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ANALYSIS OF FORCES IN DEEP DRAWING PROCESS

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ABSTRACT: Presented contribution deals with force parameters research (drawing and blankholding) in deep-drawing process of flat bottomed cylindrical cup. Experimental research was realised using steel sheets for enamelling KOSMALT produced by U.S.Steel Košice, Ltd. Deep drawing process of this steel is complicated due to contradictory requests from the view of steel structure: good drawability and good enameling. At the present, there are new ways how to ensure requested properties from both views [6].
KEYWORDS: force parameters, research, deep-drawing processes

❖ INTRODUCTION

Production of pressings is realized using forming machines, which ones act by force onto initial blank through forming die. Therefore they change its initial flat shape onto semi-finished or final product. Forming processes force parameters knows enable to technologists – forming processes designers and forming machines designers to dimension forming machine and forming die components. Besides, experimental research of forming forces allows process optimization, because they are complicated multi-factors systems. [1,2,3,5].

There are two types of sensors used in the field of force parameters research of deep-drawing processes – mechanical and electrical [3,4]. Experimental research of forces in deep-drawing processes is based on principle of non-electrical parameters measurement by electric way. Force parameters measurement (drawing and blankholding), is realized through elastic deformation element - dynamometer, which one is equipped by 4 tensometric sensors connected to Wheatston's bridge.

Experimental research of forces in deep-drawing processes is long-time realized in the Department of technologies and materials. In the past there was used measuring and monitoring system created by dynamometers (drawing and blankholding), voltage stabilizer, tensometric apparatus UM 131 and oscillograph for forces recording in force-time coordinates. Necessity of computer processing measured values required innovation of measured and monitoring system, where tensometric apparatus was developed and produced by INSPECT, Ltd. This tensometric apparatus has three canals for force recording and 1 canal for path recording and allows researching not only force-time relations, but also force-path relations.

Presented contribution deals with force parameters research (drawing and blankholding) in deep-drawing process of flat bottomed cylindrical cup. Experimental research was realised using steel sheets for enamelling KOSMALT produced by U.S.Steel Košice, Ltd. Deep drawing process of this steel is complicated due to contradictory requests from the view of steel structure: good drawability and good enameling. At the present, there are new ways how to ensure requested properties from both views [6].

❖ METHODS OF EXPERIMENTAL WORK

Experimental measuring system

Research of forces in deep-drawing process was realised using with experimental measuring system machine-die-pressing consists subsystems:

1. double action hydraulic press Fritz Müller BZE 100
2. experimental drawing die with blankholder
3. pressing
4. measuring and monitoring subsystem for forces recording

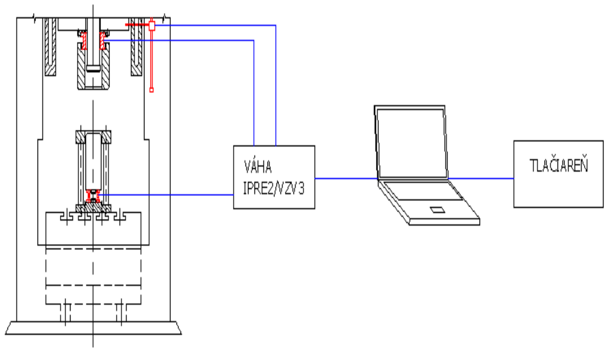

Fig. 1 Scheme of experimental measuring system. Cup, experimental material and experimental forming die

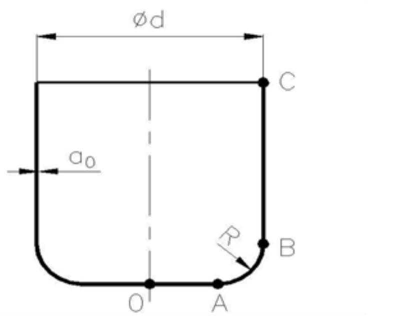

Fig. 2 Experimental flat bottomed cylindrical cup

Research of force parameters in deep-drawing process was realized on flat bottomed cylindrical cup without flange (Fig. 2). These cups were deep-drawed in experimental drawing die with blankholder (punch diameter Ø 73,5 mm, die diameter Ø 76mm, punch radius r_p = 5 mm, die radius r_t = 6 mm). Drawing of pressings with outside diameter Ø 76 mm were realised from initial blank diameters Ø 125 mm, Ø 134 mm, Ø 139 mm a Ø 145 mm.

As an experimental material there was used cold rolled drawing quality steel sheet for enamelling KOSMALT 190.21 with thickness 0,8 mm produced by U.S.Steel Košice, Ltd. Directional values of mechanical properties, normal anisotropy ratio and strainhardening exponent are shown in Table 1.

Table 1. Material formability values of KOSMALT 190.21, a_0=0,8 mm

direction [°]	$R_{p0,2}$ [MPa]	Rm [MPa]	A_{80} [%]	r	r_m	Δr	n	n_m	Δn
0°	181	287	44,7	1,910			0,203		
45°	186	304	38,2	1,438	1,802	0,727	0,215	0,212	-0,006
90°	183	289	44,7	2,422			0,215		

Drawing punch and die of experimental modelling die were fastened onto press ram first and on press bed last mentioned by blankholder and drawing dynamometers. Blankholding force in drawing process was implied by rods to which act drawing cushion placed in the press bed. Blankholder dynamometer, fastened onto drawing die in the press ram, records overall force, drawing dynamometer records drawing force only. Final blankholding force is then calculated as a difference between overall force and drawing force. Path reader was placed in the left press shoe, where press ram movement was transferred onto slider movement of digital ruler SD-60.

Measuring subsystem for scanning and recording of drawing forces

Measuring subsystem for drawing forces recording consists:

1. dynamometers - drawing and blankholding (Fig. 3a)
2. path reader – digital ruler Mitutoyo SD-60 (Fig. 3b)
3. tensometric apparatus IPRE2/VZV3 (Fig. 3c)
4. notebook PC – Pentium III (Fig. 3c)
5. joining cables CANNON 9F/9M and RS232 cable

a) b) c)

Fig. 3 Components of measuring subsystem for recording forming forces. a) – drawing force dynamometer, b) path reader Mitutoyo SD-60, c) tensometric apparatus IPRE2/VZV3 interconnected with PC

Tensometric apparatus (called weighing-machine by producer) IPRE2/VZV3 is set to continuous force measurement (weighting) and synchronised path reading from digital ruler SD-60. Electronics allows from 1 to 3 dynamometers reading and path reading. Also shows measured values of each dynamometer or path reader on display. It is also possible to set required sensor on display and set sampling frequency by which are measured and recorded data send to PC. Communication between tensometric apparatus and PC is realised through RS232 interface and apparatus is connected to PC by serial port. Data are send to PC in text file in ASCI code and allows simple importing to Excel. All communication and data sending is realised by Hyperterminal, which is standard part of MS Windows operating systems.

❖ RESEARCH RESULTS AND INTERPRETATION

Graphic courses of drawing and blankholding forces at deep-drawing of flat bottomed cylindrical cup without failure are shown in Fig. 4 to Fig. 6 for each initial blank diameter. Graphic course of drawing and blankholding forces at deep-drawing of flat bottomed cylindrical cup from initial diameter where broken cup occurs is shown in Fig. 7.

Courses of drawing force at deep-drawing of flat bottomed cylindrical cup without flange from initial blanks, where no cup breaking occurs are typical for limit drawing case – drawing from flange. Drawing force increases rapidly at first stage next grows up slowly until drawing force maximum and then decreased. There is clearly seen maximum drawing force increasing with drawing ratio m decreasing. The area below drawing force line also increases. As a limit drawing ratio could be considered here drawing ratio m = 0,547 because of maximal drawing force (F_t max = 76,75 kN) is nearly to cup breaking force (F_{por} = 76,97 kN). Limit drawing ratio was observed at deep-drawing of initial blank diameter D_0 = 139 mm, while cup breaking force was reached at deep drawing of initial blank D_0 = 145 mm, where drawing ratio is m = 0,524.

Course of blankholding force has a dynamic character at the first stage, when blankholding touch down the drawing die. After rising up to 70 kN approx. drawing process begins and blankholding force decreases rapidly. Blankholding force decreasing could be explained as a response of press hydraulic system to press ram force movement, but there is also blankholding area decreasing due to drawing-in to die. Blankholding is then stabilised on 50 kN approx. When maximal drawing force is reached and is decreased, blankholding force increased again to initial value and next drops down after cup is drawn.

Dynamical processes at the beginning and at the end of cup drawing presents response of used machine, where there was used double action hydraulic press Fritz Müller BZE 100 equipped with drawing cushion placed in the press bed. Deep-drawing was realised using Vantol S lubricant.

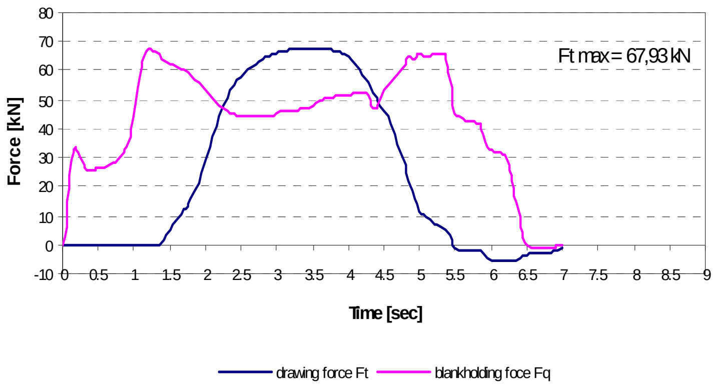

Fig. 4 Course of drawing and blankholding forces, D_0 = 125 mm, m = 0,608

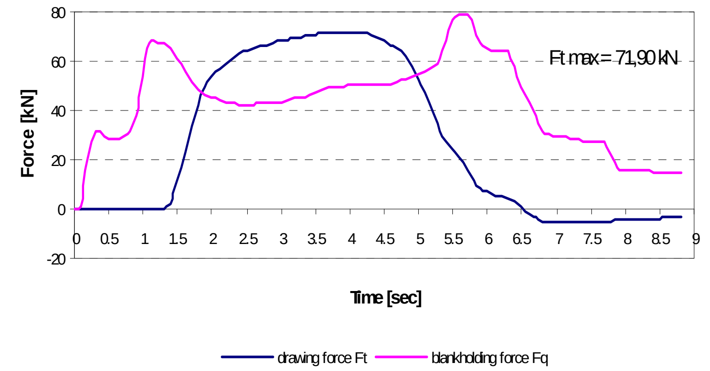

Fig. 5 Course of drawing and blankholding forces, D_0 = 134 mm, m = 0,567

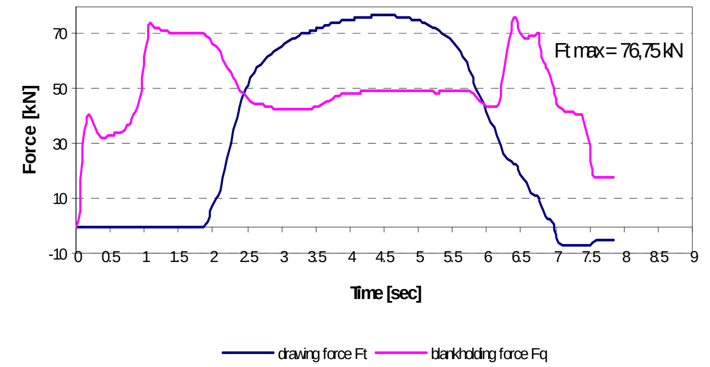

Fig. 6 Course of drawing and blankholding forces, D_0 = 139 mm, m = 0,547

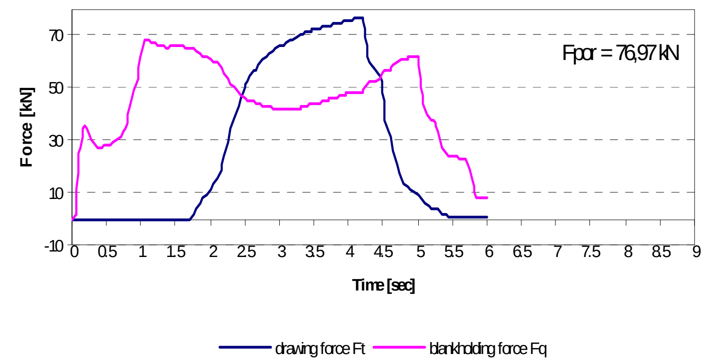

Fig. 7 Course of drawing and blankholding forces at cup breaking D_0 = 145 mm, m = 0,524

Course of drawing and blankholding force at deep-drawing process when cup broke shows the same character in the first stages, as it is in deep-drawing of unbroken cup. After maximum drawing force is reached, drawing force sharply decreased. Maximum drawing force is called cup breaking force in this case. Cup breaks at the bottom to cup wall transition – at the cup radius, whereby bottom is tear off from cup wall.

CONCLUSION

From realised experiments follows:

1. course of drawing force at flat bottomed cylindrical cup without flange deep drawing process with blankholder respond to limit drawing case of deep-drawing from flange,
2. decreasing the drawing ratio caused maximal drawing force growth until dup breaking force,
3. course of blankholding force has a dynamic character at the start and at the end of deep-drawing with stabilized course when cup is drawn. This dynamic character represents response of press hydraulic system on deep-drawing process.

Realised measuring subsystem for drawing and blankholding forces recording allows realising power parameters research of deep-drawing process in dependence force-time with sampling frequency up to 0,01 s^{-1}. When path reader Mitutoyo SD-60 is used also, sampling frequency decreased up to 0,1 s^{-1}, what suit to static processes only. For that reason we consider to buy path reader with sampling frequency up to 0,01 s^{-1}, but also modification of tensometric apparatus is needed.

The advantage of measuring and monitoring subsystem is possibility to use it on whatever machine. The main restriction is the maximal allowed loading of used dynamometers, over crossing which leads to its plastic deformation.

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