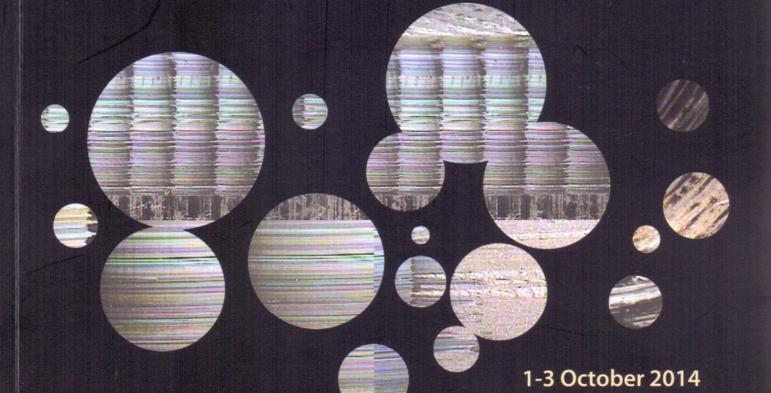


Thessaloniki, Greece

EDITOR: K.-D. Bouzakis





ICMEN
5th International Conference
on Manufacturing Engineering

PROCEEDINGS

ISBN 978-960-98780-9-8

Thessaloniki - Greece

Printed by



18th klm Thessaloniki - Perea P.O. Box 4171 – 570 19 Perea -Thessaloniki Tel.: +30 2392 072.222 – Fax: +30 2392 072.229 e-mail: info@ziti.gr

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INFLUENCE OF VARIABLE DRAWBEAD HEIGHT AND VARIABLE CONTACT PRESSURE IN AL ALLOY SHEET STRIP DRAWING PROCESS

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ABSTRACT

An electro-hydraulic computer controlled device was created for the realization of the sheet metal strip drawing test. Its main property is realization of contact pressure and drawbead height as different functions dependent on stripe travel or time. In addition, it is also possible to measure drawing force, pressure, drawbead displacement etc.

Experimental study of chosen drawbead height and contact pressure functions influence in strip sliding test are presented in this paper. The strips are made of Al alloy sheet metal AIMg4.5Mn0.7 of 0,9 mm thickness. Strip dimensions are 250 x 30 mm. Drawbead geometry, with rounding radii of 2 and 5 mm, is also varied. Drawbead thickness is 10 mm. On contact surfaces mineral oil was applied.

The results indicate that acting of combined action of constant pressure with variable drawbead height and constant drawbead height with variable contact pressure, in addition to other conditions, can influence substantially the plastic flow process.

KEYWORDS:

Al alloy sheet metal, Strip test, Variable pressure, Adjustable

drawbeads

1. INTRODUCTION

In order to succeed in deep drawing process control, it is necessary to select, out of a large number of influential factors, the ones which can be varied during the forming process course, 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 permanent dynamic feedback between the given goal function, controlled and controlling variables. The goal functions and controlled variable can be different: wrinkle height, thinning in critical zone, flange motion, flange thickness change, friction force, forming force, tension stress in work piece wall etc. Contact pressure on flange and drawbead height present the controlling variables. High velocity of reacting to controlled values change and robust expensive controlling apparatus in hardware and software meaning are required, which all implies significant investments /2, 3/.

There is also the alternative – a much simpler approach – suggested in this paper. However, first it is necessary to define optimized functions of pressure and drawbead height according to proper criterion (drawing depth, piece quality etc.). This often requires comprehensive experiments /4, 5/ 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, for example small enterprises.

Application of constant height drawbeads is still most often applied and well known /6, 7/. Similarly is valid 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 worse formability properties, in most cases it is not possible to accomplish the satisfactory results by classical methods.

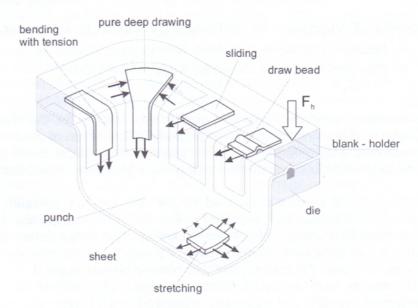


Figure 1: Scheme of physical models at deep drawing of complex geometry parts.

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° /8/.

The application of blank holding force without draw beads is the subject of separate researches based on the same previously mentioned principles /9, 10/.

In this paper, the emphasis is on investigation of the character of the connection between drawing force and various influencing factor combinations. They include friction conditions (application of lubricant), drawbead geometry (two rounding radii), six variable function of pressure, five functions of drawbead and corresponding constant values of both pressure and drawbead height. The significance of the physical model applied in actual experiments is clearly seen in Figure 1 /7/.

2. EXPERIMENTAL CONDITIONS

2.1 Material

The material of which the stripes used in the experiment are made is series 5000 Al alloy AlMg4.5Mn0.7 sheet metal with 0.9 mm thickness. The main mechanical properties, properties of formability and roughness are given in in <u>Table 1</u>.

Table 1: Material properties.

A. Mechanical and	formability prope	erties / AIMg4,5Mn0,	7 - s=0,9 mm			
CESTIVEL C	R_P , MPa	R _M , MPa	A ₈₀ , %	n	r	
Average value /	120.5	276.6	26.2	0.26	0.715	
Strengthening cur	ve approximation	/ K = 204.9 + 388.9	φ ^{0.448} , MPa			
B. Roughness pro	perties /	Last Council ha				
R _a , µm	R_t , μ m	R_z , μ m	R_p , μ m	Peak co	Peak count, 1/cm	
0.31	1.72	1.49	0.66		56	

 R_P – yield strength, R_M – tensile strength, A_{80} – fracture extension, n – strain hardening exponent, r – coefficient of the normal anisotropy. Given are the average values due to planar anisotropy. Strengthening curve approximation function corresponds to sheet rolling direction. Roughness properties: R_a – average absolute roughness height from the centre line, R_t – height from lowest valley to highest peak in roughness, R_Z – average of 5 partial R_t , R_p – height of highest roughness peak measured from the centre line.

The friction conditions are dictated by applying of mineral oil for deep drawing with the following properties at 40°C: kinematic viscosity 45 mm²/s, dynamic viscosity 42 mPas and density 0.93 kg/dm³. Contact surfaces were richly lubricated by sponge. Previously surfaces were degreased and cleaned by acetone.

Dimensions of applied strips were: length 250 mm, width 30 mm and thickness 0.9 mm.

2.2 Experimental device

The general scheme of the apparatus is shown in Figure 2. Sheet metal strip is positioned vertically between contact pairs, drawbead and die, which are changeable. Drawing force is realized 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. More details about used experimental equipment are given in references /11, 12/.

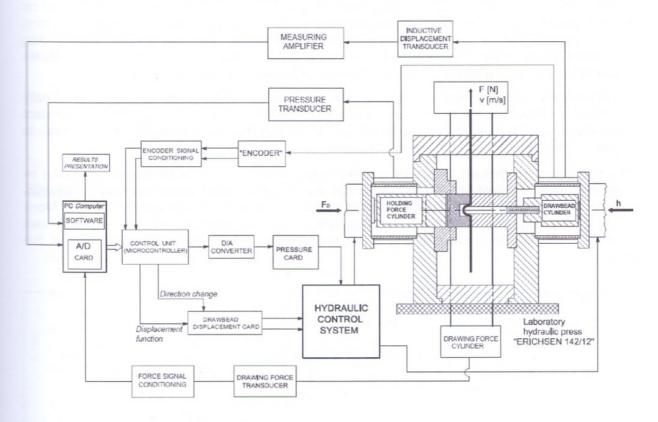


Figure 2: Block scheme of experimental apparatus.

Figure 3 shows the scheme of drawbead, die and strip contact. Drawbead is 10 mm thick and is applied with two radii: 2 mm (shown in the scheme) 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.

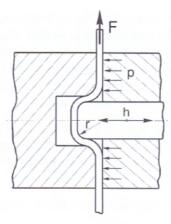


Figure 3: Drawbead, die and strip contact scheme

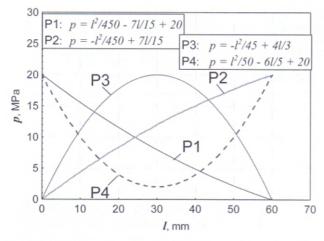
3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Contact pressure and drawbead displacement functions

For the needs of planned comprehensive experiment, 6 variable dependencies of both pressure and drawbead heights on time, as given functions, were defined. In Figures 4, 6, 8 and 10, those functions are marked with numbers 1 to 6, P-pressure, R-drawbead height. 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) and drawbead height (0-8 mm) /13/. Process duration was conditioned by limited strip displacement and adopted sliding velocity of 20 mm/min. This conditioned maximal process duration of 3 min. Dependencies signed from 7 to 10 are related to constant values of pressure and drawbead height.

Experimentally really achieved dependencies are given in <u>Figures 5, 7, 9 and 11</u>. Really achieved constant values of pressure according to scheme P7, P8, P9, P10 and constant drawbead height according to scheme R9 are corresponding, with insignificant deviations, to Figure 6_and Figure 10 and are not shown here.

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



<u>Figure 4:</u> Previously defined dependencies of contact pressure on strip displacement.

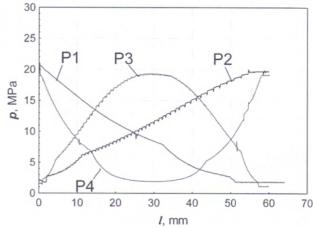
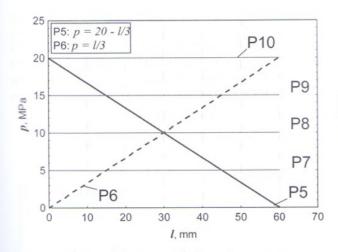


Figure 5: Experimental pressure dependence on strip displacement.



<u>Figure 6:</u> Previously defined dependencies of contact pressure on strip displacement.

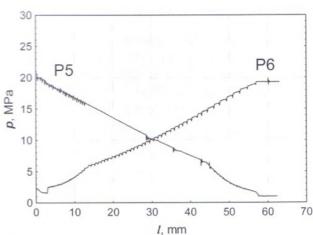
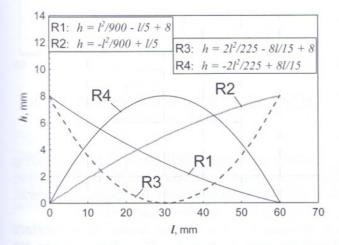
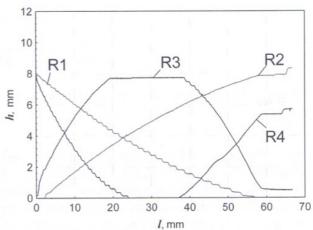


Figure 7: Experimental pressure dependence on strip displacement.



<u>Figure 8:</u> Previously defined dependencies of drawbead height on strip displacement.



<u>Figure 9:</u> Experimentally achieved drawbead height dependence on strip displacement.

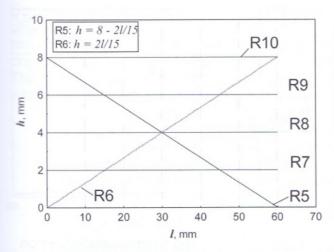
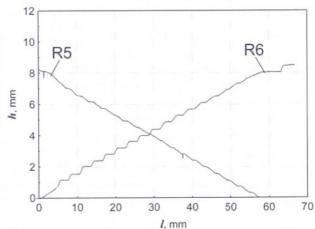


Figure 10: Previously defined dependencies of drawbead height on strip displacement.

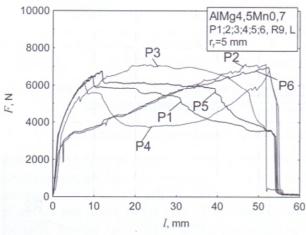


<u>Figure 11:</u> Experimentally achieved drawbead height dependence on strip displacement.

3.2 Measured drawing force values

For this particular experiment adequately combinations of pressure and drawbead height functions were chosen. This combinations are always including one constant function. In figures 12, 13, 14 and 15 it is drawbead height signed as R9 (h=6 mm). In figure 16 it is pressure signed as P8 (p=10 MPa). All a used dependencies can be seen in figures 5 to 11. Main reason for such a decision is: to see influence of the particular variable function clearly.

Friction conditions are dictated by using previously mentioned lubricant, in all cases (sign L).



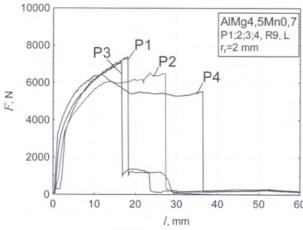
10000 AlMg4,5Mn0,7 P7;8;9;10, R9, L 8000 $r_r=5 \text{ mm}$ P10 P9 6000 P8 4000 Ŕ7 2000 0 0 10 20 30 40 50 60 l, mm

Figure 12: Drawing force dependencies on stripe displacement.

Figure 13: Drawing force dependencies on stripe displacement.

The results shown in <u>Figures 12 and 13</u> were obtained with drawbead radius of 5 mm. Sliding conditions are mild. Figure 12 shows the influence of variable pressure functions. Drawbead height is constant. Drawing force dependencies are following pressure functions in general. Strip drawing process was ended successfully, without fracture, for all six samples.

Figure 13 confirm the known dependencies of drawing force on stripe travel at a constant pressures and constant drawbead height. Sliding process is smooth. Strip fracture can be noticed before end of process, at sliding length of approximately 20 mm, only for 20 MPa (P10) pressure intensity.



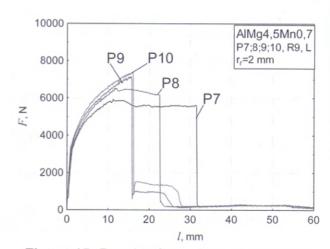


Figure 14: Drawing force dependencies on stripe displacement.

Figure 15: Drawing force dependencies on stripe displacement.

By making sliding and forming conditions more difficult due to the application of drawbead radius r=2 mm, Figures 14 and 15 shows force dependencies for unsuccessfully ended sliding

processes. In all 8 cases fracture were occurred. Only for variable pressure function P4 acting, longer sliding length can be seen.

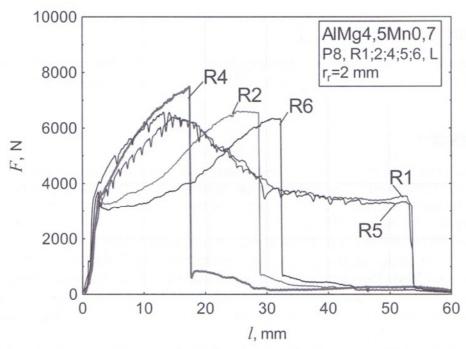


Figure 16: Drawing force dependencies on stripe displacement.

Fig. 16 shows the influence of drawbead functions R1, R2, R4, R5, R6 regardless of variable pressure. Constant pressure was applied according to scheme P8. At figure 16 can be seen that acting of drawbead functions R2, R4 and R6 lead to fracture in travel smaller than 35 mm. But also can be seen that drawbead functions R1 and R5 were made successful sliding process without fracture.

Oscillatory phenomena caused by drawing force sensitivity to gradual change of real functions R1 and R5 can be observed.

4. CONCLUSIONS

Computer controlled device for testing the various influences on drawing force in the process of strip sliding over drawbead at variable contact pressure and variable drawbead height, enables accurate monitoring and measuring 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 aluminum alloy AlMg4,5Mn0,7 strip. Based on the presented results, the following conclusions can be drawn:

- a) selection and application of appropriate functions of variable and constant pressure only, in mild sliding conditions, which are realized by application of 5 mm drawbead rounding radius and oil lubrication, makes it possible to realize successful strip drawing process,
- in more difficult sliding and forming conditions realized by using of 2 mm drawbead rounding radius, application of any kind of pressure functions is not sufficient and lead to fracture,
- application of appropriate variable drawbead height functions in combination with appropriate constant pressure intensity, makes it possible to realize successful strip drawing process, even in more difficult sliding and forming conditions,
- d) the character of drawing force response shows that the favourable combination of simultaneous acting of contact pressure, drawbead height, friction and forming conditions makes it possible to influence the course of sheet metal strip drawing process according to the desired forming force criterion,

e) by such investigations, with relatively simple apparatus, it is possible to define significant data useful for application in practice at deep drawing of complex geometry parts, and data useful for comparison with numerical simulations results.

ACKNOWLEDGEMENTS

The work reported in this paper was partially financially supported by the Serbian Ministry of Education and Science, through contracts TR 34002. The authors are very grateful for this funding.

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78 5th ICMEN - 2014