濟州大學校 尖端技術硏究所 論文集, 第13卷, 1號, pp.16-18, 2002. 6
Cheju Nat'l Univ. Res. Inst. Adv. Tech. Jour., Vol.13, No.1, pp.16-18, 2002. 6

A Parametric Study of Sheet Metal Denting Using a Simplified Design Approach

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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.

Key Words : denting, sheet metal, design, panel

Ⅰ. INTRODUCTION

Predictions of stiffness, denting energy, and critical buckling loads are integral parts of automotive body panel structural design. Body panel performance is described by several different parameters, such as stiffness, denting energy and critical buckling load. For the study of stiffness, denting and oil canning, a parametric array of panels has been analysed and the results from simplified design calculations [1] are 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. Square panels of two sizes are considered, with compound curvatures ranging from highly curved (R=100 mm) to initially flat and with fixed edges. 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 a bake hardened T8X condition with three levels of forming pre-strain. The T8XP condition with enhanced paint-bake response 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, LS-DYNA.

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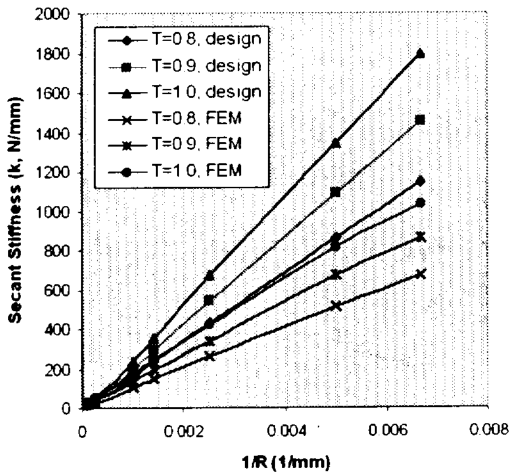
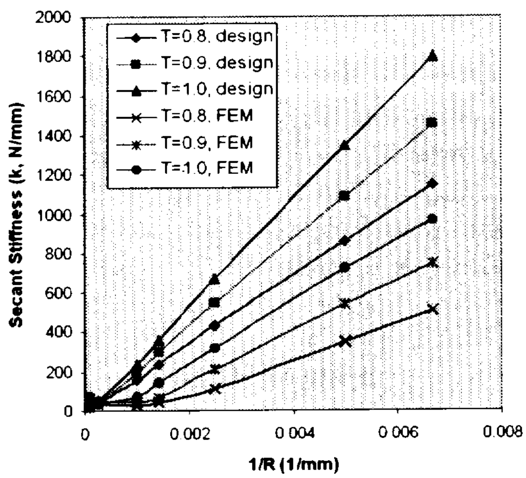
Ⅱ. RESULTS AND DISCUSSION

Predicted panel stiffness values from the analytical



(a) F=15.5 N, 6111 T8x, e=0.02



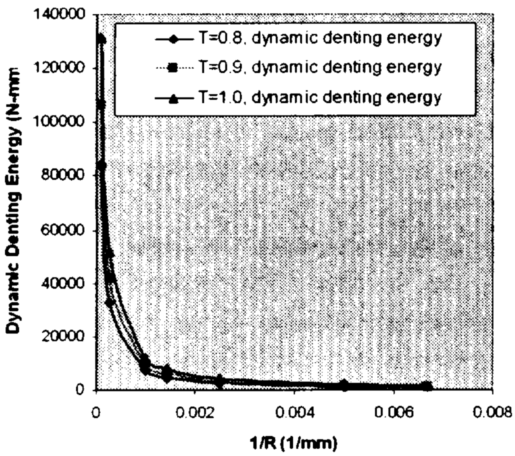
(b) F=155 N, 6111 T8x, e=0.02

Fig. 1. Predicted secant stiffness (k) as a function of curvature, L=200 mm.

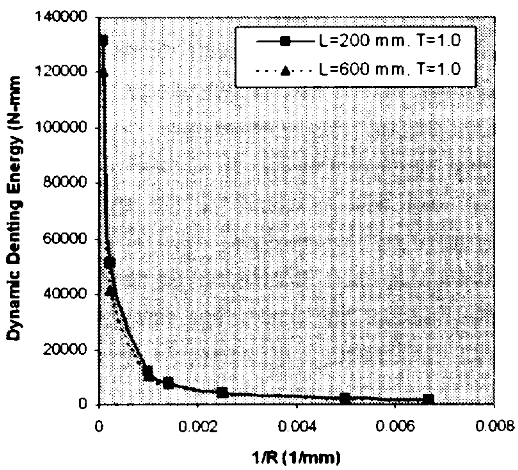
equations are plotted in Fig. 1 as the secant stiffness. Panel stiffness values from FEM predictions are also calculated as the applied load divided by displacement for loads of 155 N and 15.5 N. For the curved panels, the FEM predictions indicate that the initial stiffness is higher than the stiffness at maximum load due to geometric softening as the curvature is reduced with increased load. Furthermore, the flat panels demonstrate a stiffening response due to a transition from bending to membrane tension. The analytical equations do not predict these changes in stiffness since geometric changes are not considered. Comparison between the two models reveals that the predicted stiffness from the analytical equations is higher than that predicted by the FEM models. Overall, the analytical approach does capture the reduction in stiffness with reduced panel curvature quite well.

Fig. 2 plots the predicted denting energy as a function of curvature using analytical equations [2]. Denting energy provides a measure of the energy required to dent the panel, that is, the ability of the panel to absorb impact energy. Thus panels with higher values of denting energy are better able to elastically absorb 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. Static load-deflection curves indicate that 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. As radius of curvature decreases, denting energy drops off rapidly and panels dent more easily, as shown in Fig. 2. Thus, increasing radius of curvature is an effective means to improve dynamic dent performance. Fig. 2(b) demonstrates that the denting energy of 200 mm panels show is higher than for 600 mm panels for large radius of curvature. This result is anomalous since 200 mm panels are generally stiffer and suffer larger dynamic dent depths. For large radius of curvature, the effect of panel size on dent energy (depth) is small.

Fig. 3 shows the predicted critical buckling load as a function of curvature for the 200 mm panel using an analytical approach. Sharply curved, smaller size



(a) L = 200 mm. 6111 T8X. e = 0.02



(b) Comparison between L = 200 and 600 mm

Fig. 2. Predicted dynamic denting energy as a function of curvature.

(span). thicker panels are safer from oil canning phenomena. as shown in Fig. 3.

III. CONCLUSIONS

The analytical design equations can easily supply

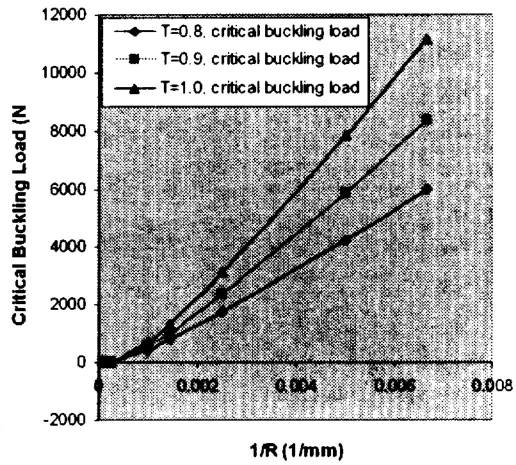


Fig. 3. Predicted critical buckling load as a function of curvature. L = 200 mm. 6111 T8x. e = 0.02

useful data, *e.g.* critical buckling loads. static denting energy and secant stiffness. for the conceptual phases of a design. The secant stiffness calculated using the analytical equations is higher than that from the FEM: however. the trends with respect to panel curvature are consistent.

ACKNOWLEDGMENT

This work was supported by Korea Research Foundation Grant. (KRF-2001-002-E00018)

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