

# STUDIES ON THE ANALYSIS OF THE STATE OF STRESSES AND DEFORMATIONS OF THE DIE FIXING SYSTEM USED IN WIRE DRAWING IN AN ULTRASONIC FIELD EXPERIMENTS

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**Abstract:** *Wire drawing is the technological process of obtaining wires by passing the semi-finished product through the inside of a mold. This technology is a classic one and is carried out in the same way regardless of the production system and regardless of the manufacturer. The wire drawing process takes place through the plastic deformation of the material due to the friction process that takes place between the mold and the semi-finished product. The friction process is very important and hence the substantial energy consumption. The use of the ultrasonic vibration field applied to the mold can lead to a substantial reduction in friction, thus being particularly useful. To prove this very important property, an experimental stand was created in which the mold was introduced into a manufactured support, in this case by 3D printing. The use of this additive manufacturing method is very important and relatively easy to apply. The problem encountered in this case is to determine whether this support can support the wire drawing process, so further tests are necessary to analyze the state of stresses and deformations that occur during the wire drawing process. In this article, the designed support and the analysis of its behavior under the action of the drawing force are presented.*

**Key words:** wire, drawing, ultrasonic, analysis, FEM

## 1. INTRODUCTION

The processing of metallic materials by plastic deformation is based on the property of plasticity of metals, that is, on their ability to acquire permanent deformations under the action of external forces [1,2,3].

The processing of metals by plastic deformation (by striking) has been known and used by mankind for over 3,000...3,500 years BC, that is, before the methods of obtaining metals and alloys by melting were known. This is explainable because at first man found iron in its natural state, originating from meteorites, which he processed by striking, shaping the oldest cult objects and weapons from iron.

The increasingly widespread use of plastic deformation as an ethnological method of obtaining parts is also the result of the advantages it presents in comparison to other processing methods, as follows:

- it achieves significant material savings, because this method achieves the geometric configuration of the part, corresponding to the functional role, by redistributing the volumes of material and not by removing it in the form of chips or microchips;
- it allows the production of parts with configurations ranging from the simplest to the most complex, with weights ranging from a few grams to several hundred tons and with dimensions

ranging from a few millimeters to tens of meters, some of which are difficult or almost impossible to achieve through other processes;

- allows the production of parts with different and improved functional properties per section, depending on how the displacement of material volumes was achieved as a result of plastic deformation, properties that confer a much better operational behavior than parts obtained through other processing methods (casting, machining, welding, etc.);
- high productivity due to the execution of processing with wide possibilities of mechanization and automation, as well as due to the production of products of simple or complex configuration, with the same section, over very long lengths;
- produces at a very low price the entire range of initial semi-finished products for other processing methods (casting, welding, machining, etc.), such as: bars, sheets, simple or complex profiles, strips, balls, pipes, wires, etc.;
- the dimensional accuracy of the machined parts can be, if necessary, very high, the parts obtained being interchangeable and often resulting in the final dimensions even for their use in industries that require very high precision (fine mechanics, electrical engineering, electronics, etc.);
- it achieves significant labor savings, because in most cases it uses fully mechanized and automated equipment with increased computerization and even robotization tendencies.

All these advantages, as well as the current trends of obtaining finished parts as quickly as possible, from materials with the most different properties and without processing by removing material in the form of waste, make plastic deformation processing one of the most frequently and widely used processing methods (in some technological equipment the share of component parts obtained by plastic deformation can exceed 60...70%). There are even synthetic indicators that define the development of a country's economy directly from this processing method: the ratio between the production of parts made by casting and plastic deformation; the production of parts made by plastic deformation reported per thousand inhabitants; the ratio between the production of parts obtained by plastic deformation and the production of steel, etc.

However, this method also presents a series of disadvantages caused by the need for high processing forces, namely:

- high initial investments, because it requires complex and expensive equipment that must develop very high forces;
  - the tools used are generally expensive, most of the time for each category of parts obtained by plastic deformation a special tool is required, which can no longer be used to make other parts.
- Considering the advantages and disadvantages listed above, plastic deformation processing should be applied when, following technical and economic studies, it proves superior compared to other technological and organizational options for performing a processing.

## **2. TECHNOLOGICAL STEPS FOR CARRYING OUT THE DRAWING PROCESS**

The technology of obtaining wires by wire drawing presupposes, first of all, the existence of a strictly defined material base for this purpose. This presupposes the existence of a hall equipped and equipped with the necessary equipment for wire drawing as well as being properly organized. In this regard, figure 1.1 shows such a hall.

In such a section, the following technological phases will be carried out:

1. - checks are made before starting the line, according to the prescriptions in the checklist at Start-up;

2. - checks and/or measurements are made at the entrance, according to ST-SL-QC-001 and FO-SL-RQMS-001 and their results are recorded;
  3. - the coil with semi-finished wire  $\Phi$  9, 12, 15, 20, 25 mm is loaded into the machine unwinder
  4. - the series of dies is chosen;
  5. - the wire is pointed for threading;
  6. - mount the dies in their housing;
  7. - thread the machine;
  8. - turn on the lubrication pump;
  9. - mount the coil in the winder;
  10. - turn on the wire drawing machine on “play” and fix the wire on the accumulator (ballerina), respectively the coil
  11. - insert and fix the coil in the wire drawing machine winder
  12. - adjust the wire distributor, by fixing the left-right limiters
  13. - adjust the wire distributor;
  14. - attach the end of the drawn wire to the coil on which it is wound
  15. - turn on the wire drawing machine and rotate the potentiometer to the right, to increase the speed, respectively to the left, to reduce the drawing speed
  16. - perform the drawing according to the command;
- in case of wire breakage during the drawing process, all the machine threading operations listed above are resumed.

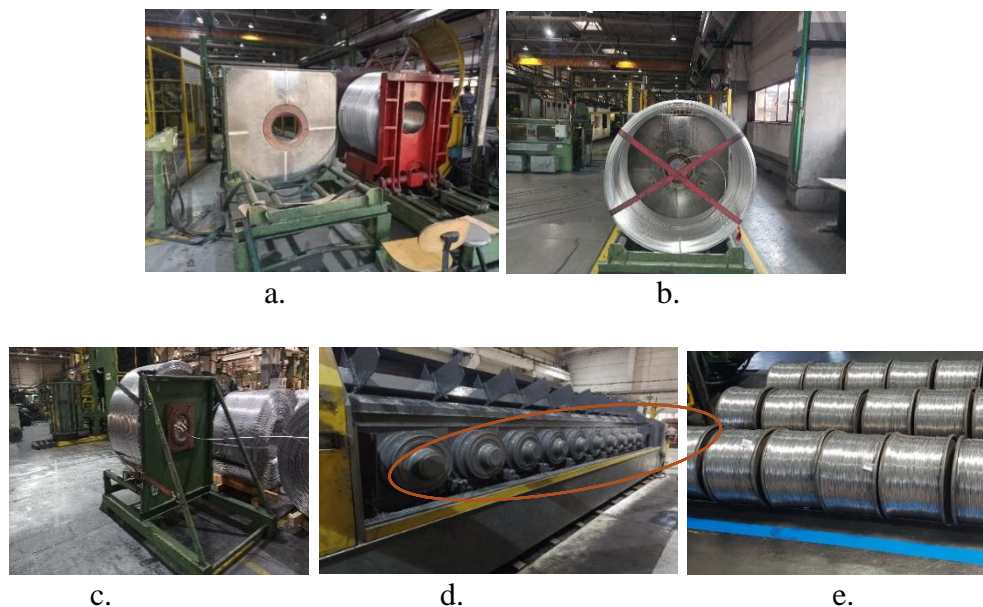


Fig. 1. Technological stages of wire drawing;

a.- placing the aluminum wire coil in the unwinder; b. - securing the Al coil with straps; c. - unwinding the wire coil for drawing; d. - fixing the dies in the recess made in the frame of the drawing machine.

Figure 1 shows some relevant images regarding the production of wires by drawing. Fig. 1a shows the placement of the aluminum wire coil in the unwinder, then the Al coil is clamped with straps (Fig. 1b), the unwinding of the wire coil for drawing in Fig. 1c and the fixing of the dies in the recess made in the battery of the drawing machine (Fig. 1d). Fig. 1e presents the finished product, the drawn wire, wound on several coils.

### 3. OPTIMIZATION OF THE WIRE DRAWING PROCESS THROUGH THE ACTION OF THE ULTRASONIC FIELD

As is known and as previously presented, wire drawing involves the passage of the semi-finished product through a die, the size of the finished product being equal to the exit diameter of the die. However, this process occurs with a high energy consumption due to the drawing process which involves overcoming the friction forces that occur between the semi-finished product and the die. To significantly reduce the friction forces, ultrasonic activation of the drawing die can be used, ultrasound contributing decisively to this process by achieving an “ultrasonic lubrication” as is known from the specialized literature [4,5]. An ultrasonic system that can be used for this purpose is shown in figure 3. This system has the advantage that it can be used in several applications such as ultrasonic welding. The proposed system consists of: 1 – the ultrasonic reflector; 2 – four piezoceramic elements that transform electrical oscillations into mechanical oscillations with the appropriate frequency; 3 – the ultrasonic amplifier; 4 – nodal flange; 5 - ultrasound concentrator.

In order to carry out experiments on reducing friction by applying the ultrasonic field to the drawing die, an experimental stand was made. One of the elements of this stand is represented by the drawing die support made by 3D printing. This die is inserted into the hole of the support shown in figure 4. For modeling and simulating its behavior, figure 4 shows the definition of the input data in the analysis, namely the embedding of the support. Figure 4a presents the 3D printed assembly where 1 represents the hole where the ultrasonic concentrator (presented in figure 4) is introduced for die activation, 2 is the die support and 3 represents the die. Figure 4b represents the zero displacement application and respectively the application of the pressure produced by the drawing die, in figure 4c.

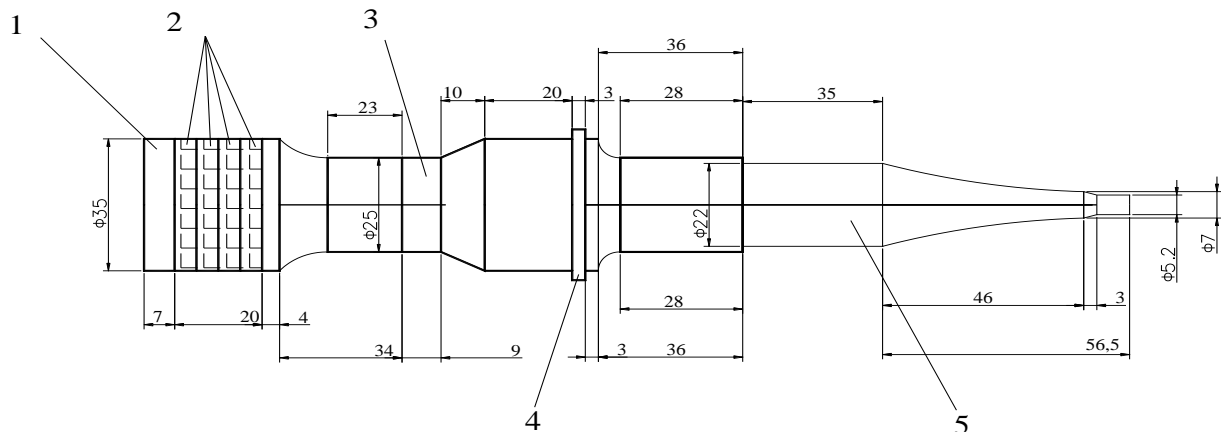


Figure 2. Presentation of the ultrasonic system used for wire drawing in an ultrasonic field; 1 – the ultrasonic reflector; 2 – four piezoceramic elements that transform electrical oscillations into mechanical oscillations with the corresponding frequency; 3 – the ultrasonic amplifier; 4 – the nodal flange; 5 - the ultrasonic concentrator

Taking into account the fact that the material from which this support was made is PLA, the Young's modulus  $E = 2.9$  GPa and the Poisson's ratio  $\nu = 0.33$  were also used as input data.

However, taking into account the fact that the structure obtained by 3D printing is not homogeneous, the value used in the calculations was considered to be  $E_r = 1.2$  Gpa. Based on this value, the analyses of the stress state that occurs in the support structure were considered.

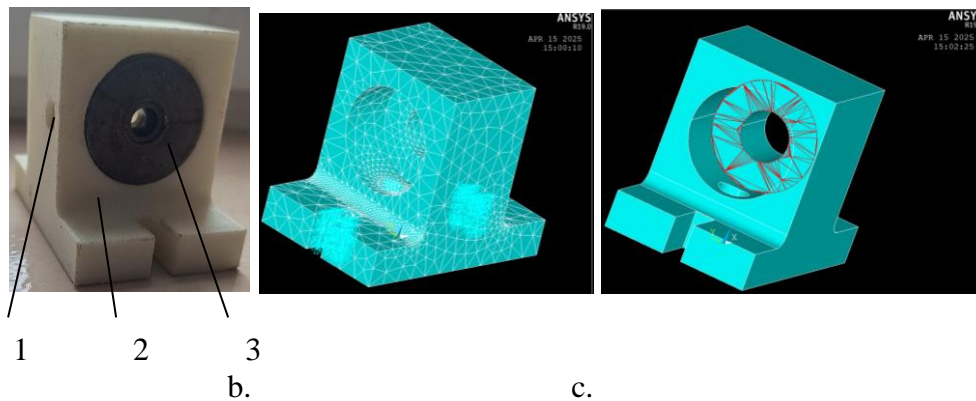


Figure 3. Input data for the Fem analysis: a. - 3D printed support; b.- applying zero displacement for the support; c. – applying pressure to the inner surface of the support.

By performing a structural, static analysis, several categories of output data can be obtained. The first type of results is the calculation of the displacements of the studied structure. In this regard, figure 5a presents the displacements reported to the OX axis. As can be seen, their maximum value is  $U_x = 0.5$  mm. In the mold area, the displacement is  $U_x = 0.3$  mm, a value that, although important, cannot influence the drawing process (green color). Regarding the displacements reported to the OZ axis, that is, in the plane perpendicular to the base plane, the maximum calculated displacements have the value ultrasonicathis experimental stand. The second category of results refers to the calculation of the stress state. As is well known, mechanical stresses are calculated using different formulas. From this point of view, in figure 6 the S1, S2 and S3 type stresses are presented. The S1 type stresses calculate predominantly the tensile stress state that occurs in the studied structure, the S2 type stresses calculate in a balanced manner the tensile and compressive stresses while the S3 type stresses calculate predominantly the compressive stresses.

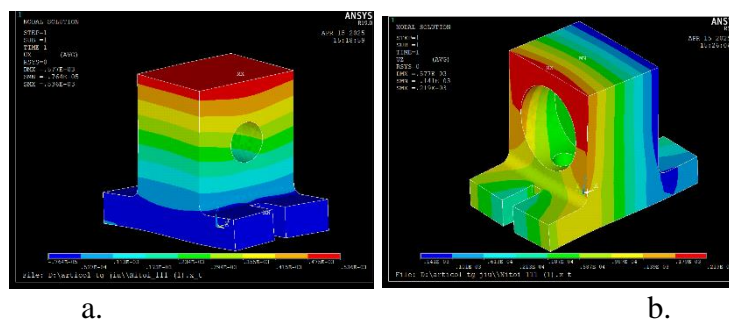


Figure 4. Analysis of support displacements when drawing pressure is applied; a.–  $U_x$  displacement; b. –  $U_z$  displacement

From the analysis of figure 6a, for the S1 type stresses, it can be observed that the maximum value of the tensile stresses is  $\sigma = 0.15$  E8 N/m<sup>2</sup>, a value that does not exceed the Young's modulus used in the calculations. Figure 6b shows the S2 type stresses in which the maximum value in tension has the value  $\sigma = 0.67$  E7 N/m<sup>2</sup> and in compression  $\sigma = 0.94$  E7 N/m<sup>2</sup>, both values being lower than the modulus of elasticity of the material. Figure 6c shows the S3 type stresses with the maximum value in compression  $\sigma = 0.22$  E8 N/m<sup>2</sup>, values also lower than the modulus of elasticity.

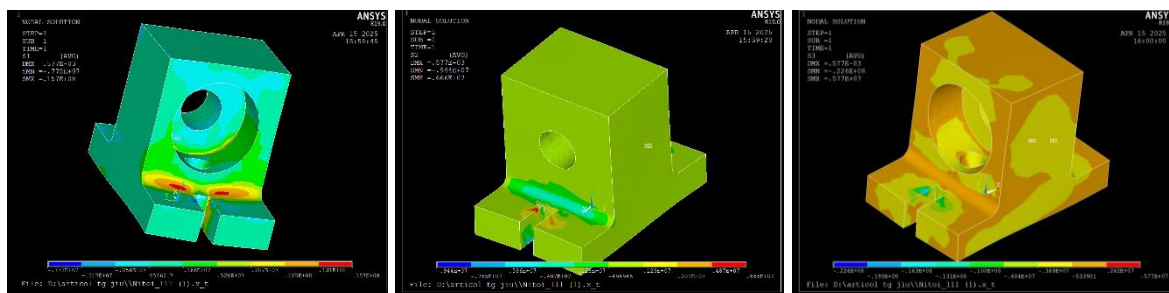


Figure 5. Analysis of the state of mechanical stresses of the type: a. – S1 stress; b. – S2 stress; c. – S3 stress

#### 4. CONCLUSIONS

The article presents part of the research on ultrasonic drawing of aluminum wires. This research is complex and starts from a very good knowledge of the drawing process but also of the production of the ultrasonic vibration field. In addition, the combination of the two processes, drawing and the introduction of ultrasonic vibrations into this process by ultrasonic actuation of the drawing die must be studied very carefully. As the analysis of the drawing process in an ultrasonic field is difficult to perform directly in production, on the drawing machine is very heavy, the creation of a drawing stand in these new conditions is particularly important. This stand includes several elements, one of which is the support of the drawing die, a support made by additive manufacturing. The solidity of this support must be studied and the only research method is finite element analysis. This analysis concluded that the support, as designed, exhibits deformations that are sufficiently small compared to the functional role of the system and that the state of internal mechanical stresses arising as a result of the drawing process is located in values below the modulus of elasticity of the material, PLA, from which the support is made.

#### 5. REFERENCES

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