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SHAPE OPTIMIZATION OF RUBBER BUSHING

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The rubber bushings are used as vibration isolators in vehicle suspension systems in order to prevent the vibration of an engine and tires from transferring into the vehicle interior. A mathematical model of the rubber bushings is to model it as a hyper-elastic body with large deformation. In the design process of the rubber bushing, static load-displacement curve is considered as an important factor to control the riding quality. However, it is not easy to design the shape of the rubber bushing which has the desired static load-displacement curve because of its geometrical and material nonlinearities.

In order to determine the optimum shape of the robber bushing, many studies have been conducted using parametric shape optimization methods[1, 2]. In these studies, only the initial stiffness of the rubber bushing is referred, i.e. the large deformation is not considered. Moreover, only the parametric shape optimization problems have been examined.

The present paper presents a formulation of the non-parametric shape optimization problem of the rubber bushing in order to fit the static load-displacement curve with the desired one, and shows the numerical solution to the problem. The domain variation defining the rubber bushing is chosen as a non-parametric design variable. The main problem to evaluate the performance of the rubber bushing is defined as a large deformation problem of hyper-elastic continuum. A squared error norm of the static load-displacement curve from the desired one is used as an objective function. A function of volume of the rubber bushing is chosen as a constraint function. The shape derivative, which is defined as the Fréchet derivative with respect to domain variation, of the objective function is evaluated with the solutions of the main problem and an adjoint problem which is derived theoretically by the adjoint variable method. To solve the shape optimization problem of minimizing the objective function with the volume constraint, we use an iterative algorithm based on the H^1 gradient method [3]. The H^1 gradient method is used to keep the

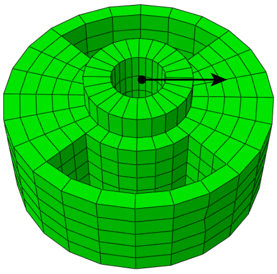

Figure 1: Initial shape

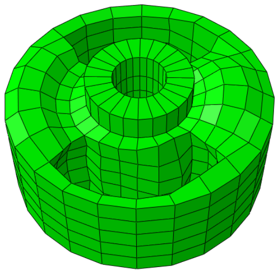

Figure 2: Optimum shape

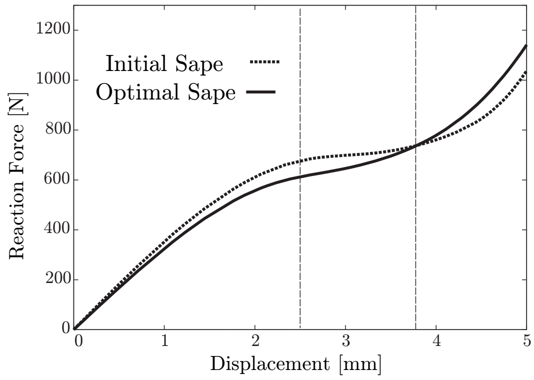

Figure 3: Static load-displacement curves

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 using commercial programs to solve the main and the adjoint problems by the finite element method and to solve the boundary value problem of the H^1 gradient method by the finite element method.

In order to demonstrate the effectiveness of the developed program, we solved a shape optimization problem of a simple model of the rubber bushing. Figure 1 shows the finite-element model of the rubber bushing. In this figure, the arrow shows a compulsory displacement 5 [mm] at center of inner cylinder. The desired curve of the static load-displacement curve is assumed such that the reaction force rises 10% at displacement of 3.75[mm], keeps the same level at displacement of 2.5[mm], and decreases 10% at displacement of 5.0[mm]. The optimized shape is shown in Figure 2. The static load-displacement curves of initial and optimized shapes are shown in Figure 3. From the result, it is observed that the static load-displacement curve agrees with the desired curve.

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