Development of an Efficient Vehicle Structure through Optimization Methodology

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1. Introduction

In response to the recent demands for improved safety and comfort of railway vehicle structures, collision safety designs have been introduced. These have caused the weight of these structures to increase and the additional installation of peripheral units is giving rise to further weight increases. Since conflicting requirements such as increased vehicle speed and energy-saving are emerging, the design of vehicle structures that are well balanced between strength improvement and weight saving is increasingly demanded. To meet these challenges, we have developed a methodology that efficiently facilitates the optimization of strength improvement and weight saving in the design of railway vehicles by using a single vehicle model.

2. Formulating a Structure Optimization Methodology

The present optimization methodology performs the stress analysis of a structure by means of finite-element analysis with a single vehicle model (Fig.1) to determine high stress regions. For such a highly stressed region as a spot-welded area, a further high-precision finite element analysis model is created. The shape of this model is optimized to define the structural configuration that will result in the reduction of stress and weight. Thus the defined structure is re-formulated as a single vehicle model to reevaluate the stress distribution in the entire model of the improved structure. Since there are trade-offs between strength improvement and weight saving, repeating the calculation until these conditions satisfy the requirements will give an optimum solution.

As an example, an optimization trial was conducted on the skeleton structure of an existing electric train on a conventional line, It was found that, if a constant mass condition is desired, a reduction in stress of 40% (Fig.2) in the stress-concentrated region is achievable. Alternatively, to maintain a constant stress condition, a reduction in weight for one vehicle coach of 7% (Fig.3) is possible.

3. Application to Vehicle Structure Design

Since thus formulated structure optimization methodology employs the finite element analysis, it facilitates not only evaluations of vehicle structures with the objectives of strength improvement and weight saving, but also it assists the study of high-rigidity and light-weight vehicle coach structures with improved riding comfort through suppression of high-frequency vibration. Further, the methodology can be used with such structural materials as stainless steel and aluminum. Above all, this methodology can be applied to a wide variety of tasks including improvement of existing structural configurations and design of novel structural configurations.

Fig.1 Stress analysis on a single vehicle model

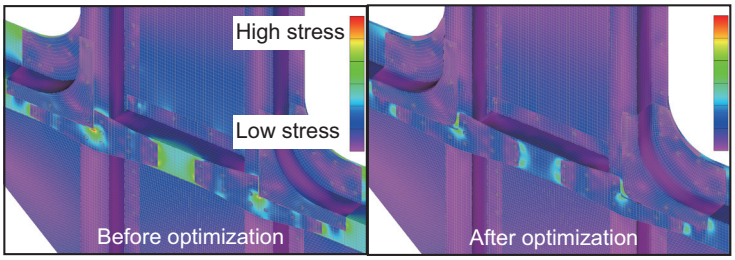

Fig.2 Optimization of shape in a highly stressed region

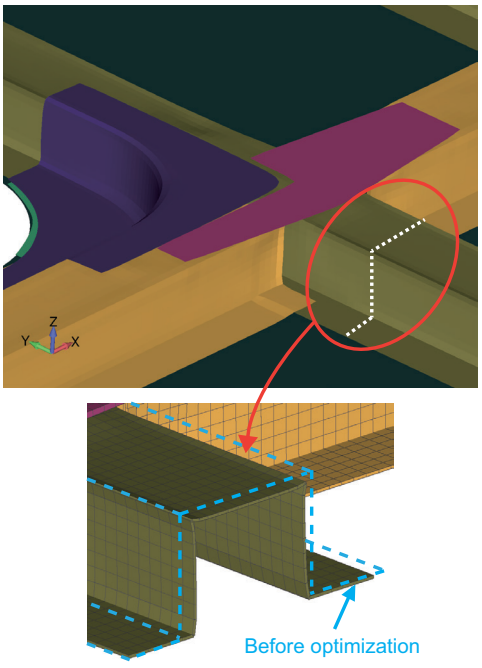

Fig.3 Cross-section of the skeleton structure after optimization
(Skeleton structure of a window corner)