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Shape optimization for brake squeal

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Abstract

Brake squeal, which usually causes in the frequency range between 1 and 15 kHz, is a phenomenon which has been one of the most difficult concerns in design of brake systems. It causes customer dissatisfaction and increases warranty costs.

The present paper proposes a cost function which is expected to be effective to prevent the brake squeal. The cost function is defined with the real part of a complex eigen frequency for a target natural vibration which causes the brake squeal.

In the present paper, we assume that a brake system consists of a rotor and a pad between which the Coulomb friction occurs. The Coulomb friction makes an equation of motion asymmetric with respect to displacement and adjoint displacement in the weak form. Then, eigen values for natural vibrations become complex values. On the other hand, it has been known that brake squeal is an unstable vibration induced by friction. From this observation, we considered the real part of a complex eigen frequency for a natural vibration which causes the brake squeal becomes a candidate of a cost function to prevent the brake squeal.

A shape optimization problem is formulated using the objective cost function of the real part of a complex eigen frequency and a constraint function of volume for the pad. The main problem consists of a weak form combining the weak forms of the liner elastic continua for the rotor and the pad including the terms of the Coulomb friction and the stiffness in normal direction on the sliding boundary. The shape derivative, which is defined as the Fréchet derivative with respect to domain variation, of the real part of a complex eigen frequency is evaluated with the solutions of the main problem and a adjoint problem which is derived theoretically by the adjoint variable method.

To solve the shape optimization problem to minimize the real part of the complex eigen frequency with the volume constraint of the pad, we use an iterative algorithm based on the H1 gradient method. The H1 gradient method is used to keep the smoothness of the boundary. The volume constraint is satisfied using the KKT conditions in the shape optimization problem.

We developed a computer program to solve the shape optimization problem based on the iterative algorithm. The boundary value problems are solved by the finite element method using an original code. Numerical example using a simple model is going to be shown in the paper.