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Investigation of Sheet Metal Behavior under Cyclic TCT Loading

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Abstract. Measurement of hardening under reversed uniaxial loading is because of its simplicity very effective mechanical test to achieve several important features of material behavior. In this paper is described special fixture which serves as a prevention of the sheet buckling during the cyclic tension-compression test. Result of the cyclic tension-compression test can consider several important features of the material behavior, which are necessary to be defined in the numerical simulation process. Experimental part of this paper consists of comparison results of strain path obtained from numerical simulation and real experiment. While in numerical simulation process was used material model describing isotropic hardening, real material behaved differently. Difference between strain paths also causes differences between results of springback values obtained in numerical simulation. New material models which include Bauschinger effect whether workhardening stagnation can diminish differences between results of an experiment and a numerical simulation and thus may also improve accuracy of the numerical simulation.

Introduction

Stamping process is the most commonly used manufacturing process to produce thin vehicle panels. The biggest challenge in a stamping process is to ensure satisfying design specifications without causing defect as splits, wrinkling, skid lines, surface distortions and springback issues [1]. There are different ways how to ensure mineralization of mentioned problematic issues. In the current time, there are several methods how to avoid problems in the manufacturing process. The most used tool is to use numerical simulation. Using numerical simulation is associated with the needs of implementation several factors, which are described by the Wagoner 2013 [2]. Wagoner et al defined following issues as key factors in the process of numerical simulation [2]: plastic constitutive equations, variable Young's modulus, through-thickness integration, describing magnesium steels. This article is devoted to the implementation of new plastic constitutive equations. Accurate springback prediction requires knowing the stress state through the body before unloading, which is controlled by the plastic response of the material during forming. Features of material model that can often be ignored in satisfactory forming simulations must be taken into account for springback simulations [2]. Among these features belong: Bauschinger effect, Hardening stagnation, permanent softening and early re-yielding in the compression phase. These features can be revealed performing cyclic tension-compression test. Not all of new material models describing this features, but material model Yoshida – Uemori [3] describes these features: kinematic hardening of the loading surface, combined isotropic-kinematic hardening for the bounding surface, Bauschinger transient similar to a general two surface models and work hardening stagnation at large plastic strain. First step in process of implementation these features is to perform cyclic tension compression test. In this process is necessary to develop special jig which prevent buckling of the sheet metal during compression cycle. Several jigs has been developed which are described in relevant articles [1, 4, 5, 6, 7]. This paper is focused to the development of the jig to the tension-compression test and subsequent verification of the results with results of numerical simulation using isotropic hardening.

Material and Methods

In this experiment was measured steel DP600 with 1 mm thickness. Mechanical properties of this steel are following: yield strength 383 MPa, ultimate tensile strength 620 MPa, material constant is 1008 MPa and strain hardening exponent is 0.179. Dimensions of testing sample are illustrated in the Fig. 1.

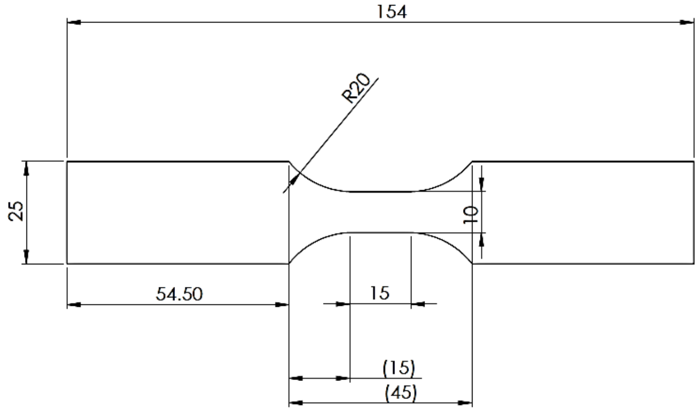

Fig. 1. Dimensions of testing sample.

First of all it was necessary, to investigate influence of friction conditions to the amount of force during process. Influence of the different friction conditions to the tension force, as the results of numerical simulation shown, is negligible. This investigation was performed in the simulation software PAM-STAMP 2G, using material model Hill 48 – Hollomon. Since experimentally was found that the blankholder force of size 8 kN was insufficient, force was increased to the value 15 kN. Final shape of the simple jig, necessary for this test is illustrated on the Fig. 2.

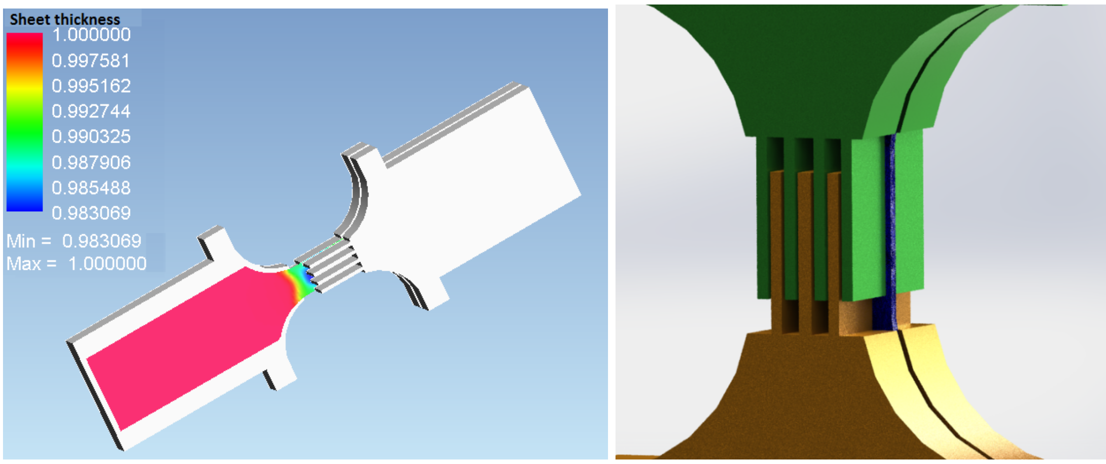

Fig. 2. Simulation of tensile-compression test in software PAM-STAMP 2G.

In Table 1 are described parameters, which were set in the process of numerical simulation. Numerical simulation was performed in the software PAM-STAMP 2G.

Table 1. Information about numerical simulation process.

Parameter	Value	Parameter	Value
Yield criterion	Hill' 48	Level of refinement	0
Hardening curve	Hollomon	Friction conditions	0.02/0.8
Mesh size	0.75 mm	Integration scheme	Explicit
No. of integration points	5	Software version	2012.2
Mesh type	Shell	Computation time	6 – 30 minutes
Mesh shape	Square	Solver	Single precision

In the next chapter, results of the tension-compression test for two pre strains level will be presented.

Results of Experiment

Stress-strain curve for the pre strain level of value 4 % is illustrated in the Fig. 3. Experimentally obtained curve of tension-compression test was obtained using specially developed fixture illustrated in the Fig. 2.

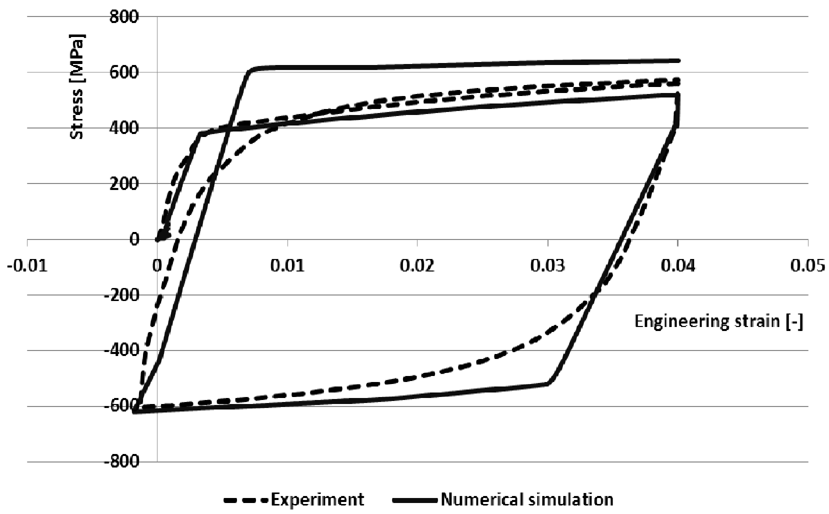

Fig. 3. Results for the experiment where pre strain was equal to 4 %.

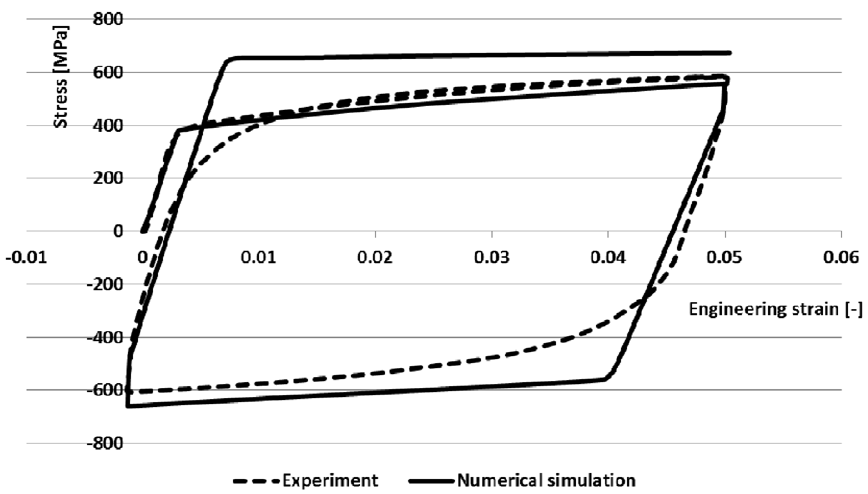

Fig. 4. Results for the experiment where pre strain was equal to 5 %.

From results shown in the Fig. 3 and Fig. 4 implies, that there are significant differences between stress strain curves obtained from numerical simulation and real experiment. These differences cause for example the difference between results of experimentally obtained values of springback in comparison with numerical simulation. Greatest difference is visible in the area of hardening in the compression phase, where material defined in numerical simulation behaves as an isotropic, while real material hardening behaved differently. Further area, where the results are significantly different is the area of the hardening after first cycle of tension and compression. Numerical simulation overestimated this result significantly, where for experimental measuring for second cycle (of 5 % pre strain) is stress in 1 % strain equal to the value 402 MPa and for experimentally obtained values it is value 654 MPa. From this implies that the difference between the stress state of real material and numerically investigated material is 61.5 %. These differences cause that the numerical simulation is less accurate in comparison with real experiment.

Conclusion

In this article was described simple fixture which serves as a prevention to the sheet strip buckling during cyclic tension-compression test. This mechanical test is necessary for describing several features, which are defined in the progressive material models of numerical simulation. If these features are not described in the material models, results of numerical simulation are not accurate enough. This is illustrated in the practical part of this paper, where real material behavior was compared with results of numerical simulation, defined using conventional isotropic hardening model. From this research implies, that it is necessary to implement new material models which describe Bauschinger effect, kinematic hardening, workhardening stagnation etc. and then use new material models as Yoshida – Uemori whether Chaboche material model as an input to the numerical simulation software.

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