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VARIABLE CONTACT PRESSURE AND VARIABLE DRAWBEAD HEIGHT INFLUENCE ON DEEP DRAWING OF Al ALLOYS SHEETS

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Abstract: *The process of deep drawing is influenced by many factors. During the forming process, only two of those factors can be controlled. They are blank holding force and drawbead height. Realisation of such control requires rather complex computerised apparatus.*
For this investigation, electro-hydraulic sheet-metal strip sliding device has been constructed. Basic capacity of realized device is obtaining contact pressure and drawbead height as functions of time or stripe displacement. Additional features consist of the ability to measure drawing force, contact pressure, drawbead displacement etc.
Presented in the paper are the first results of influencing of increasing and decreasing function of drawbead height in combination with increasing-decreasing function of contact pressure. Stripe material is aluminium alloy AlMg4,5Mn0,7 0,9 mm sheet metal. Contact condition are additionally influenced by application of mineral oil or completely dry tool and stripe surfaces. Drawbead geometry, with rounding radii of 2 and 5 mm, is also varied.
The accomplished results indicate that simultaneous effects of variable drawbead height, variable contact pressure, tool geometry and appropriate friction conditions can influence the plastic flow process in line with desired change of forming force.

***Key words**: deep drawing, stripe sliding, variable drawbead height, variable contact pressure.*

1. INTRODUCTION

Deep drawing process is widely applied in modern industry, which makes it extremely important. That is the reason for ongoing tendencies to accomplish total control of forming process. In order to succeed in that, it is necessary to select, out of a large number of influential factors, the ones which can be influenced throughout the forming process, thus correcting it until it is completed successfully. There are only two such factors: contact pressure 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 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 [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 [5, 6] 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 [7, 8]. 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.
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 investigation of the character of the connection between drawing force and various influences combinations. They include friction conditions (dry, application of lubricant), drawbead geometry (two rounding radii), one variable function of pressure of increasing-decreasing character, two functions of drawbead of decreasing and increasing character and

corresponding constant values of both pressure and drawbead height. The significance of the physical model applied in actual experiments is clearly seen in [8].

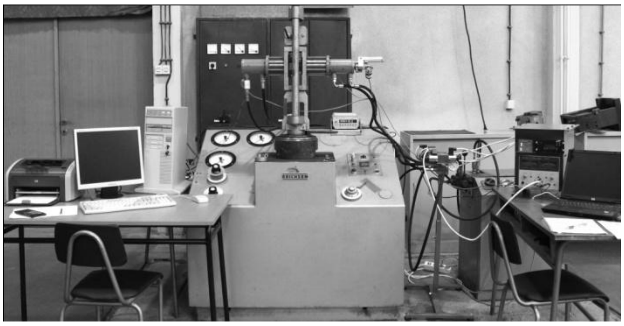

Fig. 1. Physical appearance of experimental apparatus

2. EXPERIMENTAL CONDITIONS

2.1 Material

The material of which the stripes used in the experiment are made is Al alloy sheet metal from series 5000, AlMg4,5Mn0,7. Its thickness is 0.9 mm. Main mechanical properties and properties of formability are given in table 1 (R_P – yield strength, R_M – tensile strength, A – elongation at fracture, n – strengthening exponent, r – coefficient of normal anisotropy, K – effective stress in plastic zone). Material properties are related to the condition after the following thermal treatment: glowing at temperature of 350°C in duration of 3 hours.

In one case, the friction conditions are dictated by dry surfaces – completely degreased and cleaned by acetone. In the other case, the contact surfaces were richly covered (by sponge) with oil for deep drawing of the following properties at 40°C: kinematic viscosity 45 mm^2/s, dynamic viscosity 42 mPas and density 0,93 kg/dm^3.

Dimensions of applied stripes were: length 250 mm, width 30 mm and thickness 0,9 mm.

Table 1. Material properties

AlMg4.5Mn0.7 s=0.9 mm				
R_P, MPa	**R_M, MPa**	**A, %**	**n, -**	**r, -**
120.5	276.6	26.2	0.26	0.715
$K = 443.6 \cdot \varphi^{0.26}$, MPa				

2.2 Experimental device

The physical appearance of the apparatus is shown in figure 1. Sheet metal stripe is positioned vertically between contact pairs, drawbead and die, which are variable. Drawing force is obtained from laboratory press ERICHSEN 142/12 in range 0-20 kN, as well as voltage signal for measuring the force of proper sensor. Hydro-cylinders for drawbead displacement 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 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 rotational 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.

Drawbead is 10 mm thick and is applied with two radii: 2 mm and 5 mm. Die rounding radius is 2 mm, and die opening is 12 mm. Both drawbead and die can be varied with the aim of monitoring the influence of drawbead geometry change. Active surfaces of drawbead and die are fine grinded and polished.

3. RESULTS AND DISCUSSION

3.1 Pressure and displacement functions

For the needs of planned comprehensive experiment, 6 variable dependencies of both pressure and drawbead motions on time, as given functions, were defined. Those functions are marked with numbers 1 to 6. Dependencies 5 and 6 are linear (fig. 2 and 3), and 1, 2, 3 and 4 non-linear – parabolic. Functions were defined based on empiric values of minimal and maximal pressure (0-20 MPa) and drawbead height (0-8 mm). Process duration was conditioned by limited stripe displacement and adopted sliding velocity of 20 mm/min. This conditioned maximal process duration of 3 min.

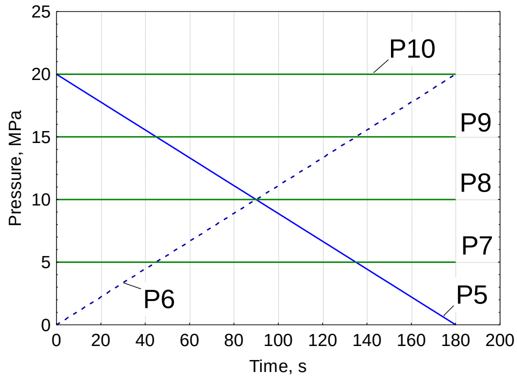

Fig. 2. Dependencies of contact pressure on time

The purpose of so defined functional dependencies, which have different characters, is the inclusion of wide range of possible influences: decreasing, increasing, combined decreasing-increasing and increasing-decreasing, linear and non-linear. Monitoring of the response of drawing force regarding the performance of such dependencies together with friction conditions and drawbead geometry is the most important part of this research.

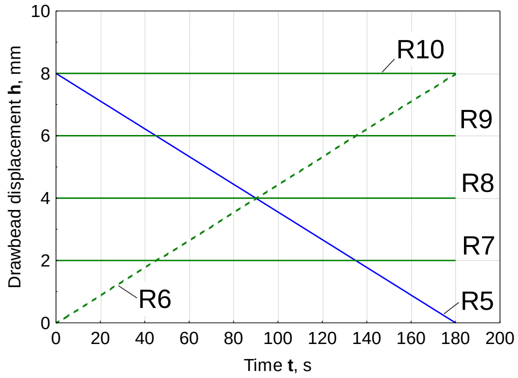

Fig. 3. Dependencies of drawbead height on time

3.2 Experimental values of drawing force

Fig. 4 shows given and truly achieved dependence of pressure P3 change. Fig. 5 shows given and truly achieved decreasing and increasing dependencies of drawbead height. Truly achieved constant values of pressure according to schemes P7, P8, P9, P10 and constant drawbead height according to scheme R9 are corresponding, with insignificant deviations to fig. 2 and fig. 3 and are not shown here. Such a combination was selected with the purpose of checking the response of drawing force to complex increasing- decreasing dependence of contact pressure during the process together with decreasing and increasing functions of drawbead height. The investigation of the following combinations was also carried out: constant pressure P7 to P10 – constant drawbead height R9, variable pressure P3 – constant drawbead height R9, as well as constant pressure P8 – variable drawbead height R1 and R2. The purpose of such combinations is the evaluation of separate influences of variable pressure and drawbead height influence. In addition to that, it was necessary to estimate the influence of friction conditions. Drawbead geometry was defined by rounding radius of 5 mm and it was not varied.

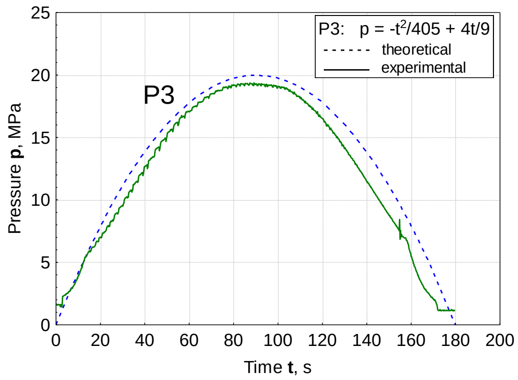

Fig. 4. Real dependence of pressure on time

Fig. 6 confirm the known dependencies of drawing force on stripe travel at constant pressures and constant drawbead height [8]. In figure 6, contact pressures are 5, 10, 15 and 20 MPa, and drawbead height is 6 mm. Dependencies were obtained in conditions of dry friction. The influence of extremely intensified friction is obvious. The intensity of force increases. In addition to that, stripe fracture before the end of process in 3 cases can be noticed, at pressures P8, P9 and P10. The combination of unfavourable friction conditions and contact pressures leads to critical sliding conditions and forming, which results in stripe fracture. At pressure P7, the process runs successfully until the end in both cases, and at extremely high pressure P10, fractures occur for both friction types.

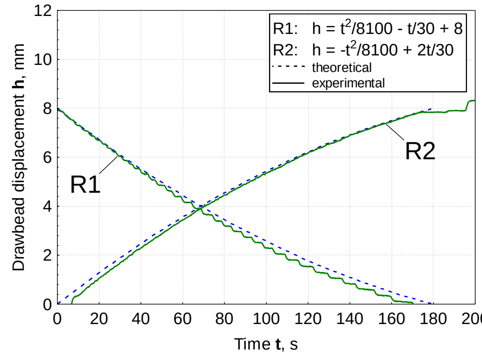

Fig. 5. Real dependencies of drawbead height on time

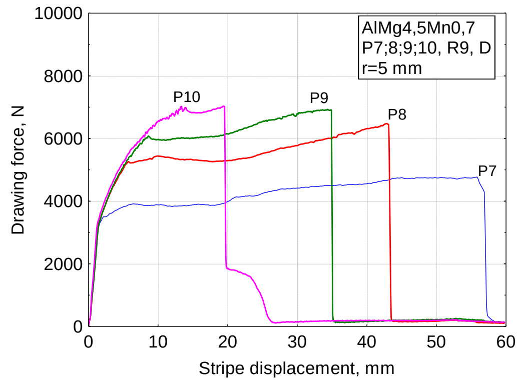

Fig. 6. Drawing force dependencies on stripe travel

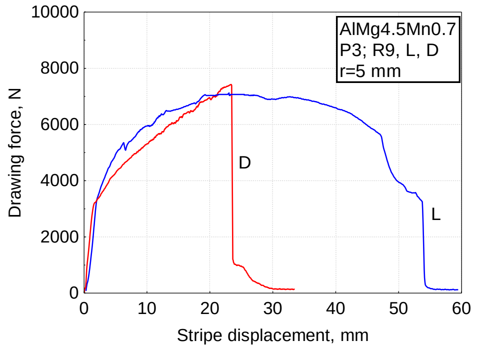

Fig. 7. Drawing force dependencies on stripe travel

Fig. 7 shows drawing force at combination of influence of variable pressure P3 and constant drawbead height R9. Drawing force response is, in a way, in line with pressure function P3. At smaller friction (L) such a conclusion is valid until the end of the entire stripe travel, while unfavourable conditions of strong friction (D) lead to fracture in travel smaller than half of the total travel.

If constant pressure value is fixed at 10 MPa, and drawbead height is varied (R1 i R2), dependencies in fig.

8 will be obtained, at oil lubrication. Due to the initial drawbead height of 8 mm for function R1, drawing force increases and only after approximately 10 mm of travel it begins to decrease less intensively than drawbead height decrease. In the case of increasing drawbead function (R2), drawing force increases almost proportionally to the increase of drawbead height. The initial force increase is conditioned by pressure P8.

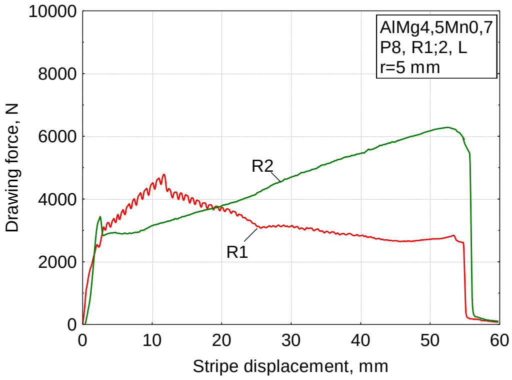

Fig. 8. Drawing force dependencies on stripe travel

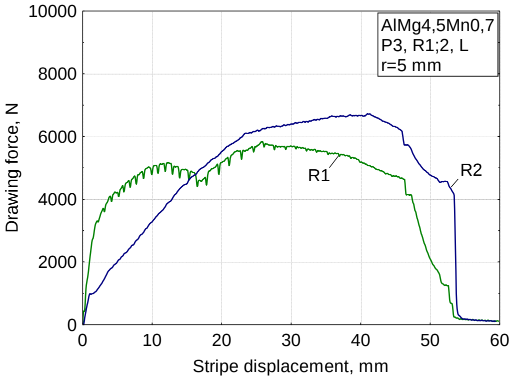

Fig. 9. Drawing force dependencies on stripe travel

Finally, in fig. 9, the effects of simultaneous influence of variable pressure (P3) and variable drawbead height (R1 i R2) at oil lubrication can be seen. According to the intensity and shape of drawing force curves, it can be seen that the intensity of influence of pressure P3 and change of drawbeads height R1 and R2 is equal. At the beginning of travel, combination P3R2 has small values of pressure and drawbead height, which results in weak intensity of drawing force which increases slowly. On the contrary, when function R2 is replaced with R1, large initial height of drawbead causes initial increase of force which lasts until drawbead height decreases sufficiently and sliding process enters a rather stable phase, with smaller oscillatory changes.

4. CONCLUSION

Computerised device for testing the various influences on drawing force in the process of stripe sliding over drawbead at variable contact pressure and variable drawbead height enables accurate registering of the influence of pressure action, drawbead height, drawbead geometry and friction conditions on drawing force.

This paper presents a part of experimental results for the sliding test for aluminium alloy AlMg4,5Mn0,7 stripe. Based on the presented results, the following conclusions can be made:

a) the response of drawing force is approximately equally influenced by simultaneously applied functions of variable pressure and drawbead height in milder sliding conditions, at larger drawbead rounding radius and smaller friction,

b) reaction of drawing force is registered even at relatively small differences in drawbead height change during the process,

c) the character of drawing force response shows that the favourable combination of simultaneous performance of contact pressure change, change of drawbead height and friction conditions makes it possible to influence precisely the course of sheet metal forming process according to the desired forming force criterion,

d) by such investigations, with relatively 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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