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THE INFLUENCE OF THE PART GEOMETRY ON THE WELDING LINE DISPLACEMENT IN CASE OF TAILOR WELDED BLANKS

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ABSTRACT

The present work deals with numerical simulation related to formability of three parts having different geometry, as fallows: square shape, cylindrical shape and semispherical shape. The parts are made from tailor welded blanks, having the welding line as symmetry axis. During the forming process, due to different base materials of the tailor welded blanks, the welding line modifies its initial position.
The current paper is trying to prove out the important role of the final geometry shape on the welding line displacement during the forming process. The Dynaform 5.6 software is used to simulate the forming process. The part obtained after each simulation is analyzed and measured to quantify the displacement of the welding line.

KEYWORDS: forming, TWB's, welding line displacement.

1. INTRODUCTION

In recent times, the auto industries have been trying to build up various types of model and high-quality low-cost cars to meet the customer's requirements and to find new ways establishing this aim effectively [1]. To attain those objectives, the car makers must decrease the car body weight without reducing the structural integrity of the final product.

A solution to the previous mentioned demands have been given by the sheet metal scrap collectors. Using the welding process to unify the smaller parts they have realise the grate benefit of the tailored welded blanks. Tailor welded blanks (TWBs) consists of two or more sheets that have been welded together in a single plane prior to forming [2].

This type of blanks has several advantages in the manufacture of automobiles, namely a low cost, reduction of car weight, and flexibility in mass production. Especially, in the laser welding process, since high strength and hardness of the welded zone and a narrow welded bead could be ensured, it is possible to manufacture superior parts. Therefore, TWBs are applied not only to simple cup deep drawing parts, but also to very complicated automobile white bodies [3-7]. The applications have spread over a wide range of press work.

Any product that requires a change in material properties within a metal sheet component can be improved by use of tailor welded blanks. The white good industry could benefit from the advantages of TWBs. For instance, in the manufacture of washing machines where steel with thicker galvanized coating could be use on the vulnerable areas (surround doors, seals, draws) and normal treated steel for the rest of the body. The manufacture of a garage door is an example from construction industry. The door could be made from strength steel on the brackets area, from steel with thicker galvanized coating in the bottom area and from normal treated steel on the rest [10].

Many studies present a wide range of information about the formability and failure patterns of TWBs. However, description of the welding line displacement is hardly to be found. Published results on welding line movement refer to one certain part shape. The final part geometry has great influence on the amplitude of the welding line movement. Another parameter that must be considered is the blankholder force.

A very important concern in TWBs is weld line movement. Whether produced with different types of materials or the same material having different thickness, the stronger material in the TWB will resist deformation more than the weaker material, causing a welding line displacement in to the stamped part. This effect limits the ability of the designer to position the specific material properties in the final stamping where desired and may create other forming problems such as wrinkling, tearing, and uncontrollable springback [8].

The welding line movement can be controlled using new stamping methods. One method is to divide the blank holder into two with respect to the side with the thicker, stronger material and the side with the thinner, weaker material. In this way is possible to vary the blank holder force applied to the two different material gauges. The thicker material was subjected to a lower blank holder force, thus allowing more material to flow into the die cavity. This process modification was successful at reducing the weld line movement and delaying tearing failure along the weld line compared to the case where a uniform binder force was applied to the TWB [9].

In the presented study, tailored welded blanks made by the laser welding process with two different steel types, having the same thickness combinations were used in the deep drawing process. Major objectives are focused on finding the weld line movement of the specimen in case of three different final part shapes. To establish this goal, simulations have been carried out using Dynaform 5.6 software. The obtained results for those three shapes were compared to realise the behaviour of the TWBs in the deep drawing process.

2. MATERIAL PROPERTIES

Simulation of the forming processes based on finite element method using Dynaform 5.6 software requires as input data the mechanical properties of the used materials. Determination accuracy of the mechanical properties has an important influence on simulation results.

To obtain the mechanical properties of the base materials and of the welding line, tensile tests were performed on a universal mechanical testing machine, equipped with Hottinger force cells of 5 tf and a Hottinger – Baldwin electronic measurement system for PCs – type Spider 8. The data acquisition, processing and visualisation were performed using Catman Express software. The measurement of specific strains for determination of stress - strain curves was performed using an Epsilon extensometer for a strain rate of 0.1 s^{-1}.

The specimens were cut as a function of the rolling direction being achieved sets of specimens corresponding to the direction of 0º and were worked by milling and grinding in order to obtain the prescribed dimensions. The reference length of the specimen was equal to 50 mm. To obtain a good accuracy of the results, 3 specimens were tested for each determination.

To determine the mechanical properties of the welding line, from the original TWB, a 4 mm wide stripe which includes the welding line, has been removed using EDM wire cutting (Fig. 1).

Fig. 1. Sample used to determine the mechanical properties of the welding line

The flow stress and true total strain were calculated for each recorded couple of the force and displacement. The total strain was decomposed on elastic strain and plastic strain using determined Young module.

To obtain a better accuracy of FEM modelling, especially in the range of small deformation, there was resigned the functional stress – strain curves in favour of the stress – strain curves in the numerical form.

The mechanical properties of FEPO steel and E220 steel determined for 0º material rolling direction are presented in Table 1. In the table below are presented also, the mechanical properties of the welding line. In Fig. 2 are presented the stress – strain curves for FEPO ans E220 steels and for the welding line material.

Table 1. Mechanical properties

Property	FEPO	E220	weld
Yield strength $\mathbf{R_{p0,2}}$ [MPa]	203	268	252
Tensile strength **Rm** [MPa]	381	458	417
Percentage elongation after fracture $\mathbf{A_{80}}$ [%]	–	35,3	–
Elongation for max. load $\mathbf{A_{gt}}$ [%]	31,8	20,4	17,3
Strain-hardening coefficient **n**	0,222	0,190	-
Plastic strain ratio **r**	1,860	1,420	1,29
Poisson's ratio **ν**	0,286	0,297	0,278
Young modulus **E** [MPa]	200825	204271	203253

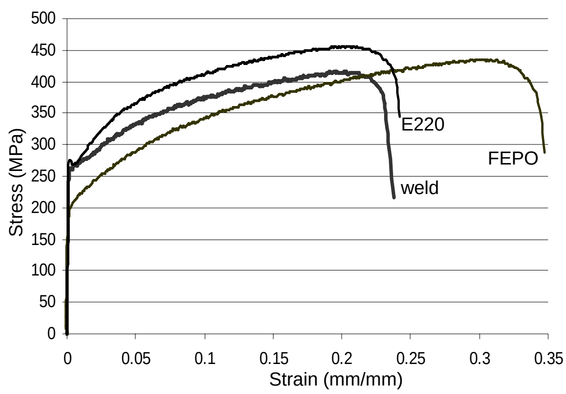
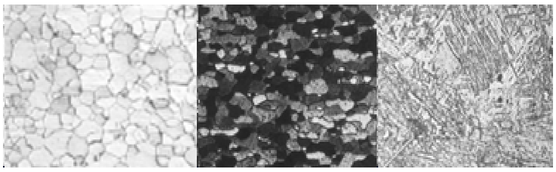


Fig. 2. Stress – strain curves for 0º

The materials microstructure has been analysed using a metallographic microscope with a magnification of 100X for base materials and 500X for welding line. The materials have uniform, typical microstructure with fine grain. The microstructure is shown in Fig. 3.



E220 FEPO weld

Fig. 3. The material microstructure

3. SIMULATION CONDITION

The simulations were made for three different shapes, one square, one cylindrical, and one spherical geometry that have been called square, cylinder and sphere respectively. The size of the sheet metal employed was 200x200 mm for the formability of the three shapes, with a punch of 100x100 mm for the square, a radius of 50 mm for the cylinder and, a radius of 50 mm for the sphere. The draw die radius was 10 mm for all. The punch stroke is 25 mm.

The mesh is done with the adaptive mesh function (Fig. 4), that the program re-mesh the blank in the parts areas where the material suffer strong deformation.

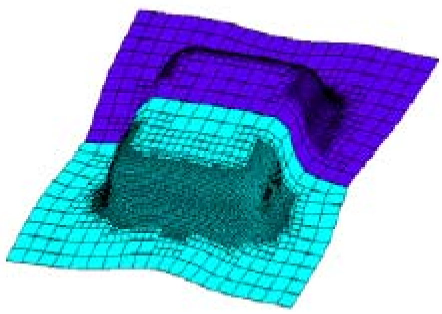


Fig. 4. Adaptive mesh in case of rectangular part.

The deep-drawing process simulation is accomplished in two phases: (i) the blank holder is moved to apply a predetermined holding force on the TWB; (ii) the punch is moved to a predetermined depth;

Weld-line displacement is an important indicator of overall deformation pattern of the TWB. It is determined by the properties of the component blank sheets and the restraining forces with little influence of local friction or local weld properties. All the measurements were done with Eta-postprocessor. For each variable studied it is shown the simulations of the three different geometries to study and compare the results between them.

The same thickness was taken for the two materials of the tailor welded blank, and the weld line was placed in the middle of the blank sheet dividing this in two parts dimensionally equal. The coefficient of friction between all the parts was chosen by default with a value of 0,125.

The objective was to study the relation between the force applied in the blankholder and how this affect to the displacement of the welding line. That will be studied is the displacement of the central node of the sheet, that has been called node A that coincides with the centre of the welded line, and with the maximum displacement of it. All the parameters are fixed except the blankholder force. The blankholder force is varied and then the displacement of the node A is measured for each value with the Eta-postprocessor.

4. SIMULATION RESULTS

In the graphic it can see the results, it is seen a tendency between the maximum distance, represented in the displacement of the node A, of the weld line and the applied blankholder force. The weaker material, in this case the FEPO steel, flows more with the increase of the binder force in comparison with the E220 steel, this could be due to the higher deformation that suffer the FEPO in the drawn square near the weld line, that increase more with the blankholder force. The relation seems to be linear, if the first point is not considered (Fig. 5).

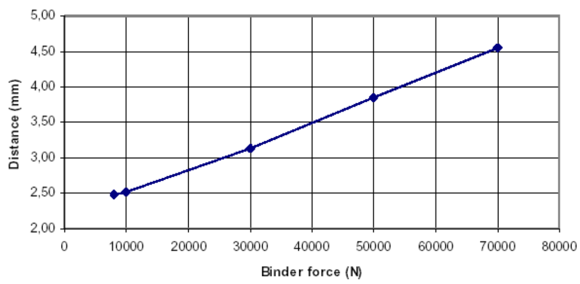


Fig. 5. Maximum welding line displacement with respect to the blankholder force for square shape

During deep drawing of the blank, the weld line shifts across the blank, depending upon the strength of the base materials. In the square section, the welding line moves towards the steel side due to greater flow in FEPO steel, whereas at the flange, the weld line moves towards the FEPO side, as shown in the simulations done before. As more material from the FEPO blank is drawn into the square section, E220 steel blank tends to encapsulate at the flange.

In the graphic presented in Fig. 6 we can see the results for cylindrical shape, which follows the same tendency like for the square shape. The welding line records maximum displacement for maximum holding force. The reason it can be the same than the square, the weaker material flows more with the increasing of the binder force in comparison with the strength one in the cup drawn.

This is due to the higher deformation that suffer the FEPO steel in the drawn cup, concretely near the welding line. The relation in this case is not linear, which was in the case of the square part. The same behaviour like in the square part it happens in the flanges, E220 area moves toward the FEPO zone.

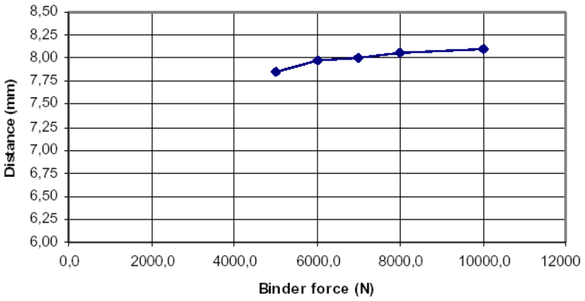


Fig. 6. Maximum welding line displacement with respect to the blankholder force for cylindrical shape

In the chart presented in Fig. 7, like in the square and the cylinder shapes it can see a tendency between the maximum distance of the weld line and the applied binder force. The reason it can be like the previous shapes, the higher deformation in FEPO steel area with the increase of the binder force in comparison with the E220 steel zone, specially near the welding line. The relation in this case is not linear.

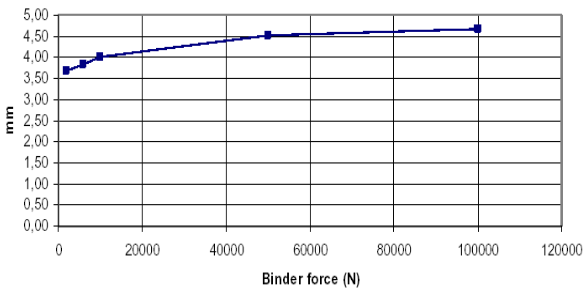


Fig. 7. Maximum welding line displacement with respect to the blankholder force for spherical shape

The tendency of FEPO steel area to move towards the E220 steel part, in this case is not very obvious due to the reduced material flow, which take part in the drawing process.

5. CONCLUSIONS

In this study simulation were conducted on deep drawing of TWBs. Three different final part shapes were used: square, cylindrical and spherical. Simulations were conducted using Dynaform software, maintaining constant all the process parameters.

It can see in the Fig. 8 an important difference between the displacements obtained in the different shapes. The displacement of the cylinder is higher than the square one, and the sphere.

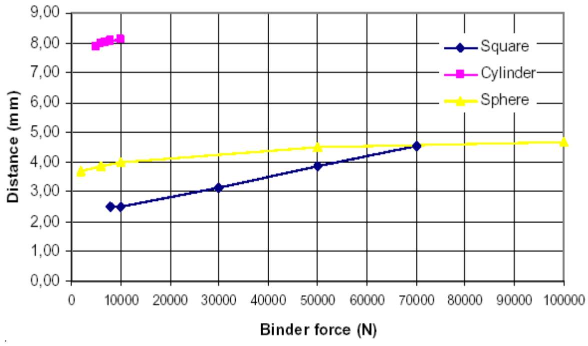


Fig. 8. Comparison of the welding line displacement for square, cylindrical and spherical shape.

It is observed that the shape of the drawn part has a very important influence in the movement of the welding line. In the spherical and cylindrical geometries the shape permits to the material to flow better than in the square one, and so, the displacement of the welding line is bigger in these shapes.

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