"Mircea cel Batran" Naval Academy Scientific Bulletin, Volume XIV – 2011 – Issue 1
Published by "Mircea cel Batran" Naval Academy Press, Constanta, Romania

REGARDING THE METHODS FOR DETERMINATION OF THE DEFORMATION LIMIT CURVES

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Abstract: *The deformation limit curves show the dependence between the two real main strains or the two logarithmic strains which arise in the plane of the deformed blank by stretching or drawing. According to the criterion used for limiting the deformation it will result the deformation limit curves either for the nick or for the break. The determination of these curves allows the removal of the danger of breaking the pieces at working by drawing.*
Keywords*: deformation limit curves, the shape of the punch, the shape of the blank, the maxim and minim strain*

1. INTRODUCTION

The notion of workability by drawing involves two aspects:

- material capacity to be processed through this process - established by the provider of materials
- the behavior of the material during processing - set of finished parts provider.

Workability appreciation is by general methods (mechanical tests, microstructure analysis, chemical analysis) and special methods. In the category of special methods is part the limit curves method [1].

2. DETERMINING THE SIZE STRAINS

To measure the local strains using experimental the networks method, preferably with circular motif. In this case, whatever the state of deformation, the main deformation axes will be oriented to the direction of ellipse axes in which the original circle is deformed (fig. 1).

Noting with d_0 - initial diameter of the circle, l_1, l_2 - large axis of ellipse, respectively axis small, deformations can be determined in proportion (elongated) and logarithmic deformations. The elongations in the three directions are determined as follows :

$$e_1 = \frac{l_1 - d}{d} = e_{max}\,;\; e_2 = \frac{l_2 - d}{d} = e_{min}\,;\; e_3 = \frac{g - g_0}{g_0}\,, \tag{1}$$

where: e_{max} and e_{min} are the maximum deformations, respectively of the minimum of plan sheet, e_3 - deformation in thickness direction, g_0, g - initial thickness after deformation of the sheet. Generally, the e_{max} and e_{min} is determined and e_3 resulting from volume conservation law $e_{max}+e_{min}+e_3=1$.

The logarithmic deformations is determined by calculation based on their relationship:

$$\varepsilon = \int_d^l \frac{dl}{l} = \ln\frac{l}{d}\,, \tag{2}$$

thus resulting in:

$$\varepsilon_1 = \ln(l_1/d) = \varepsilon_{max};\, \varepsilon_2 = \ln(l_2/d) = \varepsilon_{min};\, \varepsilon_3 = \ln(g/g_0);\varepsilon_{max} + \varepsilon_{min} + \varepsilon_3 = 0\,. \tag{3}$$

The relationship between the two types of deformation is expressed by the relations:

$$\varepsilon_1 = \ln(1+e_1);\varepsilon_2 = \ln(1+e_2);\varepsilon_3 = \ln(1+e_3)\,. \tag{4}$$

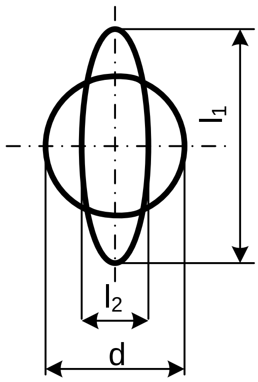

Fig.1. Element of the circular network before and after deformation of sheet

3. THE LIMIT CURVES METHOD

In principle the forming limit curves is determined using these networks of circles printed on the surface of the blank to be deformed under conditions of different state of tensions, followed by a measure the maximum deformations ε_1 and the deformations perpendicular to it, ε_2 .

Putting the deformation values in a reference system (ε_2, ε_1) is obtained the forming limit curves which provides the information on deformation capacity of the material, much more complex than those offered by conventional tests (Erichsen, traction).

The trajectory of a point described in terms of ε_1- ε_2, starting from 0 up to the limit of deformation is called strain path.

Keeler [32] get a forming limit curves in tensile - stretch area (fig. 2) under the following conditions:

- D_{semif} = 200 mm of annealed brass 70/30, copper cold rolled 1100 Al, Al alloy steel;
- Punches rigid with hemispherical, conical, elliptical head;
- Rigid withholding;
- Different lubricants.

Goodwin [3] obtain a forming limit curves in the stretch - compression area (fig. 2), so the criterion necking appearance, and appearance of fracture criterion. Keeler considered the upper limit of deformation the necking appearance. How the necking appearance means a pronounced thinning of sheet, which will entail lower corrosion resistance, mechanical resistance, and others, it is considered as a criterion to limit the strain.

Arreux [3] defines the limit stress curve (fig. 3) - which has the advantage that is independent of the deformation path (were noted: 1 - the limit stress curve , 2 - representation of plasticity criterion von Misses , 3 – the direction corresponding of symmetric stretching). Ghosh defines the height limit curve of cup, and Marciniak defines the forming limit curves on bending. Further will present the main testing used to determine the forming limit curves

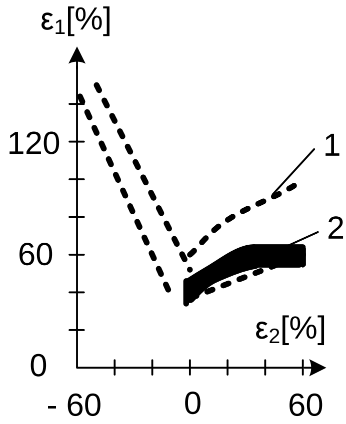

Fig.2 The forming limit curves obtained by:
a) Keeler; b) Goodwin

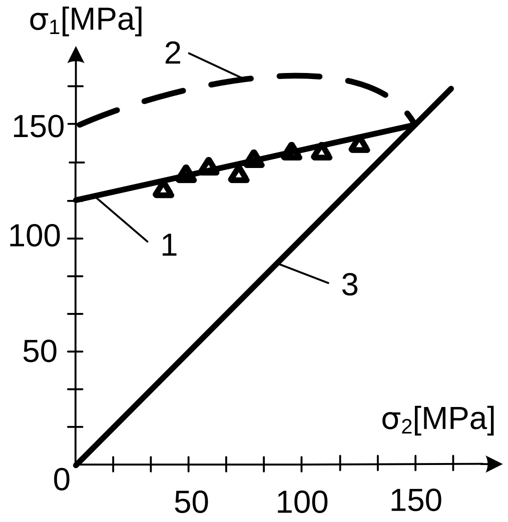

Fig. 3. The limit stress curve obtained by Arreux

a. *Tensile testing*

The specimens used are rectangular (fig. 4 [3]), with different widths and different shapes and values of radius (R = 5, 10, 15, 20, 40 mm), which allows obtaining deformation paths (fig. 5) in the range (0, - 0.5).

The advantages of test are that the test specimens are easily achieved, the test machine are in any laboratory testing, the specimen remain plane during deformation, which allows easy tracking of the deformation path and reduce measurement error ellipses. The disadvantage is that determining the forming limit curves test can not be done only in the negative area ($\varepsilon 2<0$).

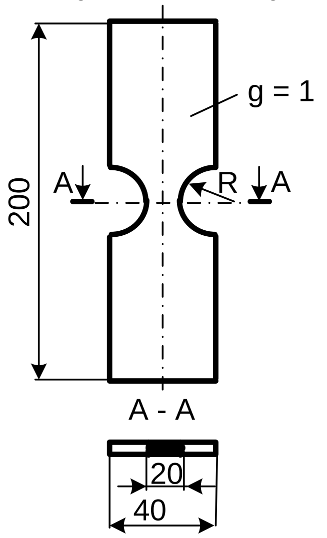

Fig. 4. The specimens used to the tensile testing

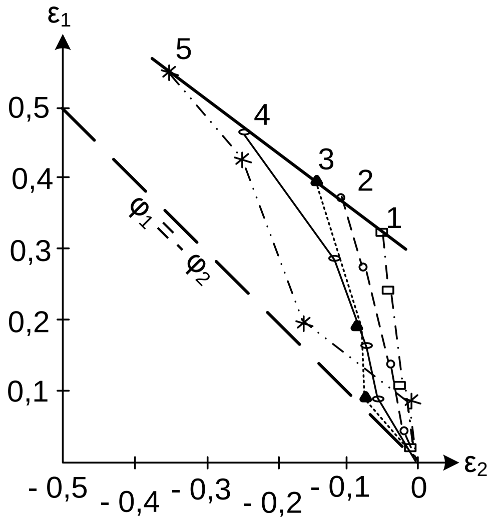

Fig. 5. The deformation path obtained after the tensile testing

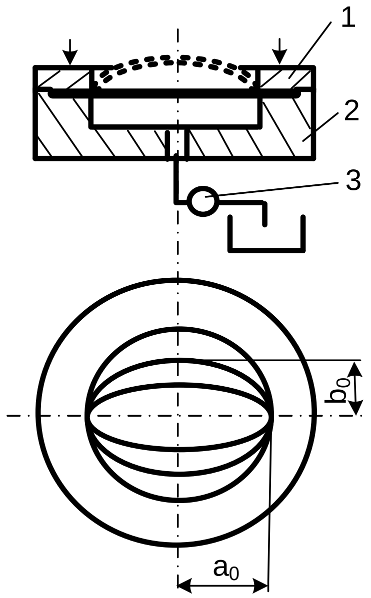

Fig. 6. The essay stretch hydraulic (Olsen-Jovignot)

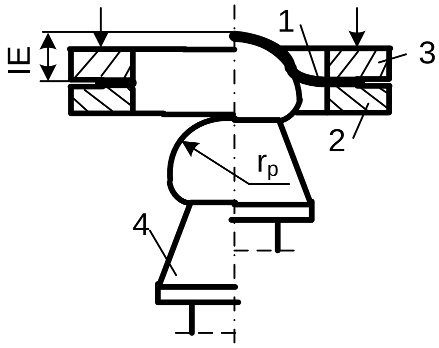

Fig. 7. The essay drawing by the stretch on the punch

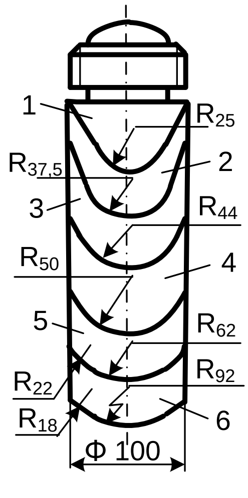

Fig. 8. The shapes of the punch used to the Keeler essay

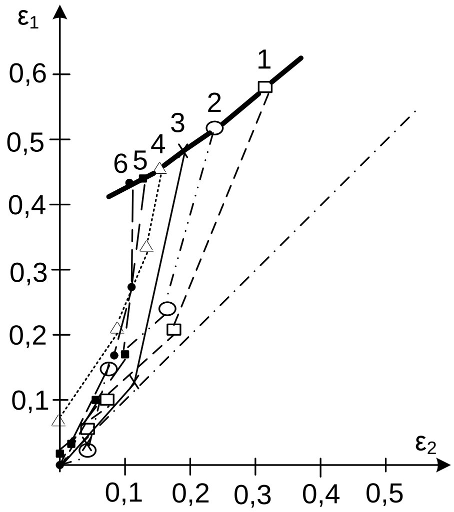

Fig. 9. The deformation path obtained after the Keeler essay

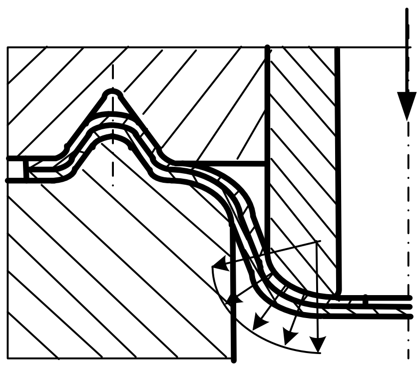

Fig. 10. The shapes of the punch used to the Marciniak essay

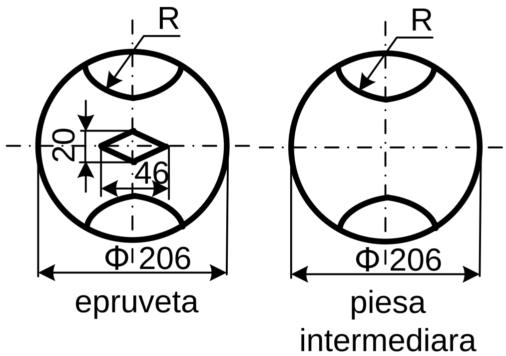

Fig. 11. The shapes of the blanks used to the Marciniak essay

b. *Attempting to stretch hydraulic (Olsen-Jovignot)*

This (fig. 6 [3]) is the „swelling" of fixed blank between the blankholder (1) and the die using the fluid pressure generated by the pump (3). To obtain of different strain paths is used elliptical plates with different a_0/b_0 eccentricities. It has advantages that there is not friction between the tool and the blank and knowing the pressure and the radius of punch is resulted the state of tension and strain of the piece. The disadvantage is that the forming limit curves is only determined for the $\varepsilon_2>0$ (the right part).

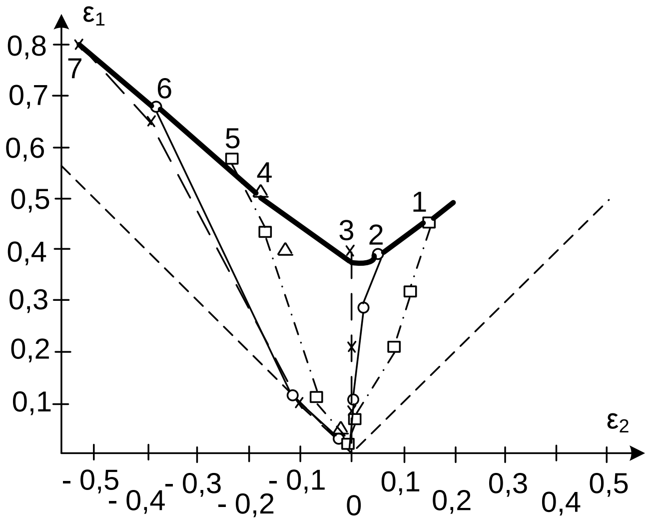

Fig. 12. The deformation path obtained after the Nakajima essay

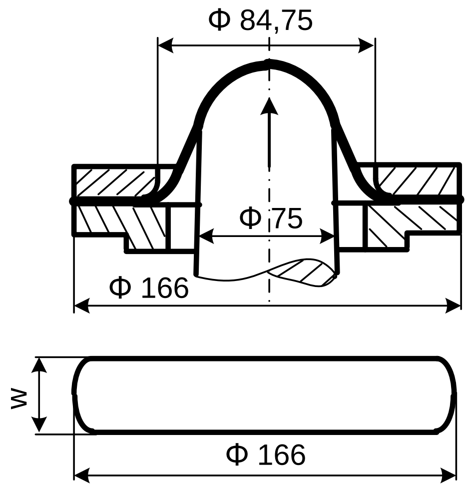

Fig. 13. The specimens used to Nakajima essay

c. *The attempt drawing by the stretch on the punch*

It consists in applying a hemispherical or ellipsoidal punch head (4) of specimens (1) fixed between the die (2) and the blank-holder (3) (fig. 7 [3]). To obtain of different stress states (so of different strain states, respectively of different deformation path) changes any of the following parameters: the radius of punch, the shape of punch, the specimen shape, the state of lubrication between the punch and the blank.

According to their changes were achieve following the punch stretching test:

The Keeler essay - involves the variation of the punch a radius (fig. 8 [3]), which determines obtaining of the pairs of limit strains (ε_1^*, ε_2^*),. which implemented the system of axes ε_1-ε_2 give the forming limit curves (figure 9 [3]) for $\varepsilon_2 \in(0,1;\ 0,3)$.

- The Hecker essay - involves the variation of the coefficient of friction between punch and blank in the conditions of use of materials with different values of parameters as anisotropy coefficient and cold-hardening index. There is a change in the current position of the point where the crack occurs, defined as the angle α and determine a forming limit curves for $\varepsilon_2>0$.
- The Marciniak essay, Swift similar test, involves the variation of punch form, having circular cross section ($\alpha=d\sigma_2/d\sigma_1=1$), eliptical or rectangular ($\alpha\cong0$), but is hollow (fig. 10). Between punch and blank is introduced a supplementary piece provided with a circular hole. The blanks are square or circular shape, situation in which the forming limit curves are obtained for $\varepsilon_2>0$. If the circular blank are provided with some circular cut-outs whose radius R

∈ (43 ... 93) mm (fig. 11[3]) to obtain full coverage of the forming limit curves area (-0.45 < α < 1). The rupture occurs at the bottom plan of the piece, thus eliminating the errors that arise due to of curvature.

- The Nakajima essay – means the variation of width rectangular specimen (w = 66, 77, 88, 99,104, 112) and the flow conditions, so they can get paths deformation between uniaxial traction (path 7, the minimum width) and stretching echi-biaxial (a way for large width) (fig. 12 [3]). This testing using a hemispherical punch and a circular plate (fig. 13) is close to the real process, existence of both the friction between the punch and part and of curvature of the punch.

4. CONCLUSIONS

From the above tests are recommended:

- the essay Olsen-Jovignot and Marciniak if it pursues the elimination effect offriction;
- tensile testing for its simplicity;
- the essay Nakajima for the broad area of possible deformation paths studied.

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