Estimation of Work Hardening in Bent Sheet Metal Products at an Early Stage of Virtual Product Development

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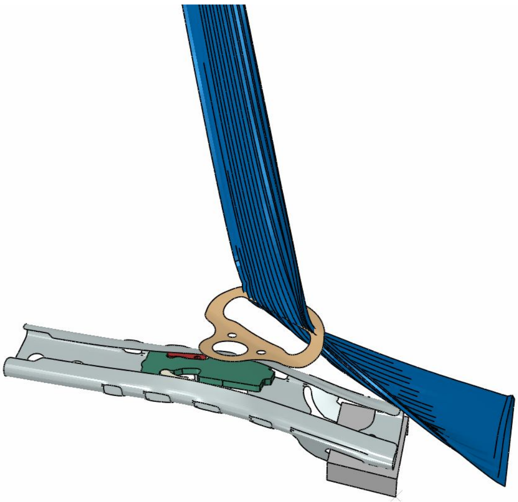
Abstract

The thesis has two aims: firstly, to investigate the influence of work hardening due to forming simulation on test simulation. The investigated question was also: Is it worth the effort to include work hardening effect into test simulation? The second aim was, to propose a quicker method to estimate work hardening without forming simulation. The first aim was investigated by two methods. In Method A, forming simulation was carried out on the steel blank sheet and followed by test simulation. In Method B, test was simulated by using just the CAD geometry of the same component with virgin properties. The 2D and 3D test simulation were performed and it was found that result of method A is about 30% higher than method B, which suggests that it is essential to include work hardening.
The problem is that at an early stage of product development the data of the forming process is not available. To solve this problem in the thesis an approach is proposed based on estimation of the hardening effect using analytical approach to calculate the strain just by geometrical parameters. This calculated so called postulated strain was then transferred to test simulation (Method C). The validation of results of test simulation with method C against ones obtained from Method A showed that they were almost identical. The results of the study showed that the proposed quick method to include forming history in test simulation can be used instead of very complex and time consuming FEM simulations of forming process.



Summary

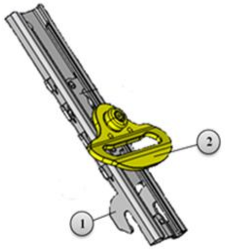
Nowadays, the demand of new products is growing every year as consumers are looking for more and more variety and attributes of products such as safety, reliability and maintainability. Therefore a quicker development process is essential [1].On the other hand, the foundation of the technical side of product development process is a new design [1]. The traditional method of design is based on the physical prototype development [2]. In this order to obtain a desirable design large numbers of physical prototypes are needed that makes this procedure expensive and time consuming. The virtual environment makes it possible to simulate, test and validate products digitally which reduces the need for physical prototypes [3]. It improves product innovation through the iterative design process and increase product quality using digital validation such as sheet metal production process.

Steel sheet metal has many applications and uses in many different industries such as the automotive industry. Sheet metal is formed into the desired shape during a forming process [4]. Both the forming process and the final shape of the product heavily influence on the performance of the products. For this reason the development of sheet metal products are particularly complex.

Autoliv is a worldwide leader in automotive safety which, develops, manufactures and markets several safety products [5]. One of these products is the seat belt system which includes many sheet metal parts such as height adjuster. This system plays an important role to save the life of car passengers in a crash situation. Therefore the performance of individual components has to be proved rigorously.

Height adjuster

The height adjuster is mounted on the door frame of the car. It includes a bracket (1) and a pillar loop (2) (Figure 2.1).



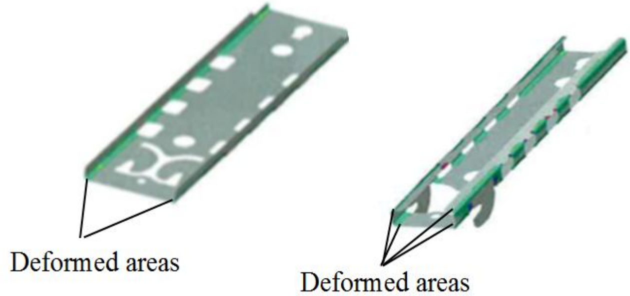


Figure 2.1 Seat belt height adjuster.

Figure 2.2 Bending process of height adjuster.

The bracket is constructed by bending a steel blank sheet twice. During the bending process some areas of the blank are plastically deformed (Figure 2.2); in other words, the blank deforms permanently. When the steel is strained beyond the yield point it becomes stiffer because of movements and dislocation generation within the crystal structure of the steel material. Therefore an increasing stress is required to produce additional plastic deformation that is called hardening[6-8].

Mechanical requirements of the height adjuster

Any new design of the bracket of the seatbelt system has to fulfill many requirements. To investigate these requirements before the phase of mass production, some prototypes of each design are produced. Therefore several different tests are carried out on the prototypes to evaluate some specified properties such as strength. It is essential that the height adjuster be able to withstand a large load without failing. It is tested by an Overload experiment. After mounting the adjuster bracket to a fixed base, the strength of this part is tested by pulling the pillar loop out of the adjuster bracket. Some other requirements for this part are also defined by customer or government standards. For example under a specified load, the deformation of the bracket has to remain under a certain limit that is carried out by a Displacement test. The hardening has the beneficial effect due to a forming process of the height adjuster that helps this part during tests to fulfill the requirements.

Simulating the HA bracket test

Nowadays, it is common to simulate the forming process of components by means of Finite Element software. The performance evaluation of parts is carried out by using test simulations in a virtual environment. In this order the test is simulated by using just the CAD geometry of the part. It is possible to simulate production process and testing sequentially as shown in Figure 2.3. In this case the test is simulated by using a model of part which includes hardening from the forming process simulation.

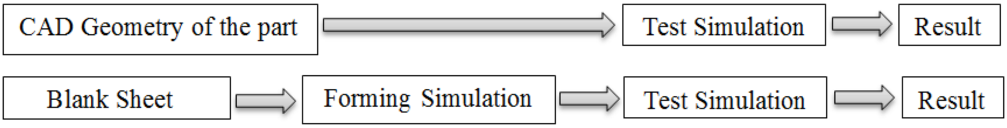


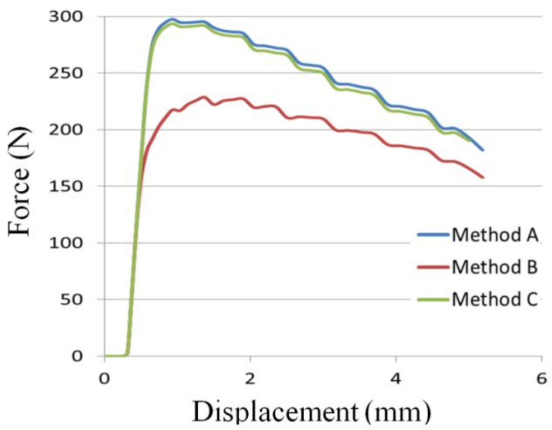
Figure 2.3 Two test simulation method.

In order to simulate forming process, the data of tools such as punches, blank holders and dies is needed. Generally, at an early stage of development, the information about the tools data is not available yet. By changing the design of the bracket, new dimensions of the tools and the blank sheet are used. Thus the forming simulation has to be done over and over. These changes in design make it necessary to adjust the process of the forming simulation again, which is very time consuming. At this point a question is raised: Is it worth the effort to include hardening effect due to forming process into test simulation? As the thesis question, this is answered by investigating the significance of the effect of hardening on the results of test simulation and comparing to the test results. However, there is a big issue in the industry to obtain the desired result with investing a minimum time. Therefore, a quicker method is required to include forming process effect in test simulation. For solving this problem the aim of current study is also to develop a quicker way that does not need tools data, forming process information and any additional simulation to compute the hardening of the forming process.

Conclusions

Sheet metal is commonly used in automotive industry. The performance of the components depends not only on a design but also on the forming process. During the forming process some areas of sheet metal become stiffer. It is called work hardening. This effect is taken into account by simulating the forming process and the result can be used as an input for the test simulation.

The first phase of the study confirmed clearly that it is essential to take the hardening due to forming process into account of test simulation to obtain a well match result of test simulation to the experimental test result.
At an early stage of the development, the forming tools and process data are not available. At this stage, the design is changed continuously and the forming process has to be adapted each time in the development process.
In the second phase of the current study, a quick method C was investigated, which does not need forming simulation and data about forming tools. This method estimates the hardening by means of an analytical equation, which calculates the plastic strain for a two dimensional pure bending process. This strain equation is based on geometric parameters and does not include material data at all. The resulting strain estimation was used as input for the test simulation. The results of method C closely match the results of test simulation with a product that includes the hardening due to forming process. Therefore, instead of forming simulation this method can be used to estimate the strain in bent areas of the steel. However, this method is limited to sheet metal products that are produced by two dimensional bending only (no unbending, no deep drawing).



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