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Comparison of technology of forming the sheet metal by numerical simulations

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ABSTRACT

Purpose: The paper is concerned about the problems in forming low-carbon and stainless sheet metal in parallel on the same tools. It describes the properties of stainless sheet metal and the comparison with ordinary sheet metal of DC04 quality. Differences in physical properties pose a source of problems occurring in forming both sheet metals of the same geometry.
Design/methodology/approach: Numerical simulation methods of deep drawing have been used for planning the technology of forming low-carbon and stainless sheet metal. For establishing basic properties of material the conventional testing methods have been used.
Findings: The target of researches was to find out what changes have to be made in the forming tools, when the sheet metal from stainless steel is formed.
Research limitations/implications: : Comparison of formability of sheet metals was limited only to materials suitable for use in production of household appliances.
Practical implications: The research is practically employed in forming sheet metal parts for household appliances.
Originality/value: By the use of the method described it is possible to determine in advance, how the forming tool must be made. Our aim was to make a forming tool suitable for forming sheet metal from stainless and low-carbon steel. The paper presents actual constructions.
Keywords: Machining; Forming sheet metal; Stainless sheet metal; DC04 sheet metal; Spring back effect

1. Introduction

The paper is aimed at presenting the problems arising in practice in parallel planning of the technology for forming low-carbon and stainless sheet metal. Comparison of forming properties of those two types of sheet metal shows great differences. The paper discusses the problems and some practical solutions in forming both types of the sheet metal on the same tools. To save in investing into expensive tools, these problems become increasingly topical. In Gorenje Orodjarna we have made already a variety of tools for the manufacture of front plates of range. Here, we meet again and again with the buyer's requirement that the manufacture must be ensured for two types of sheet steel on the same tools. Here, we face the fact that the manufacturing technology is already basically so planned that the product is made with minimum number of operations and with minimum modification of the tool. Due to formation of small chips in blanking stainless sheet metal the blanking of all holes must be shifted to final operations to avoid the transport of those small particles between the individual nests of the tool and, consequentially, to prevent damages to the surface of the pressed piece. Here below, some quite practical problems and their solutions will be presented. Most ir solutions will be presented.

Most problems in the manufacture of this product issue from the first operation of drawing the basic shape of the front plate. During drawing itself considerable strains and stresses occur in the sheet metal. Further, it must be borne in mind that this product is esthetically very delicate, particularly, its construction from stainless sheet metal. This requires that high attention is paid to cleanness of the tool as well as the sheet metal inserted into the tool. Also the fact is important that during the manufacturing process the stainless sheet metal must not be lubricated. This fact results from merely technological requirements of the manufacture and packing of the entire kitchen appliance. Therefore, the protective foil in case of stainless sheet metal must remain on the product all the time until the use of the appliance by the buyer. Moreover no fat is allowed to be present on it. Thus, quite a lot of time and negotiations with the buyer must be devoted to planning the manufacturing technology, before the design of the tools starts.

The paper discusses the properties and differences of both sheet metals and shows their influence in the numerical simulation of drawing and in practice. The spring back effects obtained numerically by simulation and the actual spring back on the stainless sheet metal product have been analyzed. It also deals with the execution of the tool modification correcting the longitudinal side and assuring that the cross profile of the front plate is not excessively open. In addition, it is necessary to take into consideration also the specific features of different shapes of front plates manufactured. In fact, any shape requires specific manufacture and settings of the tools as well as of the press.

2. Description of the approach, work methodology, materials for research, assumptions, experiments etc.

For the manufacture of the individual kitchen appliance components the company Gorenje uses, particularly, the stainless sheet metal with the designation X5CrNi18-10 and X2CrTi17. Particularly, the stainless austenitic sheet metal X5CrNi18-10 is appropriate for drawing [1].

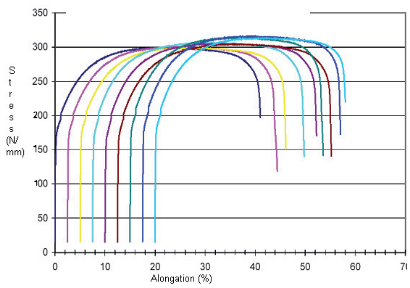

Fig 1. Tension test for sheet metal DC 04

Figures 1 and 2 clearly show the differences in mechanical properties of sheet metals. It can be seen that the stainless sheet metal has a considerably higher tensile strength than the sheet metal DC 04. Also the elongation is somewhat greater. The hardening coefficient of the stainless sheet metal is much higher. However, it is well known that the stainless sheet metal has smaller anisotropy.

Thus, the values for our case are as follows:

- r (90º) = 0.875 , r (45º)=1.187 , r (0º)=0.757
- hardening coefficient C = 718.593
- displacement ε_0 = 0.0181
- hardening exponent n = 0.30

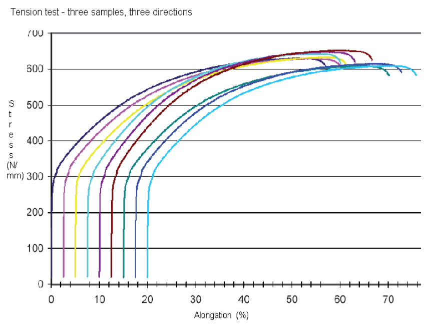

Fig 2. Tension test for sheet metal X5CrNi18-10

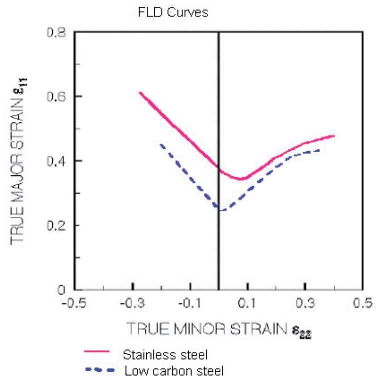

Fig 3. FLD curves for stainless and low-carbon sheet metal

The above figure clearly shows the difference in allowable strains. It can be seen that the stainless steel has significantly greater boundary strains. Excellent properties of austenitic stainless steel i.e. hig resistance to sheet metal thinning (high n) mean that deep drawing can be drawn with identical sheet metal. However, it must be borne in mind that forming of stainless sheet metal requires significantly greater forces. Experience has shown that the holding-down force, when drawing the range front plate from stainless sheet metal is as much as 100 % greater than when the sheet metal DC 04 is used [2]. [3]. [4].

However, the press size, the force on the drawing bolster and the ram force available can pose problems.

The problem arises also because of the material properties of the sheet metal DC 04. Thus, the measured values for this sheet metal are as follows [16]:

- r (90º) = 2.020 , r (45º)= 1.313, r (0º)=1.547
- hardening coefficient C = 414.020
- displacement ε 0 = 0.0181
- hardening exponent n = 0.214

The differences in the value of the anisotropy coefficients cause different behaviour – displacement of the sheet metal from the drawing flange over the drawing edge into the drawing die. It means, that drawing brakes must be provided on the drawing tool in the form of segments which are vertically adjustable and change the braking force. In this way, by changing the brake geometry and the holding-down force the conditions for the manufacture of the proper pressed piece in case of both types of sheet metal are reached. At present, problems in manufacture arise, particularly, due to great number of types of front plates requiring many tool modifications and, consequently, different behaviour of the sheet metal during deep drawing. To that end, well experienced specialists are necessary for the tool setting.

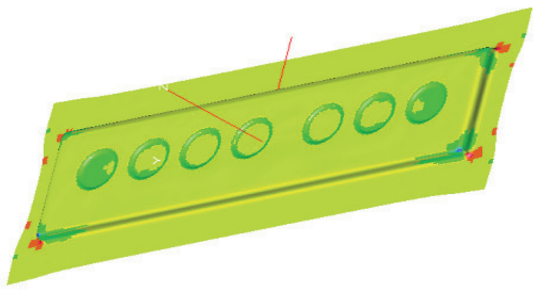

Fig. 4. Presentation of numerical simulation of the first drawing of the front plate.

Figure shows the front plate with impressions for heater control buttons. The plate is made from 0.7 mm thick sheet metal. The next figure shows the corner detail, where thinning is most critical [5].

As far as the sheet metal thinning is concerned, this product is not excessively critical. By optimizing the tool and properly setting the press it is possible to ensure a stable manufacturing process with little scrap. Greater problems arise due to spring back effect of the product after trimming of flat bar. When trimming the flat bar, the part of the plate, on which the drawing brakes have been impressed, is removed. Therefore, certain stresses are released. As a consequence, the product is elastically deformed [6], [7].

When analyzing the numerical simulation results and the actual state it is necessary to define first some data as to how the simulation was made. The material model Hill 48 was used.

$$\sigma_f^2 = \sigma_1^2 - \left(\frac{2r_0}{1+r_0}\right)\sigma_1\sigma_2 + \left(\frac{1+r_{90}}{1+r_0}\right)\sigma_2^2 \qquad r_0 = \frac{\varepsilon_{width}}{\varepsilon_{thickness}} \quad \text{........ (1)}$$

σ_1 - maximum principal stress
σ_2 - minimum principal stress
σ_F - yield stress

Basically, this model does not take into consideration the Bauschinger's effect in hardening of the material. It is necessary to take into account that the number of integration points through the plate thickness amounted to five, which, basically, suffices for analyzing the sheet metal thinning. However, for analyzing the spring back effect that number should be considerably higher. On the other hand, this prolongs the time of calculation. Another problem is the transient phenomenon when the tool touches the flat bar. Then the contact forces, having considerable influence on the stress state in the flat bar, fluctuate. That phenomenon can be slightly alleviated by the low speed of the press ram, but this strongly affects the duration of the simulation calculation. Another problem is caused by the method of measuring the spring back effect. That method was very simple and without predetermined assumptions on the measured piece. By the measuring machine simply the deviations from the ideal model were measured by assuming that the product is located ideally on the lower bearing surface [8]. [9].

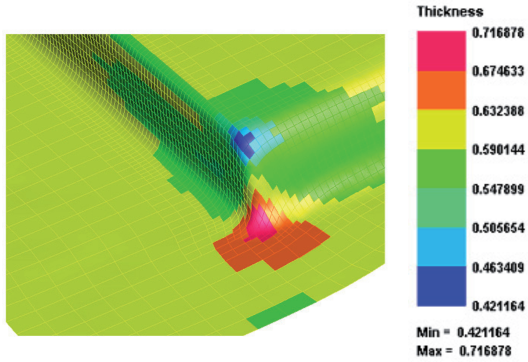

Fig. 5. Front plate corner detail

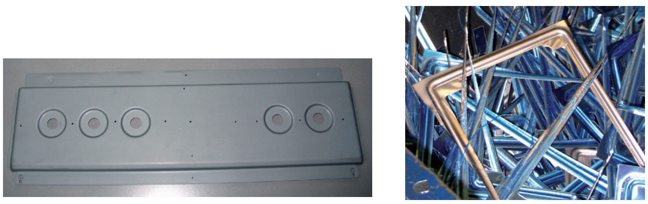

Fig. 6. Appearance of front plate after trimming of flat bar and flat bar trimming scrap

The above figure shows the shape and size if scrap resulting from flat bar trimming. The impressions of brake inserts are well visible. The scrap problems are increasingly crucial. Expensive sheet metal and pressures on the cost reduction compel us to reduction of scrap. Therefore, the tendency is oriented towards drawing of sheet metal quite without drawing brakes. That was achieved on some simpler shapes of front plates. Problems arise, particularly, in case of different combinations of impressions for buttons, where the sheet metal is drawn ununiformly into the drawing die. On the other hand, better holding down can be reached by increasing the force on the drawing bolster. Here, the disadvantage is that for that reason the press and the tools, simultaneously fixed, are excessively nonsymmetrically loaded [10], [11], [12]. One of the possibilities of elimination of brakes is the use of active holding down, where the sheet metal holding down force is controlled through segment inserts in the sheet metal holder and through hydraulic cylinders. In this way, the flow of the sheet metal into the drawing die is controlled. However, this method is still rather unknown in this country and its economic justification is questionable. [13], [14], [15].

Thus, attempts were made to optimize the flat bar size and the brake segments by numerical simulations. In spite of that practical work on the tools was necessary because the product is esthetically very delicate and must be without visible shadows and changes to surface. However, numerical simulations do not at allow to predict that. Therefore, the experienced hand of the tool-maker is still always necessary. Stainless steel has a great tendency towards scratches so that the requirements in tool manufacture are increased. In particular, attention must be paid to correct selection of materials and great enough drawing radiuses to present the protective foil from breaking during the drawing process. The problem of spring back of the plate was solved in cooperation with designers of the product itself. Reinforcing ribs were subsequently impressed into the drawn out longitudinal side. During impressing of ribs the sheet metal was a little bent into the opposite direction and the sheet metal edges were closed by pressing. In this way the side was plastically deformed and compelled into correct position. Thus, the tool is so modified that the side is corrected in accordance with the type of sheet metal from which the plate is made. In case of ordinary sheet metal only the ribs are impressed and the sheet metal edges closed by pressing, while in case of stainless sheet metal, in addition, the sheet metal is bent for 7º into the opposite direction [1].

In this way, the pressed piece meeting the esthetic and technological requirements for incorporation into the kitchen appliance, is made.

3. Description of achieved results of own researches

3.1. General remarks

In the measuring station the measurements of the plate made of XCrNi18-10 sheet metal were performed on a three-axis measuring machine.

As anticipated, the plate was curved on the longitudinal and transverse axis. The longitudinal and transverse profile of the plate has the form of a bow. Thus the deviation on the extreme external parts of the longitudinal profile was +0.6 mm and in the middle it was -0.47 mm.

The values of deviations on the transverse profile were +0.40 and +0.32 mm in the extreme external points and -0.34 mm in the middle. On the network model, used for simulation, the measured values in the extreme points of the longitudinal profile were +0.0.3, whereas a deviation of -1.3 was measured in the middle. The values of deviations along the transverse profile were +0.15 in external points and 0.2 mm in the middle.

Hill 93 requires the material data from the two-axis tension test which, however, cannot be measured in our facilities.

3.2. Scope

We researched the properties and differences of both stainless and low carbon sheet metal in the field of plastic forming. We have used numerical simulation method faced with results from the press.

4. Conclusions

We investigated a simple deep drawing case

- two different steels were compared,
- further verifications and identifications of error sources are required and improved material models are desirable especially for stainless steel.

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