

Motor Bearing Rattle in Electric Powertrains

- (First Report) Mechanism Investigation by Dynamic Analysis of the Motor and Reduction Gear Shafts -

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As electric vehicle quietness continues to improve, abnormal powertrain noise has become increasingly noticeable to customers. Predictive design methodologies for such noise phenomena are therefore becoming increasingly important. Motor bearing rattle is one of the abnormal noise phenomena observed in electric powertrains; however, its generation mechanism has not been sufficiently understood, making prediction during the design phase difficult.

This study investigated the mechanism of motor bearing rattle occurring near the motor shaft rear bearing in an electric powertrain consisting of a motor and a parallel-shaft reduction gear. A hypothesis was proposed in which motor torque induces thrust displacement of the motor shaft, opening the bearing radial clearance. Simultaneously, shaft inclination caused by gear reaction force, together with motor shaft runout, generates radial shaft whirling. As illustrated in Fig. 1, Pattern A represents a whirling trajectory that passes through the radial clearance region and subsequently re-contacts the bearing, thereby generating rattle. In contrast, Patterns B and C represent trajectories that remain outside the clearance region, resulting in continuous bearing contact and no rattle generation.

To verify the proposed hypothesis, dynamic simulations were performed using a shaft system model that considers bearing clearances, shaft alignment, bearing stiffness, preload spring force, spline friction, and shaft runout. The simulation results reproduced the proposed mechanism. As shown in Fig. 2, the shaft trajectory of Spec. A passes through the radial clearance region, corresponding to Pattern A in Fig. 1, whereas the trajectory of Spec. B remains outside the clearance region, corresponding to Pattern B in Fig. 1. These results indicate that motor bearing rattle occurs when the shaft trajectory enters the radial clearance region during whirling motion.

Experimental measurements were conducted using gap sensors installed on both the motor shaft and gear shaft. Measured thrust displacement and radial shaft behavior showed good agreement with the simulation results, supporting the validity of the proposed mechanism.

Further investigation revealed that rotor mass and gear shaft rear bearing radial clearance significantly affect the motor shaft whirling trajectory. Motor bearing rattle is governed by the interaction of multiple design factors associated with both the motor and reduction gear system. Furthermore, the occurrence region does not exist at the boundary of the design parameter range but within a limited intermediate combination of specifications, where the shaft trajectory passes through the bearing radial clearance region. As a result, even small changes in design specifications or operating conditions can alter whether the noise occurs, making prediction based solely on conventional experience-based design approaches difficult.

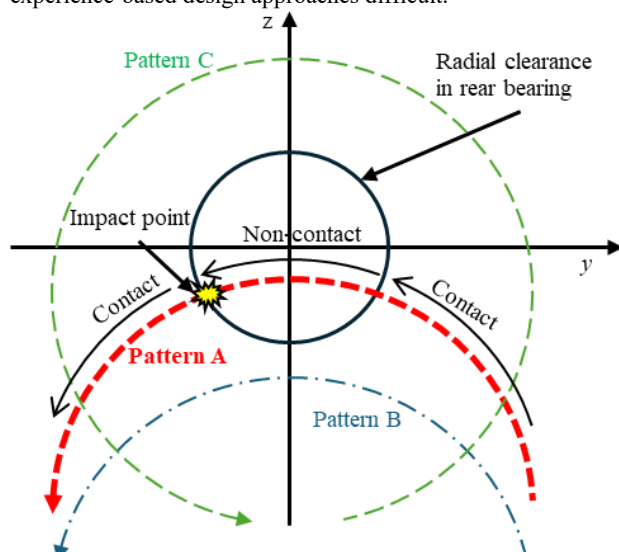


Fig.1 Hypothesized Mechanism of Motor Bearing Rattle

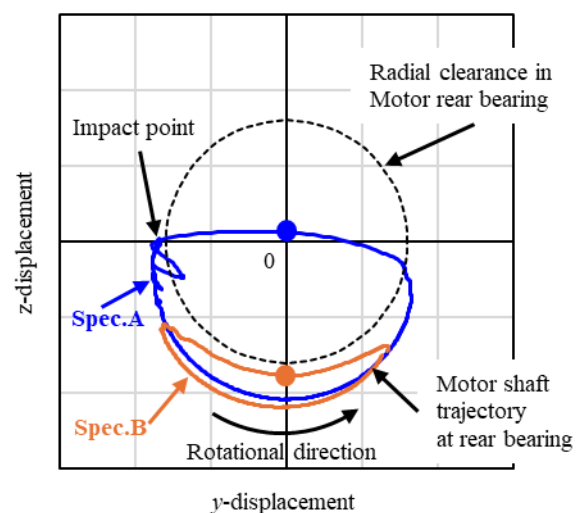


Fig.2 Comparison of Motor Shaft Rear Side Trajectories in Dynamic Simulation