Experimental report

23/05/2024

Proposal: **1-02-354** **Council:** 10/2022

Title: Influence of hot-stamping conditions on residual stress profiles in a coated press-hardened steel

Research area: Materials

This proposal is a new proposal

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Samples: Usibor steel

Instrument	Requested days	Allocated days	From	To
SALSA	5	5	16/06/2023	21/06/2023

Abstract:

Press-hardened steels, such as USIBOR© grades, have been increasingly developed in the last 10 years for their lightweight potential in automotive industry. They have an AluSi®150 coating to prevent from corrosion. During hot stamping, after austenitizing, a martensitic transformation occurs while the part is formed between dies. The simulation of such a process requires an extreme precision upon a wide range of physical topics, namely mechanics, thermic and metallurgy.A micromechanical modeling has been developed by the proposers and implemented in a fnite element simulation. The aim of this proposal is to validate the mechanical approach of the model by comparison of experimental and numerical residual stress profiles.

The presence of the coating and the complex geometry of hot-stamped parts is a real difficulty for lab X-ray diffraction ; using neutron diffraction is mandatory to overcome it. Residual stress profiles will be determined on diffrent hot-stamped parts with increasing geometry complexity and forming strain path.

Influence of hot-stamping conditions on residual stress profiles in a coated press-hardened steel:

Context

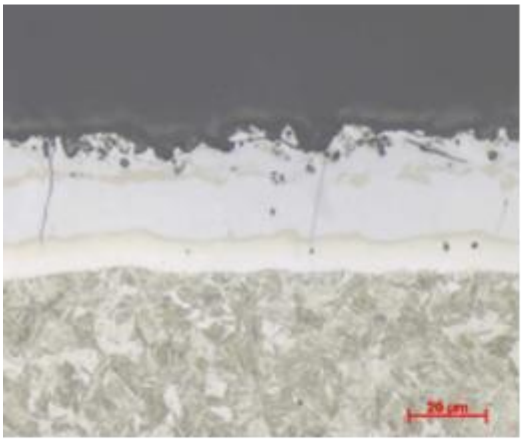

Figure 1: Alusi®150 microstructure and coating

Press-hardened steels, such as Usibor© grades, have been increasingly developed in the last 10 years for their lightweight potential in automotive industry [1]. They have an AluSi®150 coating to prevent corrosion. During hot stamping, after austenitizing, a martensitic transformation occurs while the part is formed between dies [2]. The simulation of such a process requires an extreme precision upon a wide range of physical topics, namely mechanics, thermic and metallurgy [2]. In the framework of Ph.D. work of X. Morel (2020-2023), a homogenized model has been developed and been implemented into a Finite Element Modeling software, namely Abaqus©, to better understand the coupling between the three phenomena. The aim of this experiment was to validate the mechanical approach of the model with a comparison of numerical and experimental residual stress profiles obtained by lab XRD and neutron diffraction. For this purpose, different parts have been made, with increasing geometry complexity:

1. A sheet cooled between flat dies without any forming (referred as flat quenched sheet in the following).
2. U-flanged parts.
3. V-bending parts with 2 different angles: 120 and 160°.
4. A more complex Ω-shape.

Sample preparation

Five samples have been prepared: 1 flat sheet, 1 U-bent, 2 V-bends with different angles, 1 omega-shape. Dimensions go from 150 mm by 100 mm to 200 mm by 350 mm; the sheet thickness remains to 1.5mm for all samples.

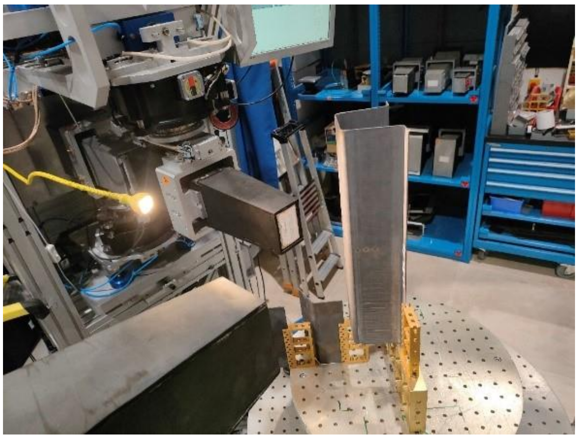

Figure 2: omega-shaped part into the SALSA beamline

Usibor® sheets are delivered in a ferritic-pearlitic microstructure already coated. During austenitising (5 minutes at 900°C), an intermetallic $Al_xSi_yFe_z$ layer appears. During hot stamping, after the part is formed in its austenitic structure, the material transforms into martensite. To avoid any stress relaxation, parts had to be considered full size. As a result, measurements have been performed on the SALSA beamline; its large working environment combined with the angular flexibility of the hexapod are of great interest regarding size and shape of hot stamped parts (figure 2).
It is especially well suited for measurements in thin materials because of low pseudo peak shifts. As the material is martensitic, the grain size doesn't disturb the acquisition and the crystallographic texture is rather anisotropic.

Measurements performed

As the elapsed time for each acquisition was greater than forecasted, only two samples could be analysed: the omega-shaped and the 160° V-bending. Figure 3 shows the acquisitions points with the three directions corresponding to the full stress tensor (local frame adapted to each acquisition point).

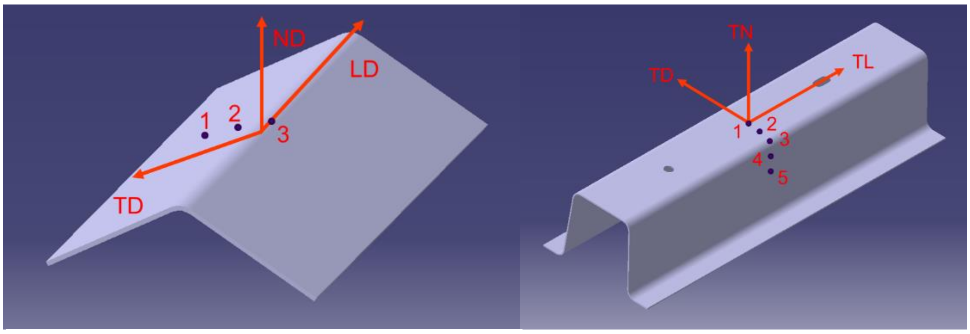

Figure 3.a: V-bend *Figure 3.b: omega-shaped part*

For each of the points depicted of figure 3, an in-depth measurement has been performed. The gauge volume has been progressively moved from the outer side of each part towards the inner side. In order to capture near-surface values, the gauge volume was partly directed outside of the sample, resulting in longer acquisition time. Figure 4 presents the centre of the gauge volume and elapsed time for each point.

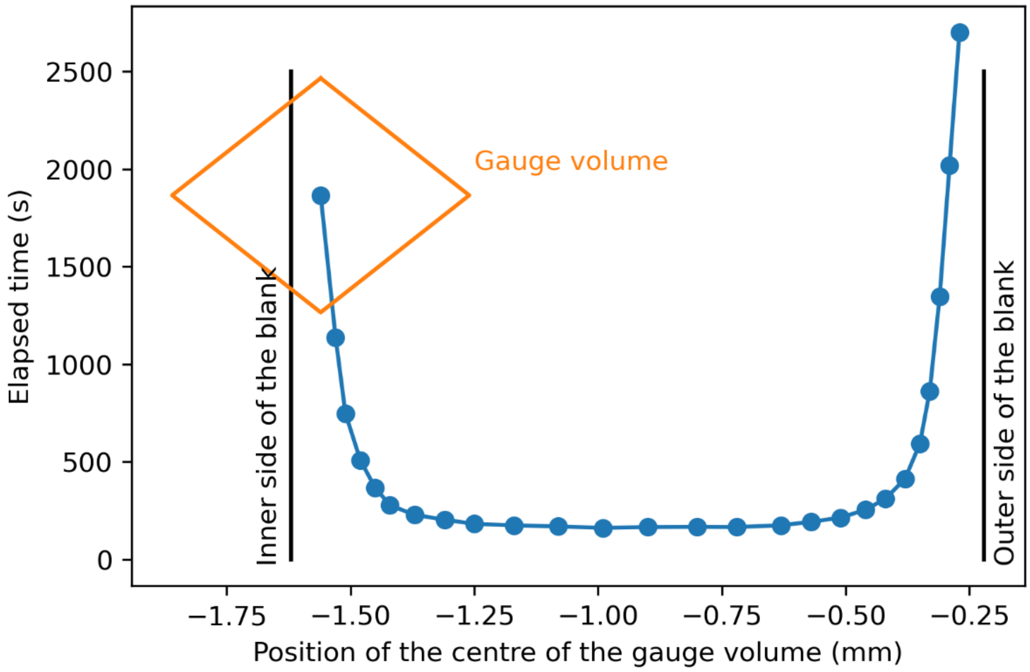

Figure 4: acquisition time and gauge volume centre positions for the 1st point of the omega-shaped part

Post-processing

The long acquisition time of the near-surface points resulted into less measurements than expected in the initial proposal. From raw data, a peak-fitting process has been performed to determine peak positions and estimate an offset regarding a zero-stress reference. Besides, a pseudo-strain correction was mandatory to account for the smaller effective gauge volume for the near-surface datapoints. These corrections have been computed by the local contact but not yet applied to all measurements.

Points n°1 of both V-bending and omega-shaped part have been post-processed and show a global strain about 1%, which fit with previously computed finite-element simulations [4]. The rest of the data is to be analysed in the upcoming months.

References

[1] K. Mori, P. Bariani, B. Behrens, A. Brosius, S. Bruschi, T. Maeno, M. Merklein et Y. J., «Hot stamping of ultra-high strength steel parts,» CIRP Annals, vol. 66, n° %12, pp. 755-777, 2017.

[2] H. Karbasian et A. Tekkaya, «A review on hot stamping,» Journal of Materials Processing Technology, vol. 210, n° %115, pp. 2103-2118, 2010.

[3] X. Morel, S. Berveiller, D. Bouscaud, M. Martiny, B. Sarre, A. Blaise, T. Sturel. "A micromechanical model for the austenite-martensite transformation in hot stamping of automotive steel sheets". 11th European Solid Mechanics Conference, 4 - 8 July 2022, Galway, Ireland

[4] X. Morel, « Etude expérimentale et numérique de l'emboutissage à chaud des aciers Usibor®1500 et Usibor®2000 », Ph.D of HESAM University, 2023.