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THE DEVELOPMENT OF A SIMPLIFIED DESIGN PROGRM FOR SHEET METAL DENTING

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Abstract Achieving significant weight reductions in automotive body panels will normally require reducing the panel thickness or using alternative materials such as aluminum alloy sheet. In this study, the correlation between panel size, curvature, thickness, material properties and dent resistance is investigated. A parametric approach is adopted, utilizing a "design software" tool incorporating empirical equations to predict denting and panel stiffness for simplified panels. This design program can be used to minimize panel thickness or compare different materials, while maintaining adequate panel performance.

Keywords: Denting, Sheet metal, Design

INTRODUCTION

Predictions of stiffness, denting energy and critical buckling loads are integral parts of body panel structural design. Body panel performance is described by several different parameters. Stiffness, denting energy and critical buckling load are design criteria for automotive body panels.

For the study of stiffness denting and oil canning, a parametric array of panels has been analysed using the design analysis method. And the results of design analysis were compared with finite element analysis for validity. The panels are highly simplified relative to real automobile components but allow variations of those parameters that are thought to influence stiffness and denting. Panels of two sizes are considered, all square in plan and with fixed edges, combined with double curvatures ranging from highly curved (R=100 mm) to flat. Three thicknesses of sheet material typical of automotive panels are considered, with the assumption that there has been no thinning during forming. All the panels are assumed to be AA6111 alloy, but with properties ranging from the T4 condition of the as-rolled sheet to the T8X condition with three levels of forming strain and paint-bake aging. The T8XP condition with enhanced paint-bake response but only one level of forming strain is also considered. The analysis of these panels for deflection under static loading (stiffness) and static and dynamic denting was done with the design software and the commercial finite element code.

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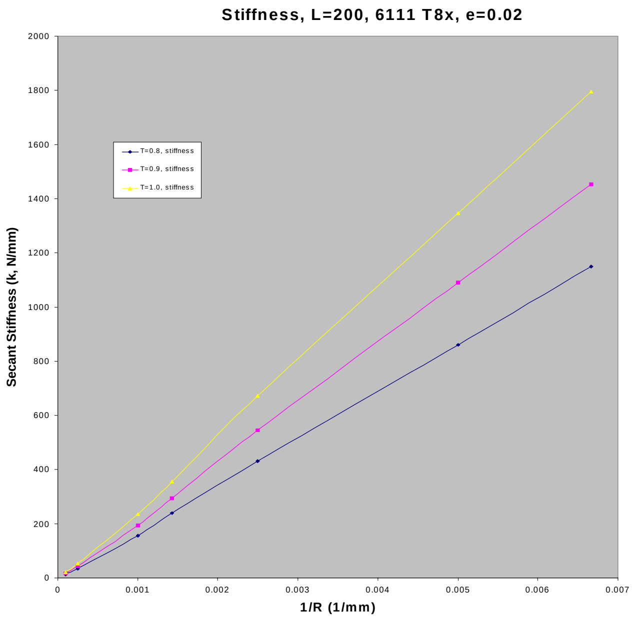
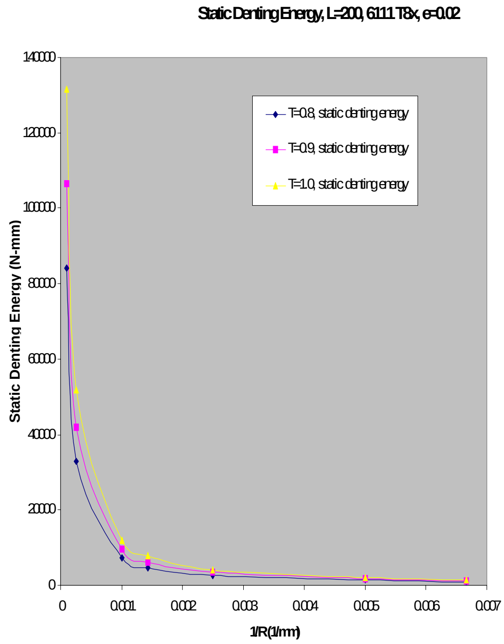
RESULTS

Predicted panel stiffness values from design analysis are plotted in Fig. 1 as the secant stiffness. Panel stiffness values from finite element analysis are also calculated as the applied load divided by displacement for loads of 155 N and 15.5 N. For the curved panels, the initial stiffness is higher than the stiffness at maximum load due to the geometric softening as the curvature is reduced by the applied load. The flat plates demonstrate a stiffening response due to a transition from bending to membrane tension. But the design analysis could not predict this initial stiffening phenomenon in Fig. 1. Comparison reveals that the secant stiffnesses calculated by design analysis are more large value than the secant stiffnesses calculated by Finite Element analysis. But whole trends are consistent well.

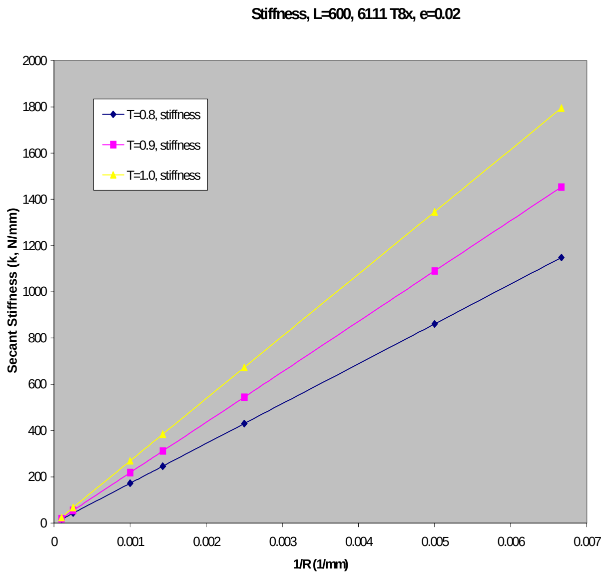
Fig. 2 plots predicted the denting energy as a function of curvature by design analysis. We can assume that the denting energy stands for the ability of the panel to absorb impact energy. So the more high denting energy panels are able to elastically absorb more of the impact energy, leaving less energy for the plastic deformation of denting. The energy absorption ability of a panel subject to a given load will correspond to the area under its load-deflection curve. The static load-deflection curves indicate that the more sharply curved panels exhibit a stiffer response and absorb less energy for a given load. Consequently, to absorb a given level of impactor kinetic energy, higher contact forces will occur for stiffer panels. When panels have larger radius of curvature, higher denting energy is predicted. In the area of large radius of curvature as shown in Fig.2, the decreasing rate of denting energy is very quick. So, we



(a) L=200 mm

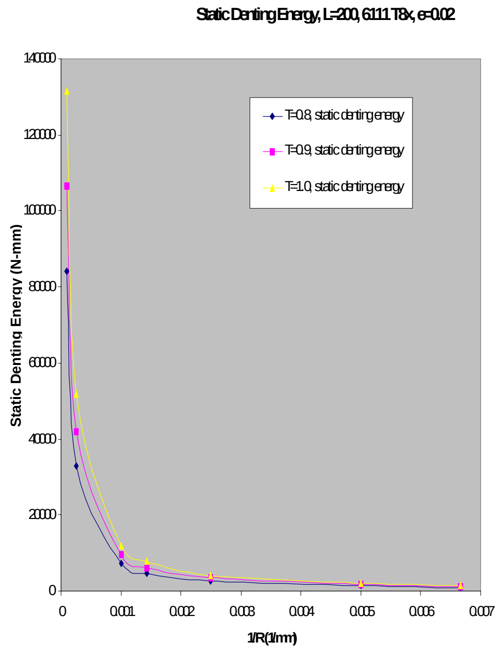


(a) L=200 mm



(b) L=600 mm

Fig. 1 Predicted secant stiffness (k) as a function of curvature by design analysis. 6111 T8x, 2% prestrain.



(b) L=600 mm

Fig. 2 Predicted static denting energy as a function of curvature by design analysis. 6111 T8x, 2% pre strain panels

can assume that the changing of curvature for small curvature panels is much more effective. Comparison of Fig. 2(a) and Fig. 2(b) reveals that the denting energy of 200 mm panels show more large value than 600 mm panels only in case of small curvature because of more large crown height. But larger dynamic dents are predicted for the smaller 200 mm panel compared to the 600 mm panel in case of finite element analysis. This panel size effect is attributed to the lower stiffness and lower dynamic contact forces for the larger panels. Note that panel size has little influence on static dent depth since static load level is not coupled to panel stiffness. So the design analysis can't predict the panel size effect correctly in this case. In case of large curvature, the variation of size and thickness can not affect seriously on denting energy as shown in Fig. 2.

Fig. 3 shows that predicted critical buckling load as a function of curvature by design analysis. Higher curvature, smaller size and thicker panels are more safe from oil canning phenomena as shown in Fig. 3.

CONCLUSIONS

The design analysis can supply easily and quickly so useful data, e.g. critical buckling loads, static denting energy and secant stiffness etc., for the conceptual phases of a design. The secant stiffnesses calculated by design analysis are more large value than the secant stiffnesses calculated by the finite element analysis. But whole trends are consistent so well. Also the design analysis can predict the denting energy and the critical buckling load easily and quickly.

ACKNOWLEDGMENT

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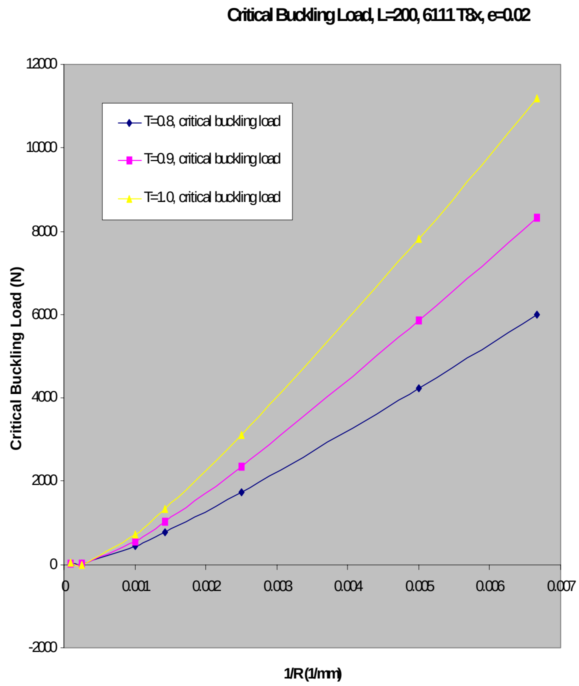
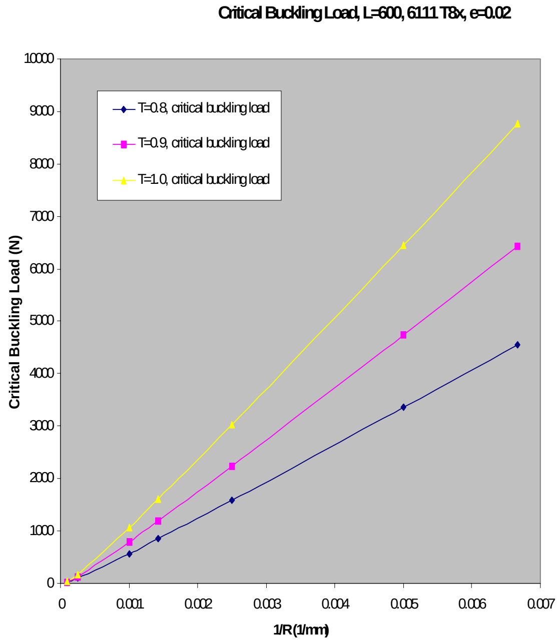


(a) L=200 mm



(b) L=600 mm

Fig. 3 Predicted critical buckling load as a function of curvature by design analysis. 6111 T8x, 2% pre –strain panels