FORMING AND DEFORMATION PROPERTIES OF DRAWN PART B-PILLAR REINFORCEMENT FROM SIMPLE BLANK AND ALTERNATIVELY TAILOR-WELDED BLANK

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Abstract

The forming properties and simulated side impact crash tests of two types of B-pillar reinforcements were analysed. The first B-pillar was drawn from simple blank made of dual phase steel DP600 with thickness of 1.2 mm. The second one was drawn from tailor-welded blank consisting of two dual phase steels DP600 and DP980 with thickness of 1.0 mm. The wall thicknesses in exposed areas of drawn parts were calculated. Both types of B-pillar reinforcements could by drawn without the cracks creation during the drawing process after optimization of blank holder forces. The simulated side impact crash tests showed similar reaction and deformation force values for both drawn parts and confirmed the same safety of B-pillar reinforcements made of tailor-welded blank as for the one made of simple blank.

Keywords: Tailor-welded blank, dual phase steel, simulation, deformation force, reaction force

1. INTRODUCTION

Tailor-welded blanks (TWBs) made of advanced high strength steels such as dual phase (DP) steels, complex phase steels, TRIP steel, etc. have been widely used for forming of drawn parts with extraordinary properties in car body structures. TWBs are semi-finished parts that consist of two or more single sheets that are welded together prior the forming process. The sheets can exhibit different mechanical properties, thickness or coatings [1 - 4]. Using of DP steels in TWB design enables to achieve the different stress-strain characteristic in particular areas of the drawn part and to satisfy the safety requirements of the part. Frames, cross beams, vertical beams, side impact beams, and safety elements are often made of DP steels [5 - 7]. The excellent mechanical properties of DP steels are the consequence of their multiphase structure. Microstructure of DP steel consists of ferrite and martensite with different portion of these phases. The increase of martensite portion from 10 to 50 % is accompanied by the increase of tensile strength approximately from 500 to 1200 MPa but the decrease of ductility from 27 to 10 %. The variations in mechanical properties of DP steels enables an adaptation to locally different loading conditions in the drawn part at the same thickness of welded DP steels. This can lead to the essential weight reduction compared to conventional structural components drawn from simple blanks [8 - 11].

2. EXPERIMENT

The experiments were concentrated on the analysis of B-pillar reinforcements made of two types of blanks during their drawing processes and side impact crash tests. The geometries of both blanks were designed in Dynaform software and are documented in **Figure 1**. The first type of B-pillar reinforcement was deep drawn of simple blank (SB) made of DP600 steel with thickness of 1.2 mm (on the left in **Table 1**). In the second B-pillar reinforcement the thickness was reduced to the value of 1.0 mm (on the right in **Table 1**) with the aim to achieve 20 % weight reduction of the part. To fulfil the same strength and stiffness requirement, the second B-pillar reinforcement was made of TWB which consisted of two DP steels DP600 and DP980 with different mechanical properties. The comparison of chemical compositions and mechanical properties of experimental DP steels is given in **Table 1** and **2**. Used DP steels differ in contents of carbon and manganese, but the maximal content of other elements is the same (**Table 1**). The DP980 grade DP steel has higher amount of these elements which is the consequence of higher portion of martensite in its microstructure and higher strength but lower plasticity in comparison with DP600 grade DP steel (**Table 2**).

Table 1 Maximal concentration of elements in DP steels (wt. %)

Steel	C	Si	Mn	P	S	Al	V	B	Cr + Mo	Nb + Ti
DP600	0.17	0.8	2.2	0.08	0.015	2.0	0.2	0.005	1.0	0.15
DP980	0.23	0.8	2.5	0.08	0.015	2.0	0.2	0.005	1.0	0.15

Table 2 Mechanical properties of DP steels

Steel	Tensile strength (MPa)	Proof strength (MPa)	Elongation (%)
DP600	min. 600	340 - 420	min. 20
DP980	min. 980	600 - 750	min. 10

In TWBs the DP600 steel was used in outer boundaries and DP980 in the middle of the part, as can be seen in **Figure 1**. The location of the weld line was designed according to the simulation of drawing process. The location of exposed area with maximal wall reduction and the highest bending stress at the crash tests were also taken into considerations at designing of the TWBs.

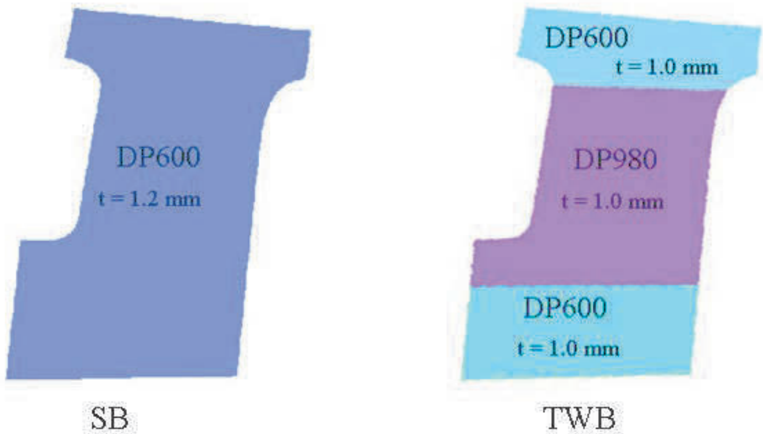


Figure 1 Geometry of SB (left) and TWB (right) used for drawing process

The CAD tool model for deep drawing simulations was designed using Dynaform software and is shown in **Figure 2**. It consists of drawing punch, blank, blank holder and drawing die and it created the base for simulations of forming process.

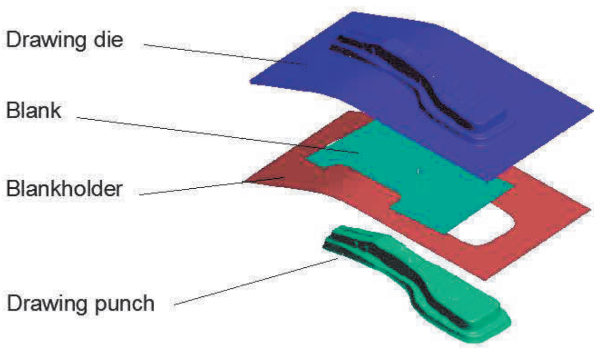


Figure 2 CAD tool model used for simulation of drawing process

To obtain the stress-strain properties for simulation of forming properties of drawn parts, the tensile tests of DP600 and DP900 steel as well as the tensile tests of fibre laser welded joints of these two steel sheets were performed. The sample consisting of DP600 and DP980 steel after the tensile test is in **Figure 3**. The tensile tests of all samples confirmed that all laser welded joints achieved the strength of DP600 steel, because all samples broke outside the weld region in DP600 steel base material.

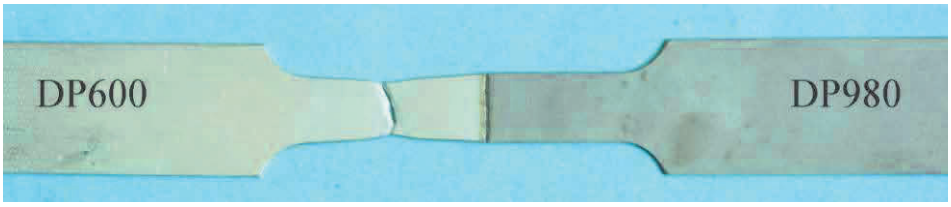
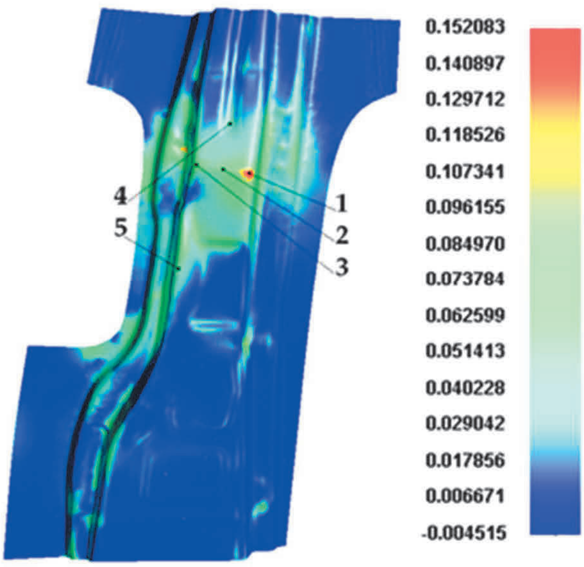


Figure 3 Tensile sample consisting of DP600 and DP980 steel after the tensile test

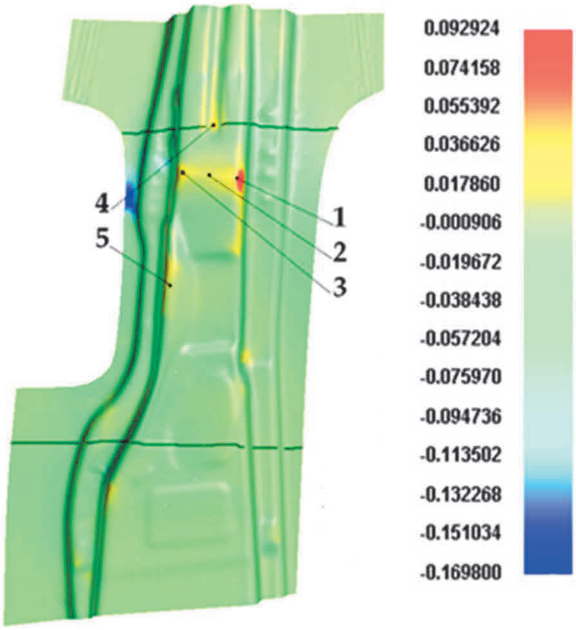


Wall thickness t	
No.	t (mm)
1	1.0121
2	1.1523
3	1.1365
4	1.1625
5	1.1521

Figure 4 Simulation of drawing of B-pillar reinforcement from simple blank (SB): true strain distribution (see the figure) and wall thicknesses in exposed areas (see the adjacent table)

The results of drawing simulation of B-pillar reinforcement drawn from SB with concentration of true strains distribution is presented in **Figure 4**. The figure shows the positions of five maximal true strain values which are marked by lines in this figure. They are concentrated in exposed area of possible cracks propagations. The true strain values were used for calculations of the final wall thicknesses and these are given in adjacent table. The highest reduction of wall thickness calculated according to the final wall thickness of 1.0121 mm reached the value about 0.2 mm and is in the true strain position No. 1 in **Figure 4**. The negative true strain values in this figure present wall thickness increase. The maximal drawing force reached 918.8 kN and the optimised blankholder force was 250 kN during the simulation of the drawing process.

The results of drawing simulation of B-pillar reinforcement from TWB is in **Figure 5**. The positions of true strains in exposed area used for calculations of the wall thickness and maximal wall reductions can be seen in **Figure 5**. The highest reduction of wall thickness was about 0.12 mm (wall thickness of 0.8821 mm) in the position No. 1 in **Figure 5.** In spite of this reduction the cracks propagations weren't observed during the simulation of drawing process. The maximal drawing force reached 1036.5 kN and the blankholder force was 180 kN during the simulation of the process. The wall thickness reduction was smaller, but the drawing force was higher in comparison with SB drawing experiment.

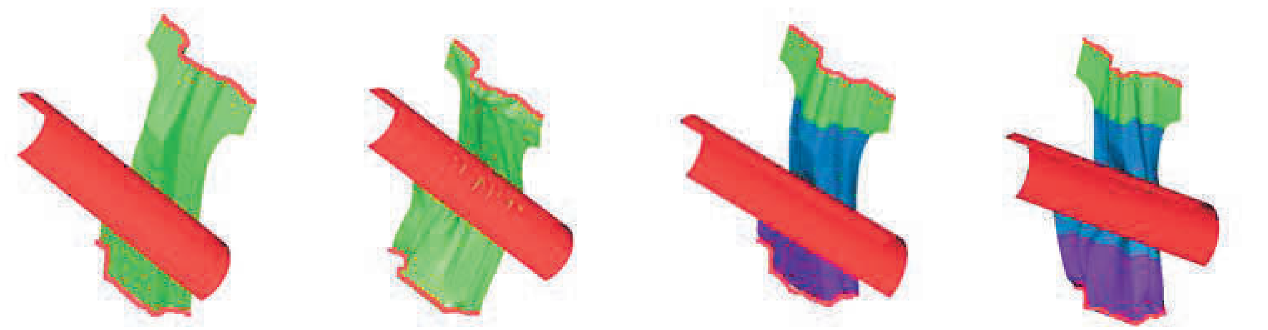


Wall thickness t	
No.	t (mm)
1	0.8821
2	0.9023
3	0.8965
4	0.9085
5	0.8971

Figure 5 Simulation of drawing of B-pillar reinforcement from TWB: true strain distribution (see the figure) and wall thicknesses in exposed areas (see the adjacent table)

3. SIDE IMPACT CRASH TEST SIMULATION OF DRAWN PARTS

To analyse the deformation of B-pillar reinforcement made of both SB and TWB the side impact crash tests of a car were simulated in Dynaform software. The position of B-pillar reinforcement was defined with anchoring at upper and lower edge of B-pillar marked by red colour in **Figure 5**.



SB at the time of 0,002 s | SB at the time of 0,020 s | TWB at the time of 0,002 s | TWB at the time of 0,020 s

Figure 6 The deformations during the side impact crash test simulation of drawn parts made of SB and TWB at chosen time intervals

The modelled velocity of deformation solid at crash tests was always 27 km.h^{-1}. The deformations of both drawn parts at the same time intervals 0.002 and 0.020 s are presented in this figure. The values of reaction forces in anchored places were evaluated during the tests. The maximal value of reaction force in case of SB made of DP600 steel was 62.8 kN. The maximal value of reaction force in case of TWB made of DP600 and DP980 steel was 61.5 kN. The progress of reaction forces in the same time intervals for both types of blanks are compared in **Figure 7** and their differences are shown in **Figure 8**. The progresses of both reaction forces were almost the same at identical conditions such as velocity, geometry, and stiffness of deformation solid. The maximal differences in reaction forces were below 5.2 kN. According to these results, stiffness and strength of both types of drawn parts are comparable.

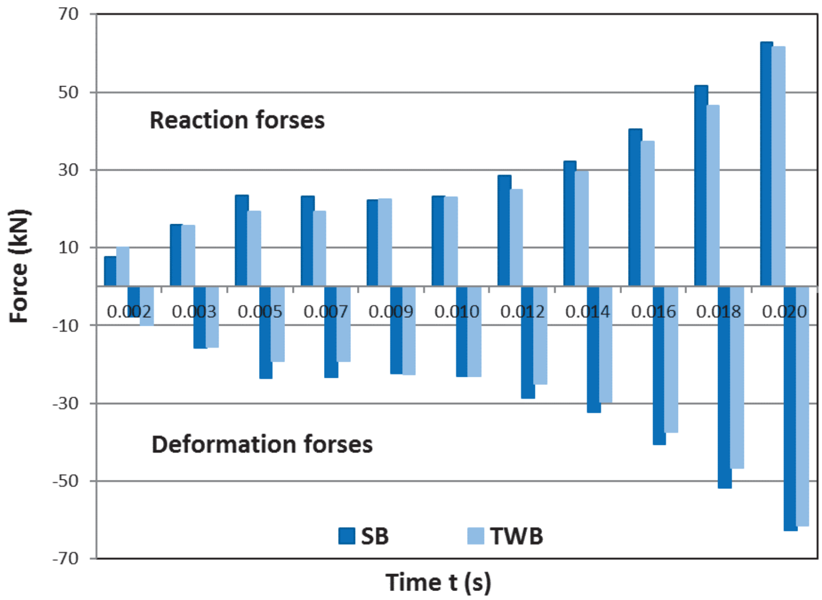


Figure 7 Progress of reaction and deformation forces during the side impact crash test simulation of drawn parts made of SB and TWB

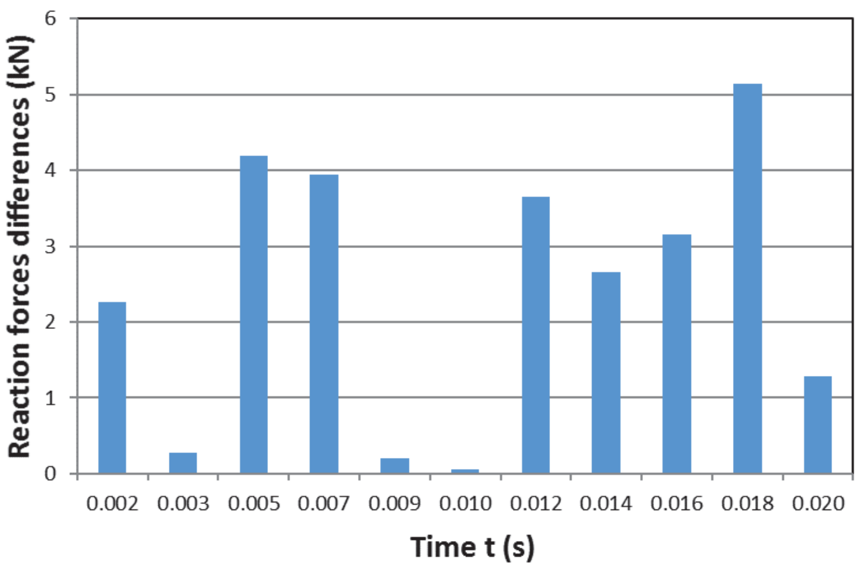


Figure 8 Differences between the reaction forces on drawn parts made of SB and TWB

4. CONCLUSIONS

The analysis of the formability of both simple blank made of DP600 steel and TWBs consisted of DP600 and DP980 steel was made using Dynaform software. The analysis showed the possibility to produce the B-pillar reinforcement from TWBs with reduced thickness, higher strength and lower formability after the optimising of blankholder forces. Although the drawing of TWB was joined with the reduction of wall thickness, the simulation of drawing process didn't show the cracks propagation in the drawn part.

The deformation properties of drawn parts simulated using side impact crash tests showed comparable properties of drawn parts made of simple blank and TWB when using DP980 steel in the area of highest bending moment and decreasing of TWB thickness. The values of reaction forces in anchored places of drawn parts reached only small difference between both types of drawn parts. The simulation confirmed the application of dual phase steels and TWBs for weight reduction of car supporting structures and satisfying of strength and stiffness properties of drawn parts.

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