Topology Optimization Used to Make Lighter Plastic Parts

In an effort to prevent global warming, countries around the world have set targets to reduce carbon dioxide emissions. The automobile industry is contributing to this effort, working to improve vehicle body structures and engine efficiency to reduce emissions. A key method to achieve these goals is to improve fuel efficiency during driving, and a highly effective way to do so is to make the vehicle body lighter. While metals such as steel and aluminum account for most of a car's weight, in recent years, plastic materials have been increasingly adopted in place of some of these materials to make automobile bodies lighter. Plastic is now said to account for around 9 percent of a car's weight.

Kanto Auto Works, Ltd. (which will become Toyota Motor East Japan, Inc. in July, 2012, because of a merger with Central Motor Co., Ltd. and Toyota Motor Tohoku Corporation) is a core member of the Toyota Group, developing and producing Toyota vehicle bodies. The company's organic-material engineering department evaluates and develops plastic parts to be used in vehicle bodies. In the initial stage of development for large plastic parts, such as instrument panels, rigidity and heat resistance are verified using computer aided engineering (CAE). While plastic is significantly lighter than metal and can be molded into complex shapes, deformation, such as warping from external force or thermal expansion in high temperatures, also occurs easily. In order to make parts lighter while still ensuring sufficient rigidity and heat resistance, there is a need to identify which areas require reinforcement.

To improve the rigidity and heat resistance of plastic parts, Kanto Auto Works combined CAE analysis with actual experiments, such as applying weight to plastic test plates or observing thermal expansion under high temperatures. However, these experimental results were insufficient for consistent diagnoses because judgment was reliant on employee experience and the actual experiment performed. "When reviewing results of experiments for the degree of deformation and stress in plastic parts, the ability of an employee to judge whether or not a part needed reinforcement was heavily reliant on his or her experience," said Ayumi Sugiyama. "This, of course, led to significant variance in diagnoses, depending on the employee, making it difficult to establish effective countermeasures."

Kanto Auto Works therefore began using OptiStruct, a structural optimization tool from Altair, to visualize areas requiring reinforcement. OptiStruct allows the user to combine a choice of optimization functions to create innovative new shapes at any stage of the design process using information that cannot be obtained through experience alone. It makes it possible to create lighter parts and reduce steps in the production process by determining optimal materials, identifying where reinforcement is and is not necessary, automatically beading or embossing, optimizing finite element modeling and determining the optimal sheet thickness and cross-sectional shape of joist structures.

Kanto Auto Works, LTD.

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Topology optimization calculations were carried out using OptiStruct to visualize areas requiring reinforcement to prevent deformation caused by external force. For heat resistance, first calculations were carried out based on the test results for the plastic test plates to determine the load required to cause deformation in the plates. Topology optimization then was carried out using OptiStruct to visualize areas requiring reinforcement for greater heat resistance.

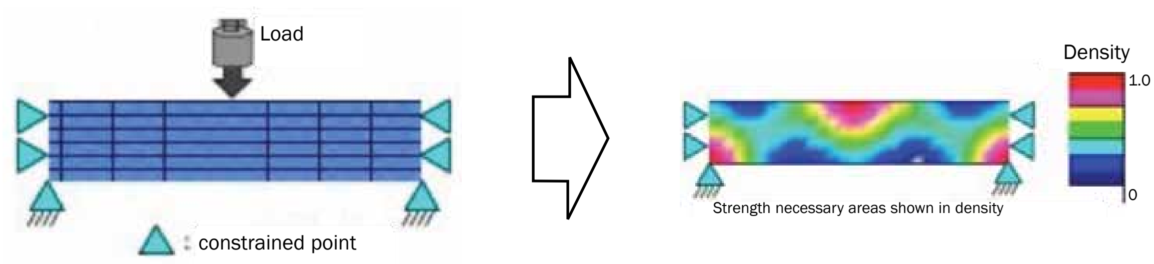

Figure 1. *Topology optimization*

“It was possible to predict with reasonable accuracy that the areas requiring increased rigidity were load-bearing sections and the areas surrounding the load-bearing sections,” said Ms. Sugiyama. “However, the areas prone to heat deformation shown by OptiStruct were different from our predictions. The typical approach to heat deformation evaluations is to reinforce the areas where major deformation is seen to occur, but the OptiStruct results differed from our experience-based predictions.”

A new plastic test plate was made based on the results, with areas requiring reinforcement made thicker and areas not requiring it made thinner. Heat resistance testing on this plate showed that thermal expansion had been prevented. Kanto Auto Works has adopted this reinforcement method for instrument panels. Based on the results obtained from topology optimization using OptiStruct, this reinforcement technique was used and evaluations repeated until target values were met.

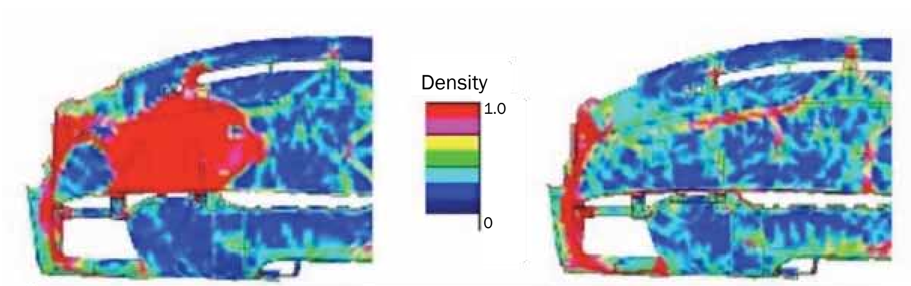

Figure 8. *Rigidity/ Thermal Resistance Topology Optimization Results*

As a result of this evaluation, Kanto Auto Works has succeeded in improving rigidity and heat resistance through reinforcement of the smallest possible areas. Additionally, Kanto Auto Works has achieved these improvements while realizing a 20 percent weight reduction.

“OptiStruct calculation results pinpoint exactly which areas require reinforcement, allowing for lighter and thinner parts to be manufactured within permissible molding conditions,” said Ms. Sugiyama. “This means that the parts as a whole can now be made lighter.”

In addition to instrument panels, Kanto Auto Works plans to expand use of OptiStruct’s topology optimization function to the development of large plastic parts, such as bumpers, to further reduce the weight of such parts.