Sensorless Control of Bearingless Permanent Magnet Synchronous Motor Based on MRAS
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Background
In the past two decades, bearingless permanent magnet synchronous motors (BPMSMs) have been developed and researched widely. Because of the advantages of high efficiency, long operation life, no friction, and so on, the BPMSMs have the prospects to be widely applied in high-speed and high-precision mechanical processing and many other industrial fields. In the control system of the BPMSM, in order to obtain a good suspension performance, the accurate rotor radial displacement detection is necessary. However, displacement sensors used in the BPMSM have some problems, such as increasing the size, cost, complexity of the motor, and measurement error that can be affected by the temperature and electromagnetic noise. Therefore, the research on rotor radial displacement sensorless control technology of the BPMSM is of great significance.

Mathematical model of the BPMSM
Radial suspension forces
\[ F_i = (\lambda_s - k_i)(i_B i_M + i_L w_M) + k_i \]
\[ F_y = (\lambda_s + k_i)(i_B i_M - i_L w_M) + k_y \]

Torque
\[ T = \frac{-w_B}{2} = P_R i_L (i_B + i_M) + \frac{P_R}{2} (i_M + i_B) + \frac{P_R}{2} i_B i_M \]

Voltage
\[ u_{ai} = R_a i_a + \frac{d e_1}{dt} + L_a i_a \]
\[ u_{Bd} = R_d i_d + \frac{d e_2}{dt} + L_d i_d \]

Simulation Results
Comparison of estimated and actual displacement in y-direction with a sudden suspension force load change.

In order to verify that the displacement fluctuation of the rotor has no effect on the accuracy of the rotor radial displacement self-sensing result, the simulation of the suspension force disturbance is carried out. The comparison waveforms of the estimated rotor radial displacements and the real rotor radial displacements with a suspension force disturbance of 5 N in the negative y-direction is shown in the figure above. The displacement in the y direction is suddenly changed from the balanced position to -1.5 mm, and then the rotor returns to the balanced position after 40 ms. The radial displacement estimation result can track the change of the actual rotor radial displacement well, and the estimation error remains at 0.0005 mm. Therefore, the rotor radial displacement fluctuation has little influence on the estimation result of the proposed self-sensing method, and this method has a good dynamic performance.

Conclusion
The proposed rotor radial displacement self-sensing method of the BPMSM based on the MRAS has good robustness and high accuracy. The rotor radial displacement sensorless operation of the BPMSM can be achieved with this method.