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Reducing Life Cycle CO_2 Emissions and Battery Cost in BEVs through Bearing Friction Loss Minimization

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1. Background and Objective

In battery electric vehicles (BEVs), rolling-bearing friction affects not only vehicle energy consumption (downstream CO_2) but can also drive battery sizing and thus upstream CO_2 and cost (Fig. 1). This paper links bearing power losses at representative WLTC operating points to lifetime energy demand and CO_2 equivalents using an assumed grid mix and charging efficiency, and demonstrates how systematic friction reduction can create measurable CO_2-equivalent emissions and battery-cost benefits at vehicle-level.

2. Method: Simulation-Based, Constraint-Driven Friction Optimization

Bearing losses are modeled as the sum of contact friction, churning losses, and seal friction, where contact friction is calculated using a physics-based approach suited for low-load WLTC-relevant conditions. A coupled workflow combines bearing/system simulation with automated optimization to handle a combinatorial design space while respecting boundary conditions such as design space, rating life, permissible contact pressure, and manufacturing feasibility. The optimization varies design variables (e.g., internal geometry, preload, arrangement) while satisfying non-negotiable constraints (interfaces, durability, manufacturability).

3. Application Examples (Summary of Results)

Three drivetrain bearing use cases demonstrate the achievable friction-reduction potential under WLTC-like evaluation while maintaining rating-life targets:

Case 1 (single high-speed deep-groove ball bearing, e-axle input shaft): friction reduction up to 9.2 W (−39%) with mass reduction and maintained life level; monetized as approx. ¥1,750 system-level benefit (battery-cost equivalent).

Case 2 (intermediate-shaft tapered roller bearing arrangement, light commercial e-axle reducer): coupled optimization of the bearing arrangement yields up to −48% WLTC friction, corresponding to a 45 W reduction and an estimated benefit of approx. ¥8,550 while fulfilling life requirements.

Case 3 (system study of motor/primary-shaft support, mid-class EV, Fig. 2): varying bearing arrangement, bearing types, and number of bearings shows that system-level configuration changes can yield up to −44% WLTC friction compared to a baseline arrangement under identical rating-life requirements, corresponding to an estimated benefit of approx. ¥4,400 (Fig. 3).

4. Conclusion

Rolling-bearing friction is a relevant lever to reduce BEV lifetime energy demand and thereby downstream CO_2 emissions as well as upstream CO_2 and battery cost via potential battery downsizing. A coupled simulation-and-optimization workflow enables robust low-friction bearing designs and arrangements under durability, packaging, preload, and manufacturability constraints, supporting system-level trade-offs.

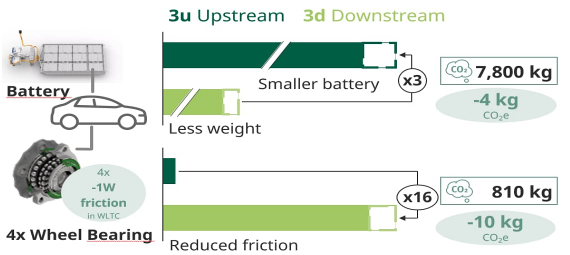

Fig. 1: CO_2e contributions associated with an 80 kWh battery and four-wheel bearings in an electric vehicle

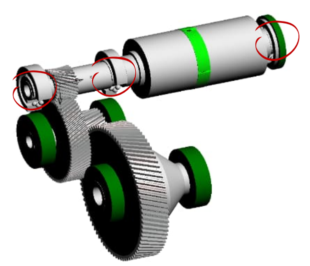

Fig. 2: Case3 primary-shaft bearing of e-reducer transmission

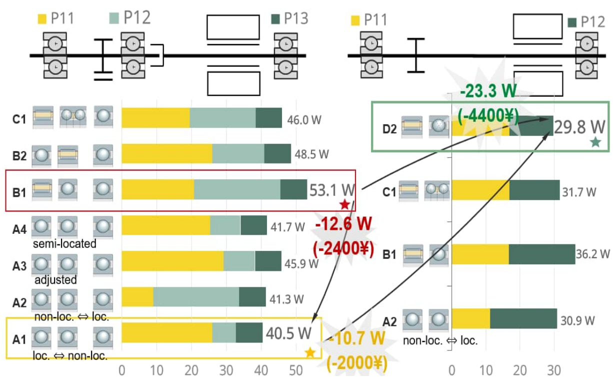

Fig.3: Influence of the bearing arrangement on WLTC friction optimization potential under identical rating life requirements (Lmr).