h)\frac{\partial E(p)}{\partial z}\right\}=12\mu\frac{\partial h}{\partial t} \tag{21}$$

$$F(N,l,h)=E[f(N,l,H)]\approx F_1+F_2(F_3+F_4) \tag{22}$$

$$F_1=h^3+\varepsilon^{'}+3h^2\alpha^{'}+3h\left(\alpha^{'2}+\sigma^{'2}\right)+3\alpha^{'}\sigma^{'2}+\alpha^{'3}+12l^2\left(h+\alpha^{'}\right)$$

$$F_2=-6Nl\left(h^2+\alpha^{'2}+\sigma^{'2}+2h\alpha^{'}\right)$$

$$F_3=\left\{1-Coth^2\left(\frac{Nh}{2l}\right)\right\}\times\left\{\frac{N\alpha}{2l}-\frac{N^3}{24l^3}\left(\varepsilon'+\alpha'^3+3\alpha'\sigma'^2\right)\right\}$$

$$F_4=Coth\left(\frac{Nh}{2l}\right)\left\{1-\frac{N^2}{4l^2}\left(\alpha'^2+\sigma'^2\right)\right\}$$

and

$$\frac{\partial h}{\partial t}=c\frac{\partial\varepsilon}{\partial t}cos\theta$$

2.1 Short journal bearing

In contrast to the axial variations, the circumferential pressure variations are abandoned by taking advantage of the short journal bearing representation. Then the modified Reynolds-type Equation (21) takes the form,

$$\frac{d}{dz}\left\{F(N,l,h)\frac{dE(p)}{dz}\right\}=12\mu\frac{\partial h}{\partial t} \tag{23}$$

Presently, it seems knowing Newtonian viscosity μ is changing through the fluid film thickness H

$$\mu=\mu_{iv}\left(\frac{H}{h_1}\right)^Q \tag{24}$$

where, μ_{iv} is inlet viscosity at $H=h_1=c(1+\varepsilon)$. The exponent Q may be studied utilizing a relation

$$Q=\frac{log\left(\frac{\mu_{iv}}{\mu_{ov}}\right)}{log\left(\frac{h_1}{h_2}\right)} \tag{25}$$

Where, μ_{ov} is outlet viscosity with film thickness h_2.The factor $Q\,(0 \le Q \le 1)$ based on the specific lubricant used, $Q = 0$ regarding perfect Newtonian fluid whereas $Q = 1$ for perfect gases. In the interest of mathematical simplicity N and l are suspected to be unaffected by changes in viscosity this can be accomplished by assuming χ and γ are differing in the same approach as μ.

Substituting Equation (24) in Equation (23) to obtain

$$\frac{d}{dz}\left\{F(N,l,h)\frac{dE(p)}{dz}\right\} = 12\mu_{iv}\left(\frac{H}{h_1}\right)^{Q}\frac{\partial h}{\partial t} \tag{26}$$

Using the non-dimensional quantities

$$\theta = \frac{x}{R}, \bar{z} = \frac{z}{L}, \bar{l} = \frac{l}{c}, \bar{h} = \frac{h}{c}, \varepsilon_1 = \frac{\varepsilon'}{c}, \alpha = \frac{\alpha'}{c}$$

$$\sigma^2 = \frac{\sigma'^2}{c^2}, \bar{p} = \frac{E(p)\,c^2}{\mu_{iv}R^2\left(\frac{d\varepsilon}{dt}\right)}$$

In a non-dimensional form, the modified Reynolds Equation (26) is expressed as

$$\frac{d}{d\bar{z}}\left\{\bar{F}\left(N,\bar{l},\bar{h}\right)\frac{d\bar{p}}{d\bar{z}}\right\} = 12cos\theta\frac{\bar{h}^{Q}}{(1+\varepsilon)^{Q}} \tag{27}$$

$$\bar{F}\left(N,\bar{l},\bar{h}\right) \approx \bar{F}_1 + \bar{F}_2\left(\bar{F}_3 + \bar{F}_4\right)$$

where

$$\bar{F}_1 = \bar{h}^3 + \varepsilon_1 + 3\bar{h}^2\alpha + 3\bar{h}\left(\alpha^2+\sigma^2\right) + 3\alpha\sigma^2 + \alpha^3 + 12\bar{l}^2\left(\bar{h}+\alpha\right)$$

$$\bar{F}_2 = -6N\bar{l}\left(\bar{h}^2 + \alpha^2 + \sigma^2 + 2\bar{h}\alpha\right)$$

$\bar{F}_3 = \left\{1 - Coth^2\left(\frac{N\bar{h}}{2\bar{l}}\right)\right\} \times \left\{\frac{N\alpha}{2\bar{l}} - \frac{N^3}{24\bar{l}^3}\left(\varepsilon_1 + \alpha^3 + 3\alpha\sigma^2\right)\right\}$and

$$\bar{F}_4 = Coth\left(\frac{N\bar{h}}{2\bar{l}}\right)\left\{1 - \frac{N^2}{4\bar{l}^2}\left(\alpha^2+\sigma^2\right)\right\}$$

For the pressure, the admissible boundary conditions are

$$\bar{p} = 0 \; at \; \bar{z} = \pm\frac{1}{2} \tag{28}$$

The solution of Equation (27) with the boundary conditions (**28**) is acquired in the form

$$\bar{p} = \frac{6cos\theta\left(z^2 - 0.25\right)}{F\left(N,\bar{l},\bar{h}\right)}\frac{\bar{h}^{Q}}{(1+\varepsilon)^{Q}} \tag{29}$$

Here, the journal has zero rotation, Integrating the mean film pressure $E(p)$ obtained mean load carrying capacity $E(W)$ is expressed as

$$E\left[W(t)\right] = -2R\int_{z=0}^{\frac{-L}{2}}\int_{\theta=\frac{\pi}{2}}^{\frac{3\pi}{2}} E(p)\,cos\theta\, d\theta\, dz \tag{30}$$

Considering that the bearing is working under a steady load W_s, the generated mean load $E\left(W\left(t\right)\right)$ due to squeeze film equals the applied load W_s, that is

$$E\left[W\left(t\right)\right] = W_s \tag{31}$$

Using Equations (29) and (31) in Equation (30), the dimensionless mean load carrying capacity $\overline{W}$ is calculated as follows:

$$\overline{W} = \frac{E[W(t)]}{\mu LR\left(\frac{d\varepsilon}{dt}\right)} = \int_{\theta=\frac{\pi}{2}}^{\theta=\frac{3\pi}{2}} \frac{cos^2\theta(1+\varepsilon co\ s\theta)^Q}{F(N,\bar{l},\bar{h})(1+\varepsilon)^Q} d\theta$$

$$= G\left(\varepsilon, N, \bar{l}, \alpha, \sigma, \varepsilon_1\right) \tag{32}$$

In various practical applications, the squeeze film journal bearing operated under dynamic conditions. While using these conditions, the path of the rotor centre varies in a manner compatible with the variations in the applied load. For this type of condition, the applied load is deliberate as sinusoidal function of time.

$$E\left(W\left(t\right)\right) = W_0 sin(\omega t) \tag{33}$$

where, W_0 is the amplitude and ω is the frequency of the applied load oscillations.

Using Equations (32) and (33) in Equation (31), the locus of the journal center leads to

$$\frac{d\varepsilon}{d\tau} = \frac{30 sin\tau}{\pi S' G\left(\varepsilon, N, \bar{l}, \alpha, \sigma, \varepsilon_1\right)} \tag{34}$$

where

$$S' = \frac{\mu N}{\left(\frac{W_0}{2LR}\right)}\left(\frac{R}{C}\right)^2, \tau = \omega t = \frac{2\pi N}{60} t$$

3 Results and discussion

This paper estimated the impact of viscosity variation on the performance of dynamic and static behaviours of rough journal bearing with micropolar fluid. The two dimensionless parameters N and $\bar{l}$ demonstrate the impact of micropolar lubricants. The effects of surface roughness on the squeeze film characteristics are studied by the roughness parameter and the variation of viscosity effects by the viscosity variation index parameter Q and α, ε_1 and σ are non-dimensional parameters encapsulate type of acerbities of rough bearing surface.

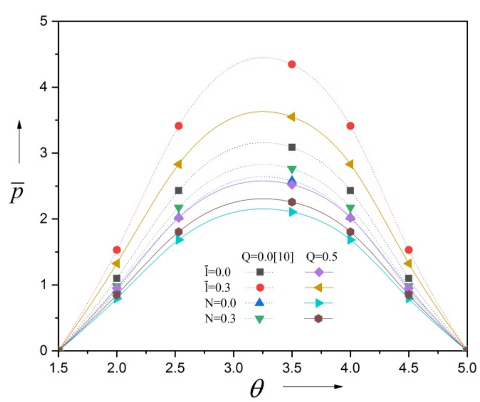

Fig 2. Variation of non-dimensional pressure $\overline{p}$ with θ for distinct values of $\bar{l}, N$and Q

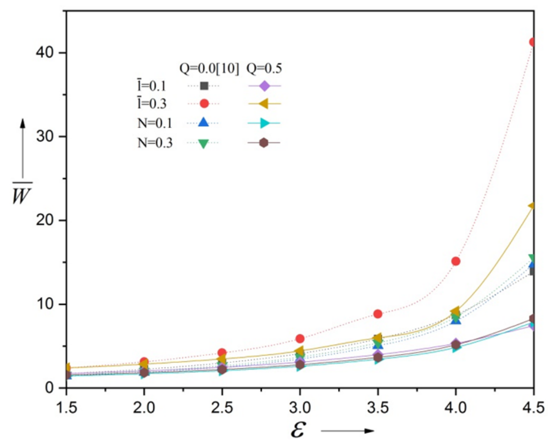

Fig 3. Variation of non-dimensional load $\overline{W}$ with ε for different values of $\bar{l}$, N and Q

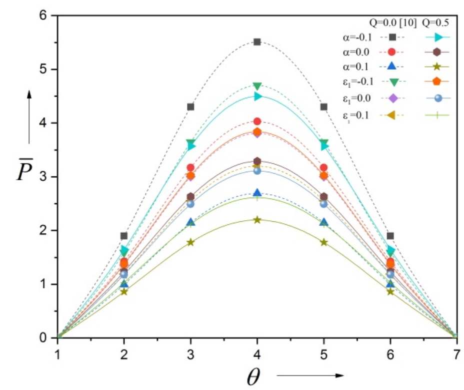

Fig 4. Variation of dimensionless pressure $\overline{p}$ with θ for distinct values of α, ε_1 and Q

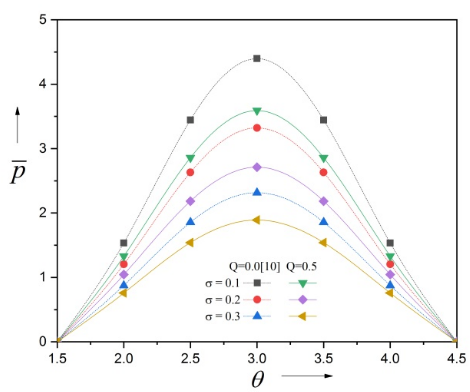

Fig 5. Variation of dimensionless pressure $\overline{p}$ with θ for distinct values of σ and Q

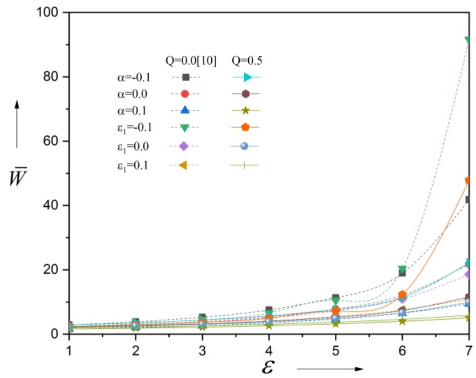

Fig 6. V ariation of dimensionless load $\overline{W}$ with ε for distinct values of α, ε_1 and Q

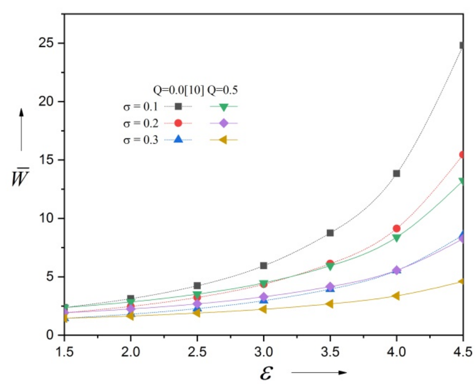

Fig 7. Variation of dimensionless load $\overline{W}$ with ε for distinct values of $\sigma$and Q

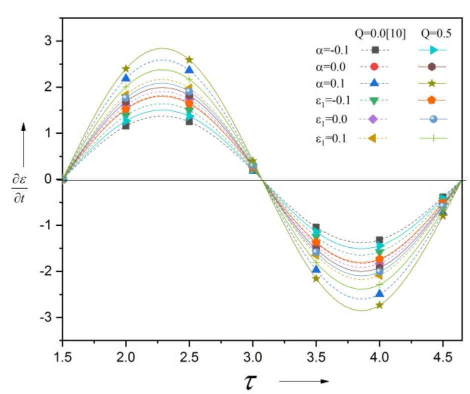

Fig 8. Journal centre velocity $\frac{d\varepsilon}{dt}$ versus τ for distinct values of α, ε_1 and Q

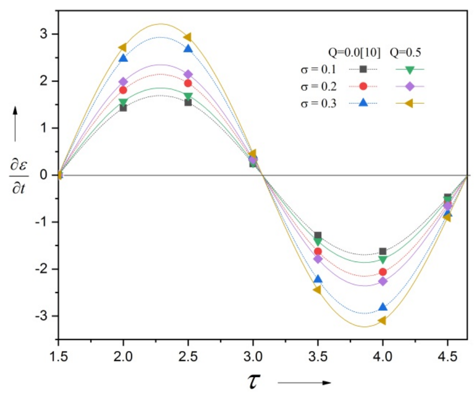

Fig 9. Journal centre velocity $\frac{d\varepsilon}{dt}$ versus τ for distinct values of $\sigma$and Q

Figure 2 represents the varying values of $\overline{p}$ with θ and Q for distinct values of $\bar{l}$ and N with the fixed values of parameters $\alpha = 0.01, \sigma = 0.15, \varepsilon_1 = -0.01, \varepsilon = 0.01$ is shown in Figure 2. It is confirmed that higher $\overline{p}$ for raising values of $\bar{l}$ and N. The effect of viscosity variation is to reduces $\overline{p}$ compared with non-viscosity variation parameter[10] with increasing values of $\bar{l}$, N and θ. Figure 3 illustrates $\overline{W}$ with ε as function of $\bar{l}$ and N respectively for different values of Q. It is delineated that $\overline{W}$ improves for rising the values of $\bar{l}$ and N with $\sigma = 0.15, \varepsilon_1 = -0.01, \alpha = 0.01$. The effect of Q is to reduce $\overline{W}$ compared with non-viscosity variation[10] along with increasing values of $\bar{l}$, N and ε. Figure 4 and Figure 5 denote the variation of $\overline{p}$ with riser θ and $Q\,(0.0, 0.5)$ for different values roughness factors $\alpha, \varepsilon_1\,(\sigma = 0.15)$ and $\sigma\,(\alpha = 0.01, \varepsilon_1 = -0.01)$, respectively. Figure 4 shows that $\overline{p}$ improves for negatively increasing values of α and ε_1 and it decreases for positively increasing values of α and ε_1 respectively. The effect of viscosity variation is to reduces $\overline{p}$compared with non-viscosity variation parameter[10]. Further, $\overline{p}$ reduces for higher values of σ as it is evident from Figure 5. Figures 6 and 7 depict the variance of dimensionless load capacity with ε regarding numerous values of roughness parameter α and ε_1 for both positively skewed and negatively skewed surface roughness along with different values of $Q\,(0.0, 0.5)$. It observed that the non-dimensional load capacity increases (decreases) for negatively skewed (positively skewed) surface roughness. Whereas, the impact of roughness parameter σ is to decrease the load carrying capacity $\overline{W}$ as it is evident in Figure 7. The effect of Q is to reduce $\overline{W}$ compared with zero viscosity variation parameter[10]. The influence of α and ε_1 on variations of $\frac{d\varepsilon}{dt}$ with time factor τ regarding different values of $Q\,(0.0, 0.5)$ is depicted in Figure 8. It is noticed that journal centre velocity rises as a result of positively skewed surface roughness as compared to non-viscosity effect[10], whereas negatively increasing values of roughness parameters on bearing surface exhibits robust resistance to journal centre velocity motion and reduces the journal centre velocity. The impact of σ on variations of $\frac{d\varepsilon}{dt}$ with τ for different values of $Q\,(0.0, 0.5)$ is shown in Figure 9. It is confirmed that journal center velocity increases for rising the values of σ as compared to zero viscosity variation parameter.

Table 1 represents the increasing values of viscosity variation parameter is to decrease the load capacity and squeeze film pressure while increases the journal centre velocity.

Table 1. Variation of non-dimensional pressure, load capacity and journal centre velocity for different values of viscosity variation parameters and its comparison with non-viscosity variation parameter

		$Q = \mathbf{0}$[10]	$Q = \mathbf{0.1}$	$Q = \mathbf{0.2}$	$Q = \mathbf{0.3}$	$Q = \mathbf{0.4}$	$Q = \mathbf{0.5}$
	$\theta = 1.5$	0	0	0	0	0	0
	$\theta = 2$	1.37994	1.34080	1.30278	1.26584	1.22994	1.19506
	$\theta = 2.5$	3.05711	2.94532	2.83762	2.73386	2.63389	2.53758
$\bar{p}$	$\theta = 3$	3.88132	3.72709	3.57899	3.43678	3.30022	3.16908
	$\theta = 3.5$	3.05711	2.94532	2.83762	2.73386	2.63389	2.53758
	$\theta = 4$	1.37994	1.34080	1.30278	1.26584	1.22994	1.19506
	$\theta = 4.5$	0	0	0	0	0	0
	$\varepsilon = 1.5$	2.16703	2.16703	2.16703	2.16703	2.16703	2.16703
	$\varepsilon = 2$	2.81726	2.76566	2.71502	2.66531	2.16703	2.56862

Continued on next page

$\bar{W}$

Table 1 continued

	$\varepsilon = 2.5$	3.75696	3.61968	3.48745	3.36009	2.61651	3.11926
	$\varepsilon = 3$	5.17467	4.88968	4.62052	4.36629	3.23742	3.89936
	$\varepsilon = 3.5$	7.44741	6.89349	6.38112	5.90716	4.12616	5.06309
	$\varepsilon = 4$	11.4624	10.3725	9.38722	8.49629	5.46871	6.96214
	$\varepsilon = 4.5$	20.0539	17.6828	15.5943	13.754	7.69067	10.7056
	$\tau = 1.5$	0	0	0	0	0	0
	$\tau = 2$	1.58456	1.61412	1.64423	1.67490	1.70613	1.73795
	$\tau = 2.5$	1.71228	1.74423	1.77676	1.80990	1.84366	1.87803
$\frac{\partial \varepsilon}{\partial t}$	$\tau = 3$	0.26574	0.27069	0.27574	0.28089	0.28613	0.29146
	$\tau = 3.5$	-1.42512	-1.45171	-1.47879	-1.50637	-1.53446	-1.56308
	$\tau = 4$	-1.80573	-1.83942	-1.87374	-1.90868	-1.94428	-1.98053
	$\tau = 4.5$	-0.52616	-0.53598	-0.54597	-0.55616	-0.56653	-0.57709

4 Conclusions

The influence of viscosity variation on dynamic and static behavior of squeeze film lubrication of rough short journal bearing lubricated with non-Newtonian micropolar fluid is examined based on the microcontinuum theory. The results are accomplished to obtain the characters of rough short journal bearing with viscosity variation and the numerical results presented in the above section enable the following conclusions to be drawn:

1. The presence of viscosity variation parameter diminishes the squeeze film pressure by 4.13% and load capacity by 13.4% and enhances the journal centre velocity by 1.83%.
2. The lubricant's microstructure additives strengthen the fluid film pressure and load capacity and it diminishes journal center velocity.
3. Implementing the micropolar fluid lubricants impart an increase in the load carrying capacity and squeeze film pressure and decreases journal centre velocity.
4. The presence of negatively (positively) skewed surface roughness structure provides an increase (decrease) in load capacity and squeeze film pressure, whereas decrease (increase) in journal center velocity.

Compared with the non-viscosity variation parameter case of short journal bearing[10], a close agreement takes on assistance for the present study of the viscosity variation on rough short journal bearing.

5 Nomenclature

c radial clearance

$c^{'}$ maximum variations from the mean film thickness

e eccentricity

E expectancy operator

$E\left(W\left(t\right)\right)$ mean load carrying capacity

$h_s{}^*$ random variable

$h\left(\theta\right)$ mean film thickness $\left(=c\left(1+\varepsilon cos\theta\right)\right)$

H film thickness $\left(=h\left(\theta\right)+h_s{}^*\right)$

l polar suspension's characteristic length $\left(=\left(\frac{\gamma}{4\mu}\right)^{\frac{1}{2}}\right)$

$\bar{l}$ dimensionless form of $\bar{l}\left(=\left(\frac{l}{c}\right)\right)$

L bearing length

N coupling number $\left(=\left(\frac{\chi}{(\chi+2\mu)}\right)^{\frac{1}{2}}\right)$

p lubricant pressure

$\overline{p}$ non-dimensional mean pressure $\left(=\frac{(E(p)c^2)}{\mu R^2\left(\frac{d\varepsilon}{dt}\right)}\right)$

R journalradius

$S^{'}$ somerfield number $\left(=\frac{\mu N}{\frac{W_0}{2LR}}\right)\left(\frac{R}{c}\right)^2$

t time

u, v, w components of fluid velocity in $x, y$and $z$directions
v_1, v_2, v_3 velocity components of microrotational in the $x, y$and z directions respectively
V squeezing velocity $\frac{\partial h}{\partial t}\left(= c\left(\frac{d\varepsilon}{dt}\right)cos\theta\right)$
$\overline{W}$ non-dimensional mean load-carrying capacity $\left(= \frac{E(W(t))}{\mu LR\left(\frac{d\varepsilon}{dt}\right)}\right)$
W_0 amplitude of the applied cyclic load
W_s mean steady load
x, y, z rectangular co-ordinates
α dimensionless form of $\alpha^{'}\left(= \frac{\alpha^{'}}{c}\right)$
$\alpha^{'}$ mean stochastic film thickness
γ, χ coefficients of viscosity for micropolar fluids
ε eccentricity ratio parameter $\left(= \frac{e}{c}\right)$
ε_1 non-dimensional form of $\varepsilon^{'}\left(= \frac{\varepsilon^{'}}{c^3}\right)$
$\varepsilon^{'}$ measure of symmetry of the stochastic random variable
μ viscosity of the lubricant
σ^2 non-dimensional form of variance$\sigma^{'2}\left(= \frac{\sigma^{'2}}{c^2}\right)$
τ dimensionless response time $\left(= \frac{(2\pi N)}{60t}\right)$
ω frequency of applied cyclic load
Q viscosity variation parameter
μ_{iv} viscosity of the lubricant at the inlet
μ_{ov} viscosity of the lubricant at the outlet
h_1 inlet oil film thickness
h_2 oil film thickness at maximum pressure

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