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A study of cavitation effect in a journal bearing using CFD: A case study of engine oil, palm oil and water

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ABSTRACT

Cavitation is a common phenomenon in journal bearing, which plays a crucial role in lubrication efficiency. However, the degree to which the cavitation phenomenon affects the lubrication performance for a different type of lubricant is still unclear. Therefore, in this paper, a comparison between the case of 'cavitation' and 'without cavitation' phenomena for journal bearing is presented. This study focused on three different types of lubricants which can be categorized into renewable and non-renewable resources, which are water, palm oil, and engine oil (SAE20W40). The uniqueness of our study is the inclusion of renewable sources, which is palm oil. Numerical analysis was chosen as an approach tool via ANSYS FLUENT. The cavitation process is investigated with a change in the pressure distribution of the oil film in the journal bearing. In the situation of non-cavitation model applied, the cavitation effect is neglected which has yielded a different value of pressure maximum and a minimum of the fluid film as compared if the cavitation concept is introduced. This study demonstrates the importance of the cavitation approach incorporation in the numerical prediction of lubrication in a hydrodynamic journal bearing.

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1.0 INTRODUCTION

Cavitation occurs when the flow reaches a divergent zone in the journal bearing (Tauviqirrahman et al., 2017). As the liquid enters a different zone, cavitation occurs, the pressure decreases, and, at a certain temperature, reaches saturated pressure. At this stage, the gas dissolved in the liquid shall be released as a bubble and then flows as free gas. Free gas rises and new liquid transmissions occur as liquid progresses further in a different field (Dhande and Pande, 2017). Agreed with the statement, Gao et al., (2014) and Wang et al., (2016), also reported that cavitation phenomena happened in the divergent zone. This is expected because of the film rupture due to a lack of lubricant supply in the divergent region. Whilst Liang et al., (2016) defined cavitation as; lubrication film breakdown and reformation. Also, Lin et al., (2010) stated that the cavitation begins at about 190° bearing angle, and a maximum vapor fraction appears at 340°. Later Chen et al., (2019) concluded that cavitation plays a crucial role in the lubrication performance of the journal bearing which can adjust the oil film's pressure distribution. Therefore, the load carrier and the friction torque also can be affected.

Braun and Hannon, (2010) categorized the form of liquid cavitation into three-part which are; first 'gaseous cavitation' involves one or even more gas forms dissolved in the fluid and occurs when the pressure drops below the gas component's saturation pressures; second 'pseudo-cavitation' is the form which the gas bubble roses from the liquid to the gas phase, due to depressurizations without further gas diffusion and lastly 'vaporous cavitation' is caused when the pressure drops below the fluid vapor pressure at the prevailing temperature by an unbalanced thermodynamic phenomenon.

A study by Song and Gu, (2015) revealed that the 'gaseous cavitation' model offers a method to investigate the efficiency of journal bearings more accurately and thoroughly. Agreed with the statement; Tauviqirrahman et al., (2017), Rom and Müller, (2018) and Chen et al., (2019) suggested that an effective approach to the cavitation model would have to be applied toward more comprehensive simulation performance, as the model for cavitation played a significant role in the pressure and thickness distribution of the oil film. In another case study, Gao et al., (2014) constructed hydrodynamic research relied on a three-dimensional approach to computational fluid dynamic (CFD) and used water as a lubricant in a journal bearing. This research study considering the effect of cavitation on hydrodynamic journal bearing through the correct model of cavitation.

Later Tauviqirrahman et al., (2017) proposed a numerical approach focused on the model of CFD as they realized that the cavitation had an enormous effect on the journal bearing research. Next Sun et al., (2019) comparing the results with conventional Reynolds equations, and they concluded that the cavitation influence and journal whirl are very compatible with the actual working conditions of the bearing journal. Agreed with that; Hanoca and Ramakrishna, (2018) suggested that cavitation and thermal effects can be useful for predicting the efficiency of journal bearings under real working conditions. In brief, the cavitation model is useful for the precise measurement of load capacity and friction. As stated by Biancofiore et al., (2019), they reported that cavitation can be helpful to fluid lubrication by enhancing lubrication and thus reducing friction. Later Tauviqirrahman et al., (2017) and Fu and Untaroiu, (2017) concluded that the cavitation model would result in a higher expected load capacity value. Lastly, Gropper et al., (2016) suggested that the cavitation and inertia effect ultimately depend on the working conditions and interaction type. Therefore, the expertise for both phenomena, depending on the application, may either enhance or adversely affect overall efficiency.

Computational fluid dynamic (CFD) is a physical phenomenon analysis involving heat distribution and fluid flow via the numerical and graphical computer calculation (Wei, 2017). In a different study, Lin et al., (2010) mentioned that with the rapid development of computational fluid dynamic (CFD), resolving the Navier-Stokes bearing equation directly may save a lot of experimental efforts and reflect some details more accurately. Whilst Jiang et al., (2011) reported that with the help of computational fluid dynamic (CFD) engineers, energy and charges can be reduced, avoid errors and trials in the design process, can get results quickly, and lastly optimize design processes and design results.

In addition, the computational fluid dynamic (CFD) approach which involves the combined heat transmission and gas cavitation model offers a better forecast in terms of temperature and load bearing than conventional Reynold solutions or computational fluid dynamic (CFD) with other cavitation models (Song and Gu, 2015). ANSYS FLUENT commercial software is used for discretizing the Navier Stokes equation with the cavitation model by using the finite volume approach (Hilmy et al., 2018). In ANSYS FLUENT, two cavitation models available, which are Schnerr-Sauer and Zwart-Gerber-Belamri. The Zwart-Gerber-Belamri multi-phase cavitation model is used in current work due to its capability (less sensitive to mesh density, robust and fast-converging) (Tauviqirrahman et al., 2017; Pratomo et al., 2017; Tauviqirrahman et al., 2019).

As a summary, Tauviqirrahman et al., (2017), Kalbande, (2016), Dhande and Pande (2017), Pratomo et al., (2017), Dhande and Pande (2018) and Tauviqirrahman et al., (2019) is an example of a case study that used engine oil as a lubricant whilst Gao et al., (2014) is an example of a case study that used water as a lubricant. The uniqueness of our study is the inclusion of renewable sources, which is palm oil. Nowadays, most bio-lubricants are composed of either totally, or partly of bio base oils. This type of oil meets the standard of international requirements in terms of technical performance, renewal sources, and biodegradation. Chan et al., (2018) also reported that the demand for bio-lubricants from renewable energy sources, such as plant oil, is growing due to the production of various types of environmentally friendly additives and basic stocks.

Farhanah and Syahrullail, (2016); Jabal et al., (2014) and Razak et al., (2015) reported that palm oil should be a multi-faceted vegetable oil, which can be used both for food and non-food products. Palm oil contains a wide range of oils, such as palm fatty acids, RBD palm kernel, RBD palm oil, and palm stearin. Later, Aiman and Syahrullail, (2017) and Hassan et al., (2016) have concluded that palm oil has excellent lubrication efficiency and future potential to minimize reliance on mineral-based lubricants. Palm oil poses problems in global health because of the environment serious damage caused during this time by insufficient and unwell biodegradable lubricants (Sapawe et al., (2016); Syahrullail et al., (2013); Syahrullail et al., (2011)). Ghani et al., (2015) have shown that palm oil-based lubricants can provide improved surface roughness due to oxygen in the palm oil formula, which provides a stronger lubricant layer on the metal surface. Also, Rao et al., (2018) were conducted a brief research analysis in Malaysia and Japan for tribological applications reported that bio-lubricants have low oxidation and weak cold flow characteristics, and these deficiencies can be prevented by chemically modifying and altering bio-lubricants or introducing additives. Bio-lubricants with stable dispersion of formulated additives are very attractive for the improved performance of tribological properties.

In this analysis, ANSYS FLUENT software is the basis for the hydrodynamic performance study of smooth bearing journals using three-dimensional computational fluid dynamic (CFD) models under two different conditions for different types of lubricants. The mass preservation model of cavitation, frequently ignored in previous studies, is regarded as showing more practical outcomes. As mentioned by Pratomo et al., (2017), numerical findings indicate a significant impact on bearing performance in the cavitation model. Failure to follow a cavitation model leads to an incorrect result.

As a summary Kalbande, (2016),Tauviqirrahman et al., (2017), Dhande and Pande, (2017), Pratomo et al., (2017) ,Dhande and Pande, (2018) and Tauviqirrahman et al., (2019) is a case study that used engine oil as a lubricant and Gao et al., (2014) used water as lubricant. The uniqueness of this research study is the inclusion of renewable sources, which is palm oil. Nowadays, mostly bio-lubricants are composed either totally, or partly of bio base oils. This type of oil meets the standard of international requirements in terms of technical performance, renewal sources, and biodegradation.

2.0 MATERIALS AND METHODS

2.1 Governing Equation

The mass conservation equation also referred to as the continuity equation, describes an increase in the mass of the variable circulation per unit time to the net mass flowing through the micro-body over the same duration (Wei, 2017). The equation involved is:

$$\frac{\partial P}{\partial t} = div(\rho v) = S_m \tag{1}$$

div described as divergence, that is $div(a) = \frac{\partial a_x}{\partial x} + \frac{\partial a_y}{\partial x} + \frac{\partial a_z}{\partial x}$, equation 1 is the mass retention equation version, which is suitable for compressible flow and incompressible flow, and ρ is the density, t is the time, v is the velocity vector, and S_m is the mass applied to the ongoing conditions of evaporation or the heterogeneous drop reaction. Law on conservation of momentum is also the basic law that any flow mechanism should adhere to, and the basics of the law come from Newton's second law. The rule can be defined as follows; the change rates from the momentum in the microelement to the time are equal to the total forces acting on the microelement theoretically (Wei 2017). The momentum equation for an inertial coordinate system is stated in equation 2:

$$\left\{\begin{aligned} \frac{\partial(\rho u)}{\partial t} + div(\rho u\bar{v}) &= -\frac{\partial P}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + \rho f_x \\ \frac{\partial(\rho v)}{\partial t} + div(\rho v\bar{v}) &= -\frac{\partial P}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + \rho f_y \\ \frac{\partial(\rho w)}{\partial t} + div(\rho w\bar{v}) &= -\frac{\partial P}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial y} + \rho f_z \end{aligned}\right\} \tag{2}$$

Where P represents pressure on the microfluidic body, τ_{xx}, τ_{yx} and τ_{zx} are the viscosity of each component that acts on the surface of the micro-body because of the viscosity molecule and f_x, f_y

and f_z are volume force for each component (f) acting on the unit mass microbody act in three directions.

2.2 Cavitation Model

In most engineering situation, assumption made that there are plenty of nuclei for the inception of cavitation. Thus, the primary focus in this study is on proper accounting of bubble growth and collapse. In a following liquid with zero velocity slip between the fluid and bubbles, the bubble dynamic equation can be derived from the generalized Rayleigh-Plesset (time dependent pressure and size of bubbles) (ANSYS, 2020):

$$\frac{p_{vap}(t)-p_{\infty}(t)}{\rho_1}=R_b\frac{d^2R_b}{dt^2}+\frac{3}{2}\left(\frac{dR_b}{dt}\right)^2+\frac{4v_1}{R}\frac{dR_b}{dt}+\frac{2S}{\rho_1 R_b} \tag{3}$$

For certain value of pressure p_{∞} (t) can be solved and bubble radius R_b (t) can be determined (in case of the pressure value in bubble known). This equation was used by scientist like Rayleigh and Plesset equation in simplified form (the term of surface tension and the term of viscosity were ignored and higher order derivatives). Common differential equation 3 has been too difficult to be applied into a multiphase flow model. That is why the first order approximately has been used in this case (Kozubková et al., 2012)

$$\frac{dR_b}{dt}=\sqrt{\frac{2}{3}\frac{p_{vap}(t)-p_{\infty}(t)}{\rho_1}} \tag{4}$$

This equation provides a physical approach to introduce the effect of bubble dynamics into the cavitation model. It can also be an equation for void propagation and hence mixture density. Assuming that; all the bubbles in a system have the same size, Zwart Gerber Belamri cavitation model proposed that the total interphase mass transfer rate per unit volume is calculated using the bubble density numbers, equation 4. The expression of the net mass transfer is (Kozubková et al., 2012):

$$R=\frac{3\alpha\rho_{vap}}{R_b}\sqrt{\frac{2}{3}\frac{(p_{vap}-p)}{\rho_1}} \tag{5}$$

Where R_b= bubble radius and p_{vap}= vapor pressure. In equation 5, the unit volume mass transfer rate is only related to the vapour phase density ρ_{vap}. This equation is derived assuming bubble growth (evaporation). To apply it to the bubble collapse process (condensation), the following generalized formulation is used(Kozubková et al., 2012):

$$R_e=F\frac{3\alpha\rho_{vap}}{R_b}\sqrt{\frac{2}{3}\frac{(p_{vap}-p)}{\rho_1}sign(}p_{vap}-p) \tag{6}$$

Where F=empirical calibration coefficient. The rate of change of mass of a single bubble follows as;

$$\frac{dm_b}{dt} = 4\Pi R_b^{\ 2} \rho_{vap} \sqrt{\frac{2}{3} \frac{(p_{vap} - p)}{\rho_1}} \tag{7}$$

If there are n_b bubbles per unit volume, we may express the vapour volume fraction as

$$\alpha = V_b n_b = \frac{4}{3} \Pi R_b^{\ 3} n_b \tag{8}$$

As the vapour volume fraction increases, the nucleation site density must decrease accordingly. To model this process Zwart Gerber Belamri proposed to replace α with α_{nuc} (1-α) in equation number 6. Applied in the current work is the Zwart Gerber Belamri cavitation model. Assume that all the bubbles in the model are same size, the final form of the cavitation model is stated in equation number 9 and number 10.

If $p \leq p_{vap}$;

$$R_e = F_{vap} \frac{3\alpha_{nuc}(1-\alpha)\rho_{vap}}{R_b} \sqrt{\frac{2(p_{vap} - p)}{3\rho_1}} \tag{9}$$

If $p \geq p_{vap}$;

$$R_c = F_{cond} \frac{3\alpha\rho_{vap}}{R_b} \sqrt{\frac{2(p - p_{vap})}{3\rho_1}} \tag{10}$$

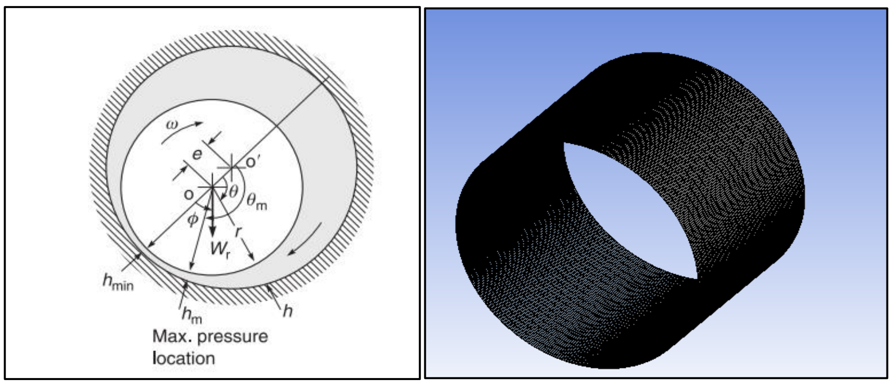
Where:
R_b= radius of the bubbles
α_{nuc}=volume fraction of the nucleation site
F_{vap}=coefficient of the evaporation
F_{cond}= coefficient of the condensation

2.3 CFD Model

For solving the Navier Stokes equation a computational fluid dynamic (CFD) package of ANSYS FLUENT software was used. By modelling the generated fluid domain, a three-dimensional simulation model is developed. The fluid flow as the laminar flow is defined. Without considering the force of gravity, the governing equations are solved in a steady-state condition and the operating pressure is fixed at 101325 Pa.

Figure 1(a) shown a schematic of the journal bearing geometry. The eccentricity ratio with an angle of the attitude 49 ° is taken as 0.8. Table 1 summarizes the dimensions of the basic journal bearings used in this simulation.

A hexahedral system mesh is used for meshing. Figure 1(b) shown a meshed journal bearing with structured types of mesh. On both surfaces, no-slip boundary condition is applied. The structured mesh comprises a total of 117600 elements with quality mesh value for minimum orthogonal quality is 0.46, a maximum ortho skew is 0.53, and a maximum aspect ratio is 3017 based on a mesh refining analysis.



(a) (b)

Figure 1: (a) Design of the journal bearing (Bhushan, 2013) and (b) Meshed journal bearing.

Table 1: Parameters used for numerical analysis.

Parameter	**Value**
Bearing inner radius	40.041 mm
Shaft radius	40.001 mm
Bearing length	80.21 mm
Radial clearance	0.04 mm
Length-diameter ratio	1.0
Eccentricity ratio	0.8
Attitude angle	49^0
Water density	998.2 kg/m^3
Engine oil density	875 kg/m^3
Palm oil density	906.5 kg/m^3
Water viscosity	0.001 Pa.s
Engine oil viscosity	0.10439 Pa.s
Palm oil viscosity	0.03929 Pa.s
Rotational speed	1500 rpm

One side of the film clearance is named as an inlet, while the other side is named as an outlet. The boundary condition for the inlet is defined as pressure inlet whilst for outlet defined as pressure outlet at zero pascal. The outside surface of the film is named as a stationary wall and the inner surface of the film is named as a moving wall with an absolute rotational speed of 1500 rpm and eccentricity ratio at 0.8.

In this analysis, the pressure-based method is selected for numerical analysis. The converging solution can be obtained more conveniently using SIMPLEC as compare with SIMPLE approach

(Canonsburg, 2011). The velocity-pressure coupling is then analysed using the SIMPLEC algorithm in the current project, and others are default. For the solution momentum equation, the first-order upwind technique is used. For all residual terms, the convergence criterion of $10e^{-6}$ is applied.

2.4 Mesh Sensitivity Analysis

The mesh quality in the simulation will affect the accuracy of the numerical results. So, the mesh sensitivity analysis is conducted before the simulation(Gui and Meng, 2018). As seen in table 2, with the increment of the used mesh number, as shown in case 1 to 5, the pressure change is nominal for case 4 as compare to other case. From the table, it can be observed that if the mesh number is 140000, the simulation results do not differ anymore but obviously the computational cost increases. Therefore, the grid system in case 4 which has total of mesh number 117600 chosen for the subsequent simulation.

Table 2: Mesh sensitivity analysis.

Case	Mesh number	Maximum water pressure (MPa)	Deviation (%)
1	33600	1.519	7.50
2	61600	1.642	0.06
3	89600	1.643	0.40
4	117600	1.650	0
5	140000	1.650	-

3.0 RESULTS AND DISCUSSION

3.1 Validation Study

The validation model of the journal bearing used in this simulation should be verified first before the analysis of the comparison between the cavitation and non-cavitation phenomena of the journal bearing are conducted. The validation included validation from an experimental study from another literature.

The film pressures are compared with standard experimental data for the smooth journal bearing from Gao et al., (2014) under the same input parameters. A study from Gao et al., (2014) validated their experiment study method at an eccentricity ratio of 0.8 and then they revealed the step method of numerical study for plain journal bearing performance.

For this present research study, similar boundary conditions are applied based on literature studied by Gao et al., (2014). As an example, two sides of the film clearance are categorized as a lubricant inlet and outlet with a pressure gauge of zero pascal. In addition, a water film's outside surface is considered stationary, and its inner surface is moving with a speed equal to the shaft's angular velocity. As shown by figure 2, the eccentricity ratio of film pressures of 0.8 suggested by the current research study is in good agreement with the related literature findings from Gao et al., (2014), which indicates that the journal bearing model used is validated by using ANSYS FLUENT simulation method flow. Simulations are carried out in the following method, based on the current bearing model.

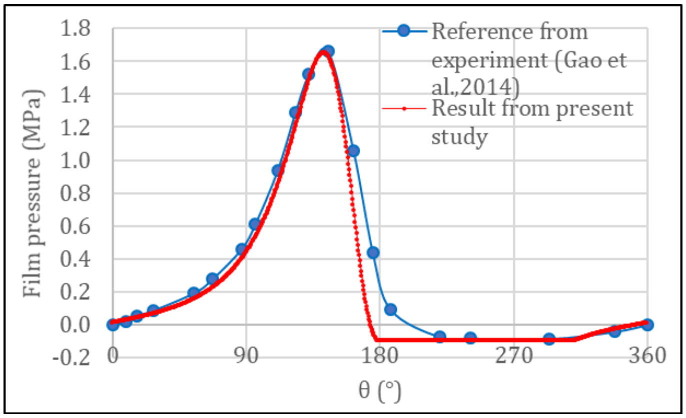


Figure 2: Comparison between film pressure for plain journal bearing by the present study and by literature from Gao *et al.,* (2014) at eccentricity ratio=0.8.

The simulation results are seen concerning the hydrodynamic pressure (and thus the load support) and the streamlines. By integrating the measured hydrodynamic pressure field and the surface contact, the load support is defined. Where there are vortexes or inconsistencies, streamlines offer a qualitative insight into how the lubricant works. For the function of the scalar stream, **Ψ** streamlines are represented along with a streamline, **Ψ** = constant. Derivations of **Ψ** refer to the corresponding velocities, i.e., $u = \partial\Psi/\partial y$. The purpose of this work is to discover the contrast between 'with cavitation' and 'without cavitation' phenomena of journal bearing for water, palm oil, and engine oil (SAE20W40). Results are presented in terms of fluid film pressure and streamlines.

3.2 Pressure Distribution

Figure 3 illustrates the distribution of pressure on the surface of the journal by considering, cavitation and non-cavitation model applied for water. The validation study as presented in figure 2, used water as a lubricant. Established method after the validation was taken as a benchmark to further study on the effect of cavitation and non-cavitation model applied for different types of lubricants. Based on figure 3, the maximum pressure for film pressure of journal bearing with cavitation effect study is 1.651 MPa and without cavitation effect applied is 1.463 MPa. In addition, the minimum film pressure value of the journal bearing is higher in the non-cavitation effect compare with the cavitation effect condition. This concludes that the cavitation effect should not be neglected as it will affect the overall value of film pressure and at the same time affect an overall evaluation of the performance of journal bearing.

Figures 4 and 5 show the distribution of pressure on the journal bearing, considering the cavitation and non-cavitation model applied for two different forms of lubricant which are engine oil (SAE20W40) and palm oil. Where film pressure (MPa) is plotted over the spatial dimension, pressure distribution comparisons are made for the journal bearing. At a speed of 1500 rpm, results are obtained with an eccentricity ratio equal to 0.8 and L/D ratio equal to 1.0.

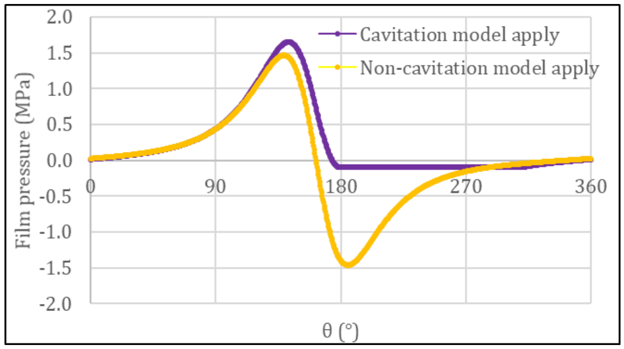


Figure 3: Water pressure distributions for analysis with cavitation and without cavitation model apply.

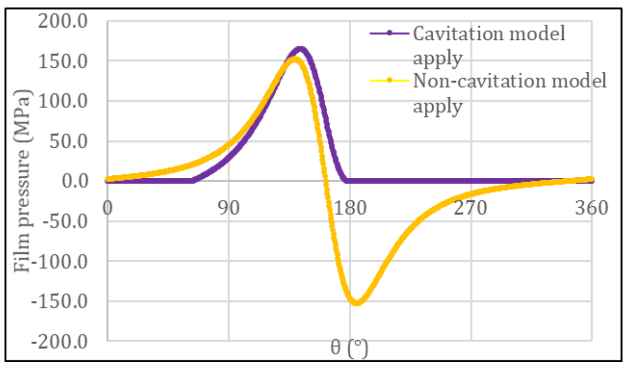


Figure 4: Engine oil (SAE20W40) pressure distributions for analysis with cavitation and without cavitation model apply.

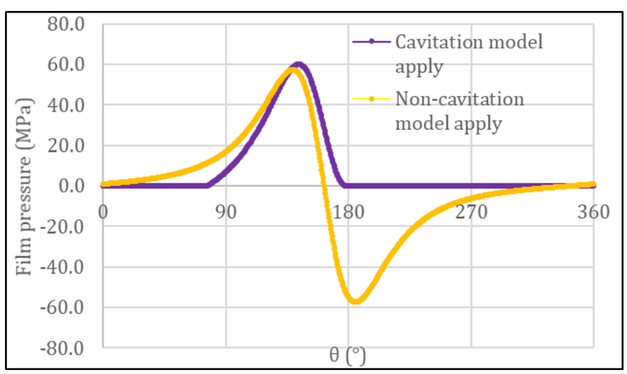


Figure 5: Palm oil pressure distributions for analysis with cavitation and without cavitation model apply.

Hydrodynamic pressure and load-bearing capacity are important parameters that need to be considered. It should be noted that, by integrating the measured hydrodynamic pressure field with surface contact, the load-carrying capacity is calculated. Other effects would have an influence on hydrodynamics, such as mechanical features and thermodynamics. In the present research, a distinction is made between a cavitation simulation analysis and a cavitation-free analysis.

It can be summarised based on all the figures that the cavitation state rejects higher negative pressure in the divergent portion of the fluid. Hence as shown in Figures 3,4 and 5 when the cavitation model is applied, the negative pressure is neglected compared with the non-cavitation model applied which can see that there has negative pressure appeared in the system. It can therefore be assumed that, based on all the findings which have ignored the cavitation condition, the overall result for the assessment of the output for journal bearing can be affected. This result for the present study fits well with the graph and result that presented by Tauviqirrahman et al., (2017), but for their case study, they applied only for the fluid with a density of 960 kg/m^3.

The maximum pressure is reported for engine oil (SAE20W40) at 165.1 MPa followed by palm oil at 60.09 MPa and lastly water at 1.651 MPa when the cavitation model is applied in the system. This happened due to the viscosity value for engine oil is higher compare with palm oil and water.

As for the comparison between the applied cavitation model and the non-cavitation model applied, the maximum pressure result for the applied cavitation model is high compared without the cavitation model. For example, in the case of palm oil, the value when applied cavitation model is 60.09 MPa, and the non-cavitation model applied is 57.38 MPa. The same situation happened when the lubricant used is engine oil and water which the pressure when applied cavitation model is higher compare with the non-cavitation model applied. Therefore, it can be concluded that the cavitation model is an important component because it will have an impact on the result of the maximum and minimum pressure of the lubricant and, in the end, will have an impact on the result for evaluating the output performance of the journal bearing.

3.3 Pressure Contour

Based on the physical point of view of Figures 6, 7, and 8, in the case of non-cavitation model applied there is no transformation modelling from fluid to vapor that could take place in the divergent field of cavitation phenomenon of the journal bearing. While the cavitation occurred in the case of cavitation was modelled in the divergent zone. It suggests that the study is very relevant to include cavitation modelling. The findings are subject to hydrodynamic stresses and related load-carrying capacities. In a conclusion, the simulation of hydrodynamic journal bearing becomes less accurate if the cavitation modelling is not considered.

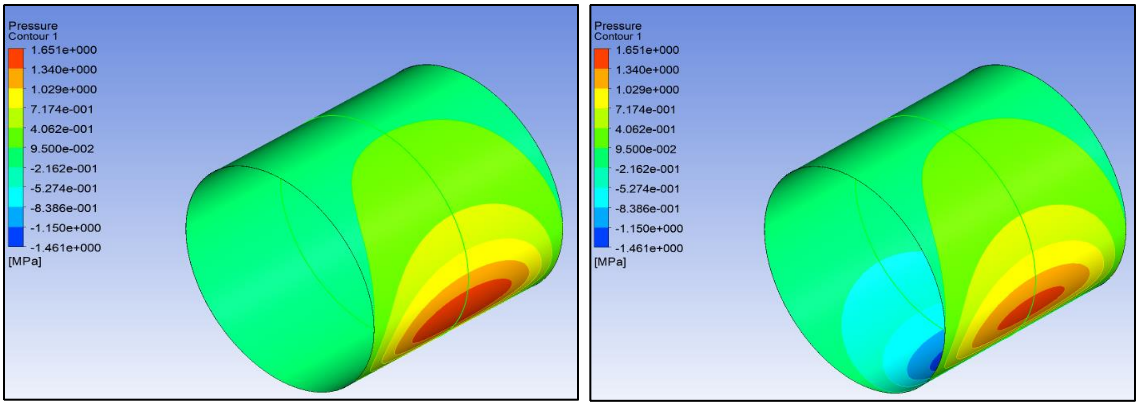


Figure 6: Water streamline for analysis (a) cavitation model apply (b) non-cavitation model apply.

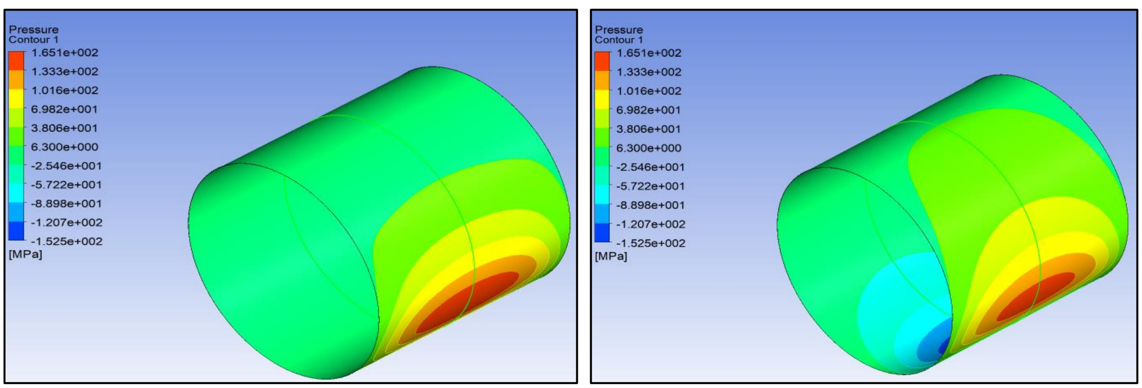


Figure 7: Engine oil (SAE20W40) streamline for analysis (a) cavitation model apply (b) non-cavitation model apply.

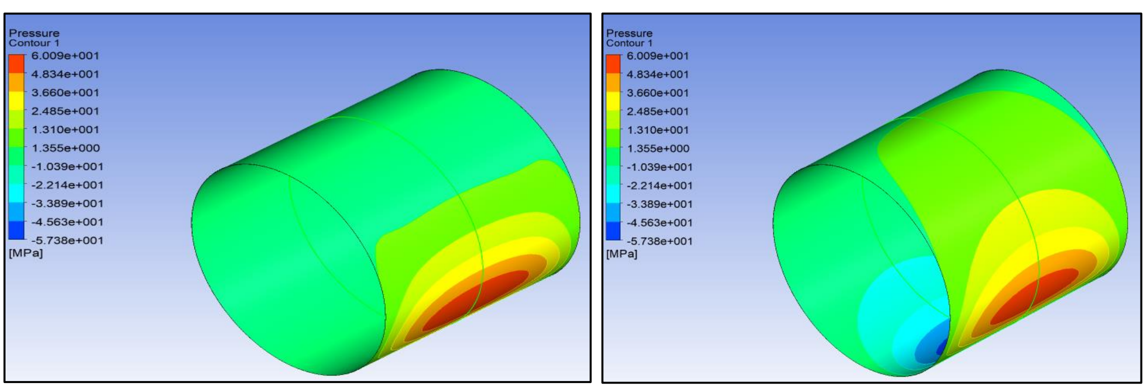


Figure 8: Palm oil streamlines for analysis (a) cavitation model apply (b) non-cavitation model apply.

CONCLUSIONS

In this research, comparison research is made between the case of cavitation and non-cavitation model applied for the lubrication assessment and it is observed that when the cavitation model is included in the analysis of the system, it provides a more accurate prediction of hydrodynamic pressures and the corresponding load-carrying ability. The results are summarised as follows:

(a) Considering the cavitation model in the study, the load-carrying ability and vortex formation are predicted more accurately.
(b) Engine oil (SAE20W40) showed better performance followed by palm oil and, lastly, water in load and friction support strength. The reduction in the overall film pressure of the journal bearing, which allows a reduction of the load support and friction strength of the palm oil, is 63.6 percent as compared to the engine oil (SAE20W40). In another view due to environmentally friendly criteria of palm oil, this type of lubricant promising high potential to replace engine oil in the future. Hence this potential lubricant needs further investigation in terms of chemical composition so it can achieve the standard of maximum pressure of film lubricant of engine oil.

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