Investigation on Vibro-impacts of Electric Powertrain in Regenerative Braking Process

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Abstract. Due to gear backlashes of electric powertrain drivelines, vibro-impacts between gear teeth easily cause serious noise and vibration problems. To analyze the vibro-impacts of powertrain excited by regenerative braking, a dynamic model of an electric drive multistage gear system is established. In this model, the electromagnetic characteristics of the permanent magnet motor and the translational-rotational vibration of the gearbox are considered. The results show the relationship between the relative deformation of the gear teeth and the relative velocity. The phenomenon of multiple impacts and rebounds of the gear teeth in each impact is revealed. The transient impact force of bearing and multistage gear during impact are compared and analyzed. The research provides theoretical support for dynamic load study of the electric powertrain.

Introduction

Numerous studies on the vibro-impacts of automobile transmission have been performed. There is little research on the vibration phenomenon of electric powertrain in electric vehicles. The electric powertrain is an underdamped system because it omits the damping components. Therefore, the reversal of electromagnetic torque may lead to the gear vibro-impacts in the regenerative braking process. Study on the mechanism of vibro-impacts is essential to improve the drivability of the electric vehicle.

Baumann et al.[1] investigated the influence of several parameters on rattle noise level, e.g. backlash and helix angle. Brancati et al. [2] proposed a flywheel equipped with a torsional vibration damper. The device shows to be effective in mitigating the rattle phenomenon. Shi et al. [3] studied the effects of load, backlash and transmission error on vibro-impact properties. Xiang et al. [4] investigated the influence of supporting forces on vibro-impact. Dion et al. [5] developed a study of phenomena involving gear impacts with one loose gear inside an automotive gearbox.

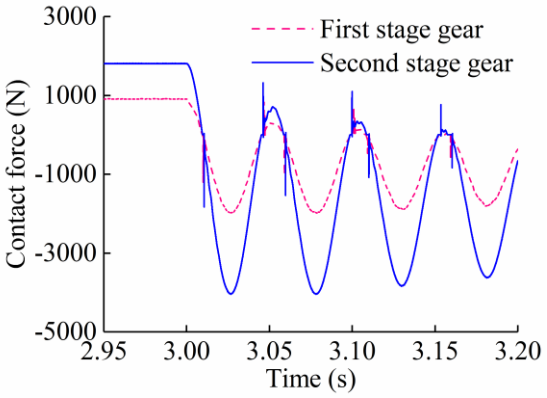

Fig. 1. Dynamic contact force of gear pair

Results and discussion

After the regenerative braking torque is applied, the low-order modal resonance is excited. Under the action of system damping, the vibration amplitude is gradually attenuated. When the teeth across the backlash, transient impact forces are generated. In the mesh state, a fluctuating mesh force is generated. The impact force of the second-stage gear pair is greater than that of the first-stage gear pair. It may be because the second-stage gear pair transmits a higher load. Both the impact force and the mesh force decrease gradually with time.

There is no transient impact force in the bearing. But after the regenerative braking torque is applied, the bearing force oscillates in a large range. The dynamic change of support force may affect the accurate calculation of the bearing remaining life.

References

[1] Baumann, A., Bertsche, B. (2015) Experimental study on transmission rattle noise behavior with particular regard to lubricating oil. *J. Sound Vib* 341: 195-205.

[2] Brancati, R., Rocca, E., Russo, R. (2019) Gear rattle reduction in an automotive driveline by the adoption of a flywheel with an innovative torsional vibration damper. *Proc. Inst. Mech Eng Pt K-J Multi-Body Dyn* 233(4): 777-791.

[3] Shi, J.F., Gou, X.F., Zhu, L.Y. (2019) Modeling and analysis of a spur gear pair considering multi-state mesh with time-varying parameters and backlash. *Mech. Mach. Theory* 134: 582-603.

[4] Shen, Y.H., Xiang, D., Wang, X., et al. (2018) A contact force model considering constant external forces for impact analysis in multibody dynamics. *Multibody Syst. Dyn* 44(4): 397-419.

[5] Dion, J.L., Moyne, S.L., Chevallier, G., et al. (2009) Gear impacts and idle gear noise: experimental study and non-linear dynamic model. *Mech. Syst. Signal Pr* 23(8): 2608-2628.