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RESEARCH

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Variable Blank Holding Force as a Factor of Tribological Influence on Deep Drawing

Tribological conditions in blank holder zone in deep drawing significantly influence the total forming process. The intensity of blank holder force i.e. contact pressure in holder and die zone influences the appearance of wrinkles and tearing in the zone of forming force transfer. In standard forming processes, holder force has constant value in course of deep drawing. The paper gives results of experimental researches, realized on special researching equipment, which make possible the change of holding force. The change of blank holding force, i.e. the change of friction force on contact surfaces of holder and sheet metal, that is die, is realized according to previously determined law, as function of the position of outer flange edge, i.e. time.Standard sheet metals and sheet metals with anticorrosion coatings, as well as various lubricants, are used in experiments. The obtained results point to the influence of contact pressure onto the drawing force, strain distribution, forming limit etc.

Keywords: *sheet metal, deep drawing, variable blank holding force*

1. INTRODUCTION

The framework for successul realization of process of thin sheet metals deep drawing is made of two possible defects: fracture and appearance of wrinkles. Fracture takes place after reaching the limit stress values in critical zones of forming force transfer. In most cases it is the surroundings of punch radius. Wrinkles appear on the work piece flange in consequnce of the activity of tangential compressive stresses.

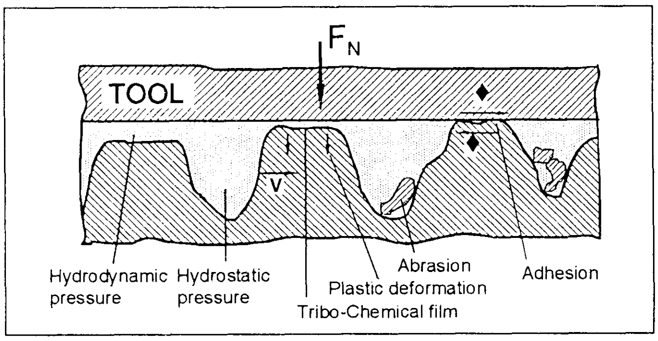

Figure 1: Rough contact between die and sheet

Waves of wrinkles cause generation of axial force, the intensity of which is, in that case, larger then holding force. In that way space is released between holder and die, and wrinkles increase until they are drawn into the die opening and in most cases the punch gets jammed in course of that. By pulling in the flange and reducing the outer diameter, the specific pressure in contact is increased, and leveling of sheet metal surface is more intensive. In course of that the sheet metal thickness on the flange perimeter is increased, because of tangential compression. The change of pressure leads to the change of lubrication regime, that is leads to the realization of boundary and mixed lubrication. With the increase of pressure, the encapsulating of lubricant between the roughness peaks takes place (hydrostatic pressure), but at the same time the disturbance of lubricant on the top of roughness peaks may appear (fig. 1 [1]).

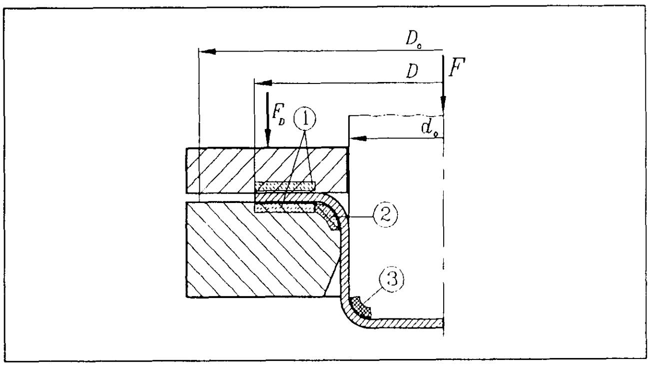

Figure 2: Friction zones

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By convenient control it is possible to extend working area in deep drawing, to achieve higher drawing ratios etc. In course of that, tribological conditions on flange have great significance, though relatively insufficiently investigated.

Tribological condition in deep drawing process are as important as other factors (material, work piece geometry, machine and tool). Tribological activities on work piece flange (zone 1 in fig. 2) shuould be especially emphasized because of activity of holding force (BHF) which is a very convenient parameter for monitoring and control [2, 3].

2. EXPERIMENTAL RESEARCHES

The experiments, the results of which are given in this paper, are carried out at Faculty of Mechanical Engineering in Kragujevac, where laboratory device for researching the variable blank holding force (VBF) influence in deep drawing has been made. Hydraulic triple action laboratory press-ERICHSEN 142/12 is the basis of this device. Maximal measuring range of the main action force is 0-130 kN and forming speed is 0-200 mm/min. Maximal punch diameter is 50 mm and maximal drawing ratio is 2.4. Originally the press was equipped with inductive transducers of force and travel for main action with Bourdon's tubes manometers for all working actions. It is possible to control BHF continually by hand regulated hydro valve. For the purposes of this research the modification in the system for BHF realization and control was carried out. Modification includes: 1) built-in electromotor drive with DC motor and two conducted worm gears applied on hydro valve for regulation of BHF axle; 2) built-in inductive transducer for BHF measuring. Considering the relatively small process speed the control of electromotor drive is integrated in computer system for data acquisition and control (fig. 3). Control of electromotor drive is performed in closed loop (by feedback) on the basis of given functional dependence of BHF and continually measured, realized BHF. PC computer with plugged-in 12-bit AD/DA card is the central part of the system. On the basis of given and momentary measured BHF value, valve axle position dependence on time during drawing process is determined, as well as BHF. By switching electromotor drive in desired moments with use of specially developed electronic unit, VBF to programme defined intensity may be obtained, and is measured directly through blank holding force transducer. The choice of any kind of force dependence type either as analitically given function or as a set of discrete values was provided through software. Developed software can also serve for other needs of experiment (deep drawing force measuring, visual proces monitoring, saving of all necessary variable values etc). Because of the limited space, it is not possible to give all details about this system [4].

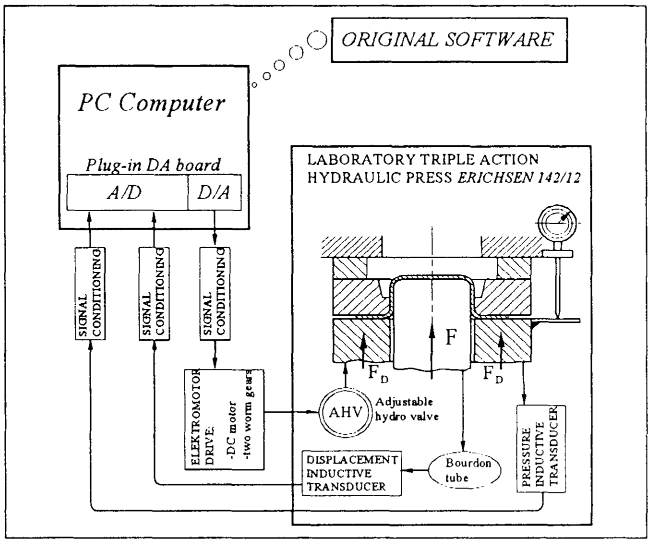

Figure 3: Scheme of experimental equipment

Material used for this investigation is low carbon autobody steel sheet metal (marked C0148P5). Details about mechanical and formability properties are given in [4].

In the course of experiment planning, the application of pure deep drawing (cylindrical part with flat bottom) was chosen in conditions of constant blank holding force (CBF) on one side and in conditions of VBF on the other side. CBF intensity was defined by three values (one value was recommended in literature and other two were obtained in special investigation, chapter 2.1). VBF was defined as monotonously decreasing function of time, i.e. punch travel in conditions: q=const. (q is specific blank holder pressure).

The influence of contact conditions was investigated by application of dry contact surfaces degreased by acetone (marked as dry or D), oil for deep drawing (oil or O) and by combination of oil and polyethylene foil (O+F).

Basic geometry was defined by: punch diameter (d=50 mm), bottom radius (r=6.5 mm) and die radius (3.5 mm). Drawing ratio was chosen in a way to be close to the limit value. At such ratio, and by the application of oil and foil the flawless workpiece is obtained, and by application of oil or dry contact surfaces the process cannot be succesfully carried out. For this example that is the ratio 2.2, i.e. blank diameter D_0=110 mm. Forming speed is fixed at 20 mm/min.

2.1. The choice of constant blank holding force (CBF) and variable blank holding force (VBF)

It is common practice (and very often the only possible solution) to determine the intensity of CBF on the basis of literature recommendations. Those recommendations usually contain particular values of the specific pressure q or formulae for the calculation of the pressure. It is always possible to discuss the universality of the application of such approach. Neverthless, we have also adopted the recommended value as one of the CBF values. Nine well-known prepositions were taken into considerations [4], and adequate medium value was chosen. For C0148P5 it is 13.72 kN.

More accurate approach implies creating of dependence of blank holding force and drawing depth (h-F_D) for each particular case in order to identify correctly the area in which wrinkles and fracture appear and in which a successful piece is obtained. Naturally, that is preceded by blank defining. The procedure is relatively complex, but that is the only right way for determining the correct value of CBF. Diagram h-F_D for investigated material and all three contact conditions are given in figure 4.

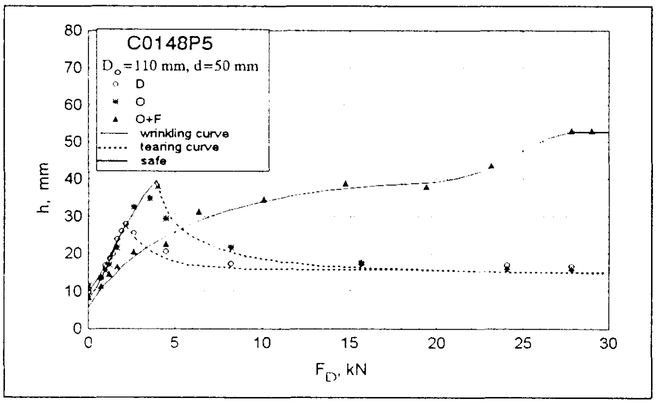

Figure 4: CBF dependence on drawing depth

Criterion for detecting wrinkles is defined as displacement of blank holder for 0.1 mm.In the area of transition from the wrinkles zone to the fracture zone the criterion is rigorous (0.05 mm) because of tendency to simultaneous appearance of both defects. The following values of CBF were adopted: for dry contact conditions (D) and oil (O) F_D=4 kN, and for the application of oil and foil (O+F) F_D=27 kN. It can be noticed that the adopted values are somewhat higher in comparison to the curves picks which relate to D and O contact conditions. The cause of this is safely the avoidance of wrinkling zone, because in the picks area there is a tendency to simultaneous appearance of wrinkles and fracture.

The basic principle on which VBF defining is based is keeping the specific blank holding pressure constant during the process. Since the blank holding force $F_D=q\cdot A$, the change of the flange area A determines the change of F_D. In order to come to the final formula for F_D it is necessary to introduce appropriate simplifications: a) flange area maintains the shape of a circular ring during the process, b) increase of sheet metal thickness on the flange can be neglected and c) there is a linear dependence of the outer flange diameter (D) and time (z).

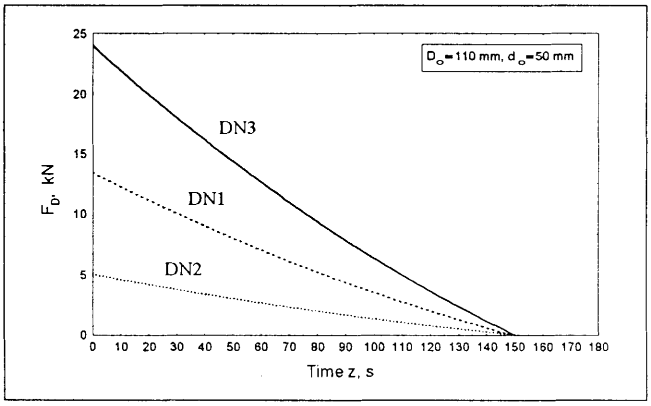

Figure 5: VBF dependence on time

Taking into consideration the work piece and tool geometry and previous hypothesis, the following dependence of the flange area on time is easily obtained.

$A=6806.34-59.209\cdot z+0.092\cdot z^2$, mm^2 , where z is time in seconds.

For each of three previously adopted F_D values, the constant value of specific blank holder pressure is determined:

$q=\dfrac{F_D}{A_{poc}}$, MPa ,where A_{poc} is maximal value of flange area.

Functions given in fig. 5 were used for application.

2.2. Results

The effects of VBF application were considered together with results for CBF through:

a) diagram of drawing force dependence on travel,

b) drawing depth with qualitative evaluation of wrinkles and fracture on piece,

c) strain distribution in coordinate system of main strains in sheet metal plane ($\varphi_1-\varphi_2$),

d) strain distribution of sheet metal thinning (φ_3) in dependence on the location on work piece.

Because of the limited space, only some results were given (for VBF of DN1 type in comparison with CBF of 13.41 kN).

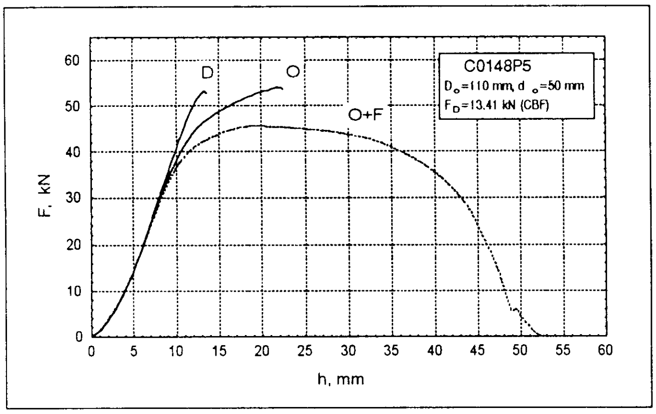

Figure 6: Forming force dependence on drawing depth

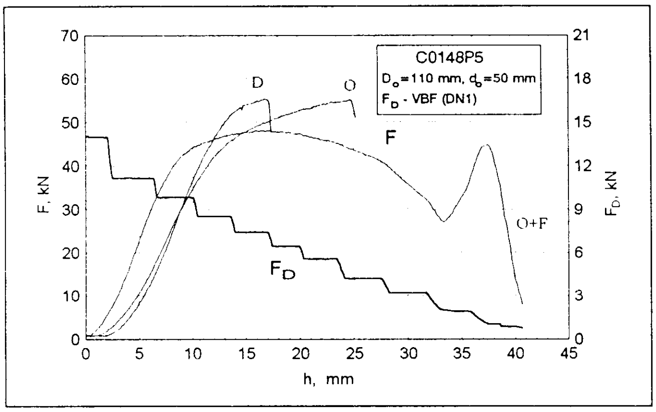

Figure 7: Forming and blank holding force dependence on drawing depth

According to the given results we can observe the favourable influence of decreasing VBF in conditions of strongly prominent friction (dry contact surfaces, oil aplication). Drawing depth, at VBF DN1 and dry friction, increases for 28.6 % in comparison with CBF (fig. 6 and fig. 7), with more favourable strain distributions (fig. 8 and fig. 9).

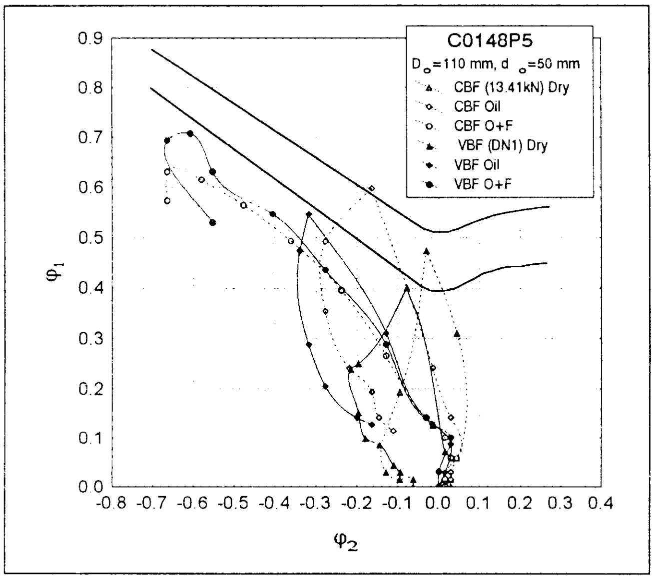

Figure 8: Main strain distributions at sheet plane

Strain loop in sheet metal plane is wider and moved to the left towards the safer zone from the aspect of limit formability (fig. 8). At VBF DN1 and mixed regime of friction (oil application), drawing depth increases for 10.8 %, with more favourable strain distributions as well. Thinning strain gradient is considerably smaller (fig. 9).

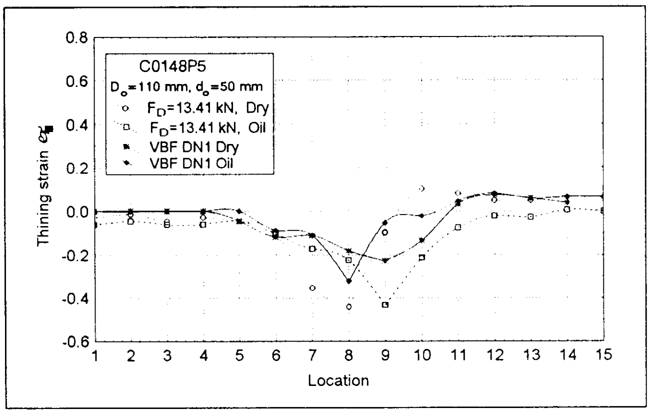

Figure 9: Thinning strain distributions

3. CONCLUSIONS

The application of VBF can be a significant manner for improvement of technological results and better knowledge of deep drawing process nature. The results given in this paper (in reduced form) clearly point to significant positive influence of VBF decreasing dependence in conditions of more prominent friction. Especially at dry regime of friction, and somewhat less at mixed one, drawing depth considerably increases with favourable strain distributions.

Comprehensive researches that had been carried out [4] included the influence of other VBF types (increasing, decreasing, combined: decreasing–increasing, pulsating), but took into consideration other influences as well: sorts of material, piece geometries, contact conditions, strain history. The final aim is finding the answer to the following question: which form of blank holding force variation is the best solution for real process conditions? In the following investigations, a significant position should be taken by the realization of active control system (closed loop), where measure–control system can independently respond to variation of some important characteristic of process. However there are certain difficulties considering the definition of such a parameter which would coincide with successful course of process (change og thickness, friction force on flange, displacement of flange edge etc.). In such investigations, numerical simulations of process, which are already giving satisfactory results, should take an important place [5].

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