講演番号	145

文献番号	20226145

Increasing Strength of Vehicle Body Frame Components Using Work Hardening of Steel Sheet

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KEY WORDS: **Material, Iron and steel material, Weight reduction,** Work hardening, Body frame (D3)

Automobile companies are under pressure to deal with the shift to EVs as a matter of EU regulation and as a measure against global warming. The move toward widespread adoption of EVs involves an increase in automobile weight because of the on-board batteries. From the perspective of collision safety, the vehicle frame is therefore being required to provide vehicle occupant protection performance as well as battery protection performance. Increasing the strength of steel sheet and increasing sheet thickness tends to cause an increase in both cost and vehicle weight. One method of weight reduction is the use of aluminum alloy, but when the use of existing production equipment is considered, steel sheet tends to be used more often. Also, increasing sheet thickness in the frame is effective as a method of increasing vehicle body strength, but the increase in vehicle body weight is an issue. On the other hand, using a higher material grade of steel sheet can increase the yield strength and thus enhance the strength of the frame. As a result, it becomes possible to reduce the sheet thickness in the frame, which can yield a weight reduction effect. However, the resulting rise in material costs and processing costs is an issue. The next place to focus on is the cross-sectional profile of the frame. The frame strength can be increased by placing weld beads on the upper surface of hat beams, and it is known that making these beads deeper will increase the frame strength. The formability of the material puts a limit on bead depth, and the higher the strength of the material, the less it will allow deeper beads. On the other hand, a method for increasing hat beam strength by adding ridges on the side surfaces has been reported. This technique cannot be used to advantage, however, when there are constraints on layout, such as when the upper surface of the hat beam needs to be wider.

This research has examined a method for increasing the strength of the automobile body frame and proposes it as a technique that avoids increasing sheet thickness or raising the material grade and also gives consideration to avoiding cost increases due to higher processing costs. It uses the work hardening characteristics when strain is applied during stamping as a method for increasing the yield strength of steel sheet. The process of the first press forms a corrugated sheet and in the second process it is flattened. In this way it is possible to apply pre-strain to the steel sheet. Figure 1 shows the processes by which corrugated sheet is formed and then flattened in this technique. The contour lines indicate the equivalent plastic strain. This technology is distinctive in that it maintains the initial cross-sectional profile without increasing sheet thickness or upgrading the material, while increasing frame strength. The process enables application only to the part of the frame where buckling is anticipated. In this report, the significance for buckling strength is clarified through comparison of the original sheet and the bending-unbending material in terms of tensile characteristics and sheet bending characteristics. Figure 2 shows an example of comparison of the stress-strain curves of the original sheet and the bending-unbending material. The material is of JSC980YL quality and the tensile direction is parallel to the corrugations. It is apparent that the yield strength of the bending-unbending material has increased by 25% over the original sheet.

Next, analysis was conducted to determine what area of the frame should have pre-strain applied in order to be most effective in increasing its bending strength. The results showed the highest sensitivity in the upper part of the side surface of the frame. Prototypes of hat beams to which this technique was applied on the upper part of the side surface were prepared. The pre-strain material was cut out of the prototype and its characteristics were evaluated. From these results it was possible to confirm that the pre-strain portions had yield strength that had increased relative to the original sheet. Static three-point bending tests and static axial compression tests of hat beams were conducted, and the results from verification of effects with the greatest load confirmed a 6% increase in strength relative to the base. In the concluding discussion, application to the vehicle body frame was envisioned and the portion of weight reduction effect attributable to that application verified by CAE.

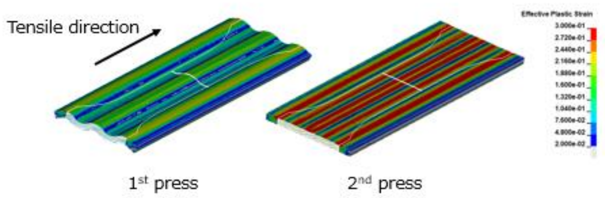

Fig. 1 Processes from corrugated sheet form to flattening and distribution of equivalent plastic strain

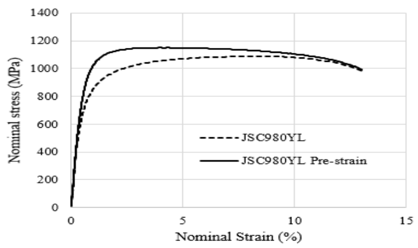

Fig. 2 Comparison of stress-strain curves of raw material and pre-strain material