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DEEP DRAWING OF SQUARE PIECES WITH VARIABLE TRIBOLOGICAL CONDITION ON THE FLANGE

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Abstract

The research results of blank holding force (BHF) influence on the process of plastic forming are presented in this paper. BHF is the normal force and very important factor of friction on the flange. BHF control enables friction control and in that way significant influence on the forming process.

Geometry of the work piece is prismatic with square cross section. Material is standard deep drawing thin sheet (0.8 mm thickness). BHF has constant intensity, on one side (based on common recommendations and performed optimization) and, on other side, regime of decreased intensity with constant specific contact pressure. Coefficient of friction is dictated by application of: dry surfaces, oil for deep drawing and polyethylene foil with oil.

The following properties are monitored: main surface strains distributions and their relationship to forming limit diagram, thickness strain distribution, change of final deep drawing depth and change of forming forces.

If there is final drawing depth (without any defects) as main criteria for successful forming process this research clearly shows significant possibilities of BHF influence on improvement of square pieces deep drawing process results.

Key words: *Thin sheets, deep drawing, variable blank holding force*

1. INTRODUCTION

Deep drawing is among the most dominant technologies in modern industry. Such statement is best confirmed by the quantities of thin sheet metals which are being consumed, as well as by their constant increase. Furthermore, the intensified development of these materials in the last decade additionally substantiates the previous statement. The current situation in the development of deep drawing technology can be described as efforts to accomplish complete control of the process. That task is very difficult, due to a large number of influential factors. Numerous computer measuring and control systems have been developed, often of very complex structure: [1, 2, 3]. In each of them, the control actions are performed in only two ways: by means of friction control and by means of sliding control, i.e. forming of flange. In the first case the key parameter is blank holding force, and in the second case it is the height of moving draw beads. Those are the only two parameters that can be controlled (modified by desirable laws) during the forming process. The framework within which the process runs consists of dangers from possible appearance of two defects: wrinkles on flange and fractures in critical zone.

The results presented in this paper are the outcome of experimental researches of, mainly, variable blank holding force (VBF) influence on process of deep drawing of prismatic piece. The significance of blank holding force increases with the increase of friction coefficient in contact on flange [4, 5]. It represents a normal force for that friction. In conditions of very small friction coefficient, the influence of blank holding force is small, i.e. its intensity should be maximal in given circumstances [4].

2. EXPERIMENTAL RESULTS

According to the conception of the experiment, during the drawing of square piece with flat bottom three types of blank holding force are applied: a) constant, determined according to the most frequent recommendations (mark – CBF,R), b) constant, optimized by special experiment (CBF, E) and c) variable, of decreasing character, whose dependency on travel is defined based on previous two forces and principle of constant value of contact pressure on holder throughout the process (VBF, DEC, R, E). The experiment was carried out on hydraulic laboratory press of triple action with computer measuring-control system, which is described more thoroughly in [6, 7]. Its main property is that it makes possible the realization of previously given functional dependency of VBF on travel (or time) of any form, in the course of forming process progress.

The geometry of the piece consists of square cross section of 40 mm side, with radius on angle of 10 mm (horizontal plane) and radius on bottom transition into vertical part of the piece

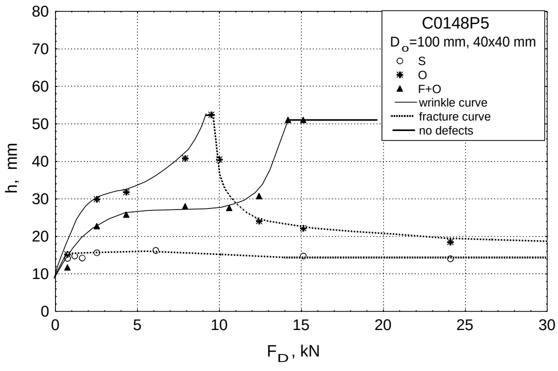

Fig. 1: *Limit diagram of wrinkles and fracture*

of 4 mm.The material is high-quality low-carbon sheet metal for deep drawing [7] 0,8 mm thick (mark – C0148P5). Geometry of blank is circular, diameter D_0=100 mm.

Due to the lack of space, only the basic data on method of defining particular types of blank holding force will be given here.

CBF (variant R) was determined based on recommendations and its intensity is 12,222 kN. For defining CBF (variant E), limit diagram of wrinkles and fractures for the actual case of forming was determined experimentally (fig. 1). It enables the optimization of CBF according to the criterion of maximal drawing depth. Three values were adopted, in dependence on friction conditions (dry-D, F_D=5 kN; oil application-O, F_D=9,5 kN; application of oil and PET foil-O+F, F_D=15 kN).

VBF of decreasing dependence type (DEC) was defined starting with the principle of constant value of specific pressure on holder during the process (q=2,152 MPa for variant R, q=0,88 MPa for variant E). The first value is applicable to all three types of friction, and the

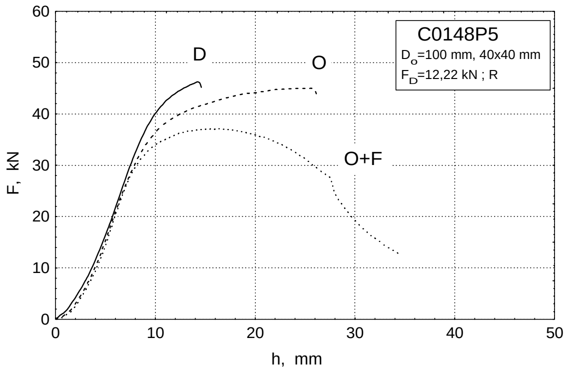

Fig.2: *Drawing forces at CBF, variant R*

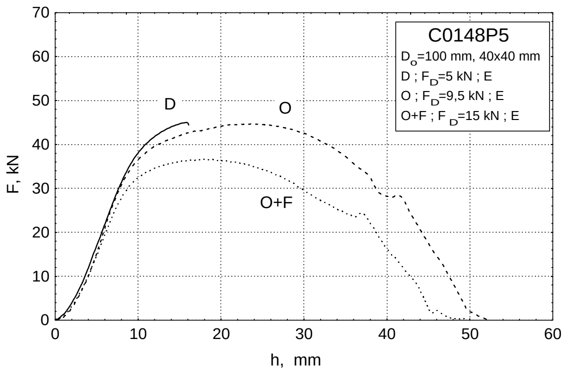

Fig. 3: *Drawing forces at CBF, variant E*

second value only to dry friction.

The process for obtaining medium value of total drawing depth of 51 mm lasts 156 seconds, so the following equations for VBF [7] are obtained:

- variant R: F_D= 12222,7-110,04t+0,1624t^2, N.

t is time in s.

- variant E: F_D= 5000-45t+0,0664t^2, N.

Both curves and their experimental realization can be observed in fig. 4. Forming speed is constant; therefore, linear connection between travel (h) and time is adopted.

The dependency of drawing force on travel at CBF-R (fig. 2) and at CBF-E (fig.3) show that optimization gives significant results, especially in the case of mixed friction (oil lubrication –O) when full depth can be obtained. The piece is successful, although at about 40 mm depth small wrinkles appear, of about 0.1 mm height, which are levelled until the end of process.

The application of VBF of decreasing type (DEC) gives even better results, partly visible in fig. 4. The case of lubrication with oil and foil was not applied due to easy realization of the process with constant blank holding force of the

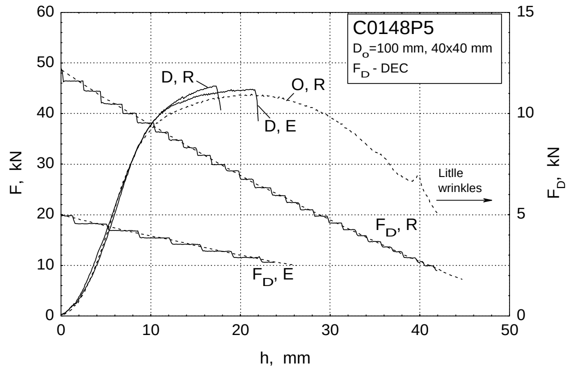

Fig. 4: *Drawing forces and blank holding forces at decreasing VBF*

simplest type (R). On fig. 4, the method of control equipment operating can also be observed. VBF is obtained as graded line which follows analytically given function.

The best estimation of realized influence of particular types of blank holding force can be made on the basis of diagrams of main strains distribution on sheet metal surface (fig. 5 and fig. 7) and distributions of the third main strain (sheet metal thinning) which is the most illustrative (fig. 6 and fig. 8). Illustrations are given comparatively, whereat the dotted lines refer to application of basic CBF (R).

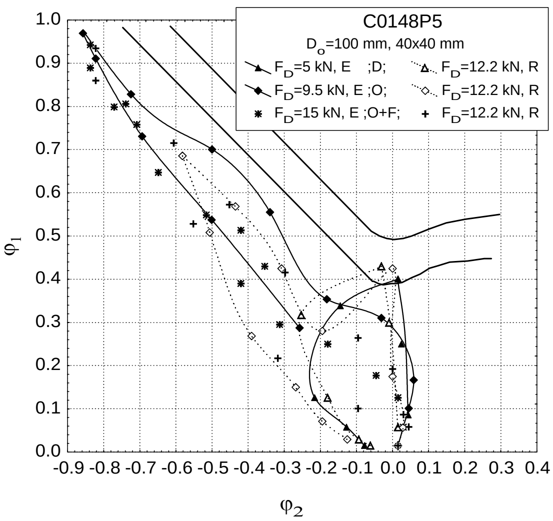

Fig. 5: *Surface strains distributions at CBF*

Loops of surface strains (fig. 5) in the case of application of CBF (E) are wider and shifted towards safer zone under the critical field defined by limit formability curves. Thinning distribution (fig. 6) is also much more favourable (CBF-E in relation to CBF-R). Even at dry friction, thinning strain gradient is smaller on the fracture point (flatter peak on curve).

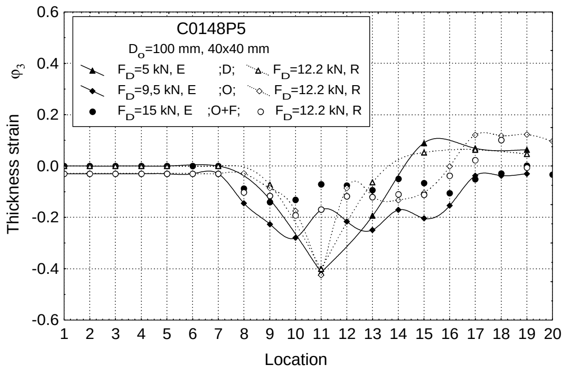

Fig. 6: *Thinning distributions at CBF*

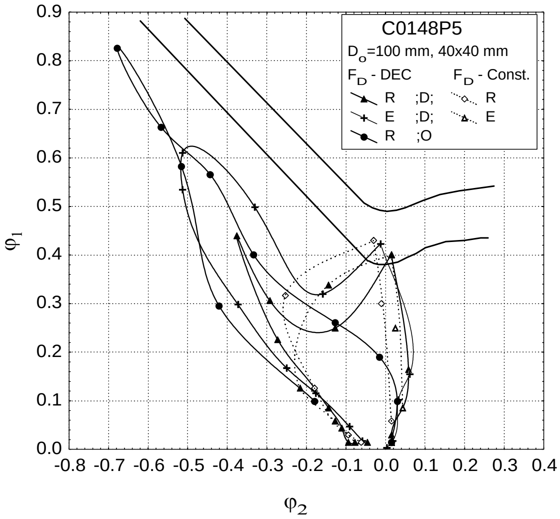

Fig. 7: *Surface strains distributions at VBF*

Table 1: Survey of realized total drawing depths

Drawing depths (mm)					
F_D=12.22 kN (R)		**F_D=5; 9.5; 15 kN (E)**	**increasing %**	**VBF (DEC)**	**increasing %**
D	14.6	16.1	10.3%	17.8 21.8	21.9 49.3
O	26.2	52.1	full	42.0	60.3
O+F	34.6	49.8	full	-	-

The same conclusion can be made for distributions in fig. 7 and 8, with one very significant change: the increase of total drawing depths occurred in both friction regimes (dry, application of oil). It is important to point out that drawing depth is a technological indicator and that it is of primary significance. The strains distributions illustrate the local phenomenological manifestations of forming process. Table 1 gives the survey of realized depths with percentage increase in relation to application of basic CBF (R).

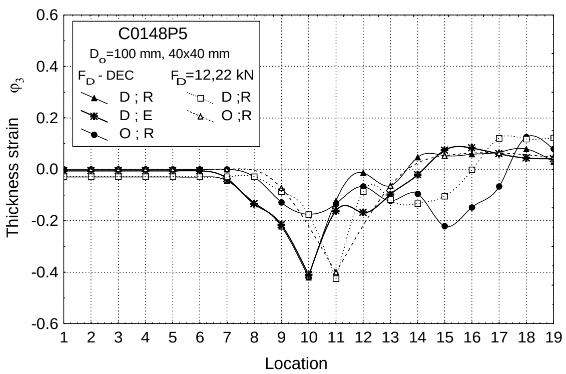

Fig. 8: *Thinning distributions at VBF*

3. CONCLUSION

Blank holding force is significant as a parameter which can be rather easily controlled throughout deep drawing process. In that way, friction on flange is controlled and all forming phases are significantly influenced. The results presented in this paper substantiate quantification of that influence on actual example, and indicate significant possibilities for improving the process results, which is of great significance in technological practice. That is especially important in forming more complex geometry pieces made of low-formability materials, as most modern sheet metals are. The trends of further development in this field are pointed towards attempts to realize integral control system for entire process, with evident problems of thinning measuring and identification of critical zone, defining of BHF dependency during the process and in particular holder zones etc.

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