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ASPECTS ON METHODS OF ASSESSING PRELUCRABILITY THROUGH COLD PLASTIC DEFORMATION OF METALLIC MATERIALS

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Abstract. In the field of cold pressing, the notion of machinability refers to the behavior of the material during deformation, the technological equipment and the machine. In this paper we presented the methods of estimating the behavior of the semi-finished material during processing.

1. Generalities

The notion of workability refers to both the ability of a material to be processed by a particular process and its way of behaving during such processing (Fig. 1 [5]).
The assessment of machinability is made using general and special methods. The general methods allow the establishment of basic dimensions characterizing the metallic material and they applies indifferently of the type of processed material and the way of processing to which it will be subjected (Fig. 2 [5]).
Special methods are specific to certain types of material (the nature, shape and dimensions of the semi-finished material) and certain processing processes (lamination, cutting, stamping, etc.) (Fig.3 [5]).
Determination of the processing capacity by certain processes is necessary because in the case of cold plastic deformation processes a complex state of stresses and deformations is observed. Methods of assessing workability for ferrous and non-ferrous metal materials are established on massive or sheet-shaped specimens.

2. Methods of estimating the behavior of the material of the blank during processing

Tests can be made on real pieces (in natural size) or on models (for which the law of similarity is taken into account). The following aspects are considered:

- Determining the influence of the technological factors on the distribution of deformations and the flow of the material;
- Determination of variation of resistance and plasticity characteristics in different parts of the part;
- Determination of tension, force and mechanical work needed for deformation.

In order to analyze the distribution of deformations and variations of resistance and plasticity characteristics, experimental methods are used, which require examination of the blank / sample before and after deformation.

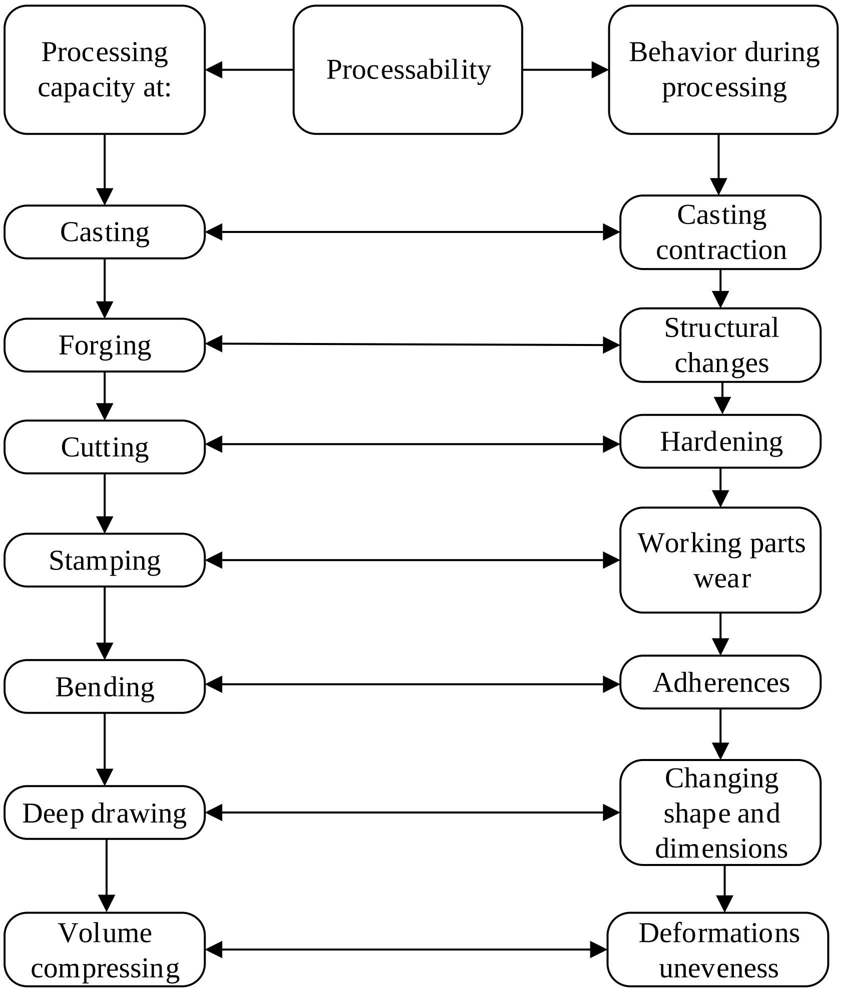


Fig.1. Scheme for definition of the concept of processability

Various deformation conditions are applied to the specimen, such as: different degrees of deformation, different speeds, different temperatures, lubricants of different types, the use of different geometries of the active zone of the stump or die.
Thus, the following methods are used [4]:

A. Methods to determine the character of deformations during processing

Causes such as the unevenness of the structure of the material, the non-homogeneity of the heat field, the shape of the blank, the internal and external friction lead to the unevenness of the deformations. These frictions in turn cause the increase of the average deformation pressure, the decrease of the plasticity and the appearance of the remaining stresses. As the stresses at different points of the deformed blank can't be measured experimentally, then the non-uniformity of the unitary effort will be appreciated according to the size and character of the strain distribution. Consequently, the distribution of the deformations is done by methods such as: the method of dividing networks, the screw method, the pins method, the hardness method, the microstructure analysis method and the analysis of the macrostructure.

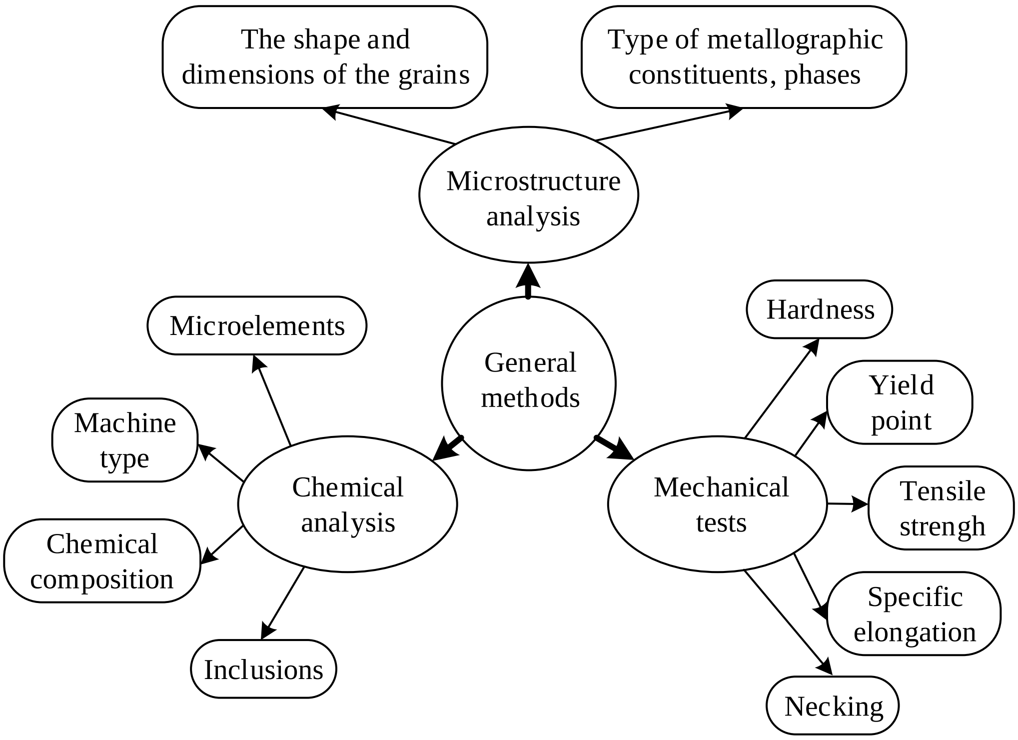


Fig. 2. General methods for assessing the machinability

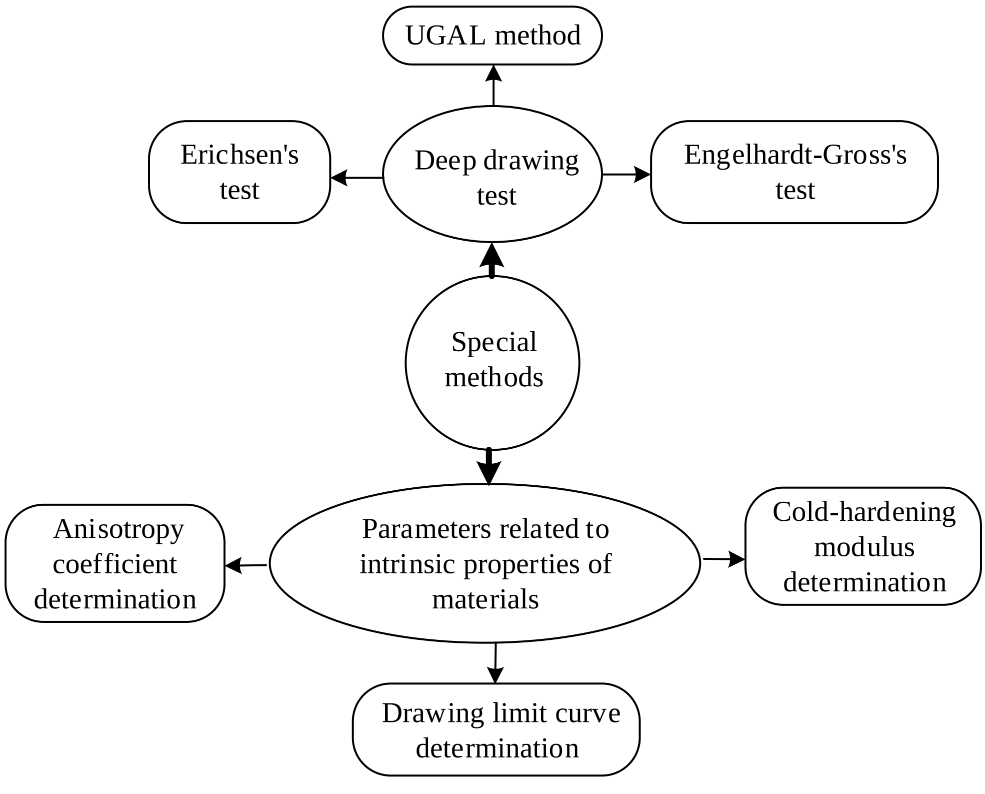
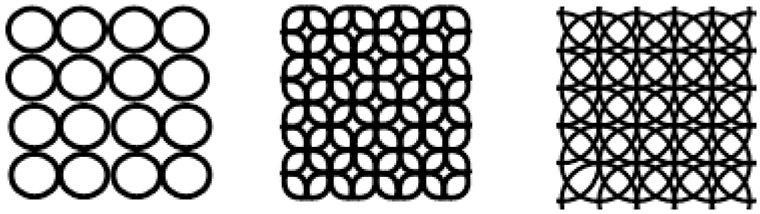


Fig. 3. Special methods for assessing the workability



a) b) c)

Fig. 4. The division networks: a) with tangent motifs; b) with interleaved motifs; c) with tangent-interleaved motifs

A1) The division networks method

The square (orthogonal) networks are the easiest to accomplish. They can be applied on solid or sheet metal sample. The way of scratch writing changes the deformability of the material, which affects the determination of the deformation limit curves. Generally, this type of network is combined with a network of circular motifs. (Fig. 4 [2]).

The circular network is designed to determine specific deformations, and the rectangular one allows a circular network domain to be identified and uses to evaluate flow lines across the entire piece.

Circular motifs networks are most used to determine the deformation curve. They are three kinds: with tangent motifs (Fig. 4a); with interleaved motifs (Fig. 4b); with tangent-interleaved motifs (Fig. 4c). The tangent circular motif has the disadvantage that in the inner areas of the circles the specific deformations can't be determined, and the tangent points reduce measuring accuracy. The interstitial circle network partially eliminates the above disadvantages, because no matter where the crack or crack appears, there will be at least one circle to be intersected by the defect. This second type of network, however, has the disadvantage of reduced visibility due to the high density of lines.

The dimension of the network motif influences the precision of determining the specific deformation and the accuracy with which the deformation is determined. Usual dimensions of the circle diameters are between 2 and 5 mm [2] or 2-3 mm [5] and these are chosen depending on various factors, such as: deformation gradient, deformation radius, etc. I.D.D.R.G. recommends choosing a 2.5mm diameter to determine the deformation curve.

The circular and radial divisions are also used for deep-drawing.

In the case of massive semi-finished products, rectangular divisions (a system of parallel and perpendicular lines, drawn at equal distances between them) are plotted in a section of the sample. This surface will have to remain flat throughout the deformation. On the surface of a half section, the network is drawn, while on the surface of the other sections a lubricant is applied, which serves to prevent the welding of the halves during processing. The two halves are assembled by 2-3 welding points, the piece is deformed, then the half-pieces are split, and the division network is being analyzed. In the case of the mechanically applied network (by scraping), it is recommended to apply the graphite / Zn / kaolin oxide, etc., on the surface to easily observe the new deformed network. Measurement of the network motif deformations is done by means of opto-mechanical or opto-electronic systems. The simplest method is to use mono or binocular magnifiers that have a graduated rectangular axis system on the lens. The movement of the part in the optical field is done manually. A more accurate measurement method is that which uses measurement microscopes and has the following advantages: large magnification (50 times), micrometric displacement and measurement. The movement of the piece in the optical field is accomplished by means of a table displaceable in two rectangular directions. Measurement of displacements is done with an accuracy of 10^{-3}mm. Usually, the optical measurement system has the ability to tilt the face from the vertical position, which allows the measurement of deformations on sloping surfaces as well. There are also automated computer-assisted

or numerical display systems to measure displacements, processing of primary data based on an algorithm (calculation of logarithmic deformations), storing, displaying and printing them.
If the square meshes of the grid turn into rectangles (after deformation), it results that the direction of the main deformation axes overlaps with those of the square sides. If the square mesh of the grid turns into a parallelogram and the circle inscribed in the square becomes an ellipse, it results that the main deformation axes overlap with the direction of the ellipse axes (Fig. 5 [4]).

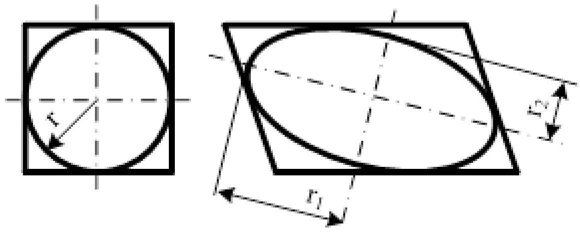


Fig. 5. Deformation of the rectangular element of the division network

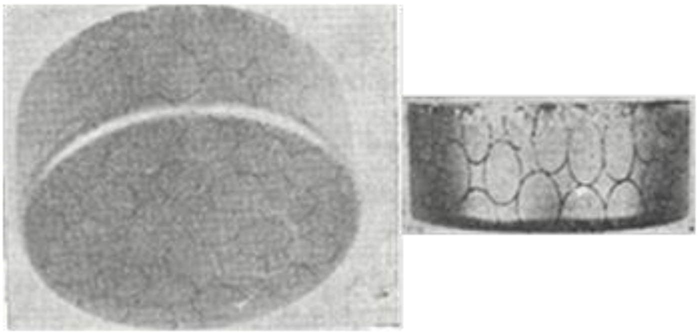


Fig. 6. Deformation of the division network on the surface of a deep drawing piece

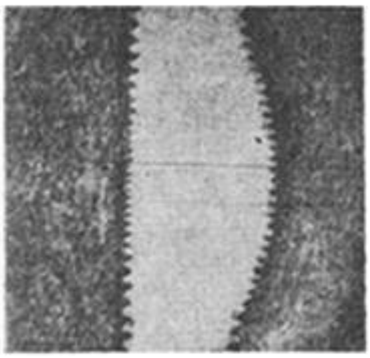


Fig. 7. The deformation characterization by changing the pitch of the screw

In addition to scratching, these division networks can also be printed using electrochemical processes or with the use of photosensitive paints or emulsions (application by shooting). In Fig. 6 [4] shows a deformed network on the surface of a drawn piece (obtained in UGAL Plastic Deformation Laboratory).

In [3] it is shown that the division network method is the "key factor" to identify the causes of breakage. It allows the experimentation and modification of materials, the correct choice of materials and lubricants. It also allows for the control of the drawing process over time by tracking changes in the mechanical characteristics of the unaltered semi-finished products in the warehouse, following the evolution of tool wear or correct tool re-positioning in the press.

A2) The screw method

It consists of inserting into the specimen a screw with a fine pitch. After deformation the specimen is cut after a plane passing through the screw axis. The longitudinal deformation is characterized by varying the pitch of the screw in different areas (Fig. 7 [4], [5]).

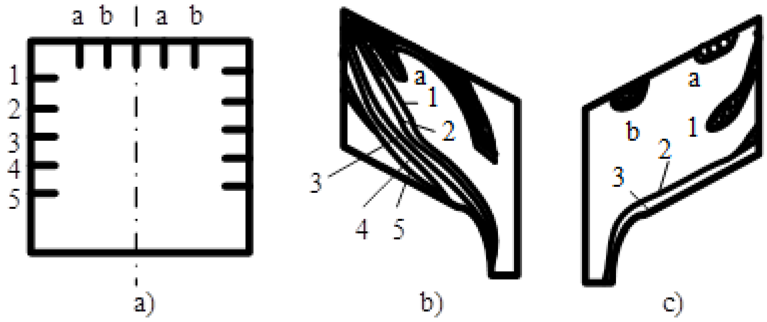


Fig. 8. Determination of the unevenness of the deformations by the studs method: a) before deformation; b) after extrusion without lubrication; c) after extrusion with lubrication

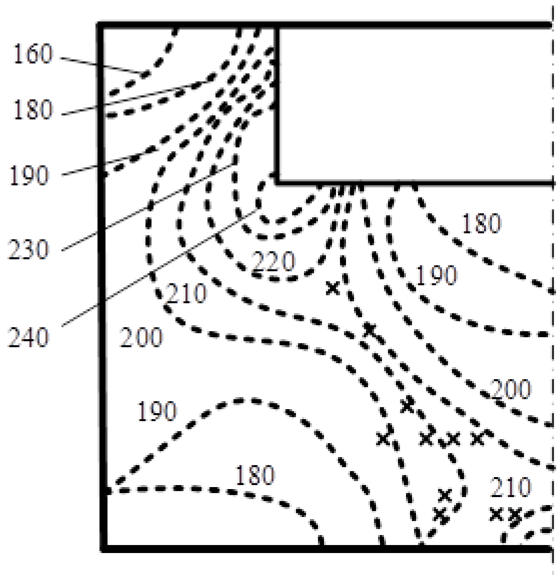


Fig. 9. Curves of equal hardness in the longitudinal section of a cold-extruded piece

A3) The pins method

It consists of inserting into the specimen some pins, which form a fitting pressed with the respective holes. They can either be made of different color materials but with physicochemical properties similar to the specimen material, or the same color as the specimen, but which react differently to attack with the same reagent. After deformation, the specimen is cut over a plane that passes through the pins axes and determines the deformation and flow of the metal (Fig. 8 [4]).

A4) The hardness method

Initially, the hardness of the specimen is measured, which may be Vickers for small ones or Brinell / Rockwell for larger ones, depending on the nature of the material and the degree of deformation applied. The specimen will be deformed and then cut in longitudinal and transverse direction. Determine the hardness in these sections and draw the curves of equal hardness (Fig.9 [4]). In this way an image is obtained on the average resistance of the metallic material to the plastic deformation, as well as on the degree of unevenness of the deformations.

A5) The microstructure analysis method

The recrystallization diagram is drawn for the material of the undeformed specimen. Se deformeaza la rece epruveta, se supune recristalizarii, se sectioneaza si se masoara dimensiunile medii ale grauntilor cristalini. The specimen deforms cold plastic, then undergoes recrystallization treatment, then cutting into pieces and measures the average dimensions of the crystalline grains. Compare these dimensions to those in the recrystallization diagram, giving indications of the degree of deformation in different areas of the deformed specimen.

A6) The macrostructure analysis method

The method consists in deforming the specimen, longitudinally and transversely cutting, followed by the macroscopic analysis. A fairly clear image of the flowing character of material is obtained, corresponding to the different stages of the plastic deformation process, but absolute values can not be collected that characterize the unevenness of the deformations.

B. The determination of unevenness of deformations

To illustrate the importance of correlating the size of the dividing network with the deformation gradient, two pieces are considered (Fig. 10 [2]), so that piece A has a very large gradient and piece B has a smaller gradient.

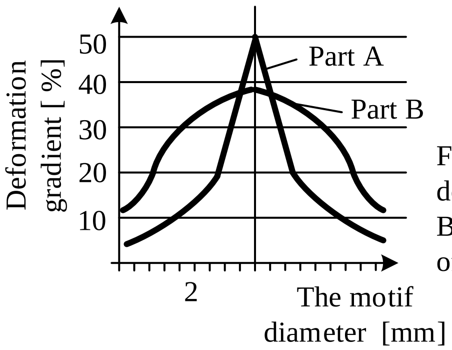


Fig. 10. The variation of the deformation gradient for parts A and B for the same value of the diameter of the division network motif

Fig. 11 [2]) shows the values of the deformations of parts A and B calculated according to the size of the motif. The analysis of the graph results in the following conclusions:

a) using a 25mm diameter circular motif, the measured deformation is not representative of any of the parts; for Part A there is a 9% deformation, and for B it is 18%, while the real values (for the infinitely small dimension of the motif) are 50% and 37%;

b) for the precision imposed on the limit deformation, the maximum diameter of the motif can be determined; for a 5% measurement accuracy, for the piece A, a maximum diameter of 4 mm is obtained, and for the piece B - one 8 mm.

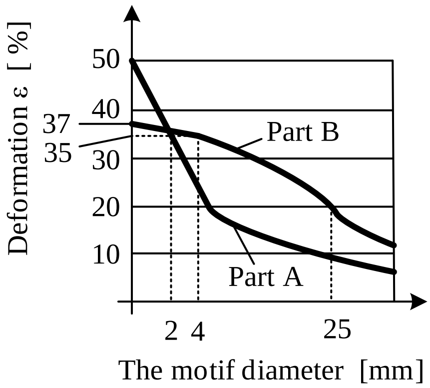


Fig.11. The values of the deformations of parts A and B calculated according to the size of the motif

Therefore, specific deformations can be determined by dividing networks.
The unevenness of the deformations is determined by knowing the local elongations in the longitudinal and transverse direction, for which the variation can be represented depending on the position in which they were identified. Determine the relative elongation value [4] as the ratio:

$$\varepsilon_r = \frac{\lambda_i}{\lambda_m} \;, \tag{1}$$

where:

$$\lambda_i = \frac{l_i}{l_0} \text{ si } \lambda_m = \frac{L_f}{L_0} \;, \tag{2}$$

in which were noted: l_0 - the division network parameter before deforming the specimen; l_i - the division network parameter after deformation; L_0 - initial length, corresponding to the blank; L_f - the final length of the deformed area of the piece or of the whole piece; λ_i - the elongation determined for each position of the lines of the network; λ_m - average elongation of the entire blank.

C. Determination of unitary stresses / tensions

Determining the stresses, when one is smaller than the other two (tension state), is done with the relationship [5]:

$$\frac{\sigma_1 - \sigma_2}{\varepsilon_1 - \varepsilon_2} = \frac{\sigma_1 - \sigma_3}{\varepsilon_1 - \varepsilon_3} = \frac{\sigma_2 - \sigma_3}{\varepsilon_2 - \varepsilon_3} = constant \tag{3}$$

For $\sigma_3 = 0$ we get:

$$\sigma_2 = \sigma_1 \cdot \frac{\varepsilon_2 - \varepsilon_3}{\varepsilon_1 - \varepsilon_3} . \tag{4}$$

Taking into account the energetic condition of plasticity, it results:

$$\sigma_1 = \beta \cdot R_c \cdot \frac{\varepsilon_1 - \varepsilon_3}{\varepsilon_1 - \varepsilon_2} \text{ si } \sigma_2 = \beta \cdot R_c \cdot \frac{\varepsilon_2 - \varepsilon_3}{\varepsilon_1 - \varepsilon_2} \tag{5}$$

The R_c (σ_c) value is taken from the hardening curve of the material of the specimen and the values of the specific deformations are determined from the analysis of the division networks before and after deformation.

D. Determination of the force and mechanical work necessary to change the shape

Deforming force measurements are of a high degree of difficulty due to the high and very high values that are applied at high speeds. Determining the value of the deforming force is required by the need to establish the actual value of the deformation resistance of the material under specific processing conditions, which is an important index in the characterization of the machinability. In the case of large pieces, the determination of the deforming force will be made on the model, and then the law of similarity will be applied. Small forces can be measured with mechanical, pneumatic and hydraulic devices. The mechanical ones allow the direct measurement of important deformations of elastic elements (helical springs, plate spring, etc.), which are then used to determine the size of the force. The other two types of devices allow the direct determination of force by measuring the pressure at the manometer or indirectly by deforming an elastic mechanical element (helical, lamellar springs, etc.).

But the most used are electric devices that contain different types of transducers (piezoelectric, inductive, capacitive, magneto-elastic, resistive) and which measure an electrical size. After calibration, the electrical size can be transformed into a mechanical one (force, moment, etc) [1]. The most widely used are the resistive tensometer transducers mounted on bridges powered by continuously or alternately current or pulsed. In this sense, the resistive tensometer transducer (tensometer marker) sticks to an elastic element of the press, die or dynamometer ring

After determining the force-stroke diagram, the area under the curve is calculated, which leads to the determination of the mechanical work required to deform the material of the blank, in order to obtain the piece.

3. Conclusions

In the field of cold plastic deformation processing, experimental methods take into account the following aspects:

- Analysis of the processed materials and how they behave during processing;
- Analysis of the behavior of stamp and die;
- Analysis of machine behavior.

They define the machinability of materials by cold pressing processes. The present paper approached the presentation of the methods that analyze the initial characteristics of the materials, as well as their modification during the processing process.

References

[1] Chiobaş A. 2004 Cercetări privind influenţa condiţiilor de deformare asupra calităţii pieselor ambutisate Teză doctorat Bucuresti

[2] Banabic D., Dorr I. R 1992 Deformabilitatea tablelor metalice subţiri

[3] Keeler, S.P. 1971 Înţelegerea plasticitaţii foilor de tabla – p. a VI-a – Aplicaţii practice, Sheet Metal Industries, 48, nr. 10

[4] Teodorescu, M., Zgura, Gh. 1980 Tehnologia presarii la rece, Editura Didacticã şi Pedagogicã, Bucureşti

[5] Teodorescu M., ş.a. 1987 Prelucrari prin deformare plastica, vol. I, II, Editura Tehnica, Bucureşti