

Effects of forming history on crash simulation of a vehicle

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Abstract. The effects of forming on the crash simulation of a vehicle have been investigated by considering the load paths produced by sheet metal forming process. The frontal crash analysis has been performed by the finite element method, firstly without considering the forming history, to find out the load paths that absorb the highest energy. The sheet metal forming simulations have been realized for each structural component of the load paths and the frontal crash analysis has been repeated by including forming history. The results of the simulations with and without forming effects have been compared with the physical crash test results available in literature.

1. Introduction

As the vehicle fatalities increase, vehicle safety has become an important design objective besides all performance and comfort criteria of vehicles. During a collision, as much as crash energy is aimed to be absorbed by the structural components of a vehicle to provide greater protection for occupants. From the view point of passive safety, the design of the load paths is important since the components building up the load paths are the major parts absorbing the kinetic energy during crash. Since load transfer is not so easy to predict, numerical methods are used to simulate the crash behavior of vehicles [1-3].

The majority of the parts of a vehicle, especially parts which build up the main load paths, are manufactured by sheet metal forming. However, it is a known fact that sheet metal forming processes alter the mechanical properties of the materials and change the thickness due to plastic deformation. Work hardening and thickness change apparently affect the crash response significantly. Effects of forming history on the crash response of the crash relevant body parts have been discussed by several studies [4,5]. The main purpose of this study is to show that the changes in material properties and thicknesses of the parts produced by sheet metal forming process alter the crashworthiness and overall crash response of the vehicle.

2. Finite Element Model

The detailed finite element (FE) model of 2006 Ford F250 Pickup, which had been verified with tests, was downloaded from the official web site of National Crash Analysis Center (NCAC) [6] and utilized in this study. The finite element model of Ford F250 Pickup consists with a total of 726629 beam, shell and solid elements. For the numerical analyses, explicit LS-DYNA code has been selected.



The load paths in a vehicle alter according to the crash type. Different components constitute the load paths for frontal crash and side crash, whereas the load paths differ from one vehicle to another. In order to find the crash relevant parts of the particular vehicle during the frontal crash, the internal energy of each part due to crash has been investigated.

In the frontal crash simulation, the particular vehicle with a mass of 3016 kg has crashed into a rigid wall at 56 km/h. This corresponds to an initial kinetic energy of 364.90 kJ. The results of the simulation showed that 86 % of this energy has been converted to internal energy. The remaining of the kinetic energy is observed for hourglass energy, spring/damper energy, springback energy and etc.

By examining the internal energy levels of the components, the basic crash relevant parts have been found. It is observed that the load path consisting of the lower front S-rails, the connected longitudinal members to these S-rails and the engine bracket absorbed nearly 45% of the total internal energy under frontal crash. Hence, this load path, which is shown in figure 1, has been focused in this study.

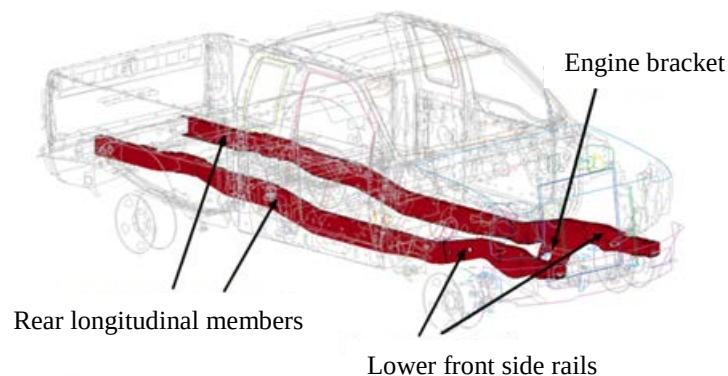


Figure 1. The first load path.

3. Forming analyses of load carrying members

To examine the forming effects on the crash response, sheet metal forming simulations have been carried out to detect the forming histories of nine crucial components building up the selected load path. In this study, it is assumed that these components are manufactured by the deep drawing process. Using the dimensions of the components, appropriate die and punch forms are modeled in order to obtain the desired geometry of the related parts. During the finite element analyses, forming tools are taken as rigid. The sheets are modeled by four node shell elements.

4. Comparison of frontal crash analysis with and without forming history

The results of the frontal crash analysis with and without forming history have been compared and presented for absorbed total energy, total displacement at the vehicle's center of gravity, the total force recorded by the load cells on the wall, the average velocity and the deceleration of the left and the right front seats.

The total absorbed energy by the main load path for the analysis without forming effects is 139.77 kJ and when the forming effects are taken into consideration its value becomes 152.67 kJ by an increase of 9.23 % as shown in figure 2.

Figure 3 shows the comparison of the resultant displacement of vehicle's center of gravity from the numerical crash analyses with and without forming history, and the crash test. The resultant displacement has decreased after the forming history has been taken into consideration, which is mainly due to the increase in energy absorption. The maximum displacement has been observed at about 0.097 s and there is a difference of about 48 mm between the results of the simulations with and without forming history. As it is seen from the figure, a good agreement is achieved with the test results, after forming histories of nine crash relevant body parts have been taken into account.

Total reaction force measured by the load cells on the wall and the values obtained by the simulations are given in figure 4 with respect to time. The maximum total force measured during the crash test is 1060 kN whereas the corresponding values obtained by the analyses with and without forming history are 1105 kN and 979 kN, respectively. It is seen that the maximum total force obtained with forming history is closer to the maximum total force measured during the crash test.

The average velocities obtained from the simulations without and with forming history for the positions of the left and right front seat accelerometers have been compared with test results and shown in figure 5. The result obtained with forming analysis shows good agreement with the test result.

Figures 6 and figure 7 show the comparison of the deceleration pulse variation from the simulations with and without forming history for the left and right seats, respectively which is very crucial since it is directly related to the injury criteria of occupants. The peak left front seat deceleration pulse has been reduced from 55.7g to 45.7g and the peak right front seat deceleration pulse has been reduced from 62.3g to 56.9g as seen from figures 6 and 7.

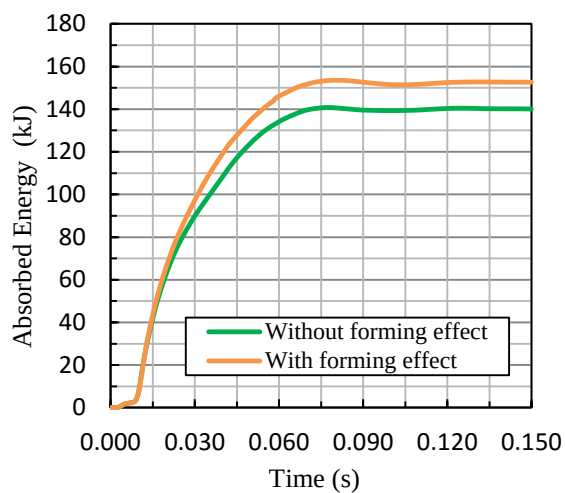


Figure 2. Change of total absorbed energy by the first load path with and without forming history.

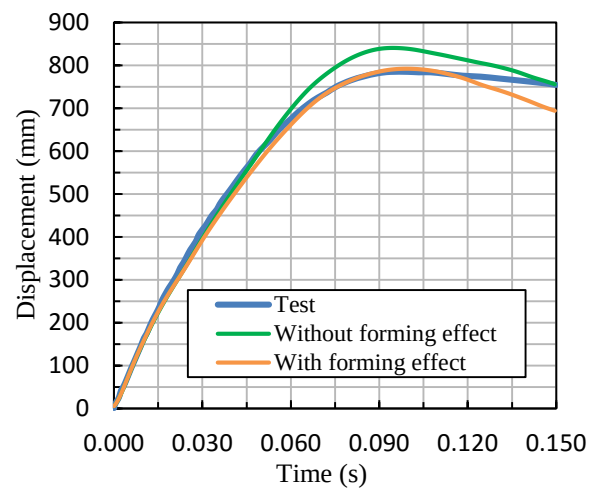


Figure 3. Comparison of simulation results and the test results [6] for resultant displacement of the vehicle center of gravity.

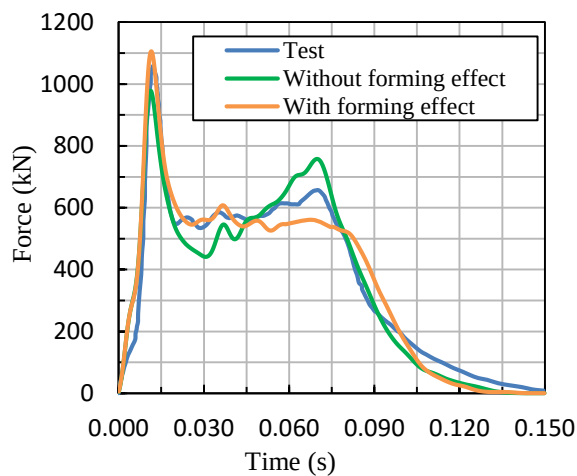


Figure 4. Comparison of total force determined by the simulations and the test results [6].

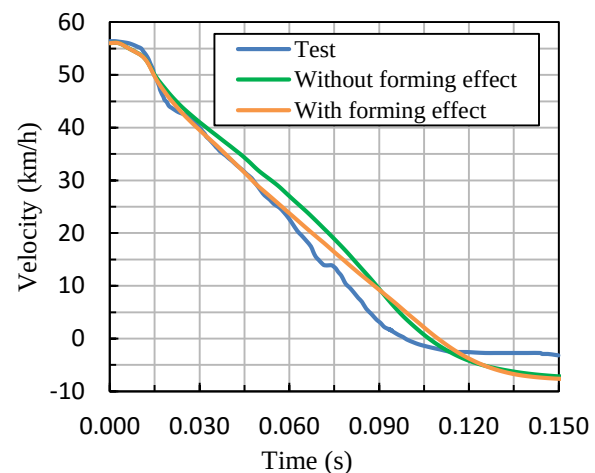


Figure 5. Comparison of average velocities of the left and right front seats obtained by the simulations and test results [6].

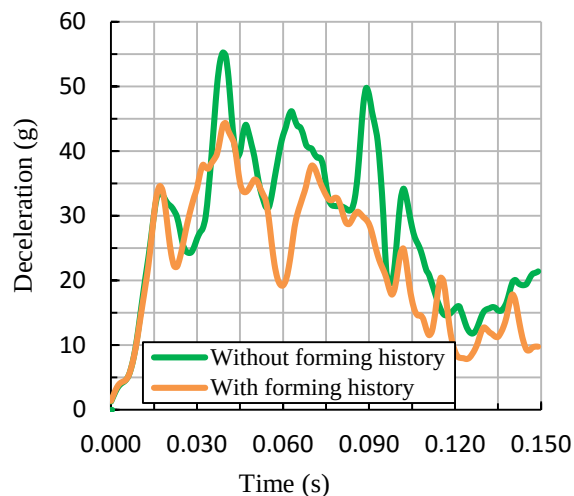


Figure 6. Variations of the left front seat deceleration for simulations with and without forming histories.

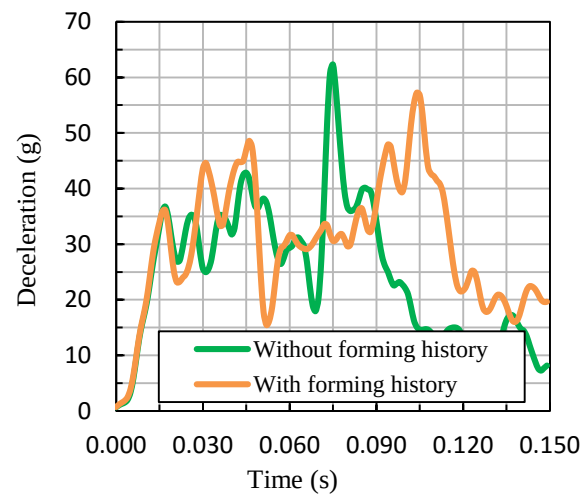


Figure 7. Variations of the right front seat deceleration for simulations with and without forming histories.

5. Conclusions

In this study, the effects of forming history on the crash simulation have been investigated. The following conclusions can be drawn from this work:

1. Consideration of the forming histories of the sheet metal components on the load path in the simulations affects the overall crash response of the vehicle.
2. Energy absorption amounts of the components of the load path change when the forming effects have been taken into consideration in the crash simulations.
3. It is found that the maximum deceleration pulses transferred to the driver's and the passenger's seats decreased when the forming effects have been used.
4. It is shown that the results obtained by the full vehicle crash simulation with the forming effects are in better agreement with the physical crash test results.
5. It is observed that the forming histories should be taken into account to get more realistic results from FE analyses.

References

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