# WELD MOVEMENT IN DEEP DRAWING OF TAILOR-WELDED BLANKS

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When applying tailor-welded blanks (TWB) composed of parts with different properties for deep drawing and other forming processes, problems with non-uniform material flow occur. Welding of various parts of TWB into usable units, their different stress-strain properties, respectively different thicknesses influence their formability and the weld movement. This results in inaccuracy of the drawn parts [Mainders 2000, Fracz 2013].

Various tool designs for deep drawing, stretching or bending process can influence the material flow and avoid errors on the drawn parts. One of the solutions is to use a blankholder able to adapt to different properties of the blank and enabling the non-uniform distribution of the blankholder pressure around the perimeter of the drawing edge [Evin 2012, Bílik 2010, Slota 2014].

Described drawing experiments were conducted on rectangular-shaped part drawn from TWB, which was manufactured from steel TRIP 780 with a thickness of 1 and 1.2 mm. The experiments were focused on comparison of the behaviour of different weld orientation at approximately uniform and controlled uneven distribution of the blankholder pressure on the elastic blankholder of the laboratory tool. The experimental results were compared with the simulation of the drawing process in a finite element simulation software DYNAFORM using explicit method.

Experiments confirmed that minimisation of the weld movement, more uniform material flow in the die and better dimensional precision of the drawn part during TWB drawing process can be achieved by optimised uneven distribution of the blankholder pressure whilst ensuring uniform lubrication.

**Keywords**

deep drawing, tailor-welded blank, weld movement, blankholder pressure.

## 1 INTRODUCTION

TWB used for production of drawn parts with special properties are made of parts of two or more materials having different stress-strain characteristics, or different thicknesses welded for example by laser. A requirement to obtain acceptable drawn part is to manage with the specifics of TWB drawing. The main complication is uneven plastic flow of materials of different blank parts. Typical imperfections are movement and rotation of the weld, waves respectively cracks. The solution to these problems is to design forming tools and their blankholder systems with optimised distribution of the blankholder pressure, making plastic flow of material even and preventing the formation of the above-mentioned phenomena.

Simulation of technological processes on the basis of material model, tool geometry and process parameters allow to predict the material behaviour and the properties of the final product. The more accurate description of the input parameters is, the more effective optimisation of process parameters (or design changes of the tool functional parts in the preparation of production) can be achieved.

Described experiments and simulation in finite element simulation software DYNAFORM explain behaviour of the various weld orientations on the footprint of TWB from steel TRIP 780 with different thicknesses at different distribution of blankholder pressure. Its optimisation enables to achieve the required quality parameters of TWBs.

## 2 EXPERIMENTAL METHOD

The experiments were based on the drawing of rectangular box from a blank composed of two parts with different thicknesses of 1.2 mm and 1 mm connected by butt welding using robotic a laser device. The blank shape was optimised using a Dynaform software, increasing accuracy of the product. The used material was steel TRIP 780. The weld position was oriented parallel to the axis along the length and width and diagonally across the blank. The behaviour of the weld at approximately uniform and at controlled uneven pressure distribution on the elastic blankholder was analysed. The prerequisite was absolutely solid die [Zitnansky 2008]. The aim was to minimise weld movement and to optimise the resulting drawn part shape by an appropriate distribution of the blankholder pressure.

## 3 EXPERIMENT

The experiment was performed using laboratory tool for deep-drawing. It is designed for double press PYE160S with a nominal power of 1.6 MN and the ejector force of 320 kN. Non-uniform blankholder force and pressure around the perimeter of drawing edge enable optimising of forming conditions in the experiments of TWBs drawing. Measuring system of the tool allows the measurement of the forces on the punch, at three points on the die, at four transmission pillars dealing with blankholder forces as well as the stroke measurement [Zitnansky 2008].

For the analysis of deep drawing, the rectangular shape of the drawn part was chosen which combine different states of stress in the flat and curved parts (Fig. 1). Internal length of the part is 120 mm, width 80 mm and simulation-optimised shape allows to reach a height of about 40 mm. Rounded corners has a radius of 20 mm, a fillet radius of bottom and drawing edge is 8 mm.

The proposed system of quasi-elastic blankholder plate with a height-adjustable transmission pillars allows to create optimal conditions and distribution of blankholder pressure for deep drawing of blanks with different thicknesses [Schrek 2011].

## 4 PROCESS SIMULATION

Process analysis of deep drawing and research of weld movement was implemented in an environment of finite element simulation software Dynaform using explicit methods. The results obtained by computer simulation were stress, strain and a weld movement. Input parameters for the simulation were blank material parameters, geometry and process parameters.

To monitor the drawing process, the size of strain and the weld movement, a deformation grid with a circular pattern, with a mean diameter of 4.75 mm was created on the blanks according to Fig.1. The same type of the grid was used in the computer simulation for a direct comparison of the simulation results with the real experiments.

**Figure 1**. Experimental drawn part with a deformation grid of round elements

## 5 EXPERIMENTAL AND SIMULATION RESULTS

The input parameters for the experiments were material parameters, the shape and dimensions of the blank, uniform distribution of the blankholder forces, the dimensions and geometry of the tool as well as drawing gap between the punch and the die. Drawing process was carried out on blanks composed of parts with a thickness of 1 mm and 1.2 mm, while each experiment differed in the weld position. To verify the positive impact of uneven distribution of the blankholder force, a constant force around the perimeter of the drawn part flange was used to match them up. This led to the creation of non-uniform flow in the die - the flow intensity of the thinner material was larger, while the weld moved to the side of thicker material. Originally a direct weld has been changed on the walls of the drawn part to the curve. So it has been moved as well as twisted on thicker material side. The intensity of the weld movement and twist depends on the thickness and increases with the greater thickness. To minimise the weld movement it is necessary to change the distribution of the blankholder forces either experimentally through a trial and error or through a computer simulation. In case of complex shaped products a weld orientation has a key role for its stability with a respect to the shape of the product [Slota 2014].

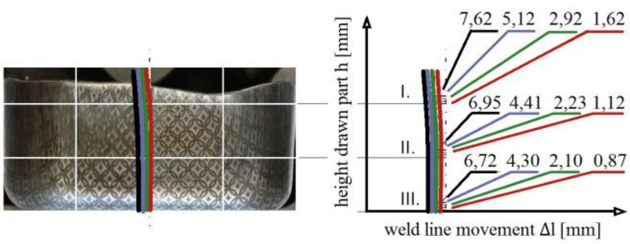


**Figure 2.** Weld movement on the wall of longitudinally welded blank

■ – uniform blankholder pressure distribution, ■ – non-uniform blankholder pressure distribution (regime A), ■ – non-uniform blankholder pressure distribution (regime B), ■ – simulation of the weld movement for non-uniform blankholder pressure distribution (regime B)

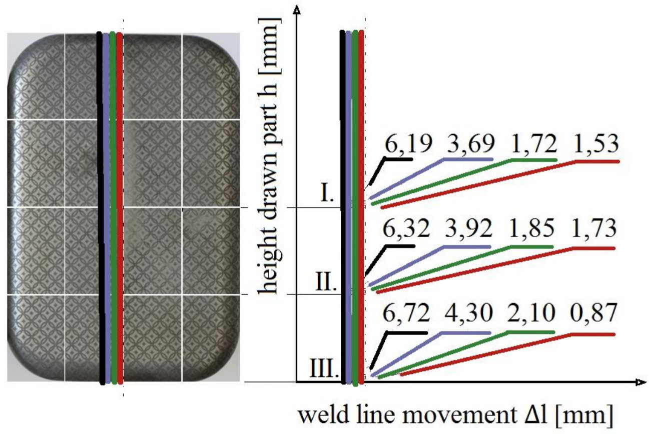


**Figure 3.** Weld movement on the bottom of longitudinally welded blank

■ – uniform blankholder pressure distribution, ■ – non-uniform blankholder pressure distribution (regime A), ■ – non-uniform blankholder pressure distribution (regime B), ■ – simulation of the weld movement for non-uniform blankholder pressure distribution (regime B)

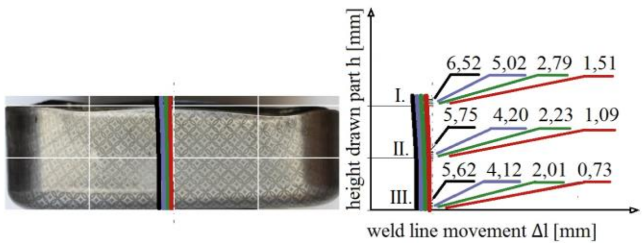


**Figure 4.** Weld movement on the wall of transversely welded blank

■ – uniform blankholder pressure distribution, ■ – non-uniform blankholder pressure distribution (regime A), ■ – non-uniform blankholder pressure distribution (regime B), ■ – simulation of the weld movement for non-uniform blankholder pressure distribution (regime B)

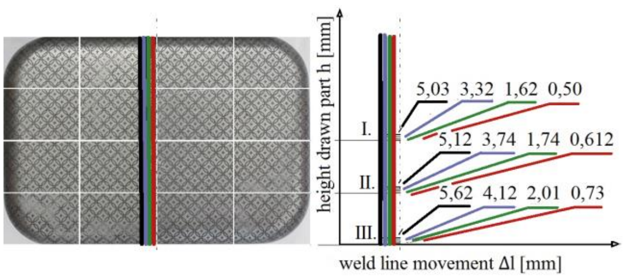


**Figure 5.** Weld movement on the bottom of transversely welded blank

■ – uniform blankholder pressure distribution, ■ – non-uniform blankholder pressure distribution (regime A), ■ – non-uniform blankholder pressure distribution (regime B), ■ – simulation of the weld movement for non-uniform blankholder pressure distribution (regime B)

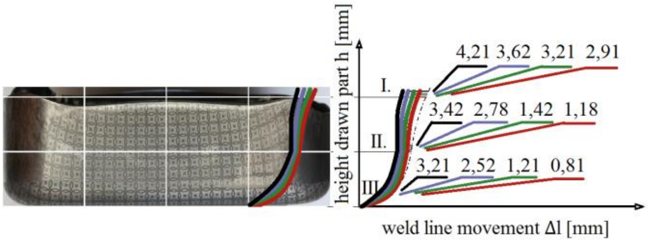


**Figure 6.** Weld movement on the wall of diagonally welded blank

■ – uniform blankholder pressure distribution, ■ – non-uniform blankholder pressure distribution (regime A), ■ – non-uniform blankholder pressure distribution (regime B), ■ – simulation of the weld movement for non-uniform blankholder pressure distribution (regime B)

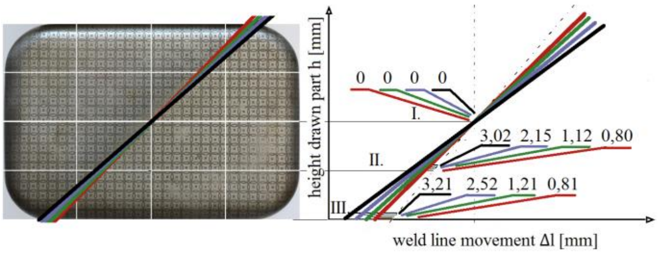


**Figure 7.** Weld movement on the bottom of diagonally welded blank

■ – uniform blankholder pressure distribution, ■ – non-uniform blankholder pressure distribution (regime A), ■ – non-uniform blankholder pressure distribution (regime B), ■ – simulation of the weld movement for non-uniform blankholder pressure distribution (regime B)

Using the uniform distribution of the blankholder pressure causes the weld movement. The weld position varies according to the orientation of the footprint geometry of the drawn part. Three options are possible as follows: in the middle along the long side of the rectangle (horizontal orientation), in the middle along the shorter side of the rectangle (vertical orientation) or diagonally. The weld movement is increased by the increasing of its length, so in the case of horizontal orientation, the weld movement is the most significant. The smallest movement and the smallest values of strain were observed in the diagonal weld orientation. In this case, the weld is "anchored" in the corner of the drawn part, and thus, the weld movement depends on the local increase of the blankholder pressure. Effects on the strain in this area is critical related to the achievable depth of the drawing part. The weld movement can be influenced and controlled by applying a suitable blankholder pressure distribution. The increase in blankholder force on the side of the thinner part of the blanks causes reduced weld movement, thus enabling to obtain the drawn part with improved symmetry. DYNAFORM software allows to predict the weld movement with acceptable reliability. It was able to predict the direction of the weld movement in a scale appropriate for real experiments.

## 6 EVALUATION OF RESULTS

Position respectively the weld movement in deep drawing of TWB is influenced by the different thicknesses of the blank parts, contact conditions between the die face, blank and blankholder plate, blankholder force distribution and the relative friction between the individual elements. The behaviour of the weld can be effectively controlled by the tool design with a blankholder plate enabling the creation of non-uniform distribution of the blankholder pressure around the perimeter of the drawing edge. Proper non-uniform distribution of contact pressure (assuming of uniform lubrication) results in the elimination of the weld movement, more consistent material flow in die and better dimensional precision of the drawn part.

The size of the weld movement for different arrangements and selected operating modes, along with the simulation results are shown in Fig. 2 to Fig. 7. When drawing using uniform blankholder pressure, the original straight weld twists and moves towards the thicker part of the blanks more significantly. The intensity of the weld movement depends on the thickness combination of the blanks – an increase of their difference causes an increase of strain value. An appropriate application of non-uniform distribution of the blankholder pressure can significantly affect and minimise the weld movement. At the optimum distribution of the blankholder pressure the weld retains its original position before drawing.

For drawing of rectangular box from TWB, we cannot neglect an influence of the weld orientation. Using the selected operating modes and the blakholder pressure distribution, a weld movement is different, depending on its orientation - at the middle along the long side of the rectangle (horizontal orientation), at the middle along the short side of the rectangle (vertical orientation) or diagonally. The weld movement is increased by the increasing of its length respectively by the reducing the blankholder area. For horizontal orientation, the largest weld movement was observed in all experimental cases (7.62, 5.12, 2.92, 1.62 mm). In vertical orientation the obtained weld movement values were 6.52; 5.02; 2.79; 1.51 mm. The smallest weld movement and smallest values of strain were obtained in the case of diagonal weld orientation (4.21; 3.62; 3.21; 2.91 mm). In this case, the weld is "anchored" in the corner of the drawn part, and thus, the weld movement is related to the stress state, the strain size, the increase of the thickness and the increase of the local blankholder pressure. The influence of strain in this area is critical related to the achievable depth of the product, e.g. to the point of taking the local thickness reduction and subsequent cracking.

DYNAFORM software allows to predict the weld movement on the bottom and walls of the drawn part with a reasonable reliability. It was able to correctly predict the direction and value of weld movement in the scale appropriate for the real experiments. The smallest difference between the measured and simulated movements with the value of 0.3 mm was found in the diagonal weld orientation.


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