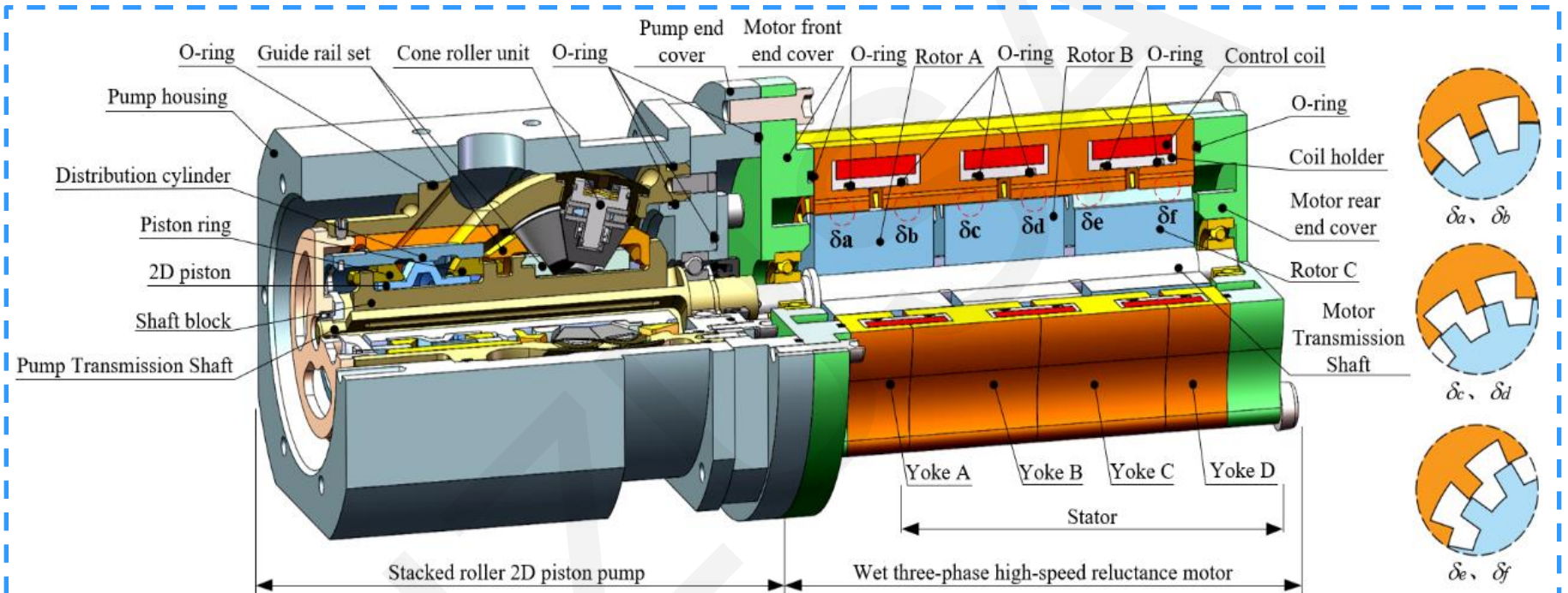


# Churning loss characteristics of a wet three-phase high-speed reluctance motor

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# Structure



**Fig. 1 Schematic diagram of the structure of the wet three-phase high-speed reluctance motor pump**

# Analytical Modelling

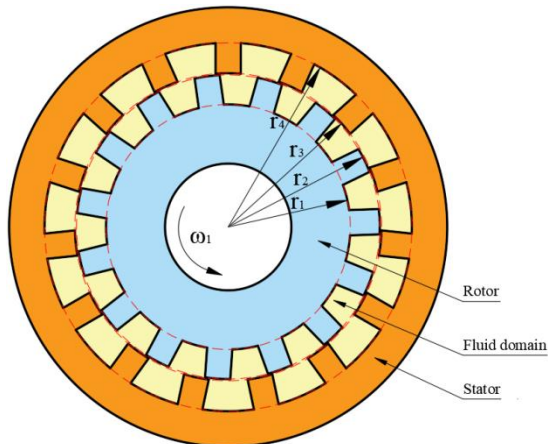


Fig. 2 Sectional diagram of the stator and rotor

Churning torque of the rotor circumference :

$$T_R = C_R \pi \mu \omega_1 \left( 0.64 \frac{r_2^2 r_3^2}{r_3^2 - r_2^2} + 1.12 \frac{r_2^2 r_4^2}{r_4^2 - r_2^2} + 0.8 \frac{r_1^2 r_3^2}{r_3^2 - r_1^2} + 1.4 \frac{r_1^2 r_4^2}{r_4^2 - r_1^2} \right)$$

Churning torque of the rotor side :

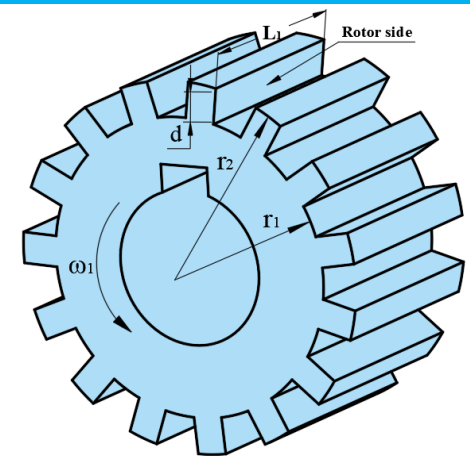


Fig. 3 Schematic diagram of the rotor side

$$T_D = \int r dF_D = \frac{1}{8} C_D \rho \omega_1^2 L (r_2^4 - r_1^4)$$

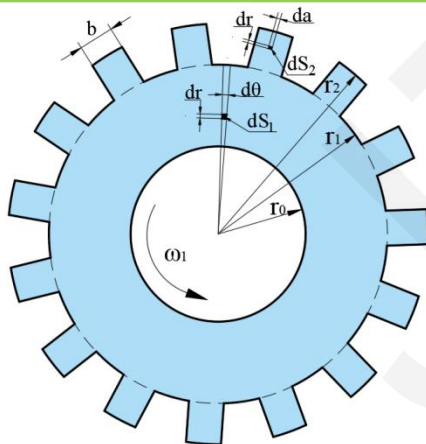
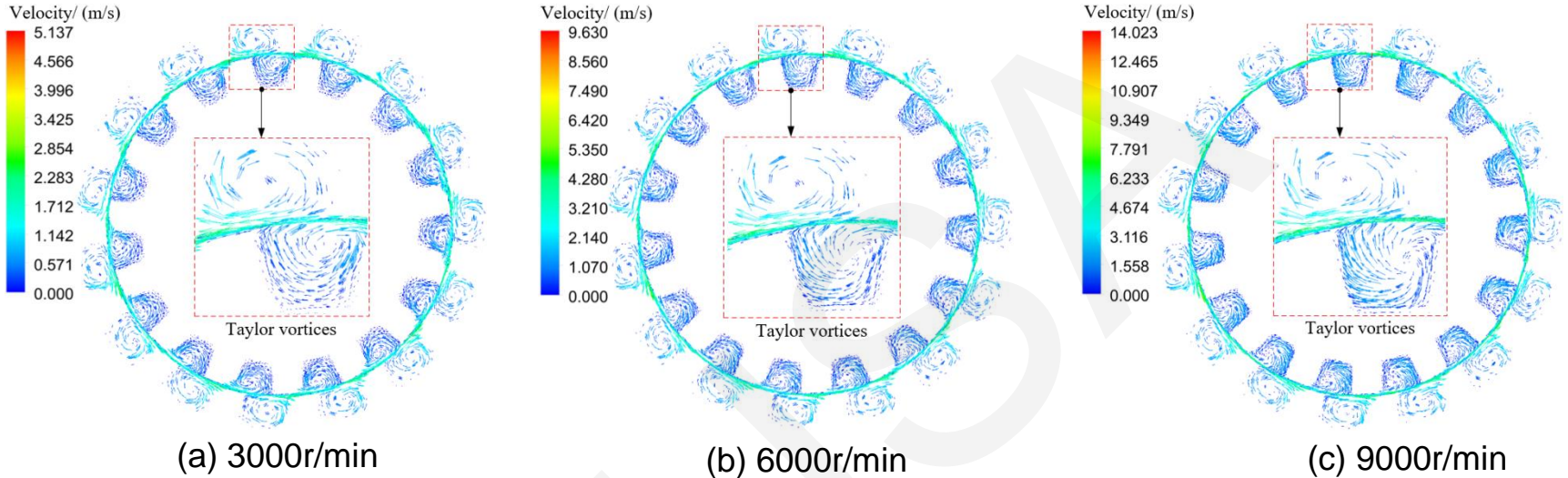


Fig. 4 Schematic diagram of the rotor end face

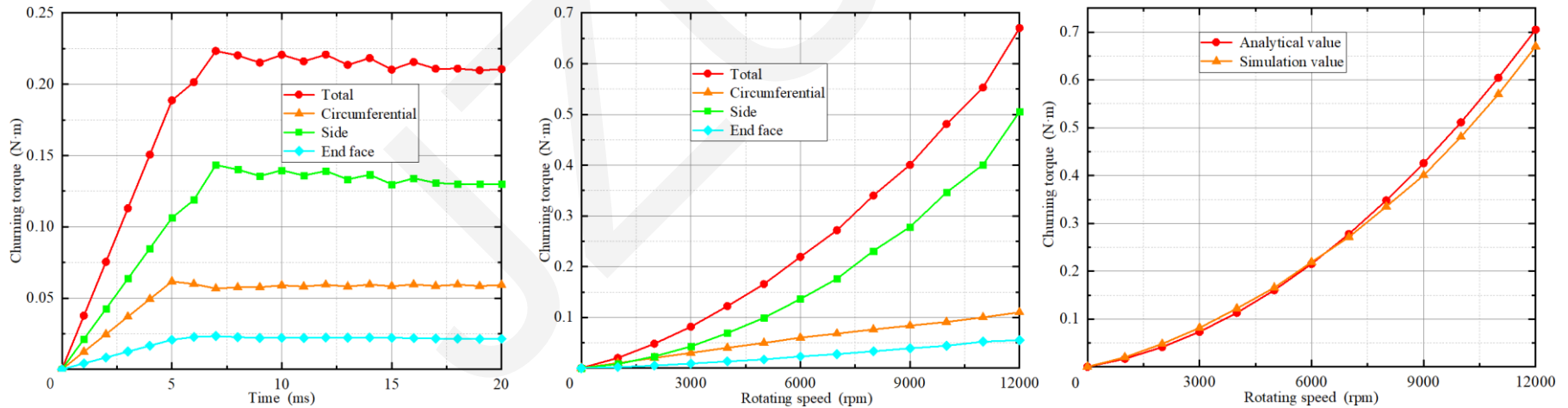
Churning torque of the rotor end face :

$$T_E = 6C_E \left[ \pi \mu \frac{\omega_1}{2\delta} (r_1^4 - r_0^4) + 5\mu \frac{\omega_1}{\delta} b (r_2^3 - r_1^3) \right]$$

# Simulation results



**Fig. 5. Velocity vector distribution of the flow field section**



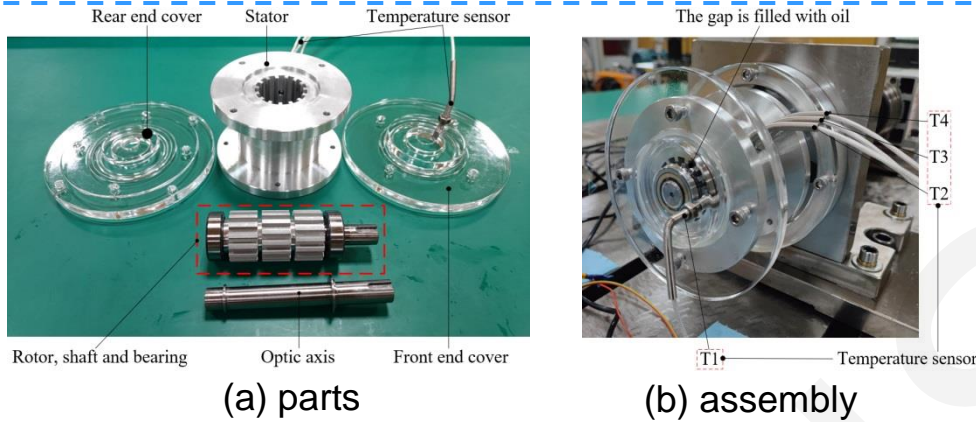
(a) Curve of churning torque of each part

(b) Churning torque of each part at different rotation speeds

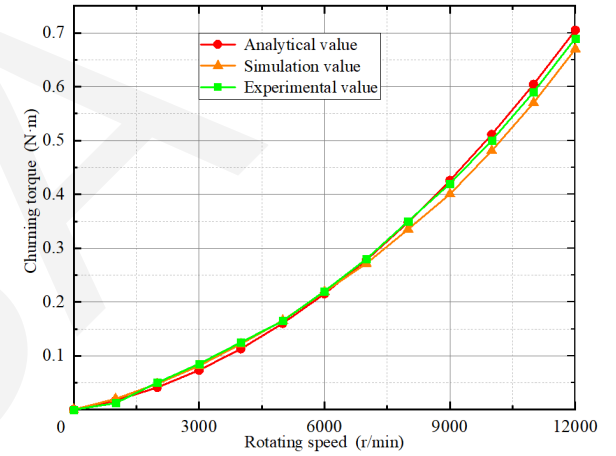
(c) Total churning torque at different rotation speeds

**Fig. 6. Analysis of Churning torque**

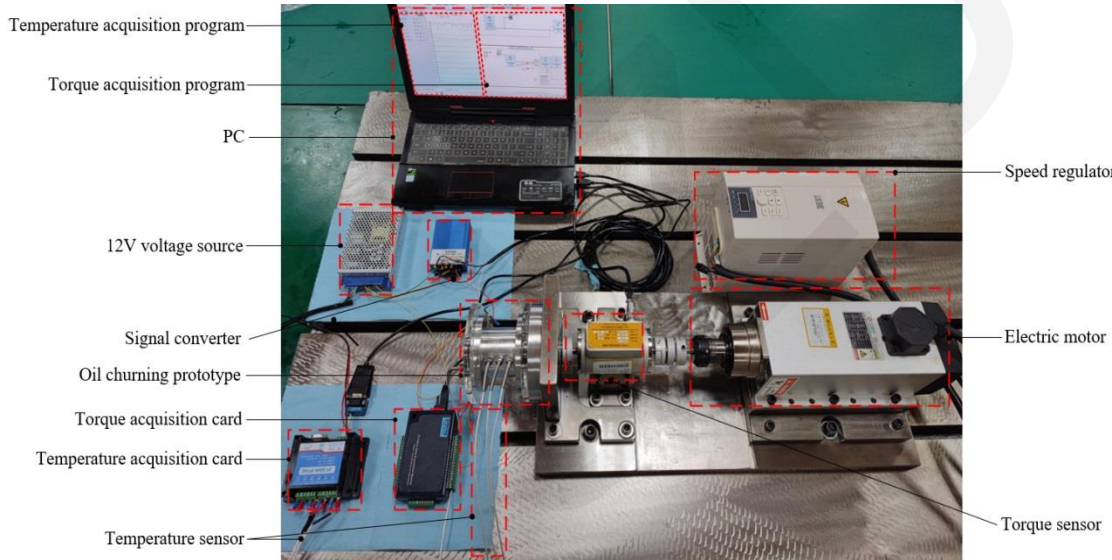
# Experimental study



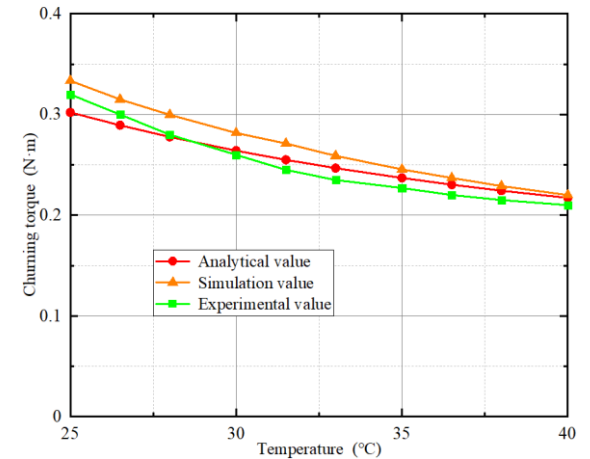
**Fig. 7. Churning prototype**



**Fig. 9. Comparison of churning torque at different rotation speeds**



**Fig. 8. Oil churning test bench of the prototype**



**Fig. 10. Comparison of churning torque at different temperatures**

# Conclusions

- A novel structure of a wet three-phase high-speed reluctance motor pump is proposed, which eliminates the need of a dry motor structure for a dynamic seal at the pump shaft by using a so-called “wet motor”. This also simplifies the structure and improves the motor integration level and heat dissipation by the circulating flow of oil.
- Based on the theory of fluid mechanics, an analytical model of churning torque was deduced, and a fluid domain simulation model of oil churning based on CFD was established.
- An experimental bench was built to study the oil churning of the wet motor. The accuracy of the analytical and simulation results was verified by measuring the churning torque at different temperatures and speeds. The trends of the three curves were basically the same, indicating that the method can provide a reference for further study of structure design and churning loss reduction optimization of wet motors.