Influence of forming processes on crash performance of vehicle body components

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Abstract. The production process of car structural components can affect their crashworthiness owing to the introduction of modifications in the material characteristics during the sheet metal forming process. The deep drawing and the subsequent operations induce material work hardening, sheet thickness variation and geometry variation. Such modifications are not uniformly distributed and may relevantly affect local features. As a consequence, the forming process of a component results to have an impact on the vehicle crashworthiness.

1 Introduction

The stricter regulations on emission and safety requirements are pushing the automotive industry to find innovative solutions to reduce vehicles weight and, in the meantime, increase occupant safety. The above mentioned effort is leading to a more extensive use of advanced high strength steels in new car models.

The manufacturing of most of the automotive body in white structural components is usually performed using deep drawing and forming processes. These cold forming processes introduce a modification of the physical properties of the material with respect to the nominal characteristics of the material.

Several studies show that the forming processes could cause a not negligible alteration of the crashworthiness of the component [1-5]. Indeed, several deviations from the characteristics of the raw material are observed after the production process [6-7]. The thickness reduction introduced by the forming processes is generally cause of a stiffness reduction of the component respect its nominal conditions. On the other side, material work hardening is responsible for an increase of the yield strength that leads to a stiffness increment. These effects are usually not constant along the part and can be locally important.

During the definition of production process of structural parts of car body in white, the influences of the production method on the crash behaviour of the component are often not considered.

On the other side, also numerical crash simulations performed during the development of a car model generally neglect the alterations introduced by forming processes. In some cases, these alterations are taken into account scaling the stress strain curve of the material. This last solution implies that such modifications are constant along the component and consequently lead to an inaccuracy of the simulation. This inaccuracy is always negligible and could lead to numerical simulation results not in accordance with the results obtained in a real crash test.

The effect assumes a major importance for components made in advanced high strength steel. In some cases, the real crash test presents a stiffer structural behaviour than the one showed in the simulation [8].

The hardening behaviour of advanced high strength steels causes a locally not irrelevant effect on the component strength. As a consequence, the inaccuracy of fem simulations is higher when these materials are used.

This work analyses the effect of cold forming production process on four (8 considering symmetry) structural components of a car in a crash test (figure 1). The four chosen components are one of the main load paths during the frontal crash. In detail the two components constituting the crash box and the two components constituting the lower front rail are analysed. These components are supposed to be made in Dual Phase Steel for the aim of the analysis. The forming process is simulated with the commercial code Autoform.

The frontal crash from Euroncap is the load case considered in this work to simulate the crash. The crash simulation is carried out with nominal material parameter and then repeated importing the results of forming simulations in order to take into account the material history. The crash simulations are performed using LS-Dyna code.

2 Production Process

The manufacturing process of a component can usually be performed using several methods. In this study, the components are supposed to be produced with a first drawing operation followed by a trimming operation and for some components additional forming operations to the final component shape.
2.1 Main alterations introduced by production process

2.1.1 Thickness Variation

The production process generally introduces a thickness variation on the components produced by cold forming. This variation is commonly not constant over the part and has a dependence from the material, the part geometry and the tooling. Depending on the material, local thickness reductions of 20-25% and local thickness increases of 5% are commonly accepted. Generally, the thickness reduction causes the crash simulation with nominal parameters to locally overestimate the stiffness of the part.

2.1.2 Yield strength variation

The plastic deformation of the material caused by forming and deep drawing processes causes a local variation of the yield strength. This is due to the strain hardening that is a phenomenon caused by the dislocation movements and dislocation generation within the crystal structure of the material during plastic deformation. A little strain variation can cause a great major work hardening variation in advanced high strength steels [9]. Consequently, the plastic strain distribution is usually not constant over the components and it is dependent on the part geometry, on the material and on the process tools. Thus, a different material behaviour in each local area of the component is to be observed.

3 Crash Simulation

The load case considered for the crash simulation is the Euro NCAP frontal crash. This test is performed simulating the impact between a vehicle travelling at 64 km/h and a deformable barrier having a 40% overlap (40% of the width of the widest part of the vehicle without including wing mirrors). A zero-degree impact must be insured. The analysed components have a primary importance in this load case because they constitute one of the three main load path that dissipate the energy during a frontal crash.

3.2 Result comparison

First, the frontal crash simulation is performed with the nominal parameter of the material in order to have a reference simulation to compare the results. The simulation is repeated importing the result of the stamping simulation for the four parts analysed (eight parts considering symmetry) in order to take into account the material history. The components shows in the two cases a different behaviour. The component collapse during the crash partially absorbs the energy of the crash, but in the case that takes into account the material history, the collapse is reduced as shown in figure 2.
correlated with some biomechanical damages to the occupant.

The two above mentioned nodes have a bigger intrusion when the material history is taken into account respect to the reference case, as it is possible to see in Figure 3. In the upper chart of figure 3, the evaluation point has an intrusion that is about 20 mm more than the reference case (20% difference), while in the second reference point in the lower chart the difference is about 10 mm (30% difference).

The difference observed could be ascribed to the bigger energy dissipated in the collapse of the analysed components in the reference case. Taking into account the material history, the components behaviour is stiffer and causes a bigger load transfer to the back components and thus a bigger intrusion in the firewall area.

4 Conclusions

The analysis of four structural car components has been performed in order to investigate the influence of the material alterations, induced by forming processes, on their crashworthiness.

The forming process results obtained from finite element simulation showed, as expected, a variation of the thickness and a material hardening not uniform along the parts. These results were imported to a full car model frontal crash (Euro NCAP) simulation. The crash simulation was compared to a reference one with the nominal material characteristics.

The comparison of the simulation results shows that the modification of material properties introduced by forming processes has a not negligible impact on the component behaviour during the crash test. This impact is not limited to the single components but could have an influence on the complete crash test results.

The investigation points out that the material alterations introduced during the production process should be taken into account in crash simulation in order to reach a higher simulation accuracy in the developing of automotive body in white structural components.

References

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