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A NEW STRUCTURAL OPTIMIZATION METHOD BASED ON THE LEVEL SET METHOD AND ITS APPLICATIONS

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ABSTRACT

Many structural optimization methods have been proposed in order to obtain superior structures in many design problems. Structural optimization methods recently well studied are generally classified by shape optimization methods[1][2] and topology optimization methods[3][4].

In shape optimization methods, the shape boundaries of the target structure are explicitly represented using certain design variable function, and it is updated based on the shape sensitivity. One can obtain clear optimal configuration using shape optimization method, however, changing the topology of the target structure is not considered in the shape optimization framework. Therefore, the topology of the target structure is not basically changed during the optimization procedure, and, the topology of the obtained optimal configuration strongly depends on the topology of the initial configuration.

On the other hand, in topology optimization methods, the optimization problems are replaced by the distribution problems of the micro-structures. Topology optimization methods have been extensively applied in many design problems, since the optimal solutions whose shape and topology are considered, can be obtained using topology optimization methods. However, numerical problems such as checker-board patterns and grayscales often spoil the obtained optimal configurations.

Nowadays, structural optimization methods based on the level set method[5][6][7] have been attracted. The level set method was originally proposed as a method tracking fronts and free boundaries by Osher and Sethian[8]. Structural optimization methods based on the level set method are the moving boundary type optimization methods, and the topology of the target structure can be easily changed in the level set framework. Therefore, structural optimization methods based on the level set method can be powerful methods.

Allaire et al.[6] and Wang et al.[7] were proposed the optimization methods where the target structure is represented using the level set function, and the level set function is updated based on the shape sensitivity. After their research, several optimization methods based on the level set method have been proposed. However, to update the level set function, certain Hamilton-Jacobi partial differential equation, so-called "the level set equation" must be solved. Solving this equation is problematic, therefore, sophisticated but cumbersome methods such as the up-wind scheme, the Petrov-Galerkin method and the least-squares finite element method, are required.

In contrast, we propose a new structural optimization method where the level set function is always re-initialized when the level set function is updated based on the level set equation. In this manner, we can perfectly guarantee the signed distance nature of $|\nabla\phi| = 1$, and can simplify the level set equation. We need no sophisticated methods to update the level set function based on the simplified level set equation. We adopt the explicit method for the time discretization and the normal FEM for the spatial discretization. In our proposed method, the level set function is re-initialized at every iteration, therefore, the re-initialization scheme is very important for computational accuracy and computing costs. Unfortunately, through our numerical experiments, we confirm that the previously proposed re-initialization schemes are not sufficiently for our purpose. Therefore, we newly developed a re-initialization scheme where the level set function is re-initialized based on the original definition of a signed distance function.

In this presentation, first, we briefly explain our newly developed structural optimization method and newly developed re-initialization scheme. Next, in order to confirm the usefulness of the newly developed method, this optimization method is applied to various optimization problems, such as the minimum compliance problem, the lowest eigen-frequency maximization problem and the eigen-frequency matching problem. These optimization problems are formulated based on the newly developed method, and several numerical examples are provided to demonstrate that we can successfully obtain the optimal configurations using the newly developed method for various optimization problems.

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