Influence of Forming Effect on the Headform Impact Performance of an Engine Hood

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Abstract: In the past, the thickness changes and work hardening arising during the forming process of parts of engineering hood assembly are generally ignored in headfrom impact analysis, and those parts were assumed to have a uniform thickness and material character. This paper describes the effects of forming simulation results on pedestrian safety performance of an engine hood assembly and the method of transferring results from forming simulation to impact simulation. The study show that the engine hood deformation after impact is reduced 10% by the work hardening effects, and headfrom peak acceleration is increased by 10%. The results also demonstrate that to improve the accuracy of headform impact simulation, it is preferable to consider the effects of metal forming.

Keywords: forming effect; pedestrian head impact; finite element analysis; work hardening; thickness change

1. Introduction

Improve the Pedestrian safety performance of car front out body structures, using simulation, are an important part of the CAE development chain for the modern car design. In recent years, the requirements on pedestrian safety of cars have grown to high standards, leading to a permanent demand on an increase in simulation accuracy. To improve the accuracy of pedestrian impact simulation, various approaches have been performed. These approaches have included modeling of detailed part shape, application of modeling to more parts, and re-determination of the properties of materials.

Material data derived from tensile tests is an important input to finite element models. However, the test samples are normally taken from the coil, not from formed parts. The forming process is likely to modify the properties of the materials due to work hardening (Figure 1); thickness changes (Figure 2) and residual stresses may also be important. This could lead to errors in predictions of impact response.

Finite Element tools are now able to predict the as-formed material properties and use these in subsequent crash analysis. In recent years， there are many literature about the forming effects on the crashworthiness performance of individual components, even whole vehicle[1-7][8].However，there are few papers reporting the consequence of including formed properties in pedestrian headfrom impact analysis. In this study, the authors used a very similar approach to that reported by H. Huh et. al[5], which reported about forming effects of body members on vehicle crashworthiness. The application of this methodology was extended to investigate the effect of forming on engine hood headform impact performance.

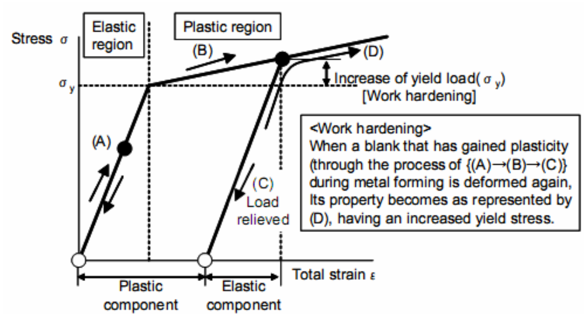

Figure 1. Concept of work hardening process during forming [3]

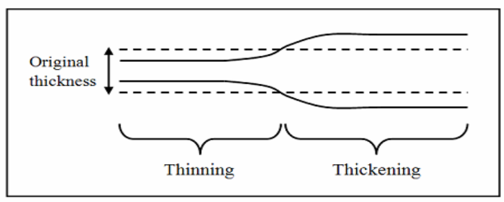

Figure 2. Thickness change after forming process[4]

In this paper, the forming effects of inner and outer panel of an engine hood assembly are obtained from simulation of stamping and forming processes so that they can be considered in estimation of its performance impacted by a headform. Since inner and outer members of hood assembly should play an important role in absorption of the kinetic energy during the headform impact, they are fabricated from sheet metals. Forming analysis is carried out with an explicit non-linear finite element analysis code LS-DYNA, and using a pre-processor eta/DYNAFORM. Headform impact on the engine hood is carried out imposing the forming analysis result on the initial condition. Numerical simulation is performed with LS-DYNA in order to evaluate the impacted performance of the hood . In order to consider the non-uniform distributions of the effective plastic strain and the thickness as the condition for crash analysis, the forming histories are mapped into the new finite element mesh system.

2. Forming Analysis of the Engine Hood

One of the most important components of a vehicle in pedestrian head impact safety is engine hood assembly which absorbs most of impact energy during impact. The engine hood assembly was comprised of five individual panels (Figure 3): an inner panel, an outer panel, a latch reinforcement, and two hinge rein reinforcements.

2.1. Forming System

There are many software codes could use for metal form simulation, like AutoFOAM, DynaFOAM or FAST-FOAM. In this study, DynaFOAM was selected as the pre-processor to build the forming system, which includes a Die, a Punch, and a Blank holder.

DynaFOAM module DEF, Die Face Engineering, has been used to generate the die and punch for hood inner and outer panel forming system (Figure 4, Figure 5).

Adaptive remeshing was used so as to increase the number of elements in the blank in areas of high curvature of the tooling and hence reduce discretization errors. Material properties representing a DC04 mild-steel for inner panel, and a B180H1 bake harden steel for outer panel were input to material model (*MAT_TRANSVERSELY_ANISOTROPIC_ELASTIC_PLASTIC). The Blank sheet metal is modeled with shell elements ELFORM 16 (fully integrated shell element) with side medium length of 30 mm. All tools are defined as rigid bodies and their motion is entirely prescribed in DynaFOAM. The number of integration points through the thickness has been defined as 7 for precise simulations.

2.2. Forming Simulation

It is a well known fact that shaping a sheet metal into its final shape may not be possible with a single process. A sheet metal may come into the desired shape after series of metal forming stages. However, in this study, it is assumed that the inner and outer panels are manufactured with a single forming stage, deep drawing process. The main reason is that deep drawing process, which is the forming of a sheet metal into a die by means a punch, leads to a much larger plastic deformation of the material than other forming stages [4][16].

Forming results has been mapped to the original inner and outer parts using DynaFOAM, and save in DYNAIN file. The results were shown in Figure 6 and Figure 7.

According to Barthel, C.[16] ,energy due to springback is quite low compared to the plastic strain energy in the impact analyses, and the residual stress after springback across the thickness may be assumed as negligible compared to the stresses occurred after the crash. In this study, only the plastic strain and the thickness change effects of the sheet metal forming process have been taken into account.

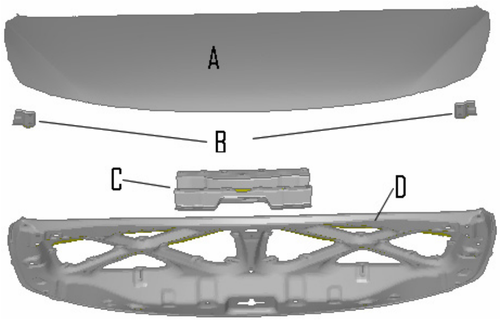

Figure 3. Hood Assembly: A. outer panel, B. hinge reinforcements, C. latch reinforcement, D. inner panel

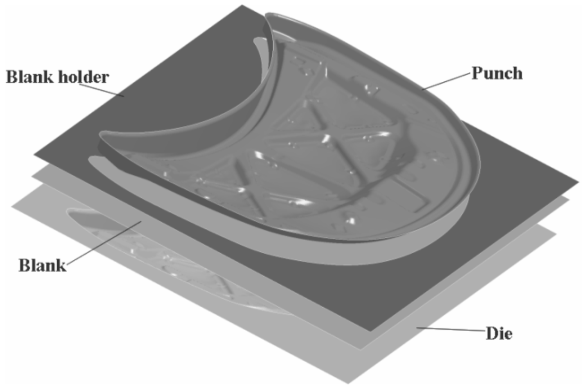

Figure 4. Hood Inner Panel Forming System

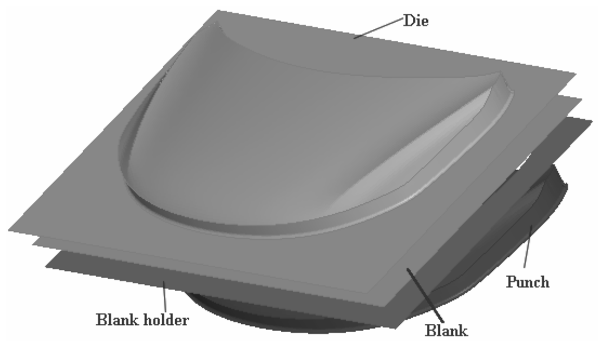

Figure 5. Hood Outer Panel Forming System

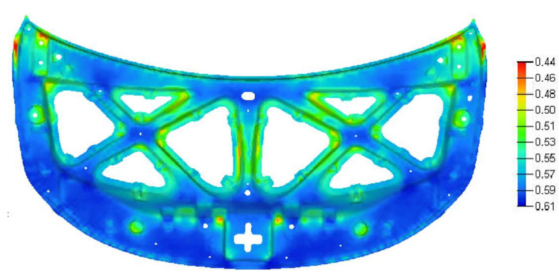

Figure 6. Hood Inner Panel Thickness Distribution

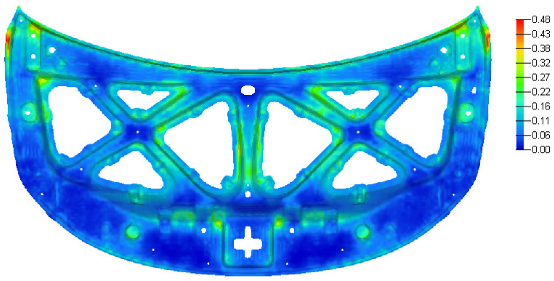

Figure 7. Hood Inner Panel Plastic Strain Distribution

2.3. Transfer Forming Results

The thickness and effective strain distribution resulted from the forming analysis were transfered into FE model for headform impact analysis using the option 'INCLUDE_STAMPED_PART implemented in LS-DYNA.

3. Headform Impact Analysis

3.1. Finite Element Model

Figure 8 shows the FE model for pedestrian impact simulation. This model includes one headform impactor and a front sub structure model of vehicle. The impactor model was bought from our code supplier ARUP china. The FE model including headform impactor consists of approximately 382789 nodes, 358401 shell elements that employed element type 16 full integration in LS-DYNA and 18735 solid elements where gluing portion and rubber are modeled. The material properties were defined using real test data.

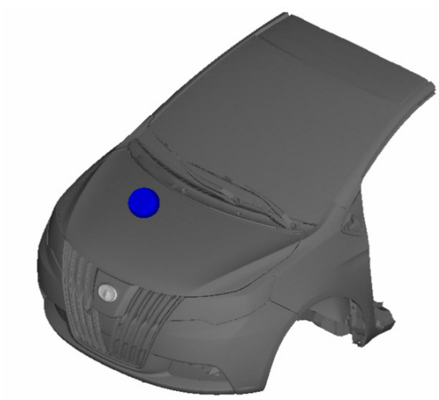

Figure 8. Impact simulation model

3.2. Impact Simulation Model Type

Four types of models are defined to examine the influence on the simulated impact performance of several (combined) aspects of the forming results. These models are:

Exclude model: In this model, only the geometry after the complete forming simulation is imported into the crash simulation. This means that the thickness distribution and plastic strain distribution are deleted.

Plastic strain model: In this model, next to the geometry, also the plastic strain distribution is imported into the impact simulation.

Thickness model: In this model, next to the geometry, also the thickness distribution is imported into the impact simulation.

Include model: In this model, all forming results data, effective plastic strain and thickness distribution, is imported into the impact simulation.

3.3. Result Discussion

In Figures 9, the intrusion distance of impact target points on the outer panel of engine hood as a function of time are presented, whereas Figure 10 compare the max intrusion distance of these different cases.

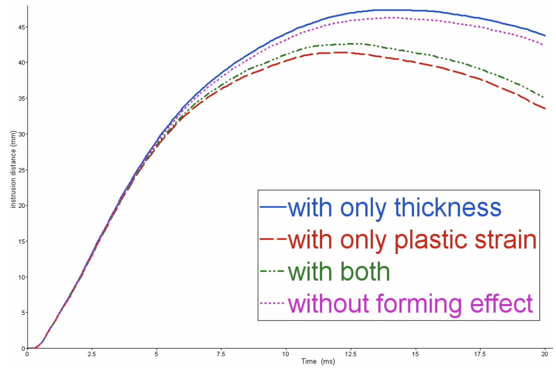

Figure 9. Intrusion Distance vs. Time

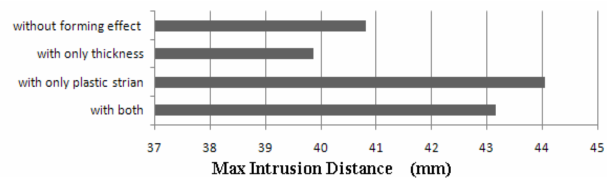

Figure 10. Max Intrusion Distance

The max intrusion distance is 40.8 mm when the forming effect is not considered and 43.2 mm when all forming effects are considered. The max intrusion increases by 8% when only the effective plastic strain is considered and decreases slightly when only the non-uniform thickness is considered compared to the one without the forming effects.

The absorbed energy by engine hood during forming process is plotted in figure 11. The figure also demonstrates that energy absorption increases remarkably when the effective plastic strain is considered and decreases slightly when the non-uniform thickness distribution is considered. The energy absorption of the hood assembly has a larger value when all forming effects are considered than the one without forming effects.

In Figure 12, the impactor accelerations during simulation are presented. It show that, with only plastic strain effects, the peak acceleration of impactor is 144.9 g, and without forming effects the peak acceleration is 139.8, and with both thickness change and plastic strain distribution the peak acceleration is 140.6 g. The peak acceleration increases smaller than 1%.

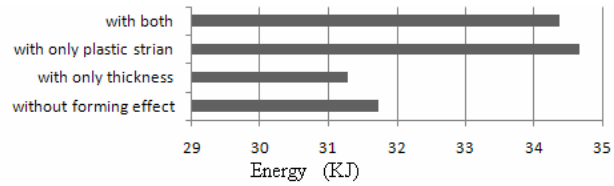

Figure 11. Hood Absorbed Energy

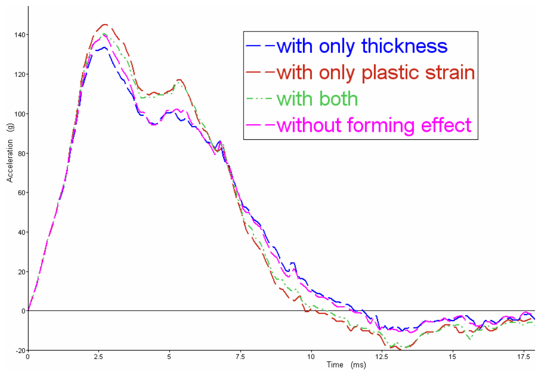

Figure 12. Impactor Acceleration

Figure 13. shows the calculated impactor's HIC from the four different models. It's about 562 without forming effects and 630 with both thickness change and effective plastic strain. The HIC increases by 12% after consider the effects of forming process.

These results demonstrate that the strain hardening resulted from forming processes is dominant in calculation of the impactor HIC and hood member energy absorption. It is noted from the results that the headform impact simulation of the engine hood assembly has to be carried out considering the forming effect, especially the effective plastic strain, for accurate assessment of the impact performance.

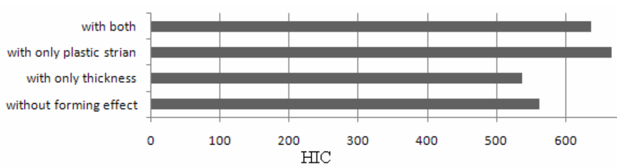

Figure 13. Impactor HIC

4. Summary and Conclusion

Forming effects include work hard and thickness change on the inner and outer panel of engine hood assembly impact performance have been investigated on this paper. The first step was the simulation of the forming process of the inner and an outer panel of the engine hood assembly, to estimate the plastic strain distribution and thickness change induced by the forming. The second step was transfer the forming results to headform impact simulation modal as initial conditions, Then the third step was simulate head impact on engine hood with and without forming effect. And compare the simulation outputs. The results show about 10% increase of HIC of the head impactor, and 8% decrease of intrusion of hood outer panel.

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