Effect of forming on crash performance of automotive structure – an analytical study

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Abstract

Traditionally, engineers performing crash analysis do not account for the forming-induced effects such as thinning and work hardening of sheet metals. This is due primarily to the fact that the forming simulation and subsequent mapping of the resulting gage and material hardening history to crash models are often difficult. There is a feeling among engineers that the forming effects do not influence the vehicle-level crash response significantly. Commercial application tools are now available to map forming simulation results into crash models and thereby allow engineers to explore in details the effect of forming on crash responses with relative ease. In this paper, we have used commercially available tools to perform forming simulation and subsequent mapping of results to crash model. Full vehicle-level crash analyses are performed with and without forming history and the results are compared. It is shown that there are cases where the inclusion of forming effects is critical to accurately predict crush modes and the responses.

Keywords: Forming; Crash analysis; Thinning; Work hardening

1. Introduction

Sheet metals undergo significant work hardening and thickness change during forming operation. Engineers performing crash analysis often do not account for the forming-induced effects in their analyses. This is due primarily to the fact that the forming simulation and subsequent mapping of the resulting gage and material hardening history to crash models are often difficult. There is a feeling among engineers that the thinning and work hardening effects compensate for each other and thereby do not influence the vehicle-level crash responses significantly [1].

In recent years, various groups have shown that forming effects have a measurable influence on the overall vehicle crash responses [2,3,4,5]. Recently, the authors have investigated the effects of forming on crash responses in course of their evaluation of advanced high-strength steel (AHSS) and their application for crash critical body structure components. This paper summarizes the findings of the study. A set of 32 components that can affect the frontal impact performance are chosen. An inverse method is used to determine the thickness and work-hardened material properties throughout each part. An in-house-developed application is used to map the thickness and property distributions from the forming simulation model to the crash analysis model. Full frontal and offset frontal impact simulations are performed with and without the forming effects. A comparison of deformation modes and crash responses for these cases indicates clearly that forming effects are important.

2. Forming analysis

A set of 32 parts are considered for the forming simulation (Fig. 1). A third-party program, Hyperform, is used to determine the thickness and the plastic strain profile of these parts due to forming. Fig. 2 shows the plastic strain contours as determined by the forming simulation code. Since forming mesh is often much finer than the crash analysis mesh, one requires a mapping operation to transfer the thickness and plastic strain distribution from the forming analysis model to crash analysis model. An application developed at Ford [6] has been used to accomplish this objective.

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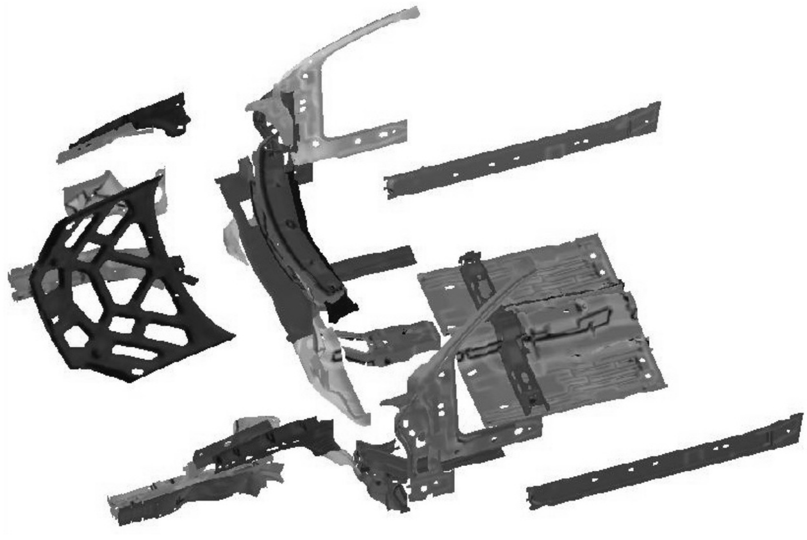


Fig. 1. Critical components for the frontal impact model considered in forming analyses.

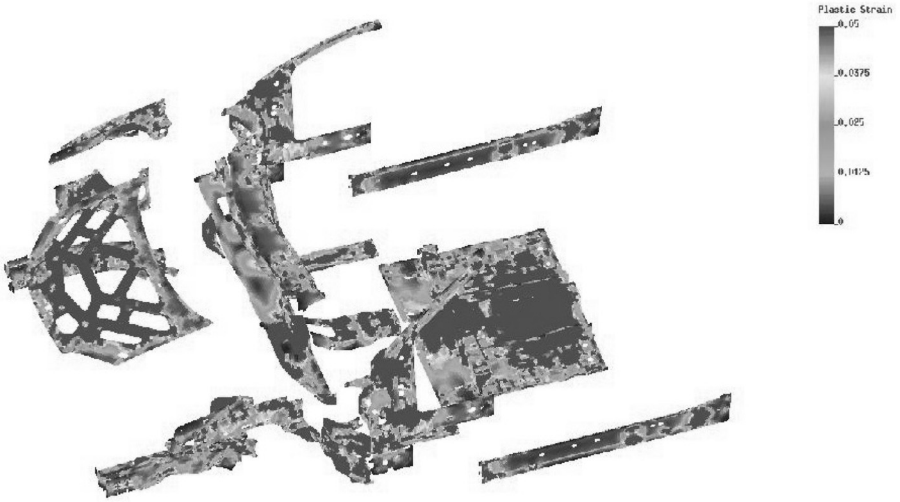


Fig. 2. Plastic strain contours obtained from forming analyses.

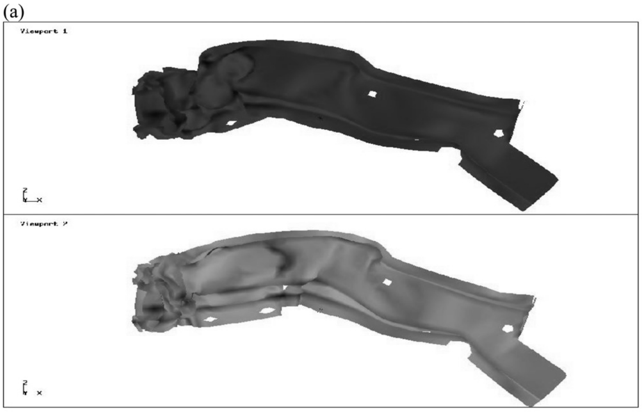
3. Crash analysis

Two separate frontal crash modes are considered for this investigation. The first case is that of a full frontal impact at 35 mph. The second case is a 40% offset frontal impact at 40 mph on the driver side. The results of these analyses are summarized below.

3.1. Full frontal impact

Two full frontal FEA models, one with and one without forming effects, are created. The models are identical in all other respects. The finite-element analysis (FEA) models have approximately 225 000 shell elements. 35-mph full vehicle impact simulations are carried out using RADIOSS (a commercial crash analysis code used at Ford and other OEMs) for a total of 100 ms against a rigid wall. Fig. 3a shows a comparison of the front rail deformation with and without forming effects. It is clear from this comparison that the front rail not only deforms measurably less but also has an observable crush mode difference when the forming effects are included. Fig. 3b shows the comparisons between the deceleration histories and dynamic crush for

(a)



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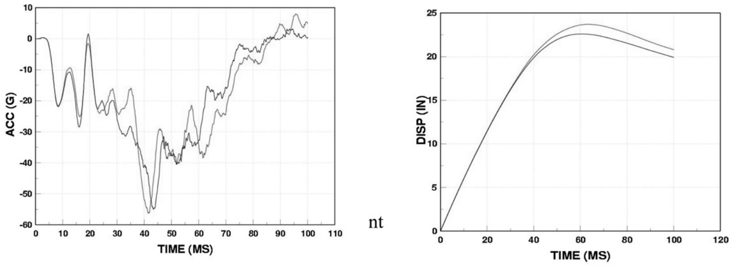
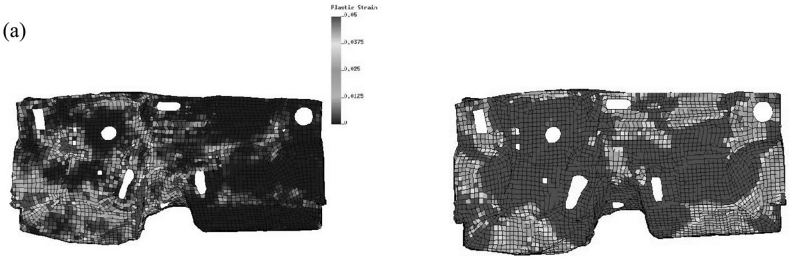


Fig. 3. Full frontal impact simulation results. (a) Front rail inner deformation mode; (b) vehicle deceleration and dynamic crush.

(a)



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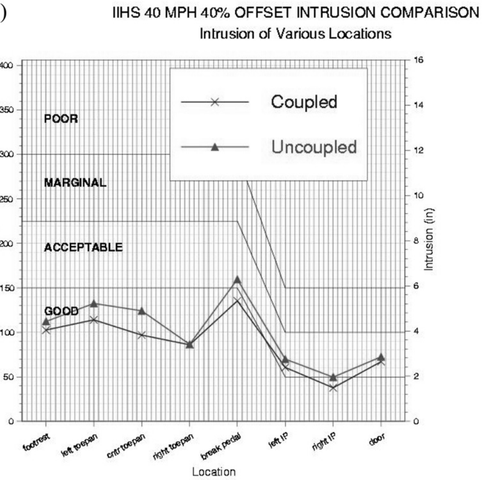

Fig. 4. 40% offset frontal impact. (a) Deformation and plastic strain for dash panel; (b) intrusions.

these two cases. It is observed from these comparisons that the maximum dynamic crush is ~5% less when the forming effects are incorporated.

3.2. 40% offset frontal impact

Two FEA models, with and without the effects of forming, are prepared to simulate 40-mph 40% offset frontal impact against a deformable barrier. Fig. 4a shows the plastic strain contours for the dash panel. It is clearly evident that the plastic strain distribution of the dash panel is different for these two cases. Fig. 4b shows the comparison of the intrusions at some key locations for these cases. Once again, there are measurable differences in the intrusions obtained from these analyses.

4. Conclusions

An investigation has been carried out to determine the effect of forming on full vehicle crash simulation results. It is found that the forming effects have a measurable impact on both deformation modes and crash responses when incorporated in crash simulation.

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