COMPUTER CONTROLLED EXPERIMENTAL DEVICE FOR INVESTIGATIONS OF TRIBOLOGICAL INFLUENCES IN SHEET METAL FORMING

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Summary: *Sheet metal forming, especially deep drawing process, is influenced by many factors. Blank holding force and drawbead displacement are two of them that can be controlled during the forming process.*
For this purpose, electro-hydraulic computerized sheet-metal strip sliding device has been constructed. Basic characteristic of this device is realization of variable contact pressure and drawbead height as functions of time or stripe displacement. There are both, pressure and drawbead, ten linear and nonlinear functions. Additional features consist of the ability to measure drawing force, contact pressure, drawbead displacement etc.
Presented in the paper are the device overview and the first results of steel sheet stripe sliding tribological physical model.
Key words: *deep drawing, drawbead, variable contact conditions, tribology*

1. INTRODUCTION

Technology of deep drawing of thin sheet metals is extremely important in modern industry. Due to the development of new materials of more complex formability and raising of the technological requirements to the higher level, the need for realisation of complete control of forming process increases. In order to succeed in that, it is necessary to identify, out of a large number of influential factors, the ones which can be influenced throughout the forming process. It was determined that there are only two such factors: contact pressure on flange and drawbead height [1].

Process control through active complex (closed-loop) systems requires constant dynamic feedback between the given function of the objective, controlled and controlling variables [2]. The functions of the objective and controlled variable can be different: wrinkle height, thinning in critical zone, flange motion, flange thickness change, friction force, forming force, stress in work piece wall etc. The given objective

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functions are defined either by computer simulations or by previous experiments. Pressure on flange and drawbead height present the controlling effects. High velocity of reacting to controlled values change and robust controlling hardware and software apparatus are required, which all implies significant investments [2, 3, 4].

There is also the alternative – a much simpler approach – used in this paper. However, first it is necessary to define optimal functions of pressure and drawbead height according to proper criterion (drawing depth, piece quality etc.). This often requires comprehensive experiments [3, 4] in order to identify the character of specified factors influence. With such information, it is possible to form the controlling apparatus for practical application whose main objective is to realise previously defined optimal functions of pressure and drawbead height. Such equipment requires considerably smaller investments regarding hardware and software and is far more accessible to a wide range of users.

Application of constant height drawbeads is still most often applied and well known [5, 6]. The same goes for application of constant blank holding force on flange. The main reasons for this are smaller forming process costs. However, due to the development of new materials of more complex formability properties, in most cases it is not possible to accomplish the satisfactory results by classical methods.

There are also some new ideas, such as application of drawbeads in which the angle between drawbead axis and sheet metal plane is different from 90^o [7]. There is also the increased interest in many numeric simulations and virtual application of drawbeads in processes of complex work pieces forming [8].

The application of blank holding force without draw beads is the subject of separate researches based on the same aforementioned principles [9].

In this paper, the emphasis is on the display of properties of apparatus for investigation of the character of the connection between drawing force and various influences combination, installed at the Faculty of Mechanical Engineering in Kragujevac. The properties include friction conditions (dry, application of lubricant), drawbead geometry (two rounding radii), one variable function of pressure, variable functions of drawbead height and corresponding constant values of both pressure and drawbead height.

2. EXPERIMENTAL APPARATUS

2.1 THE DEVICE

General block scheme of the apparatus is shown in fig. 1, central part assembley in fig. 2, and physical appearance in fig. 3.

Sheet metal stripe is positioned vertically between contact pairs, drawbead and die, which are variable, fig. 3 and fig. 5. In fig. 3, the positions are as follows: **1**-right cylinder ø70x40 mm, **2**-bolt M8x80, **3**-tube 1, **4**-die nut, **5**-bolt M8x30, **6**-plate 2, **7**-die guide, **8**-stud bolt ø12x55 mm, **9**-lower plate, **10**-upper plate, **11**-die, **12**-drawbead, **13**-bolt M6x45, **14**-nut M6, **15**-washer A6,4, **16**-lateral guide, **17**-plate 1, **18**-guide, **19**-stud bolt ø12x45 mm, **20**-tube 2, **21**-drawbead nut, **22**-bolt M8x100 mm.

The needed stripe width is 30 mm, and recommended length is 250 mm. Drawbead and die are variable, which enables monitoring of the influence of various rounding radii.

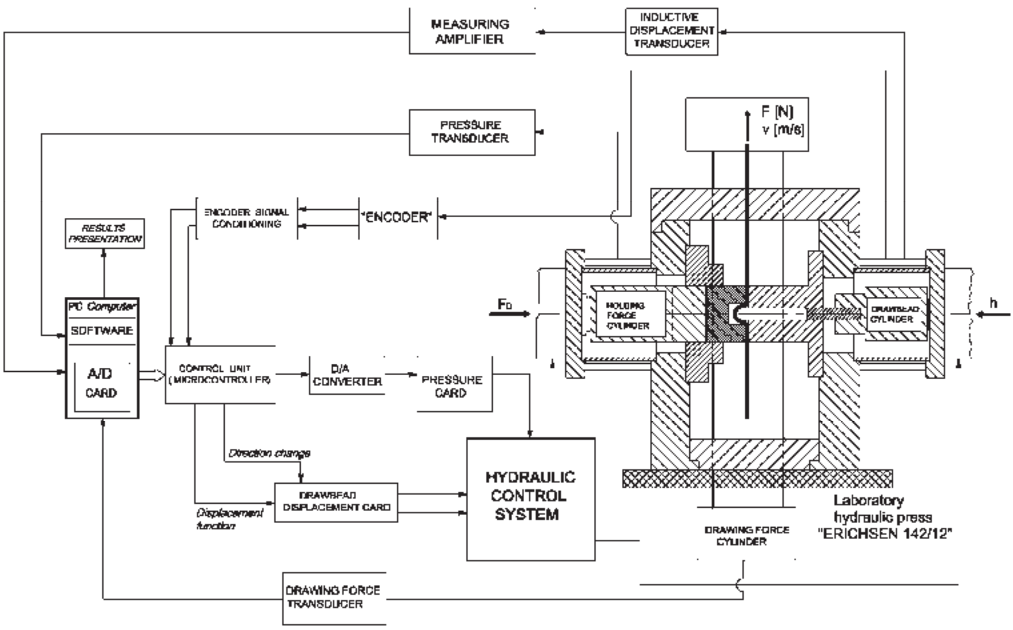

Fig. 1 *Block scheme of experimental apparatus*

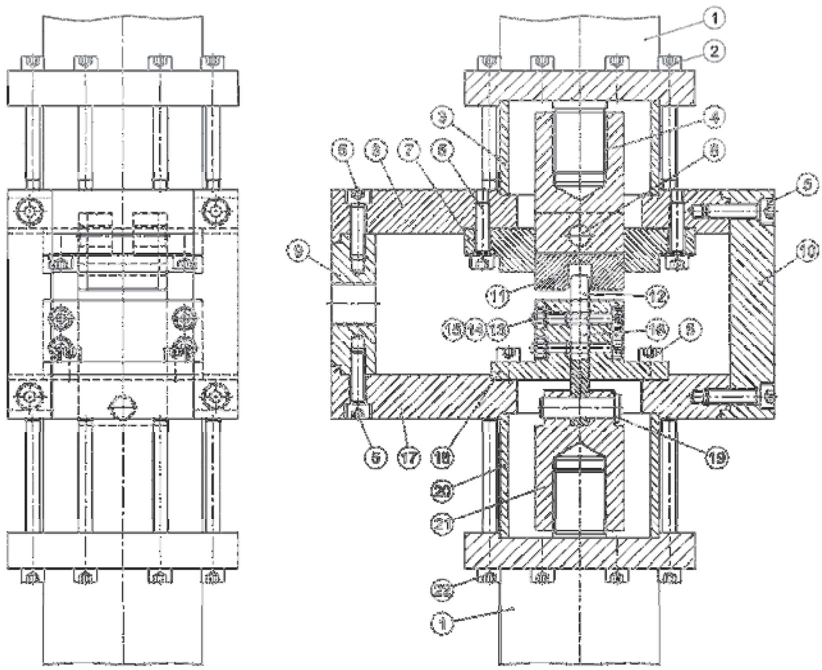

Fig. 2 *Assembley of main device part*

Fig. 3 *Physical appearance of experimental apparatus*

Drawing force is obtained from laboratory press ERICHSEN 142/12 in range 0-20 kN, as well as stress signal for measuring the force of proper sensor. Hydro-cylinders for drawbead motion and pressure realization are fed by aggregate ERICHSEN of nominal pressure 100 bars and flow 1,5 l/s. The oil from the aggregate runs through the series of controllable proportional hydro valves to both cylinders.

Measuring and pressure controlling branch (fig.1) consists of pressure sensor which gives the current true value signal and control unit (micro-controller) which receives the given desired value from the software and sends signal D/A to the convertor. The received analogous signal is transmitted to the control card of the proper hydro-valve connected to the pressure cylinder.

In controlling branch, due to drawbead motion, the current true drawbead position is read by rotation encoder. After processing, the signals are sent to the control unit (micro-controller), and then to the card for control of hydro-valve for drawbead cylinder. One signal is related to the direction change, and the other one to the value of drawbead motion function. For measuring and reading the true drawbead position, supporting branch with inductive sensor and proper amplifier is made.

All true values signals are brought into PC computer with integrated A/D card and proper original software, which enables monitoring of all values, their memorizing, presentation as well as generating of pressure and drawbead motion functions necessary for micro-controller performance.

2.2 PREVIOUSLY GIVEN AND REALLY REALISED FUNCTION OF PRESSURE AND DRAWBEAD HEIGHT

For the needs of planned comprehensive experiment, 6 variable dependencies of both pressure and drawbead motions on time, as given functions, were defined. In figures 4 to 6, those functions are marked with numbers 1 to 6. Dependencies 5 and 6 are linear, and 1, 2, 3 and 4 non-linear. Functions were defined based on empiric values of minimal and maximal pressure (0-20 MPa) and drawbead height (0-8 mm).

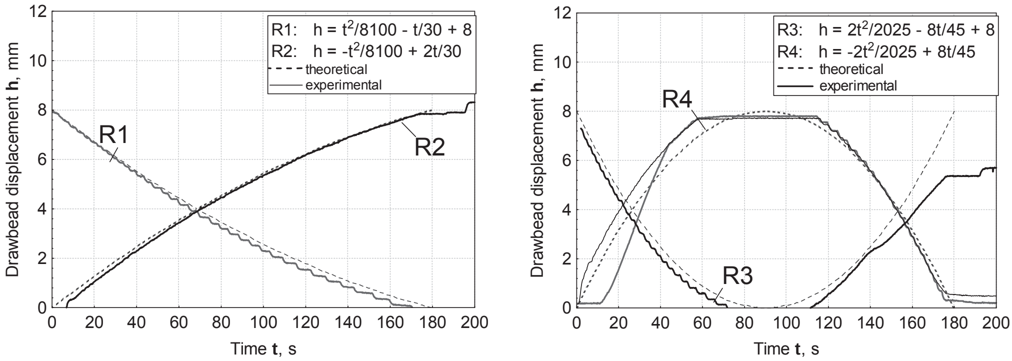

Fig. 4 *Previously defined and really realised dependences of drawbead height (R) on time*

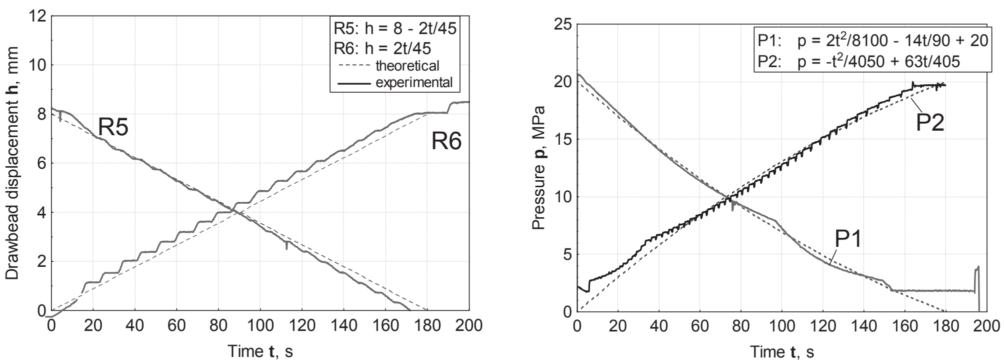

Fig. 5 *Previously defined and really realised dependences of drawbead height (R)and contact pressure (P) on time*

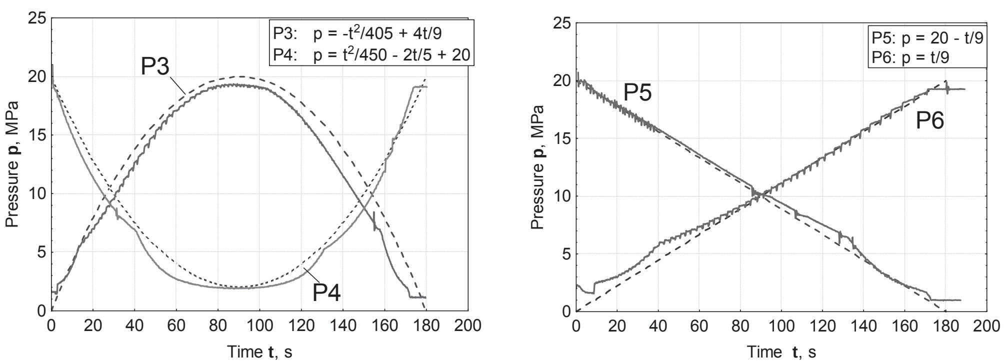

Fig. 6 *Previously defined and really realised dependences of contact pressure (P) on time*

3. CONCLUSION

Based on the concise presentation of the developed apparatus and the preliminary results, it can be concluded that specified computerised device for testing various influences on process of stripe sliding over drawbead enables accurate registering of the influence of variable pressure, variable drawbead height, drawbead geometry and friction conditions on drawing force.

Based on preliminary results obtained by investigating steel sheet metal DC04 on the basis of character of drawing force response, it is possible to make the following conclusions:

a) due to favourable combination of simultaneous performance of contact pressure change, change of drawbead height, drawbead geometry and friction conditions, it is possible to influence precisely the course of sheet metal forming process according to the desired forming force criterion,

b) by such investigations, with rather simple apparatus, it is possible to define significant data for numerical simulations and immediate application in practice at deep drawing of complex geometry parts.

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