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Influence of vibration on the lubrication effect of a splash-lubricated gearbox

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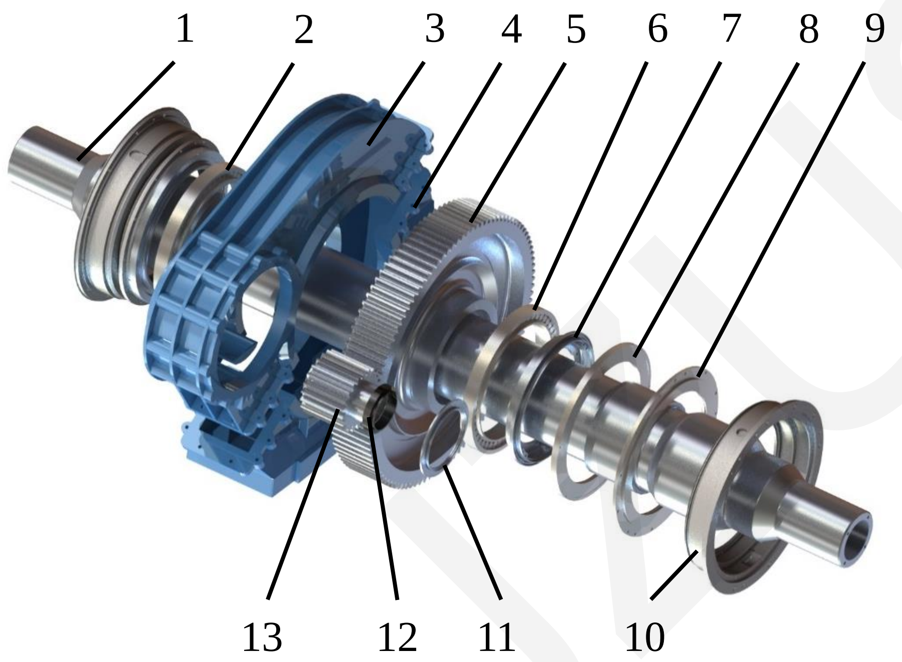
Model and Simulation conditions

Gearbox model



No.	Name
1	Output shaft
2	Output shaft cylindrical roller bearing (GW)
3	Upper case of gear box
4	Lower case of gear box
5	Driven gear
6	Output shaft cylindrical roller bearing (GM)
7	Output shaft seal ring
8	Snap ring
9	Output shaft bushing
10	Output shaft end cover
11	Input shaft end cover
12	Input shaft bushing
13	Driving gear

Fig. 1. Exploded view of the gearbox. GW represents the outgear wheel side; GM represents the outgear motor side;

Model and Simulation conditions

■ Gearbox parameters

Parameter	Value	Parameter	Value
Module (mm)	9	Center distance (mm)	567
Tooth number of input gear	22	Helix angle (°)	0
Tooth number of output gear	103	Pressure angle (°)	20
Tooth width (mm)	150		

■ Diagram of the gearbox model and mesh

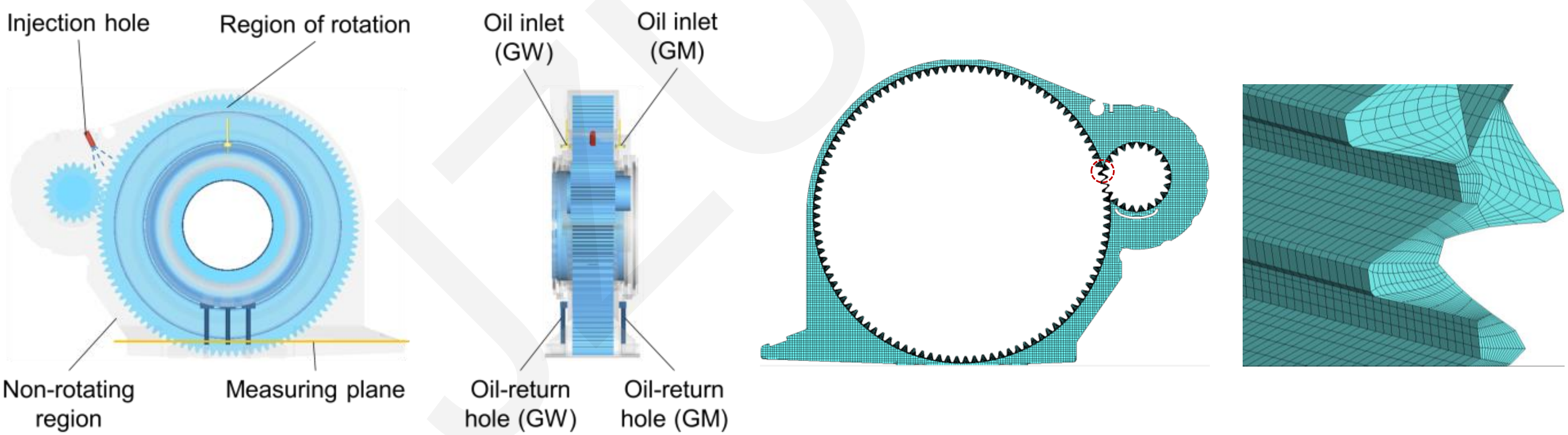


Fig. 2. Diagram of the gearbox model and mesh

Boundary conditions

■Track excitation

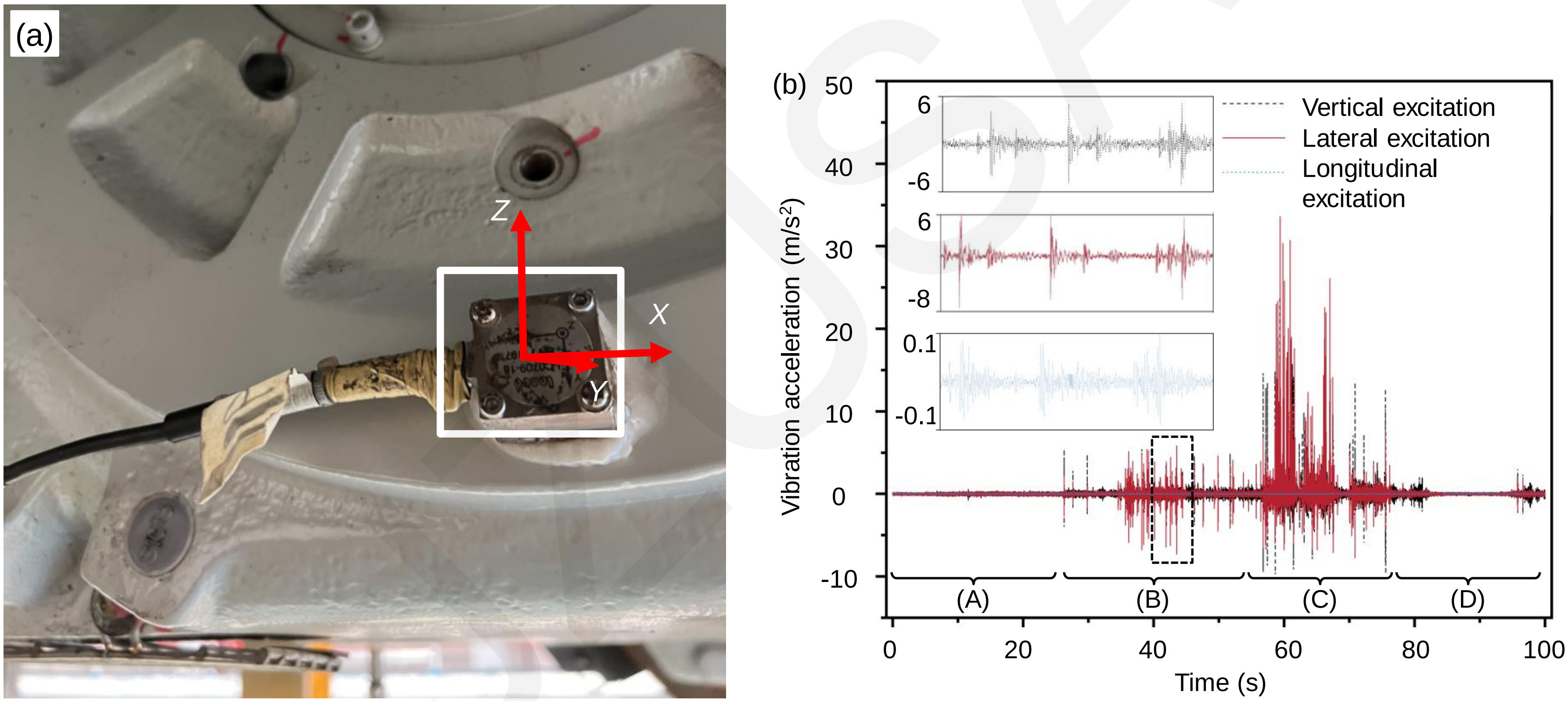


Fig. 3. Track excitation: (a) distribution of an acceleration sensor; (b) vibration excitation

Numerical fitting of power loss

■Numerical fitting of power loss

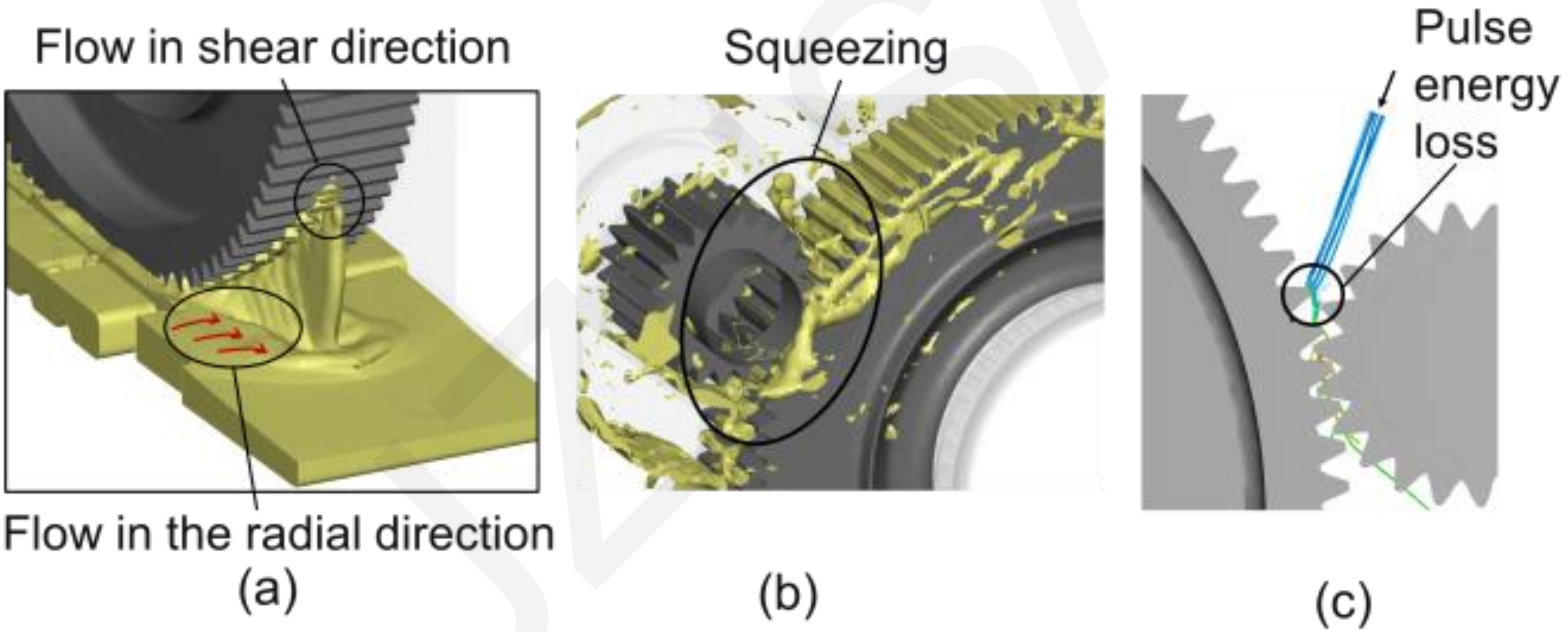


Fig. 4 Energy-loss diagram: (a) energy loss caused by shear-directional flow and radial flow; (b) squeezing loss; (c) pulse energy loss

Results and discussion

■Effect of vibration direction

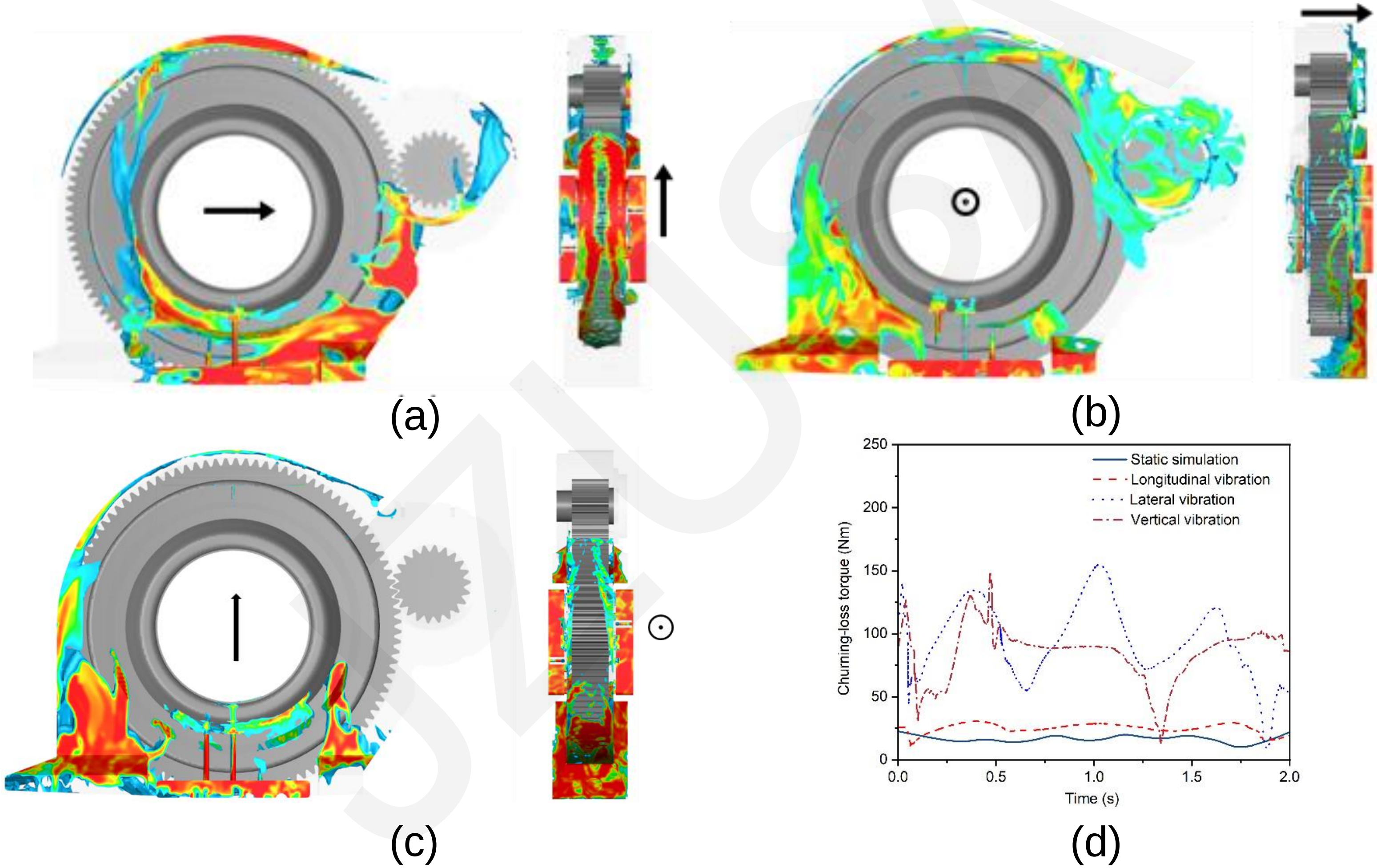


Fig. 5 Simulation of flow field under vibration: (a) longitudinal vibration; (b) transverse vibration; (c) vertical vibration; (d) churning loss under different vibration directions

Results and discussion

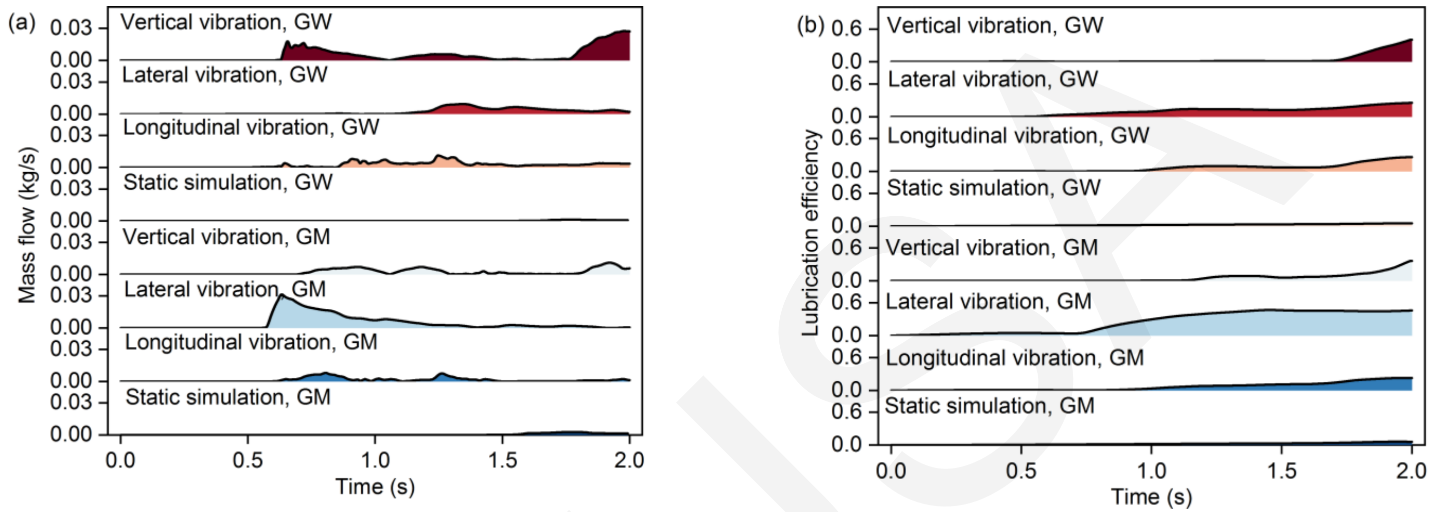


Fig. 6 Bearing lubrication with different vibration directions: (a) mass flow; (b) efficiency

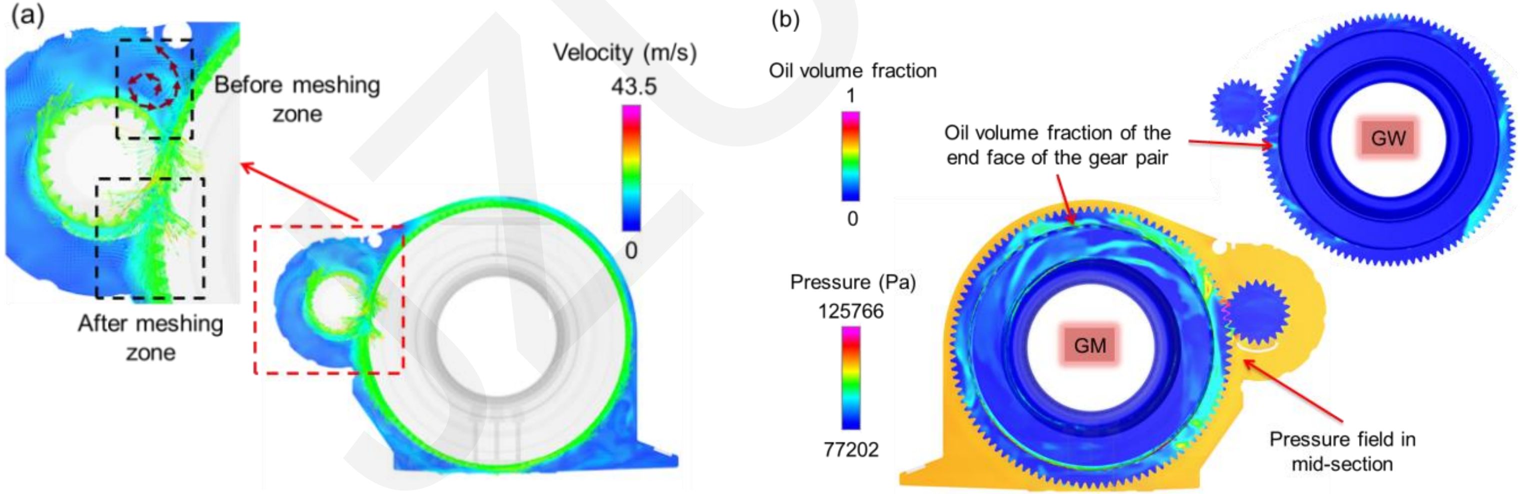


Fig. 7 Internal lubrication of the gearbox with lateral vibration direction: (a) velocity; (b) pressure and oil volume fraction

Results and discussion

Influence of with different rotational speeds

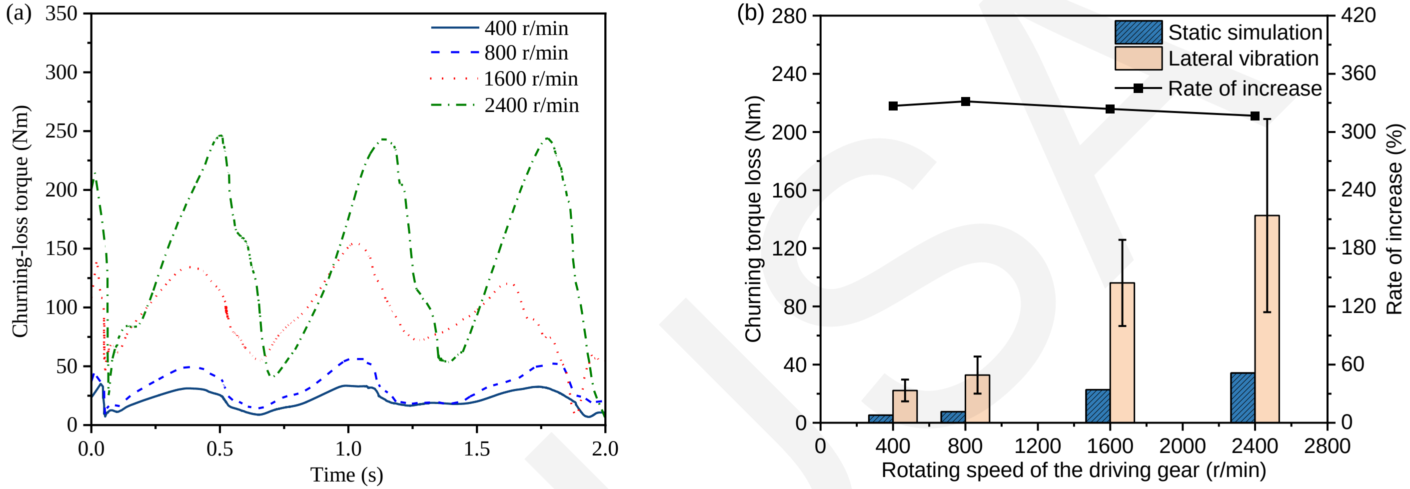


Fig. 8 Churning-loss torque with different rotational speeds: (a) time-history curve; (b) comparison of average value of churning-loss torque in different states

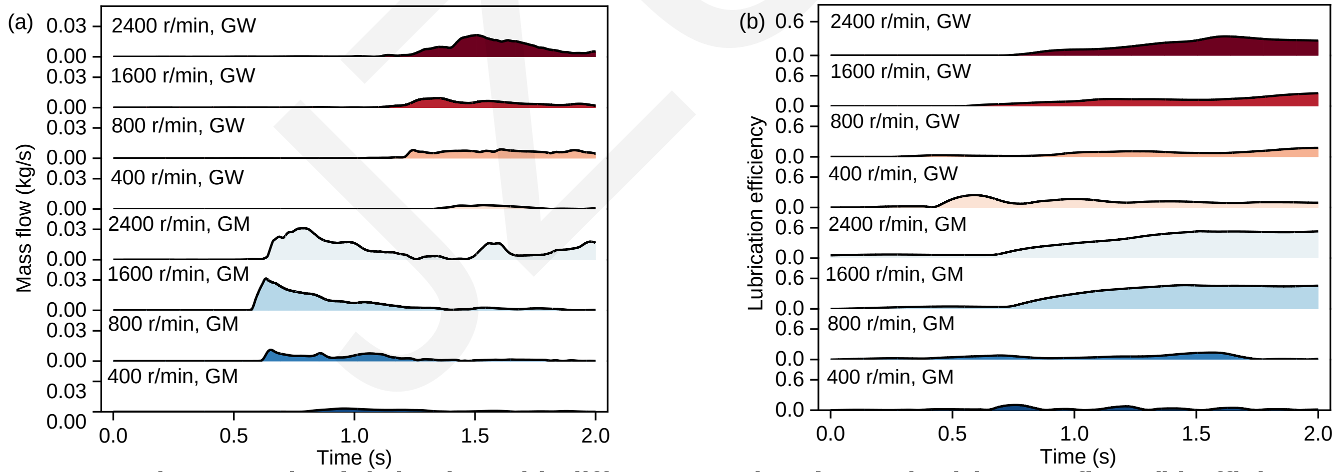


Fig. 9 Bearing lubrication with different rotational speeds: (a) mass flow; (b) efficiency

Results and discussion

Influence of with different immersion depths

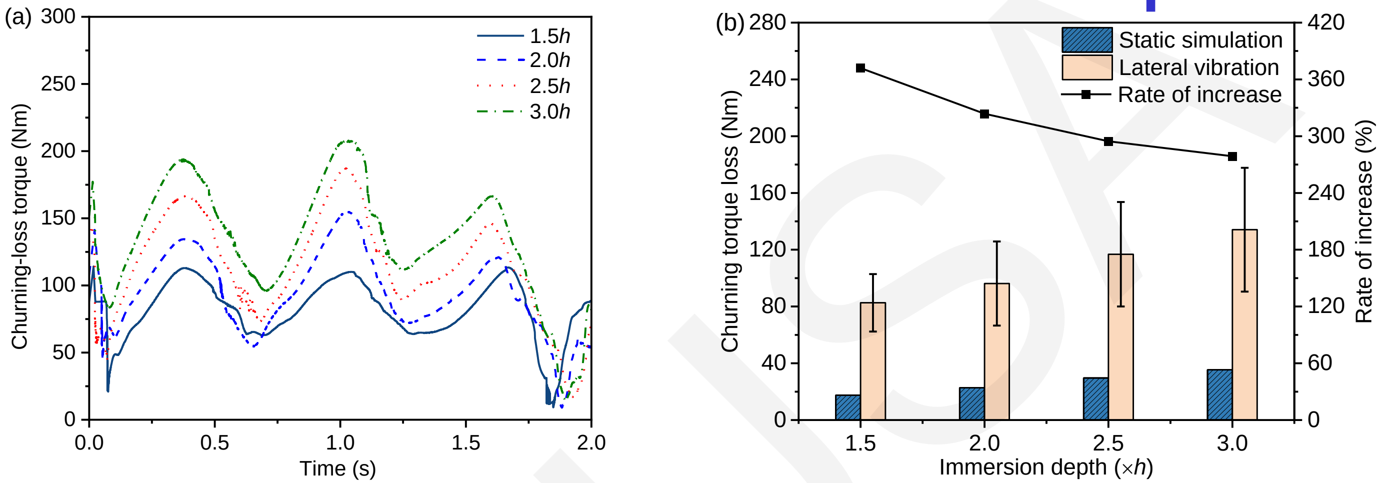


Fig. 10 Churning-loss torque with different immersion depths: (a) time-history curve; (b) comparison of average value of churning loss in different states

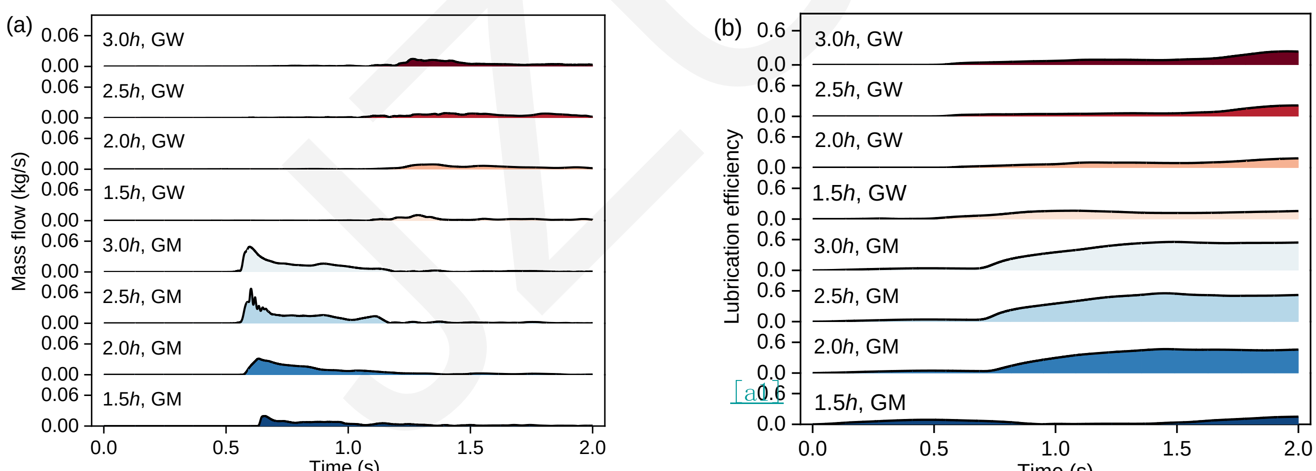


Fig. 11 Bearing lubrication at different immersion depths: (a) mass flow; (b) efficiency

Results and discussion

■ Influence of with different vibration amplitudes

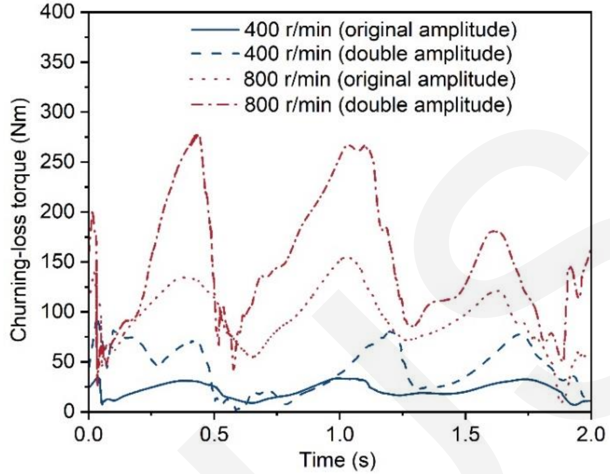


Fig. 12 Churning-loss torque with different vibration amplitudes

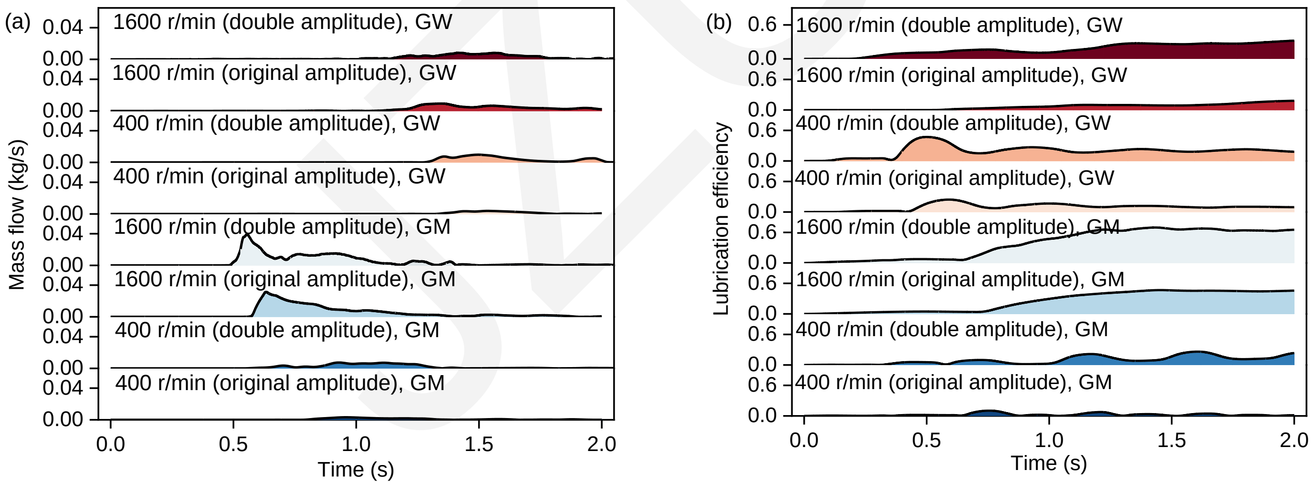


Fig. 13 Bearing lubrication at different immersion depths: (a) mass flow; (b) efficiency

Results and discussion

Influence of with different vibration frequencies

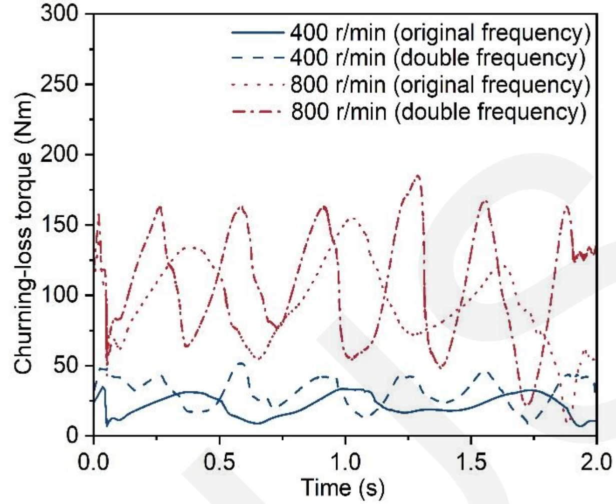


Fig. 14 Churning-loss torque with different vibration frequencies

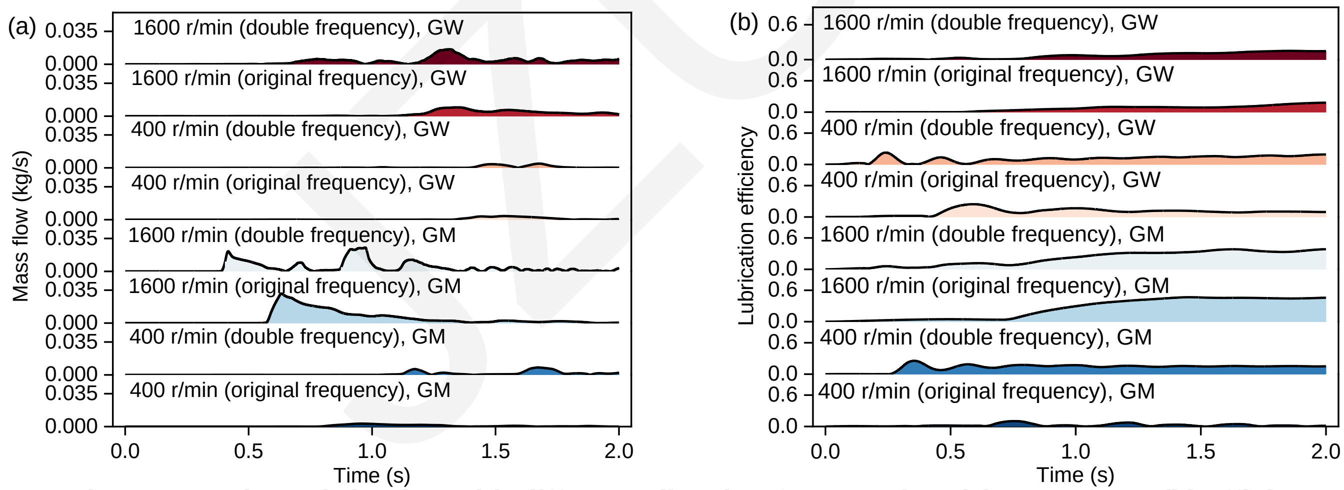


Fig. 15 Bearing lubrication with different vibration frequencies: (a) mass flow; (b) efficiency

Results and discussion

■ Comprehensive evaluation of lubrication and efficiency

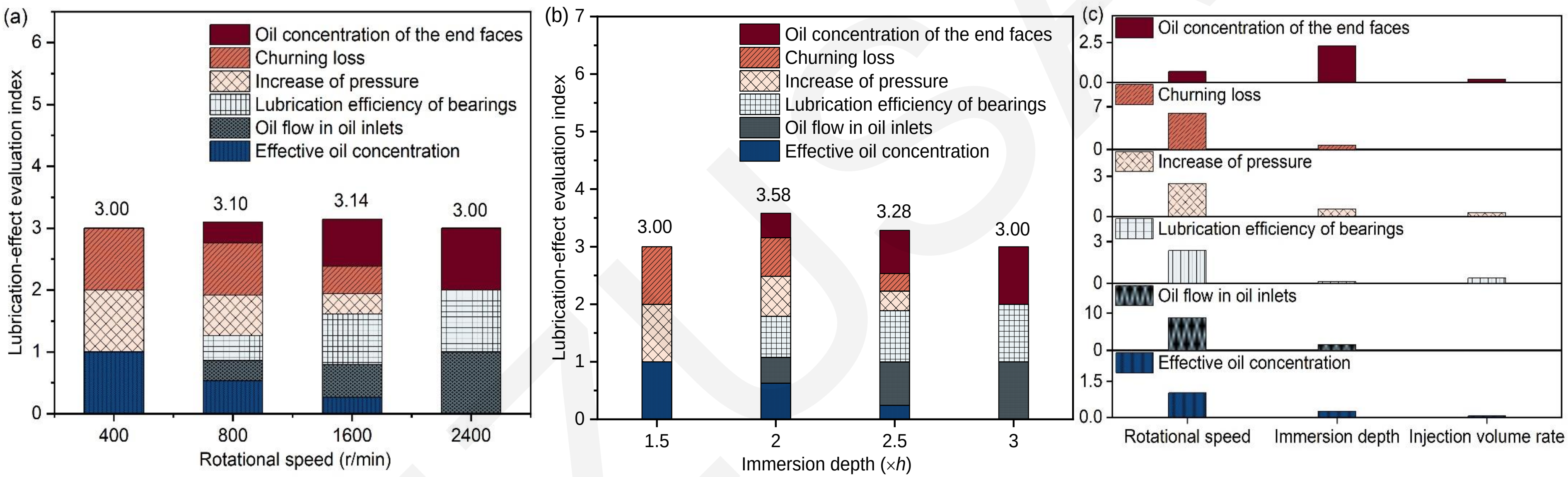


Fig. 16 Evaluation of comprehensive lubrication performance of the gearbox: (a) different rotational speeds; (b) different depths of immersion; (c) quantitative comparison of the effects of different operating parameter

Experimental verification

Oil distribution

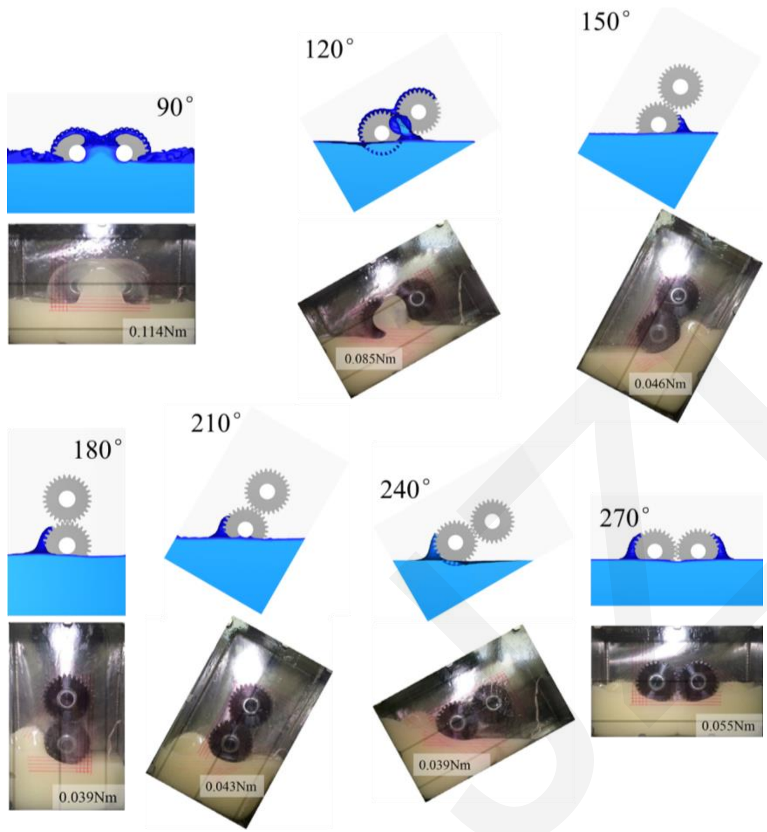


Fig. 17 Comparison of simulation results and experimental results

Churning loss

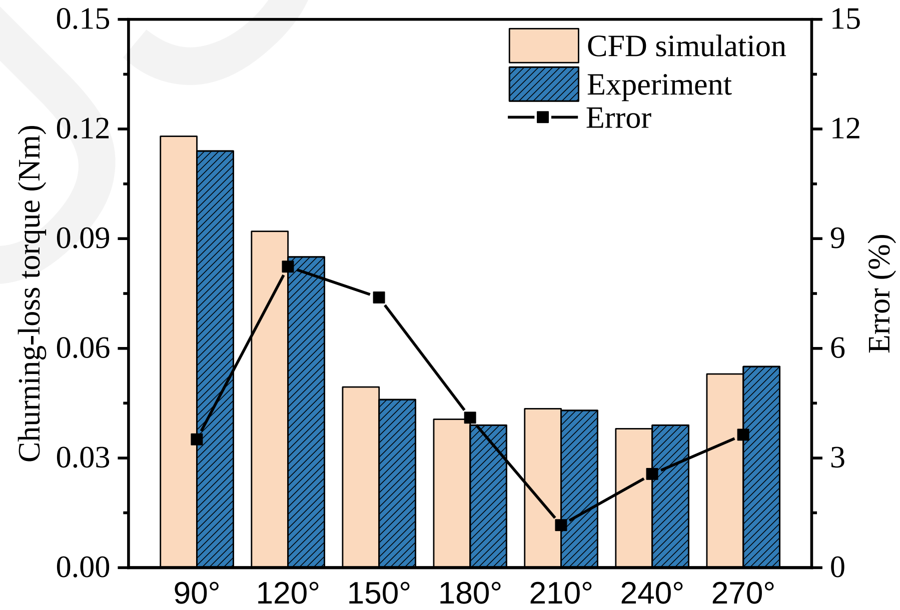


Fig. 18 Comparison of churning losses in the experiment and simulation

Conclusions

This study investigated the effect of vibration on the lubrication and efficiency of a splash-lubricated gearbox. The applicability and accuracy of the numerical method are verified by the available experimental results, and the following primary conclusions can be drawn:

- Under vibration, the churning loss and oil supply for the bearings of the gearbox increase significantly compared with static conditions. Among the three directions of vibration, the amplitudes of the churning-loss curve and the unilateral bearing mass flow curve are the largest with transverse vibration. Compared with longitudinal vibration and vertical vibration, the effect of transverse vibration on oil flow in the gearbox is both regular and asymmetric.
- The churning loss, oil supply for the bearings, and lubrication efficiency of the bearings all increase with gear speed, oil-immersion depth, and oil-injection volume rate. An increase in amplitude increases the peak value of each curve. An increase in frequency increases the number of peaks on each curve, and there is no obvious law for the size of the peaks.
- We comprehensively evaluated the lubrication performance and efficiency of the gearbox with six lubrication indices. For the gearbox evaluated in this study, speed is the parameter that has the most significant effect on lubrication status and efficiency. In addition, the best lubrication condition is achieved when the rotational speed is 1600 r/min and the oil-immersion depth is 2.0h.