Investigation of Accuracy Improvement on Crashworthiness Simulation with Pre-Simulation of Metal Forming.

Katsuhiko TAKASHINA, Kazuhiro UEDA, Takeo OHTSUKA

MITSUBISHI MOTORS CORPORATION,

Okazaki Aichi Pref., JAPAN

Abstract:

To improve the accuracy of crashworthiness simulation, it is preferable to consider the effects of metal forming. However, this approach was difficult in practice since analyzing the stamping simulation in detail requires much work. This paper describes the influence of residual strain, work hardening and material thickness changes resulting from the stamping process on the crashworthiness simulation. In almost all impact load cases, the results show that deformation is reduced by the work hardening effects. These results are verified by actual experimental data.

Keywords: Crashworthiness, CAE, Forming.

1. Introduction

To improve the accuracy of crashworthiness 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. This paper studied the influence of residual strain and change in metal thickness during the stamping process on the crashworthiness simulation, in order to improve the accuracy.

2. A method to apply a stamping result to crashworthiness simulation model

One effective method to include the influence of residual strain and metal thickness changes during metal forming into crashworthiness simulation is to conduct stamping simulations using actual dies (called “detailed stamping simulation”) and to apply the results to the crashworthiness simulation model (Fig. 1). However, this type of simulation is difficult to apply in practice particularly that it requires almost the same amount of calculation time as needed for crashworthiness simulation at every part. Furthermore, the process of providing the stamping results to the crashworthiness simulation model is very complicated. To solve these difficulties, an inverse method can be applied to an implicit finite element model (“FE”) to estimate the developed shape of the blank from an FE that represents the shape of the finished product, and to estimate the residual strain and metal thickness distributions (called the “simplified stamping simulation”) (Fig. 2). By this method, the stamping results on hundreds of parts are provided to the crashworthiness simulation model without modification in about one hour. However, it is necessary grasping the simulation accuracy by comparing the results of the detailed stamping simulation, because the method is a simplified one.

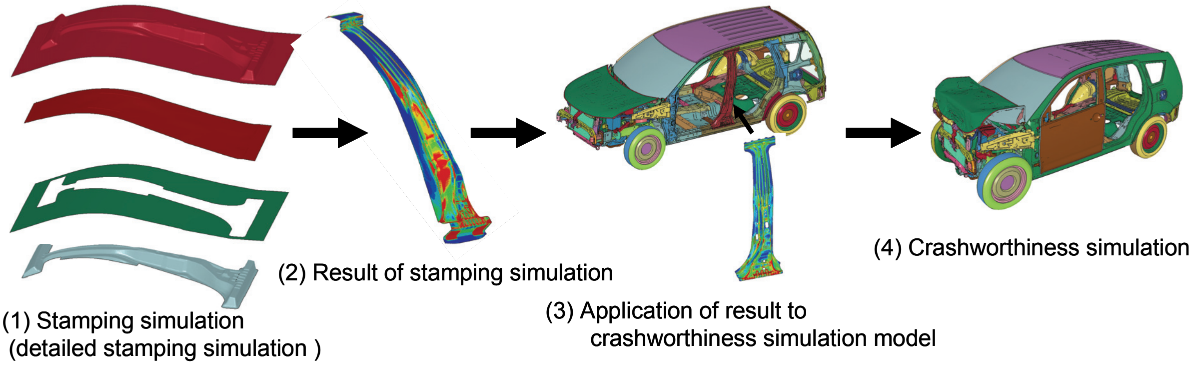

Fig. 1 Conventional process

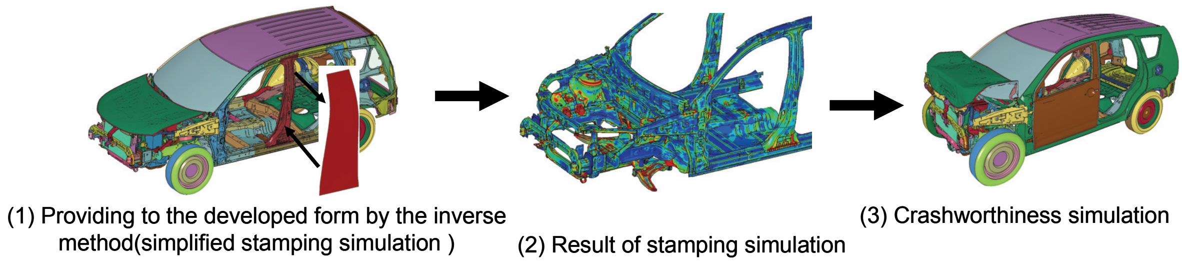

Fig. 2 Newly adopted process

3. Accuracy of the simplified stamping simulation

To grasp the accuracy of the simplified stamping simulation , its results are compared with those of the detailed stamping simulation in terms of the residual strain and metal thickness distribution of a cowl top panel, which is a drawn panel part (Figs. 3 and 4).

Although the residual strain obtained from the simplified stamping simulation is smaller than that from the detailed stamping simulation, the distributions are similar. The detailed stamping simulation shows relatively large strain in the peripheral areas of the panel, but these areas are cut off after stamping, so these strains are not included in the crashworthiness simulation model. Also, the two results show almost the same metal thickness distributions. The main reason why the simplified simulation estimated smaller residual strain than the detailed simulation is considered to be the following: On an actual draw die, the blank is held constrained at its peripheral areas, which causes a tensile force to be generated there during metal forming (Fig. 5), but this constraint condition is not considered in the simplified simulation.

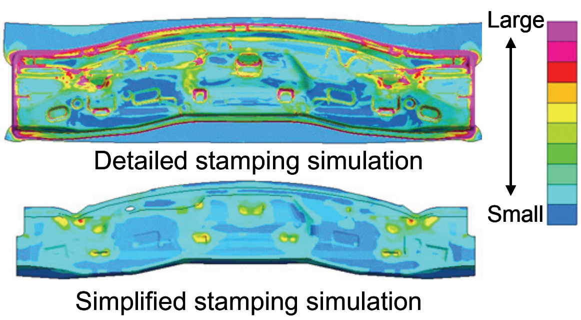

Fig. 3. Residual strain distribution.

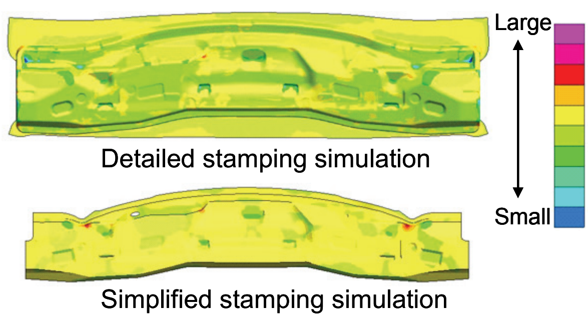

Fig.4. Sheet thickness distribution.

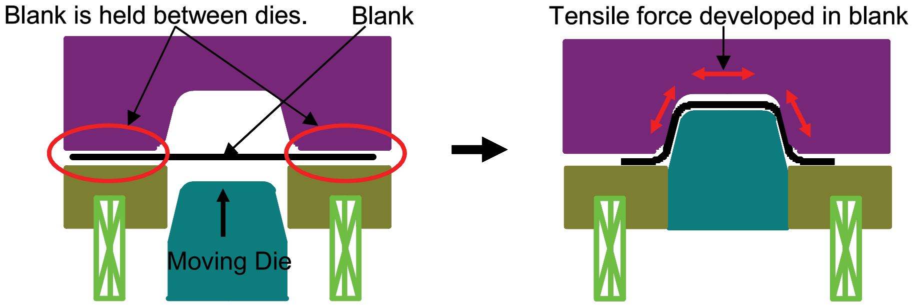

Fig. 5 Structure of draw Die.

4. Crashworthiness simulation providing residual strain estimated by stamping simulation

4.1 Impact load cases and parts subjected to stamping simulation

The simplified stamping simulation is carried out for the multiple impact load cases. . The parts chosen for the simulation are those most likely to have an influence on vehicle crashworthiness. Table 1 shows the number of parts subjected to the stamping simulation and the time (in hours) taken for the simulation. Incidentally, the detailed stamping simulation takes roughly 10 hours per a part. Examples of the residual strain distribution derived from the simplified stamping simulation are shown in Figs. 6 and 7. These results are provided to the crashworthiness simulation model. .

Table 1 Load cases

	Impact load case	Number of analyzed parts	Calculation time by simplified stamping simulation
[1]	35mph frontal impact	Approx. 250	Approx. 1.0H
[2]	18mph side pole impact	Approx. 250	Approx. 1.0H
[3]	50mph rear offset impact	Approx. 350	Approx. 2.0H
[4]	Pedestrian head impact	Approx. 130	Approx. 0.5H
[5]	5mph bumper impact	Approx. 50	Approx. 0.2H

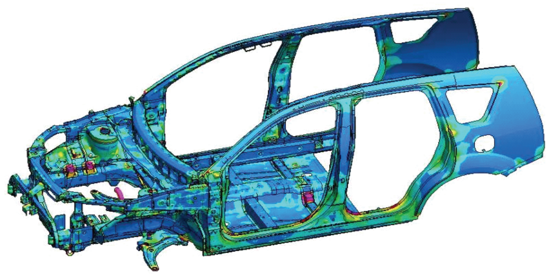

Fig.6 Residual strain distribution (example for parts in frontal impact simulation)

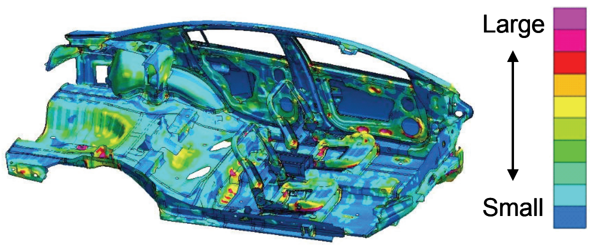

Fig.7 Residual strain distribution (example for parts in side impact simulation)

4.2 Results of crashworthiness simulation

In the impact load cases where deformation extends to a large number of parts (case[1], [2] and [3] in Table 2), the application of the stamping results allows the hardening to be included in the estimation for the areas subjected to plastic deformation. The deformation of a vehicle body is reduced to a similar level to actual experimental results. On the other hand, in those impact load cases where deformation occurs only locally (cases [4] and [5] in Table 2), the work hardening effect does not reach the areas subjected to plastic deformation, and thus there is little difference (approximately 2%) in body deformation between the simulation and experimental results. Comparison of the results between the simulation and the experimental are shown for the load cases of frontal impact (Figs. 8 to 11), side impact (Figs. 12 to 14) and pedestrian head impact (Figs. 15 and 16).

Table 2 Influence on crashworthiness simulation

	Impact load case	Extent of deformation	Accuracy
[1]	35mph frontal impact	Reduced	Improved
[2]	18mph side pole impact	Reduced	Improved
[3]	50mph rear offset impact	Reduced	Improved
[4]	Pedestrian head impact	No change	No Influence
[5]	5mph bumper impact	No change	No Influence

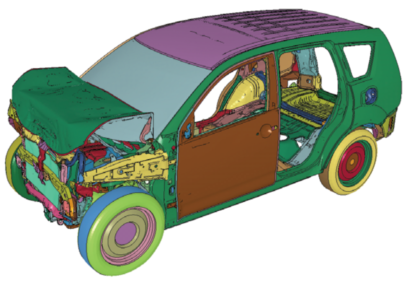

Fig.8 Vehicle deformation([1]Frontal impact)

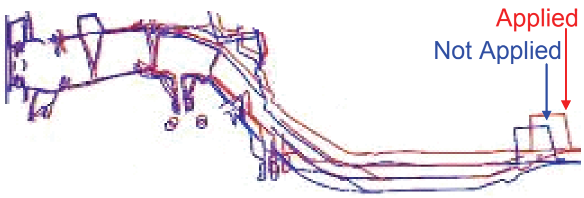

Fig.9 Side member deformation([1]Frontal impact)

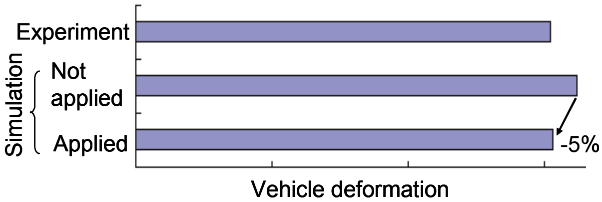

Fig.10 Comparison of extent of vehicle deformation([1]Frontal impact)

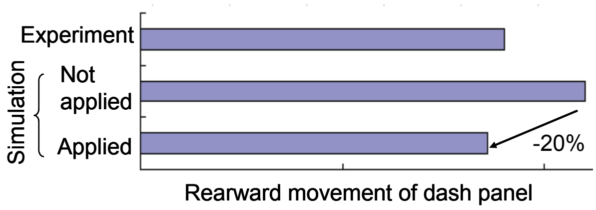

Fig.11 Comparison of extent of rearward movement of dash panel([1]Frontal impact)

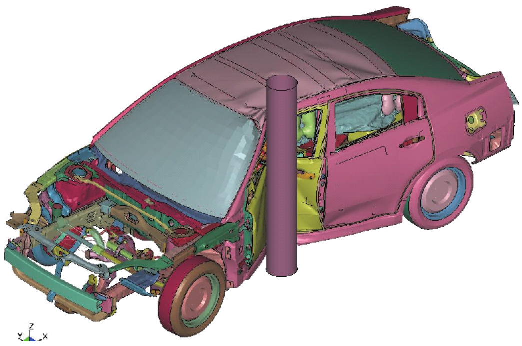

Fig.12 Vehicle deformation([2]Side impact)

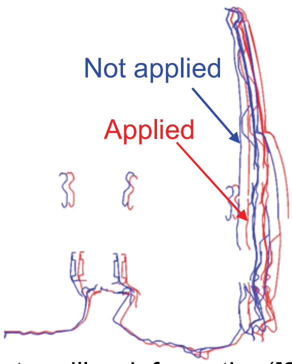

Fig.13 Center pillar deformation([2]Side impact)

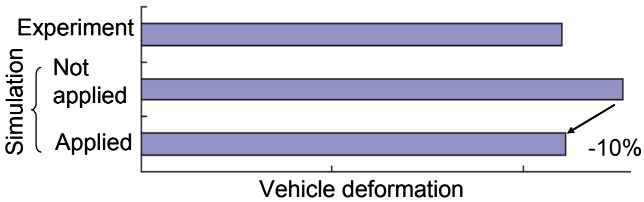

Fig.14 Comparison of extent of vehicle deformation([2]Side impact)

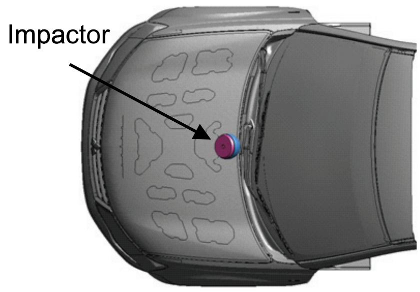

Fig.15 Impactor Location([4]Pedestrian head impact)

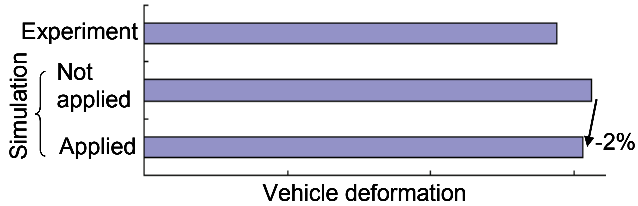

Fig.16 Impactor displacement ([4]Pedestrian head impact)

5. Conclusion

By applying the residual strain and metal thickness distribution change derived from the simplified stamping simulation to the crashworthiness simulation, the deformation is reduced to a similar level to actual experimental results in almost all impact load cases. This reduction in deformation is considered to be due mainly to the work hardening during the stamping process (Fig. 17), and its influence overcomes the influence of the reduction in metal thickness. This approach takes only a few hours even when applied to hundreds of parts, and requires no detailed data for metal forming. Therefore, this approach enables the metal formability to be included in the crashworthiness simulation, thus improving the accuracy of the results. However, the simplified simulation method tends to estimates less residual strain than the detailed stamping simulation. It must be improved in the future.

Finally, we sincerely thank JRI Solutions Limited and all concerned for their assistance throughout the study.

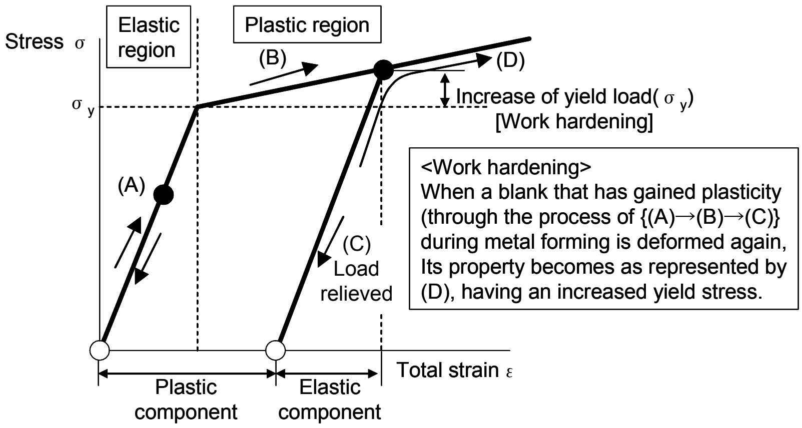

Fig. 17. Concept of work hardening process during metal forming.

References

(1) JRI Solutions, Ltd.: HYCRASH Ver1.1(rev061214)USER'S Manual,2006
(2) Yasuyoshi. Umezu, Yuko. Watanabe, Ninshu. Ma: Development of JSTAMP-Works/NV and HYSTAMP for Multipurpose Multistage Sheet Metal Forming Simulation, 2005