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Topology Optimum Design of a Commercial Vehicle Coupling Structure Considering Sliding Frictional and Driving Loads

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Abstract

The fifth wheel coupler is a heavy automotive coupling structure which connects a tractor and a trailer used for heavy-duty trucks widely. It is subjected to various loads simultaneously such as rolling, pitching and yawing impacting loads as well as coupling frictional loading. Most of the currently used couplers have been overdesigned and, therefore, it is necessary to reduce the dead weight to increase the fuel efficiency. The seven conditions of loadings were considered to perform the topology optimization of the coupling structure: (1) a gravitational force when a trailer is connected; (2) an inertia force when a truck starts; (3) an inertia force when a truck stops; (4) a centrifugal force when a truck rotates to the left or the right; (5) a frictional force when a king-pin contacts with the coupler; (6) a frictional force when a truck connects with the trailer; (7) an inertia force when a truck rotates to the left or the right. The dynamic frictional loading along the coupler guide surface was calculated using acceleration and a friction coefficient of 0.78.

The topology optimization was applied in order to find conceptual layout designs [1-3] which could show major load paths and ribs (or stiffeners) locations, and then the size structural optimization was performed in order to determine the heights and thicknesses of coupler ribs with the predetermined various loading conditions for the development of a new slim coupler with a minimum weight and high enough strength and stiffness on the basis of finite element analyses. The new coupler design was finalized by the shape optimization on the topology result. The strengths under each loading were calculated by FEM stress analyses.

As the results of the topology optimum design, an efficient new coupling structure for truck trailers was designed. The weight of the new fifth wheel coupler was reduced by 10.0% (from 170 to 153 kg), compared with the existing one, even though all strength requirements were satisfied. The fatigue test of the new coupler was performed with cyclic vertical loads (+78.4 to +235.2 kN) and horizontal loads (-91.2 to +91.2 kN) simultaneously at 1 Hz and the life of 2,000,000 cycles were achieved without failure.

References

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