Application of IF-WS_2 Nanoparticles as Nanofluid Lubricant to Improve Load Carrying Capacity of Plain Bearings

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INTRODUCTION

Hydrodynamic journal bearings have been extensively used in heavy industry machines and turbomachinery to support rotating shafts due to their superior durability, low maintenance cost, and excellent load carrying capacity.

An efficient way to reduce the wear of contact parts would be to improve the oil lubrication performance by surface modification and texturing or by using nanofluids–colloidal suspensions of nanoparticles (NPs) in the base lubricant.

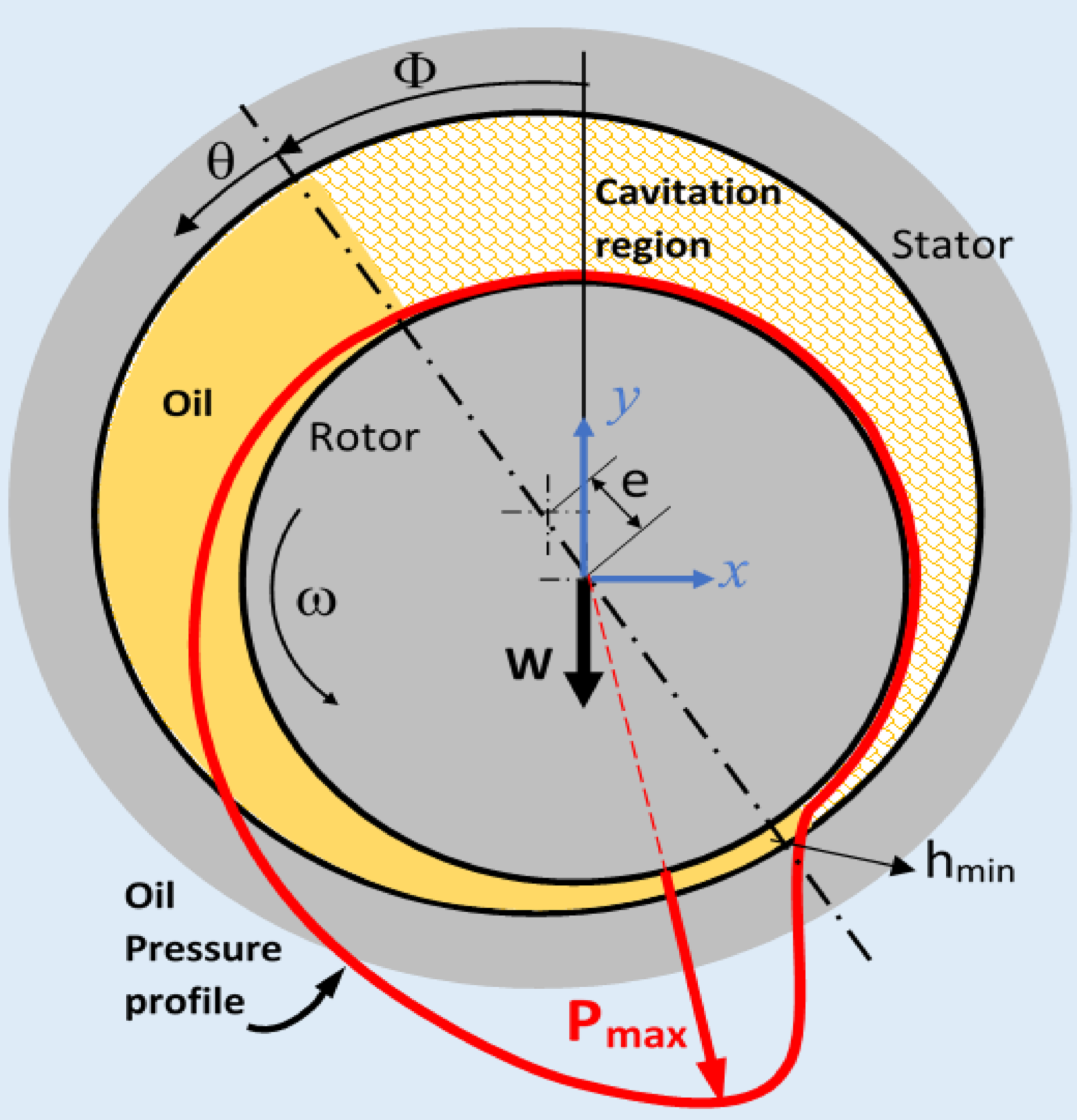
Tungsten disulfide nanoparticles (WS2 NPs) are undoubtedly the focal point of researches around additive NPs for lubrication purpose because of their excellent tribological and mechanical properties.

MATERIALS ANS METHODS

For short bearings with low L/D ratio, the solution known as Ocvirk's solution (Eq. 1) and for long bearings with high L/D ratio, the closed form solution known as Sommerfeld solution (Eq. 2) :

$$P_s = P_{short}(z,\theta) = \frac{3\eta U L^2}{R C^2}\left[\frac{1}{4} - \left(\frac{z}{L}\right)^2\right]\frac{\epsilon \sin\theta}{(1+\epsilon \cos\ \theta)^3} \qquad \text{(Eq. 1)}$$

$$P_L = P_{long}(\theta) = \frac{6\eta U R}{C^2(2+\epsilon^2)}\left[\frac{\epsilon \sin\theta\,(2+\epsilon\cos\theta)}{(1+\epsilon \cos\ \theta)^2}\right] \qquad \text{(Eq. 2)}$$



Journal bearing parameter	Value
Rotor radius	R=19 mm
Rotor Length	L=76 mm
Rotor angular speed	N=200 rpm
Radial clearance	C=0.038 mm
Base Lubricant viscosity (@100 °C)	μ = 0.02756 Pa.s
Oil Density	ρ = 885 kg/m3

A Computational fluid dynamics (CFD) simulation approach with discrete phase modeling (DPM) of suspended nanoparticles was used.

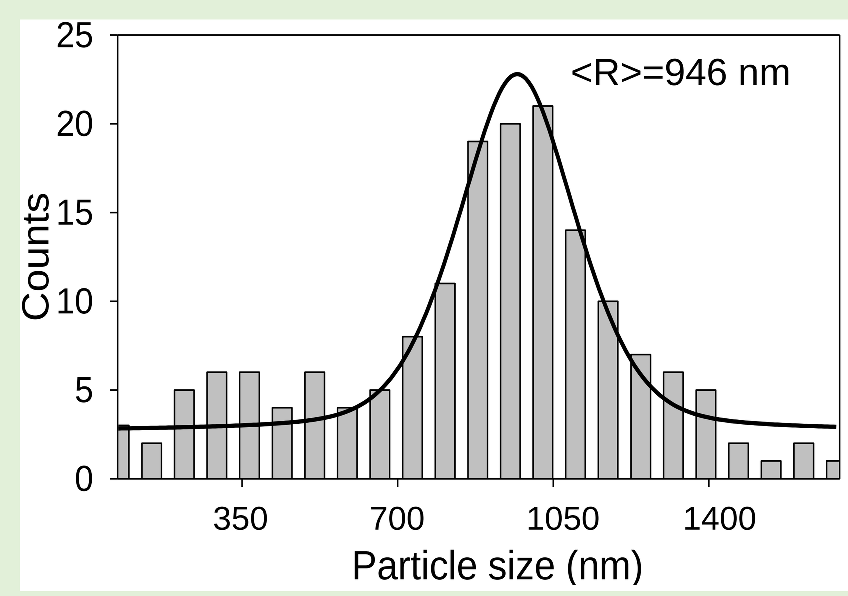
For flow regime modeling, the realizable k-ε turbulence model was used. Prior to running the simulations, for the case with base lubricant without NP additive, a mesh size sensitivity was performed to ensure independency of the results to mesh size. In the last step, to calculate the load carrying capacity, the *y-directional* polar integration of the pressure was obtained. A model that correlate relative viscosity with volume fraction ∅ of nanofluids were used where a_a and a are average size of aggregates and size of individual NPs respectively.

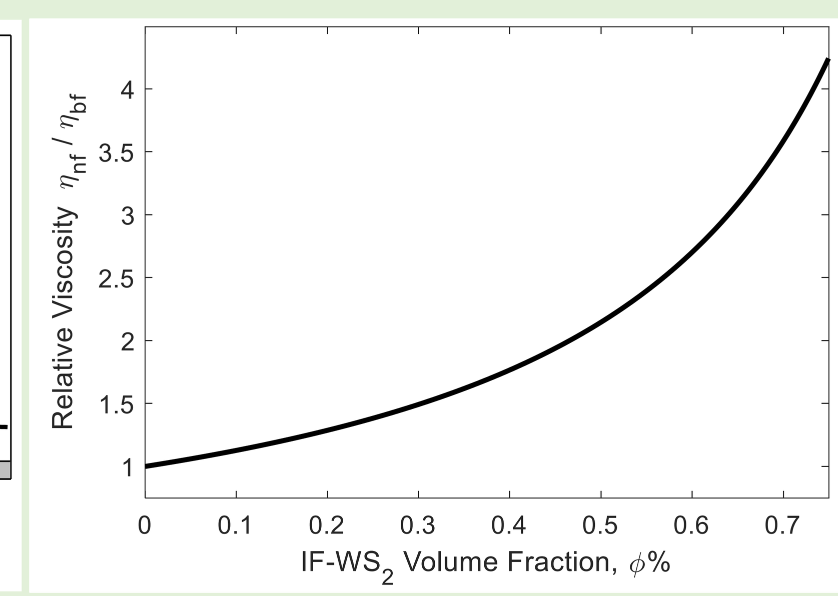
$$\frac{\eta_{nf}}{\eta_{bf}} = \left(1 - \frac{\emptyset}{0.605}\left(\frac{a_a}{a}\right)^{1.3}\right)^{-1.25}$$

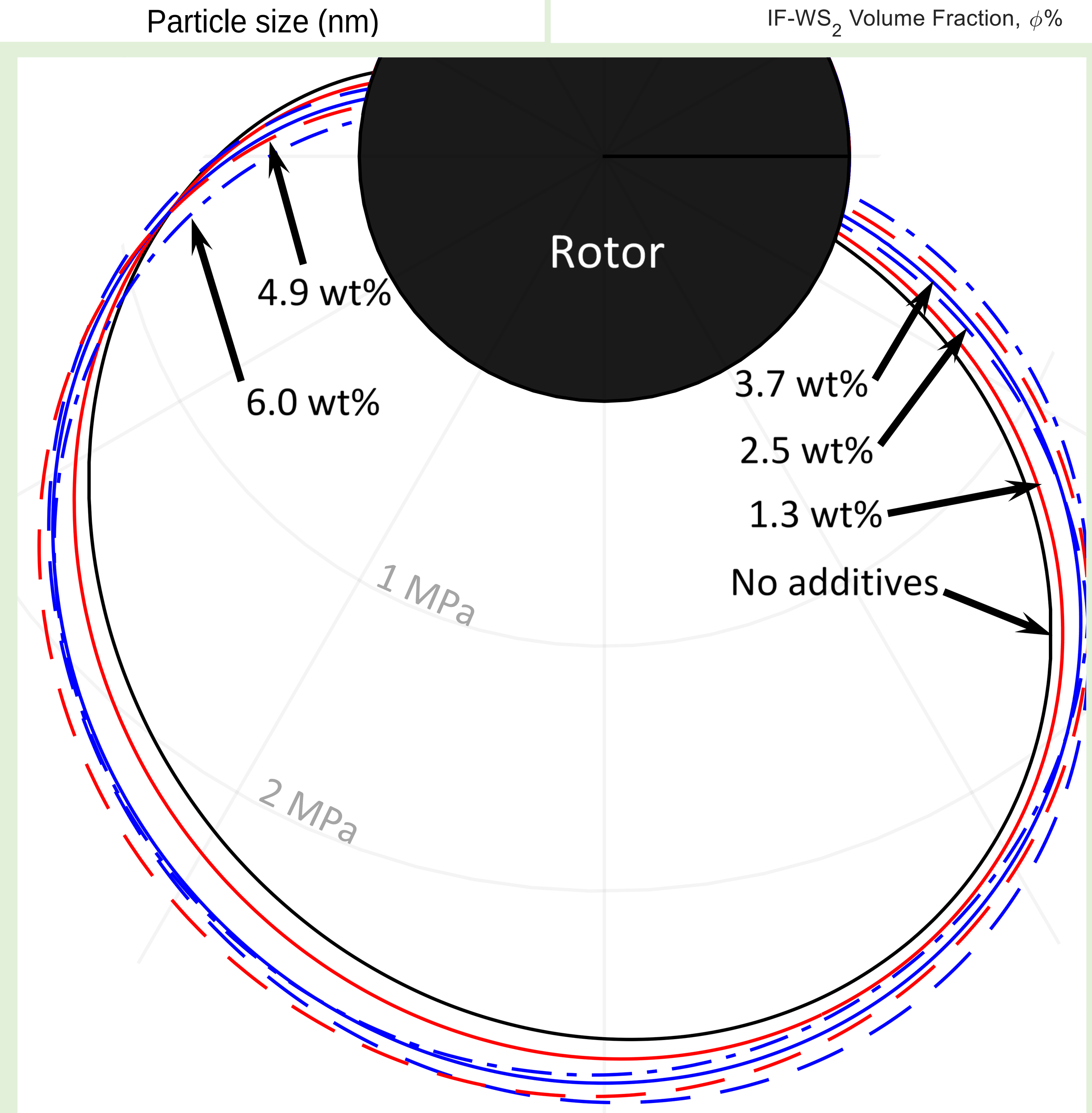
RESULTS AND DISCUSSIONS

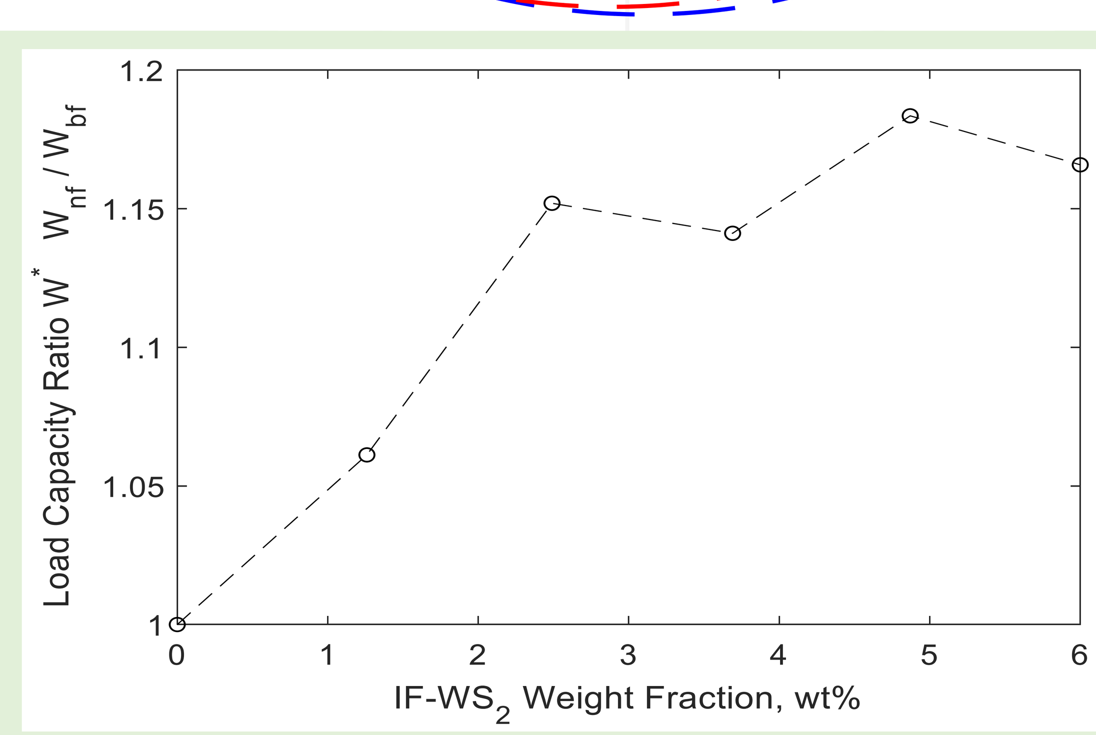
Size distribution graph of agglomerates for 3.7 wt%. NP agglomerates have an average size of a_a=946±175 nm. The results obtain by SEM imaging of several samples.

Relative viscosity of the nanofluid as a function of NP Volume Fraction then obtained and used in CFD analysis. Then simulation for different weight fractions have been done to obtain the pressure profile. Finally the pressure profile was used to calculate the load capacity. The Polar plot of pressure profile and load capacity are provided.









CONCLUSIONS

- CFD simulation was used to model the effect of nanofluid lubricant on load carrying capacity of industrial journal bearings.
- The simulation was implemented for six different nanofluid scenarios (various WS_2 weight fractions).
- The results show that the load carrying capacity of the bearing can be improved by 20% using a practical 5 wt% IF-WS2 NPs additive.
- SEM images showing that the high aggregation tendency of WS_2 NPs limits the application of nanofluid lubricant at fractions above 6.0 w%.