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Characteristics of Volumetric Losses and Efficiency of Axial Piston Pump with respect to Displacement Conditions

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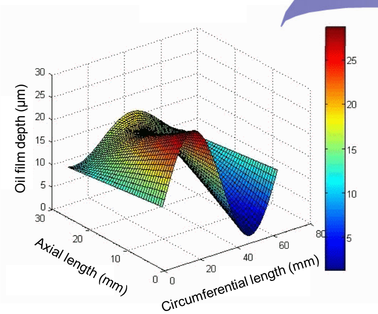
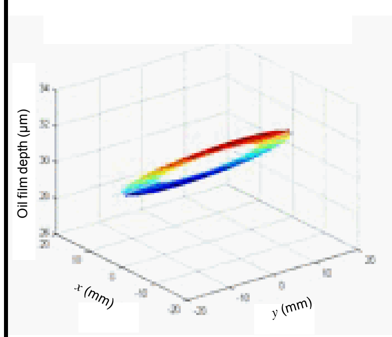
Simulation Modeling

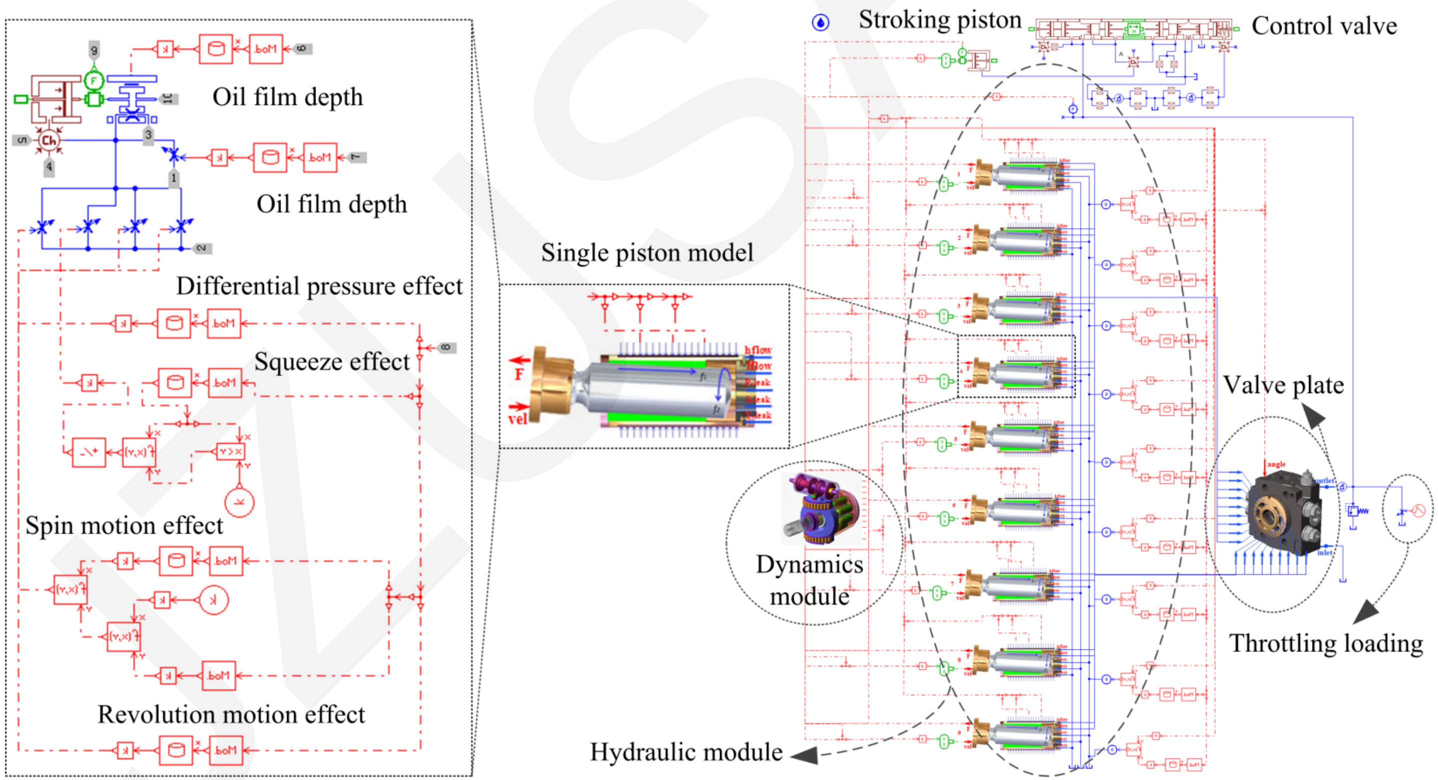


Dynamic oil film depth of piston cylinder pair



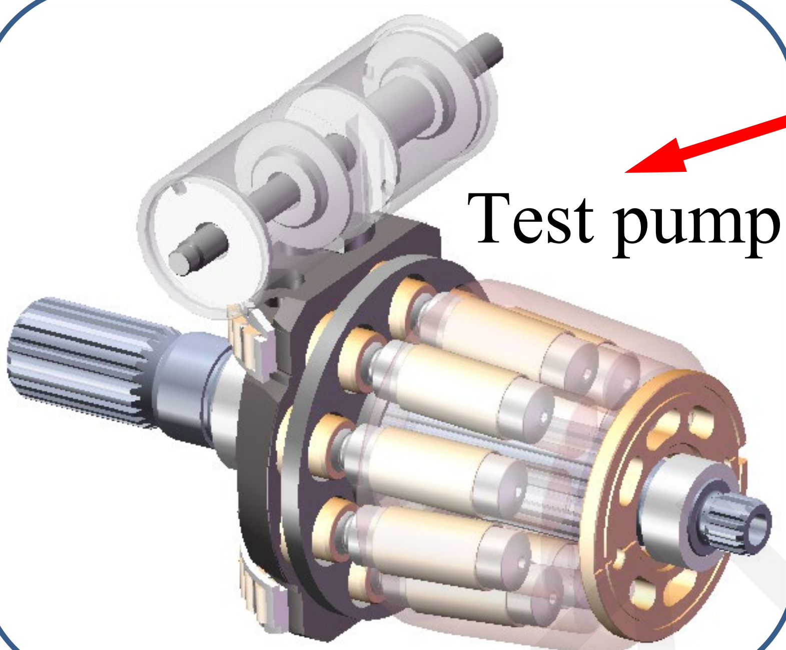
Dynamic oil film depth of slipper swash plate pair

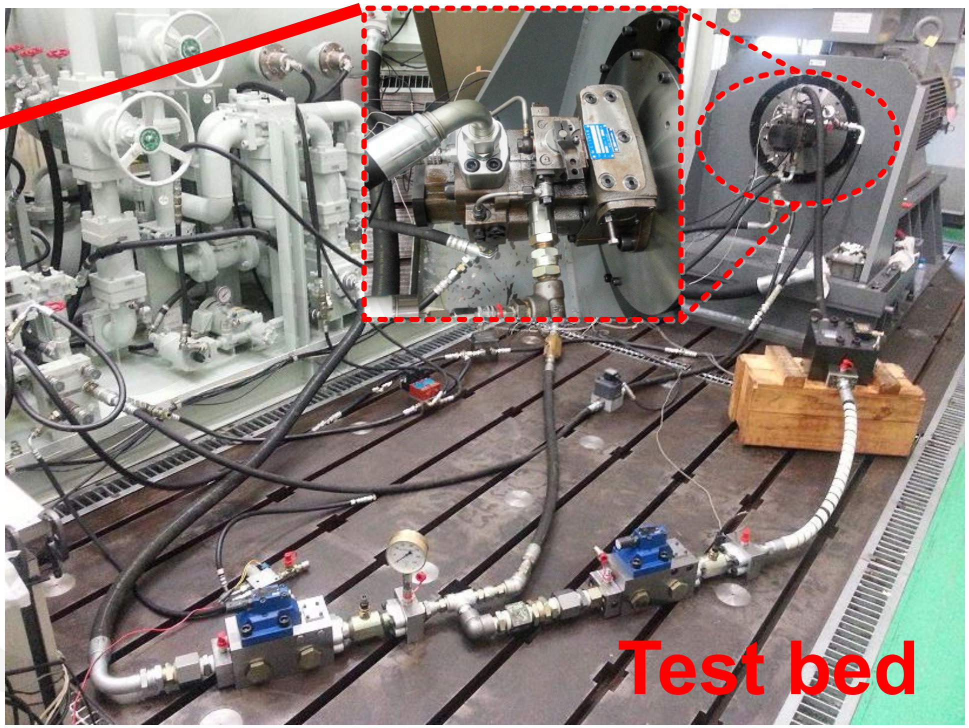
A more complete equation to calculate the leakage via the slipper / swash plate gap and a novel explicit volumetric loss simulation model



$$q_{ls} = \frac{\pi\delta_s^3\Delta p_s}{6\mu\ln(R_s/r_s)} + \frac{\pi\rho\delta_s^3\omega_{sm}^2}{60\mu}(R_s^3 - r_s^3) + \frac{\pi}{2}\frac{(R_s^2-r_s^2)}{\ln(R_s/r_s)}\frac{d\delta_s}{dt} + \int_{r_s}^{R_s}\int_{z=0}^{\delta_{s1}}\int_{\theta=0}^{\pi/2}\upsilon_{or1}drdzd\theta + \int_{r_s}^{R_s}\int_{z=0}^{\delta_{s2}}\int_{\theta=\pi/2}^{\pi}\upsilon_{or2}drdzd\theta$$
$$+ \int_{r_s}^{R_s}\int_{z=0}^{\delta_{s3}}\int_{\theta=\pi}^{3\pi/2}\upsilon_{or3}drdzd\theta + \int_{r_s}^{R_s}\int_{z=0}^{\delta_{s4}}\int_{\theta=3\pi/2}^{2\pi}\upsilon_{or4}drdzd\theta$$

Experimental Setup

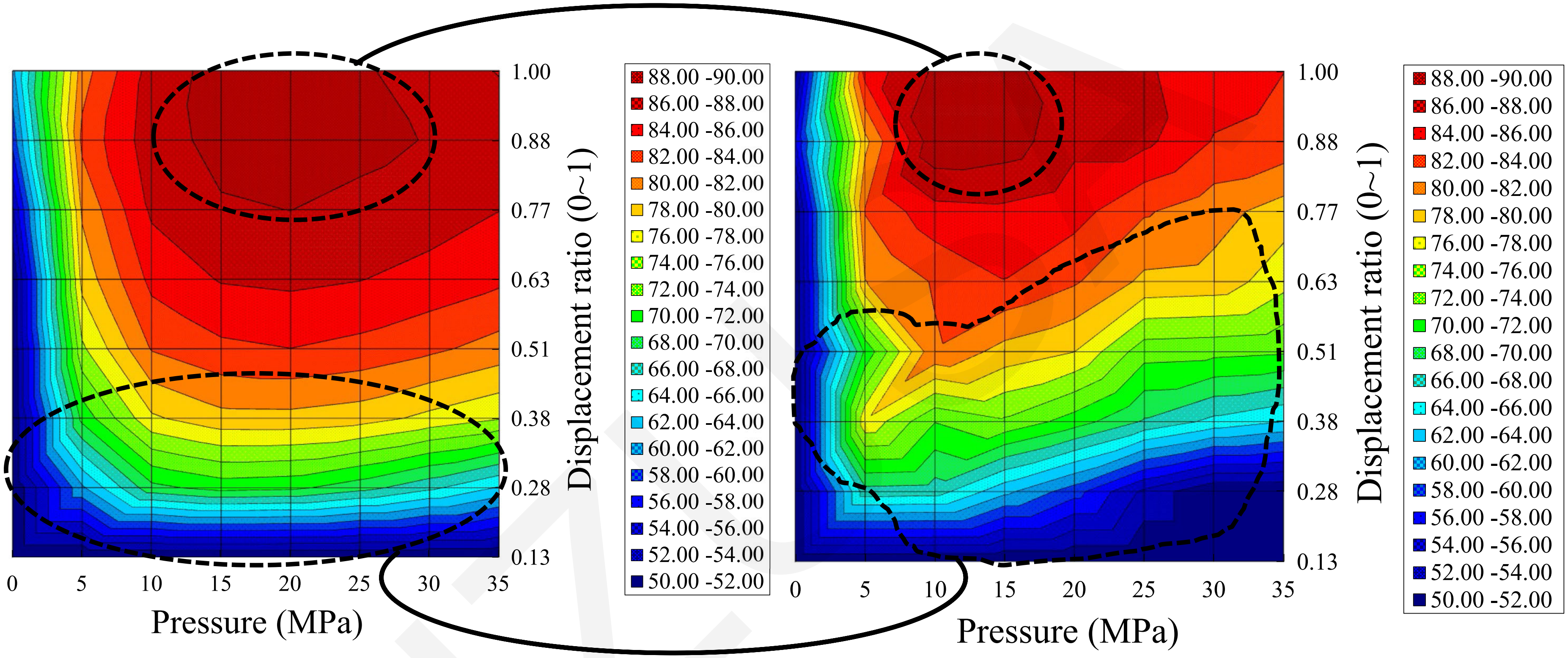




Displacement： 90 ml/r
Rated pressure： 35 MPa
Rated speed： 2100 r/min
Oil temperature： (-20 ~ 80)℃

Working conditions：
pressure： 0, 5, 10, 15, 20, 25, 30, 35 (MPa)
displacement： 0.13, 0.28, 0.38, 0.51, 0.63, 0.77, 0.88, 1.00 ($q_{d,max}$)
speed： 1000, 1300, 1700, 2100 (r/min)

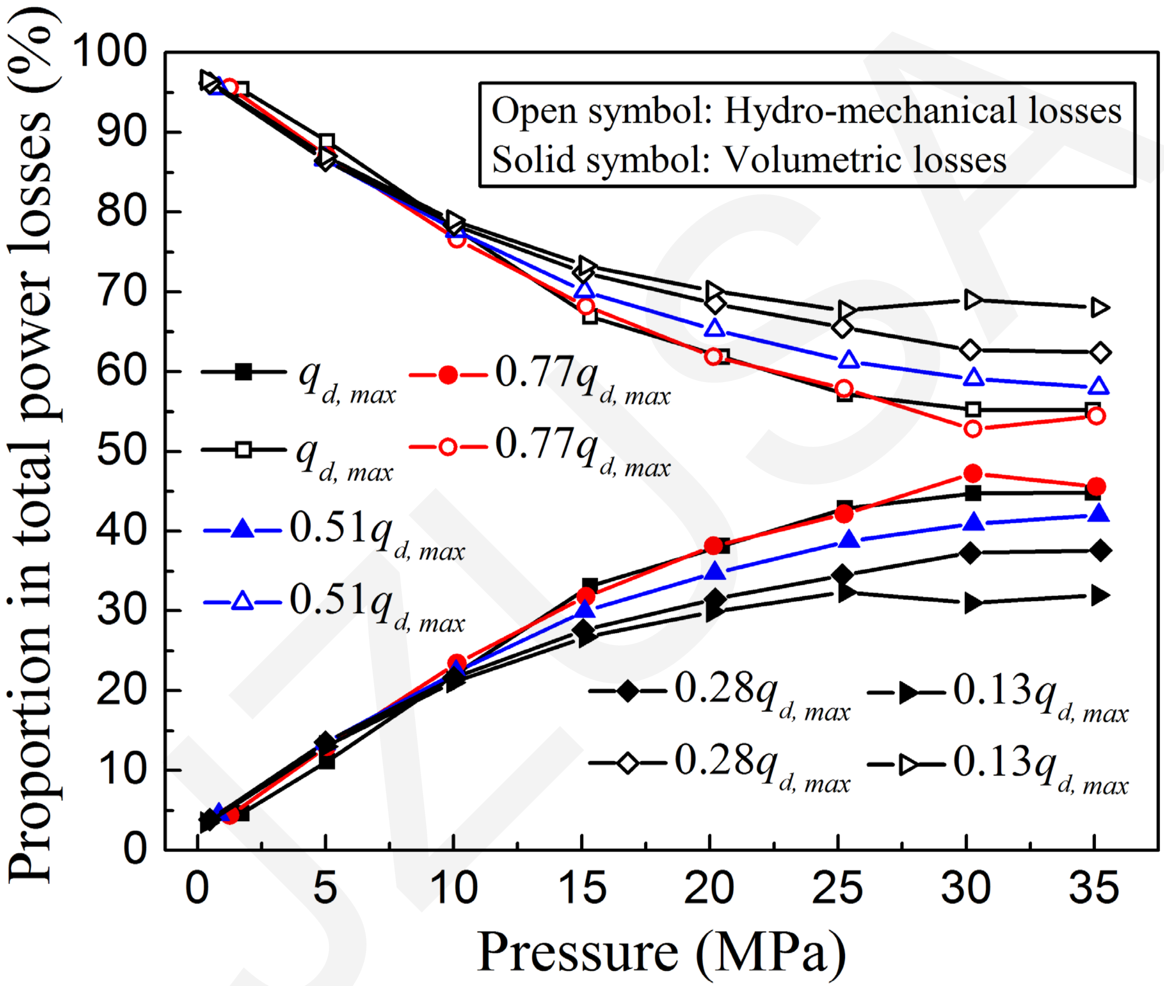
Results and Discussion



Overall efficiency of pump measured by experiment at 2100 r/min pump speed

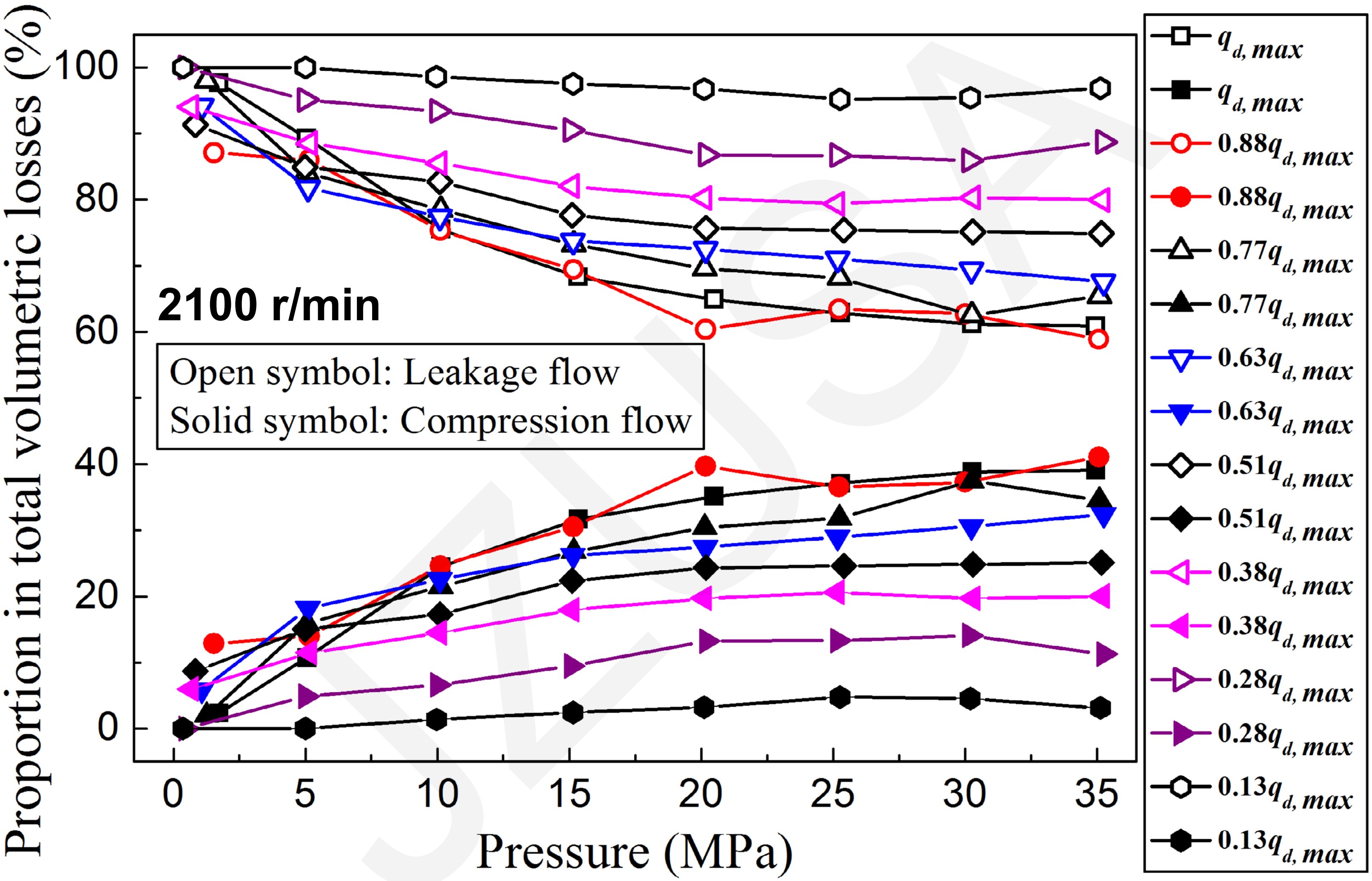
Overall efficiency of pump measured by experiment at 1000 r/min pump speed

Results and Discussion



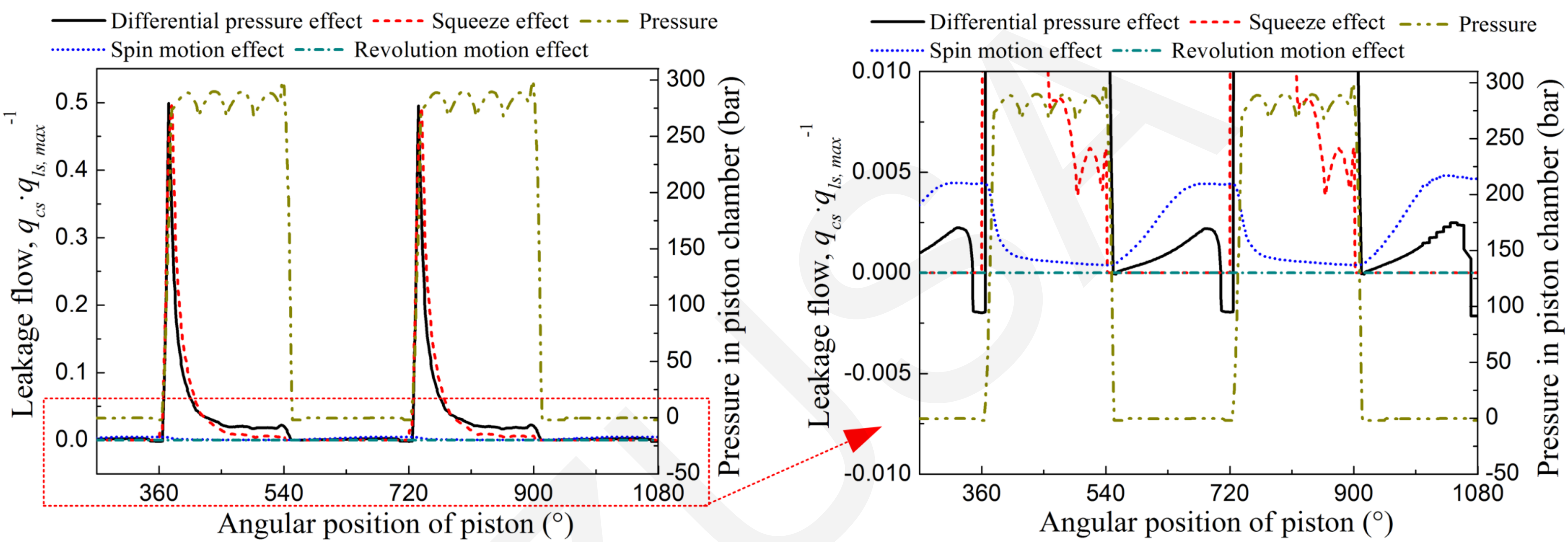
Comparison of power losses of pump at the rated speed of 2100 r/min derived from the test data

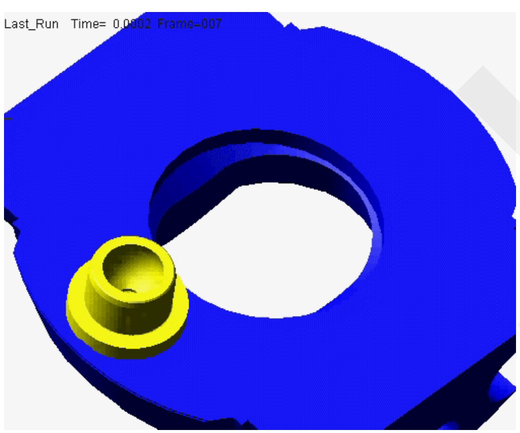
Results and Discussion



Comparison between leakage flow and compression flow of pump at the rated speed of 2100 r/min, derived from the test data

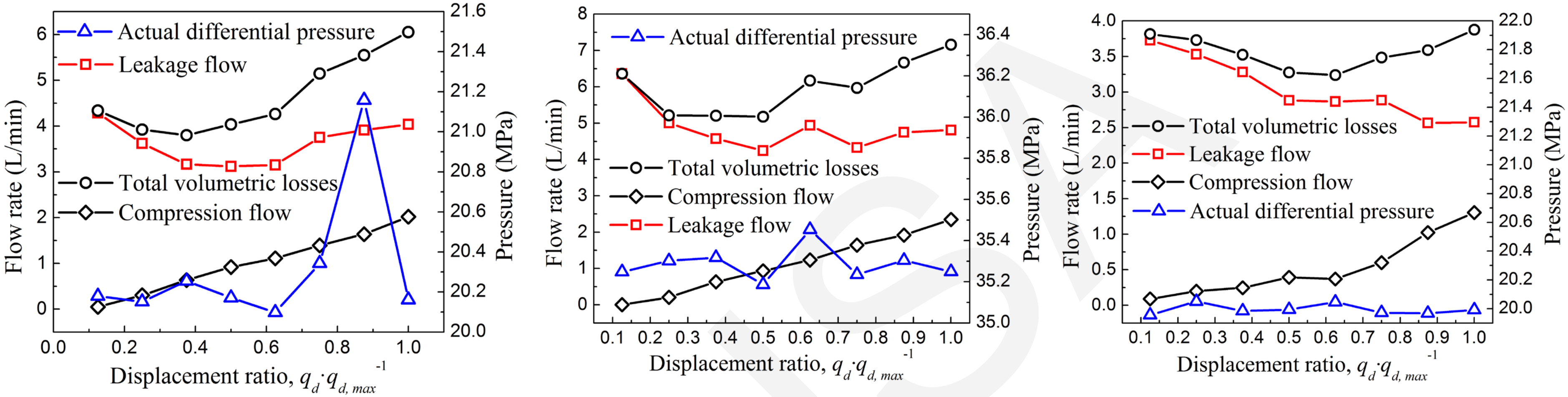
Results and Discussion





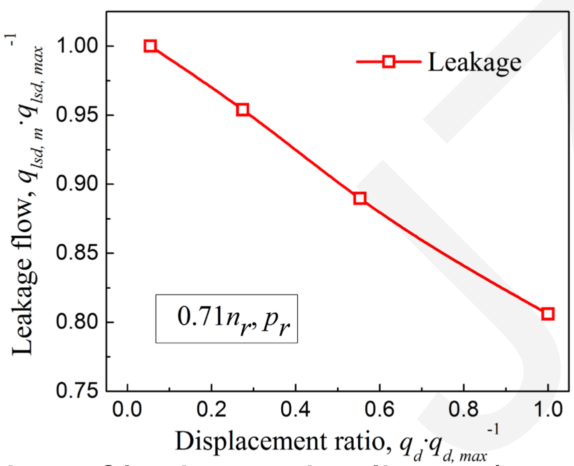
Components analysis of leakage via the gap between slipper and swash plate obtained by simulation at 1500 r/min pump turning speed and full displacement

Results and Discussion

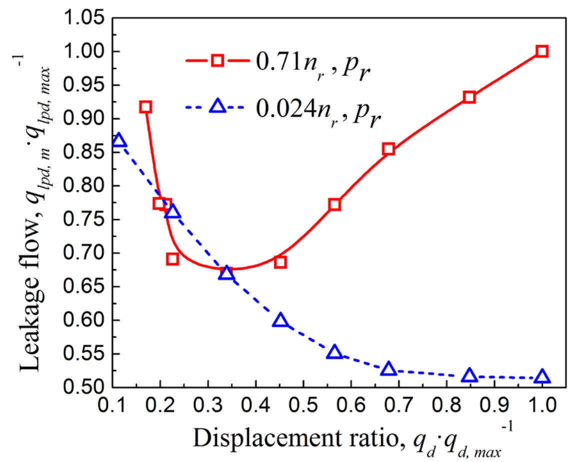


(a) 1700 r/min and 20 MPa (b) 1300 r/min and 35 MPa (c) 1000 r/min and 20 MPa

Volumetric losses versus pump displacement, measured by experiment



Variation of leakage via slipper / swash plate gap versus pump displacement obtained by simulation



Leakage flow of piston / cylinder pair versus pump displacement obtained by simulation

Conclusions

- The mechanism of leakage via slipper / swash plate gap was analyzed in detail by the proposed novel volumetric losses model, with a more complete equation to calculate the leakage via the slipper / swash plate gap. Compared with the previous models, the beauty of the novel model is that it allows explicit insight into the components of leakage flow. For the leakage of the slipper / swash plate pair, the squeeze leakage caused by the squeeze micro-motion of the slipper is found to reach a magnitude equal to that of the Poiseuille flow caused by the differential pressure effect.

Conclusions

- The overall efficiency is found to drop considerably with the decreasing displacement. The volumetric losses range from 13% to 47% of the total power losses of pump at the rated speed, under the conditions of pressure ranging from 5 to 35 MPa and displacement ranging from 13% to 100% of full displacement. The highest proportion of compression flow losses in the total volumetric losses of pump at the rated speed can reach up to 41% when the pressure and displacement are, respectively, greater than 30 MPa and 88% of full displacement; after that, the proportion gradually decreases with decreasing displacement. However, the leakage flow generally increases with decreasing displacement, or may decreases first and begins to increase after the minimum with the further decrease of displacement.