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

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Resume

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, an electro-hydraulic computerized sheet-metal strip sliding device has been constructed. The 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.

The device overview and first results of steel sheet stripe sliding over rounded drawbead are presented in the paper.

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1. Introduction

Technology of deep drawing of thin sheet metals is very 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, out of a large number of influential factors, it is necessary to identify, the ones which can be changed and controlled throughout the forming process. There are only two such factors: contact pressure on flange and drawbead height [1].

The process control through active, intelligent complex systems requires constant dynamic feedback between the given goal function, controlled and controlling variables [2]. The goal functions and controlled variable can be different: wrinkle height, thinning in the critical zone, flange motion, flange thickness change, friction force, forming force, tension stress in work piece wall, etc. The given objective functions are defined either by computer simulations or by previous experiments. Pressure on flange and the drawbead height present the controlling effects. High reacting speed to controlled values change and robust controlling hardware and software apparatus are required, which all implies significant investments [2 - 4].

There is also an alternative – a much simpler approach – in a way used in this paper. However, first it is necessary to define optimal functions of pressure and drawbead height according to proper criteria (drawing depth, piece quality, forming force, tension stress 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 goal 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.

The 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 the 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 numerical 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 research based on the same aforementioned principles [9, 10].

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

2. Experimental apparatus

The general block scheme of the apparatus is shown in Fig. 1, central part assembly in Fig. 2, and physical appearance in Fig. 3.

The sheet metal stripe is positioned vertically between the contact pairs, drawbead and die, which are variable, Fig. 3 and Fig. 5. In Fig. 3, the positions are as follows: **1-** hydro cylinder ø 70 x 40 mm, **2-**bolt M8 x 80, **3-** tube 1, **4-** die nut, **5-** bolt M8 x 30, **6-** plate 2, **7-** die guide, **8-** stud bolt ø 12 x 55 mm, **9-** lower plate, **10-**upper plate, **11-** die, **12-** drawbead, **13-** bolt M6 x 45, **14-** nut M6, **15-** washer A 6,4, **16-** lateral guide, **17-** plate 1, **18-** guide, **19-** stud bolt ø 12 x 45 mm, **20-** tube 2, **21-** drawbead nut, **22-** bolt M8 x 100mm.

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

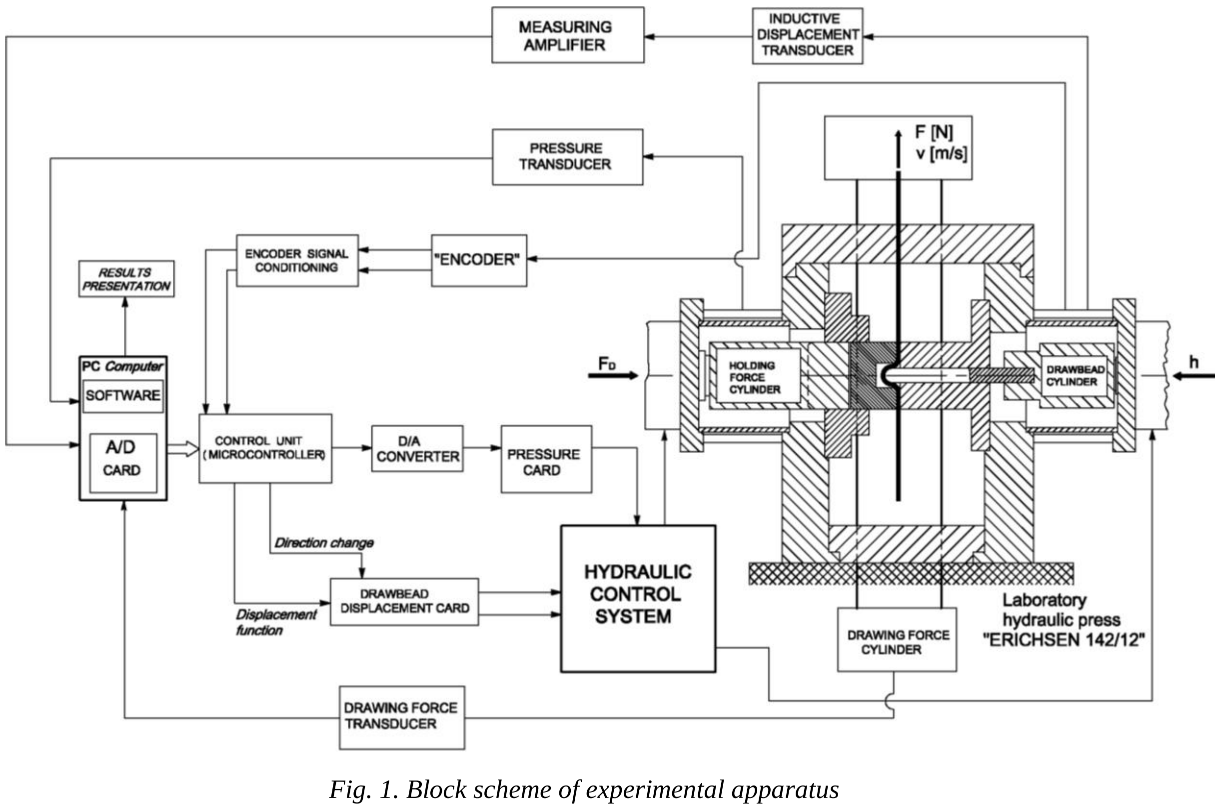

Fig. 1. Block scheme of experimental apparatus

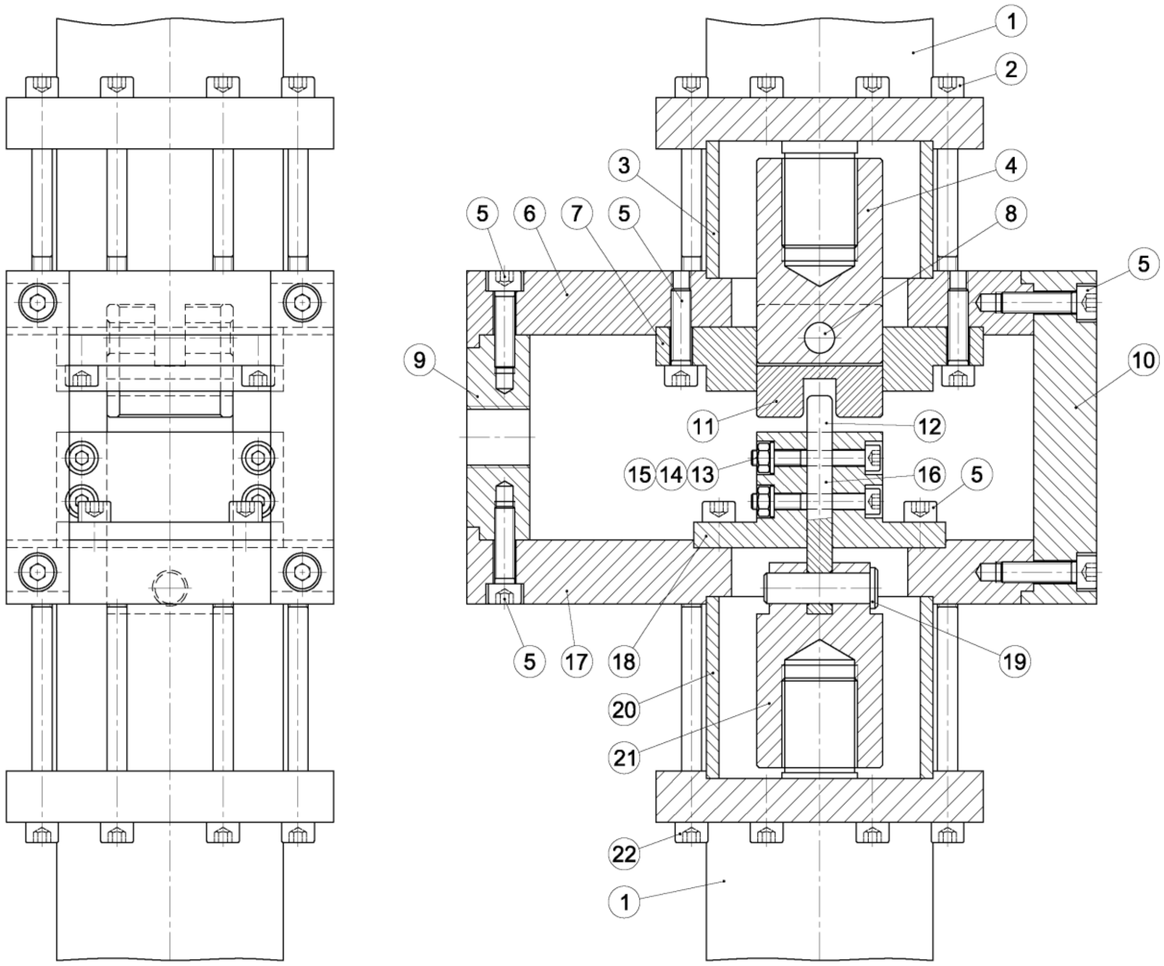

Fig. 2. Assembly of main device part

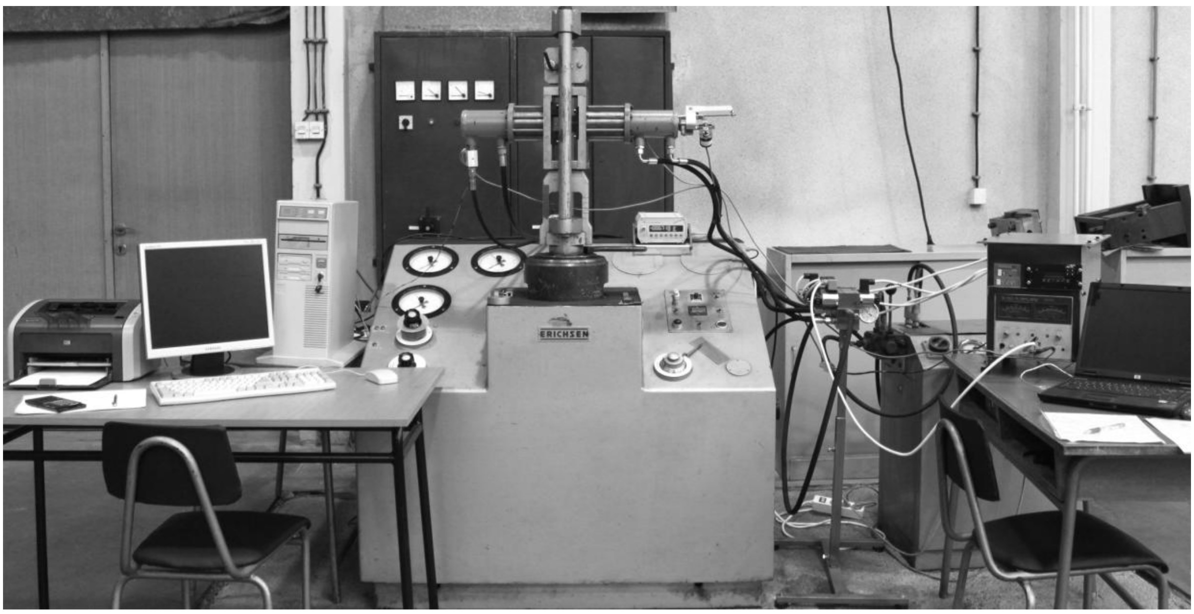

Fig. 3. Physical appearance of experimental apparatus

The drawing force is obtained from laboratory press ERICHSEN 142/12 in range 0-20 kN, as well as a 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 a pressure sensor which gives the current real value signal and control unit (micro-controller) which receives the given desired value from the software and sends signal to the D/A converter. 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 real 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 real values signals are brought into a PC computer with integrated A/D card and proper original software, which enables monitoring of all the values, their recording, presentation as well as generating of pressure and drawbead motion functions necessary for micro-controller performance.

3. Previously defined 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 Figs. 4, 5 and 6, those functions are marked with numbers 1 to 6. Dependencies 5 and 6 are linear, and 1, 2, 3 and 4 non-linear, parabolic. Functions were defined based on empiric values of minimal and maximal pressure (0-20 MPa), drawbead height (0-8 mm) and process duration. The process duration was restricted by the limited stripe displacement of 60 mm and adopted sliding speed of 20 mm/min. This caused maximal process duration of 3 min (180 s).

The purpose of functional dependencies defined in such a way is the inclusion of a wide range of possible actions: decreasing, increasing, combined decreasing-increasing and increasing-decreasing, linear and non-linear. Monitoring and analyzing of the response of drawing force change on action of such dependencies together with friction conditions and drawbead geometry is the most important part of this device operation.

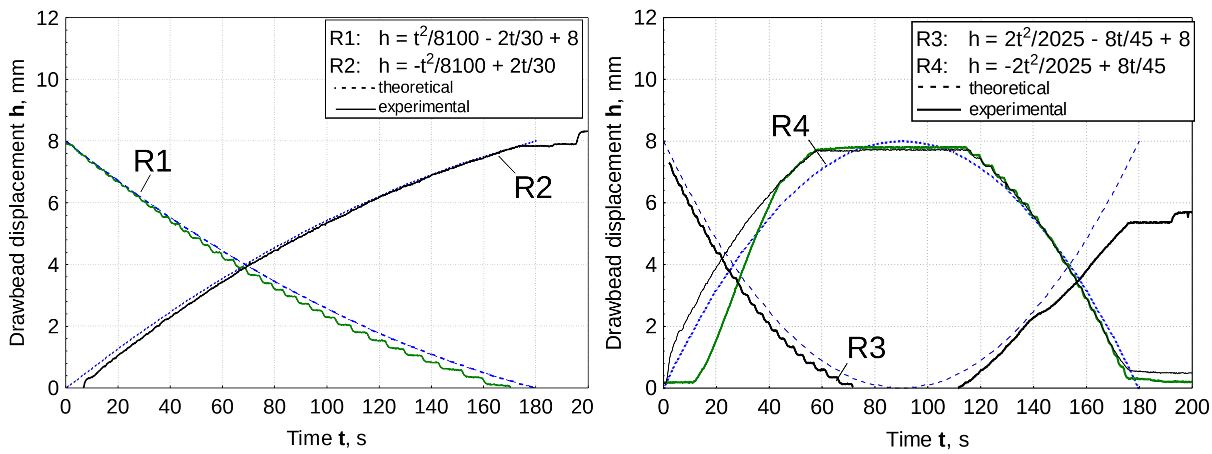

Fig. 4. Previously defined and really realised dependences of drawbead height (R) on time

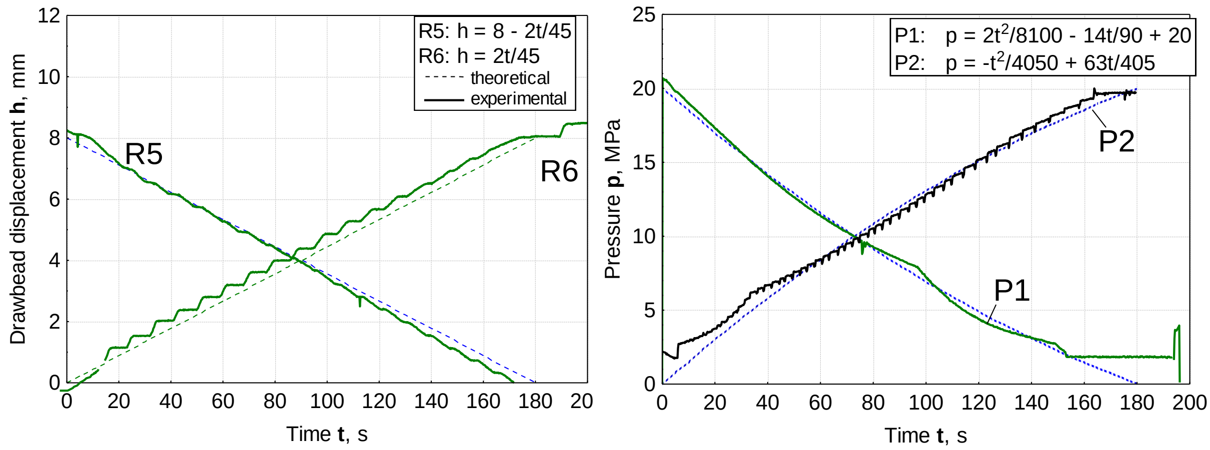

Fig. 5. Previously defined and really realised dependences of drawbead height (R) and contact pressure (P) on time

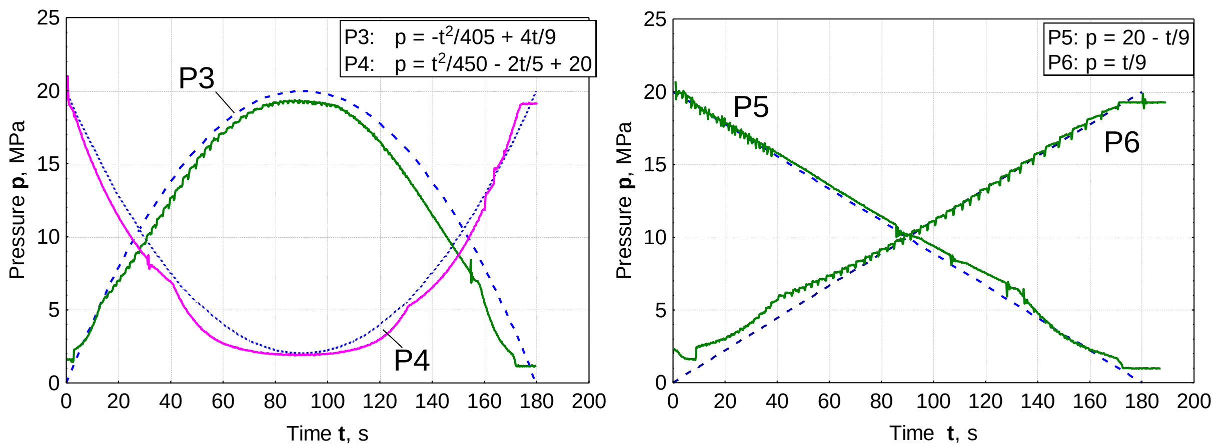

Fig. 6. Previously defined and really realised dependences of contact pressure (P) on time

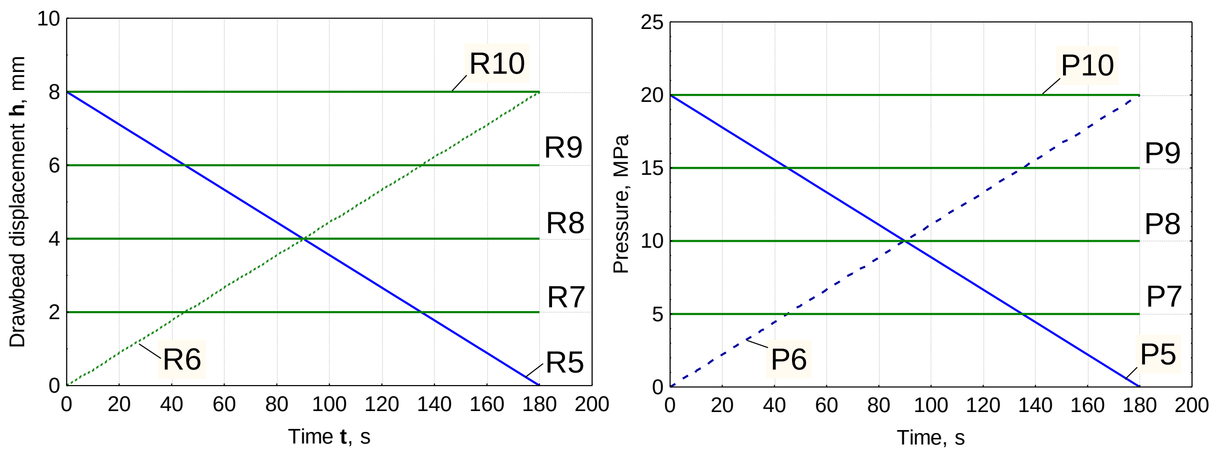

Fig. 7. Previously defined linear and constant dependences of drawbead height (R) and contact pressure (P) on time

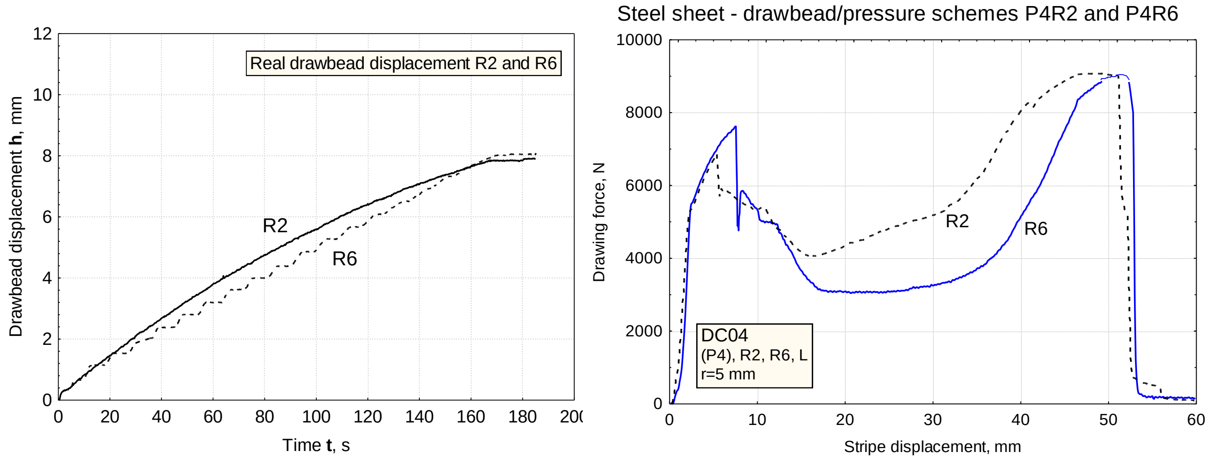

Fig. 8. Variable drawbead height (a) influence on drawing force (b)

In Fig. 7 constant values are marked with numbers 5 to 10. Figs. 4, 5 and 6 are showing acceptable difference between the given and really achieved values. This difference is due to the way in which this apparatus is operating. Constant values are achieved with negligible errors and because of that real values are not shown.

Fig. 8 shows an example of the first obtained results. Fig. 8a shows really realized functions of the drawbead height change R2 and R6 (according to Fig. 4 and Fig. 5). Fig. 8b shows drawing force dependence on stripe displacement. The material is low carbon sheet metal DC04. Pressure relate to function P4 (Fig. 6), and drawbead rounding is 5 mm. Friction was determined by lubrication with the appropriate oil. Dependences in Fig. 8a are increasing, where at parabolic dependence R2 has more intensive increase in the first half of the stripe displacement. This difference contains the cause for drawing force reaction which shows higher intensity decrease for milder process conditions at linear dependence of drawbead height R6 (Fig. 8b).

4. Conclusions

Based on the concise presentation of the developed apparatus and the preliminary results, it can be concluded that the 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 the steel sheet metal DC04, about the character of the 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 the 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 needed numerical simulations and immediate application in practice at deep drawing of complex geometry parts.

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