INFLUENCE OF MATERIAL PROPERTY COMBINATION AND ITS COMPENSATION DURING DEEP DRAWING OF TAILOR-WELDED BLANKS

Činák, Michal; Gajdošová, Veronika, Schrek, Alexander

Institute of Technologies and Materials, Námestie slobody 17, 812 31 Bratislava 1
michal.cinak@stuba.sk, veronika.gajdosova@stuba.sk, alexander.schrek@stuba.sk

Keywords: deep drawing, tailor-welded blank (TWB), simulation, elastic blankholder, anisotropy

Abstract Application of TWB is proved to be very effective in the current trend of body parts construction. However, their formability can be limited in some ways. One of the negative phenomena in the forming process is instability of the weld interface position on the blank, which reflects the uneven plastic flow of materials of different mechanical properties. Simulations carried out in LS-Dyna software and real deep drawing experiments of rectangular parts have been made to study this phenomenon on ÚTM STU in Bratislava. Blanks have been welded of high strength (HCT600X) and conventional deep-drawing steel (DC01) of the same thickness. The aim of the study has been to verify the effect of non-uniform blankholder force distribution on the weld interface movement and to determine the conditions in which this movement will be eliminated. For this purpose, the special drawing tool equipped with the elastic blankholder system controlling blankholder force distribution on the blank flange has been used.

1 INTRODUCTION

TWBs have been successfully used in automotive industry since the 80s of 20th century. They are made by welding together flat steel sheets of different thicknesses, grades and coatings, providing the "best material in the right place in the right thickness" without post-joining operations or sheet overlap [1]. This enables them to fulfill contending claims of the current trend – to reduce weight, increase stiffness, impact resistance and to improve safety of the car body. These blanks can be drawn into the final body part design only in one step, which brings advantage of decreasing production costs but also disadvantage of decreasing formability [2].

This paper is focused on different mechanical properties of high strength (HCT600X) and conventional deep-drawing steel (DC01) and their influence on the drawing process of TWB. The simulation and experimental deep drawing process of rectangular part is focused on examination non-uniform blankholder forces distribution and its influence on weld interface movement.

2 DETERMINATION OF MECHANICAL PROPERTIES

Determination of accurate mechanical properties of HCT600X and DC01 (Tab.1) is especially important for material model definition necessary for high simulation process accuracy. The basic mechanical properties have been examined by the static tensile test (Tab.2). The flow curves have been calculated based on the tensile test data of specimens removed in 0°, 45° and 90°
direction considering to the rolling direction and transposed by regress analyse into the functions (Fig.1) [3].

**Table 1: Chemical composition of the tested steels [4]**

| Chemical composition                        | 0.17% C; 0.8% Si; 2.2% Mn; 0.08% P; 0.015% S; 2.0% Al; 1.0% Cr+Mo; 0.15% Nb+Ti; 0.2%V; 0.005% B |
|-------------------------------------------|------------------------------------------------------------------------------------------|
| HCT600X                                   |                                                                                           |
| DC01                                      |                                                                                           |
| 0.17% C; 0.6% Mn; 0.045% P; 0.045% S; 0.1% Si                                      |

**Table 2: Measured mechanical properties**

|        | $R_{p0.2}$ [Mpa] | $R_m$ [MPa] | $A$ [%] |
|--------|------------------|-------------|---------|
| HCT600X| 406.8            | 651.8       | 27.8    |
| DC01   | 281.8            | 359.4       | 34.9    |

**Figure 1: Flow curves of materials HCT600X and DC01**

The Lankford parameters – coefficients of normal anisotropy have been examined based on the deformation image of deformation pattern on the specimens (Fig.2).
3 SIMULATION

The weld interface movement of the blank have been firstly observed by deep drawing simulation of the rectangular part from the blank with longitudinal weld interface (Fig.3). Universal FEM software LS-Dyna has been used.

![Figure 3: Deep drawing process simulation of rectangular part](image)

Simulation series have been performed with uniform and non-uniform force distribution acted on the blankholder (Fig.4). The ideal rigid blankholder model has been changed to elastic due to the ability of transferring the blankholder forces. The friction coefficient on the both sides of the blank has been set to 0.12 in the contact definition.

![Figure 4: Pressure distribution during uniform blankholder force distribution (left) and non-uniform force distribution (right)](image)

Blankholder forces act on the blankholder by four pressure pins, whose position along the blankholder circumference can be seen in Fig. 4 by the red color area with higher contact pressure. The blankholder force value of uniform pressure distribution transferred by one pressure pin has been set to 17kN (UNI mode). Influence of different mechanical properties of TWB materials results in uneven material flow followed by intensive weld interface movement towards HCT600X material. Subsequently, simulation series of non-uniform pressure distribution have been performed (NON mode). In each subsequent simulation the blankholder force value on the side of
DC01 material (pictured in yellow colour in the Fig. 4) has been increased with the aim of zero weld interface movement on the part bottom (Fig.5) [5].

Figure 5: Nodal displacements on weld interface during different settings of force distribution

4 DEEP DRAWING PROCESS EXPERIMENT

According to the simulation results, experiments have been performed using tool with elastic blankholder and pressure pins transferring blankholder forces from the draw cushion onto the blankholder. Four pressure pins are equipped with piezoelectric load cells enabling accurate optioning of simulated blankholder forces. Simulated contact conditions have been kept by constant parameters of deformation pattern etching process and constant Wedolit N22-3N lubrication layer on the blankholder and die surface. First experiment series have been performed in simulated UNI mode with blankholder forces set to 17kN observing the most intensive weld interface movement. Second experiment series have been performed in NON mode with three blankholder forces set to 17kN and one to 32kN acted on the side of DC01 material, because of simulated elimination of weld interface movement [6].
Figure 6: Tailored blank laying on the blankholder and the system of pressure pins equipped with load cells.

5 WELD INTERFACE MOVEMENT

All drawn parts (drawn in UNI and NON modes) have been measured by the photogrammetric method. The measured weld interface movements have been compared to the simulated nodal point displacements. The character of weld interface movement has not been the same along the entire length – the movement on the wall has been opposite to the movement on the part bottom (Fig. 7).

Figure 7: Weld interface movement on the wall of drawn part. Photography superposed by simulation mesh (left). Weld interface movement in a) UNI mode, b) NON mode.

The weld interface movement in UNI mode measured on the part bottom has been greater than simulated one of approx. 0.3 mm. The weld interface movement measurement on the part drawn in NON mode has confirmed successful movement elimination. The both measured and simulated movements in NON mode have been negligible (Fig. 8).

Figure 8: Comparison of measured and simulated (sim) weld interface movement on the bottom of the drawn part.

The accuracy of the weld interface movement measurement on the part bottom has been limited by their small values and accuracy of the drawn part shape. Described influence of the different mechanical properties of TWB materials has been compared to the different thickness
influence. Simulations have shown that 20% difference in the thickness values results in two or three times greater weld interface movement. Fig. 9 shows simulated movement values for the both types of weld interface position – the longitudinal and transversal.

![Image: Figure 9: Comparison of weld interface movement of TWB with combination of thicknesses (left) and blanks with combination of materials (right)]

6 STRAIN MEASUREMENT

The simulation reliability has been experimentally verified also by means of strain measurement. Major and minor strains ($\phi_1$, $\phi_2$) have been measured by photogrammetric method of photographing the deformation pattern consisting of circles. Fig. 10 shows conformity between simulated and measured strains. Strains have been measured in the corners and on the bottom of the drawn part.

![Image: Figure 10: Measured (solid line) and simulated strains (dashed) in the corners and on the bottom of the drawn part.]

CONCLUSION

Simulation software explicit FEM code LS-Dyna has enabled modelling of the conditions of the complicated deep drawing process of TWB in the tool with the elastic blankholder. The parameters influence (especially the blankholder force distribution) on the weld interface movement has been reliably predicted. Comparison of the simulated and experimental results confirms the accuracy of non-uniform blankholder force distribution, which has eliminated the weld interface movement. According to the presented results it can be claimed:
1. Weld interface movement on the examined TWB is result of different plastic properties of the materials that TWB consists of.

2. The blankholder force value and distribution acted on the elastic blankholder has a significant influence on the deep drawing process of TWB. So use of rigid material model instead of elastic one for the blankholder can be much distorted.

3. FEM simulation method is very reliable in prediction of TWB formability and factors observing in deep drawing process under the condition of exactly defined initial and boundary conditions of the process.

This paper has been supported by R&D project VEGA 1/0149/13 Laser welding of high-strength steel blanks for parts in automotive industry.

REFERENCES

[1] http://www.arcelormittal.com/automotive/saturnus/sheets/catalogue.pl?id_sheet=S3&language=EN

[2] GEIGER, M., HOFFMANN, P., HUTFLESS, J. Laser technology in synergy with forming technology. Blech Rohre Profile, 4 (40) 1993, s. 324-330

[3] MONACO, A., SINKE, J., BENEDICTUS, R. Experimental and numerical analysis of a beam made of adhesively bonded tailor-made blanks. International Journal of Advanced Manufacturing Technology, (44) 2009, s. 766

[4] REISGEN, U., SCHLESER, M., MOKROV, O., AHMEDN, E. Statistical modelling of laser welding of DP / TRIP steel sheets. Optics & Laser Technology, (44) 2012, s. 92-101

[5] ČINÁK, M., KOSTKA, P., SCHREK, A.: Ťahanie zváraných polotovarov s nerovnomernými mechanickými vlastnosťami (Deep-drawing of Tailored-welded Blanks with Uneven Mechanical Properties). Hutnické listy č.4/2013, roč. LXVI, ISSN 0018-8069, s.22-25.

[6] SCHREK, A., ČINÁK, M., ŽITŇANSKÝ, P.: Experimental laboratory tooling for deep drawing process. In Vol. 19/2011. s. 57--64.