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Design

Experimental researches concerning the rolling of silver (ag999,96) and of the silver alloy (agcu800)

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Summary

One of the most beautiful branches concerning the projection activity of a designer is the manufacturing of precious metals domain. From the precious metals category, the silver was chosen to be studied, because this metal is more accessible from the cost price point of view, and also because of its many ways of utilisations (there is no other domain in which this metal is not present). The accessory industry, specially the sector that serves the fashion world (buttons, buckles, decorative shackles (chains), jewels, it is in a permanent development, the silver is becoming more and more for this domain, an "industrial" metal because of its massive utilization. The cognition from the technological behaviour of this metal, represents a necessity in the designer activity, this designing technological forms, possible ones, answering both the market needs (requirements) and the production possibilities.

For the manufacturing of the silver objects are used, specially, semi-manufactured rolling band type or wire. The semi-manufactured of the wire type can be rolled and transformed in flat bar, for a later manufacturing, according with the shape conceived by the designer. This work recommends the establishment of some parameters needed to obtain the flat band through the rolling of the silver wire.

KEY WORDS: design, silver, micro rolling, technical parameters

1. THE PURPOSE AND THE IMPORTANCE OF THE RESEARCHES

The metal manufacturing in Romania dates since the neolithic period (5500 – 2500..Chr). Through its special qualities concerning the aesthetic, ornamental aspects, resists at the chemical agents and also through its possibilities that offers through processing in a diverse range of shapes, sizes and aesthetic effects, silver remains one of the used metals in the multiple domain.

The silver is a metal that belongs to be precious metal category (noble), the native metal group. Its name comes from the Latin word **argentum** = a light colour, white [8, 9, 14, 26, 31].

The precious metal (noble metal) are those metals that present a high rate (degree) of malleability and are very resistant to the chemical agents, specially to the acids. These metals:

- they oxidize hard, and their ions have a great inclination to pass into a metal state.
- can be find in metal state in the nature
- they have high melting points
- are ductile (plastic)
- they have a nice aspect because of the shiny metallic polish (gloss) that is kept in the atmospheric conditions and in contact with the most active chemical substances (excepting the royal water).

The precious metals can be found rarely in the nature and are usually used for the manufacturing of the jewels (as ornament objects), as currency standard, and in the manufacturing of some pieces and instruments in the electrical engineering industry, in the fine mechanics etc. From the precious metals category there are: the gold, the silver and the platinum metals (ruthenium, radium, palladium, osmium, iridium, platinum).

The attribute of precious belongs to these metals as a nobility title, for their economical value importance and also for the role that played and still plays in the man's life.

Even though the silver has a large utilisation and its manufacturing dates since the oldest times, "the caste secret" made to be less studied from its technological behaviour point of view and the information that exists cannot be transmissible.

The study of this metal was made in comparison (as against) with aluminium and copper, metals witch presents a near technological behaviour (states the speciality literature), these metals belonging from the same group of metals, being used in the toolmaker adjustment, the checking of the technology or the tracing of the unfolded product that is supposed to be manufactured.

Studying the literature of speciality, different products and objects from silver, as well as different departments of a jeweller, it came to the conclusion that the main types of the used processing are: the pouring and the manufacturing through cold plastically deformation. There are preferred the following ways of manufacturing through cold plastically deformation: the rolling, the drawing, the upsetting, the forming (the shaping), because the precious metal wastages are minimal and the processing, considering that the silver is a very malleable and ductile material, is realised with small deformation forces. [19] Considering the legally processing of this metal and for the safety of the value title, the silver and the silver alloy used in this processing, have been obtained from the State Monetary.

The obtained date by studying the behaviour of the silver allows:

- the realization of the pieces through plastically deformation at cold with a minimal consumption of energy and precious material, in good aesthetical conditions (without any processing defects that can affect the visible part of the piece);
- the realization of the pieces with thin walls, of small dimensions, with complex shapes, with a reduced consumption of material, with a good precision;
- the obtained pieces from silver (characterized by a small hardness) to be resistant, to not need a high capacity of manual labour, to need a few number of thermal treatments of returns;
- the establishment of the needed deformation forces values;
- the conceiving of the toolmakers and simple devices that allows both the processing of good precision and the realisation of the series products;
- the establishment of the specific technological ways, considering the necessity of the application of the thermal recrystallization treatments for the restoration of the workability of the material properties, which, eventually, have been hardened during the manufacturing process [13].

2. A BRIEF HISTORY

The jewels an the accessories are ornaments form precious metals, decorated sometimes with precious stones, worn from the ancient times, by persons belonging to all the cultures, civilizations, religions, as a supplement of the personality, as a social or official symbol, as a religious, social or political emblem. These objects have been and are executed form other materials also, organic or inorganic (hair, pits, plants, shells, wood, plumes, skin, flakes, crusts, bones, ceramics, metals, minerals). The jewels express those objects of ornament made form precious metal with or without precious stones.

The jewels are worn on: the head (crowns, tiaras), arms, neck, legs, bust, tongue, ears, nose etc. they can be worn directly like we just said or can be worn as accessories: buckles, buttons, needles for neckties, hats, badges, fasteners, dresses, belts, small recipients (elegant, nice decorated for perfumes or liquors), etc.

The archaeological researches brought out objects which were made in ancient times that proves that the manufacturing profession if the jewels dates from the most ancient times, reaching very precious artistic values. The oldest ornament and luxury objects discovered are over 10 millenniums old (the cult objects discovered in the temples from Ceatal Huiyk, Anatolia) or 6 millenniums old (from the sumerian old cities or form Susa from the prehistoric Elam). The processing techniques of the ornament or cult objects from those periods (from Mesopotamia, Egypt, Levant, Troia, Creta Minoica, Antiq Grece, Micenia) are used: the filigree, granulation, cloisonné, enamelling, that allow the realization of the wonderful artistic compositions with a scenery character, from the animal kingdom, scenes from religion or life.

3. THE PHYSICAL – MECHANICAL PROPERTIES OF THE SILVER AND ITS ALLOYS

The most important physical – mechanical properties of this metal are: [2,.3, 4, 5, 8, 9, 10, 11, 12, 14, 15, 16, 18, 20, 21, 22, 24, 25, 26, 31, 32, 33, 34, 35, 36]: the silver is the whitest metal; its trace can be white – silvery, yellowish, grey; in contact with the air it is covered by a film (scab) of a dark colour; when it is polished, has beautiful glint because of its great power to reflect the rays of light; even though it is opaque, in the reflected light it appears white – silvery; its capacity of reflection in the air for green colour is 95,5% and for red is 93%; the refraction index is 0,181; it is isotope; the silver hardness is 2,5 (on the Mohs scale); the specific weight is 10,4293 g/cm3; the melting point is 960,5°C; the boiling point is 2170°C; the vaporisation temperature is 2212°C; it can be rolled in foils with a 3μm thickness, the silver allowing to pass (at this thickness) o bluish light; it is very plastic A_5 = 48 – 50%; is soft (softer than the copper and harder than the gold), malleable, ductile (from one gram of silver it can be pulled one thread of 1800 – 2600 mm length) and stainless; the silver tenacity is quite reduced (one thread of 1mm^2 in section it brakes under a load of 16,5 Kg); the tenacity of the silver is between the tenacity of the copper and the tenacity of the palladium; the breakage load is 28,5 kg at a 0°C temperature; it doesn't combine with the oxygen, but it dissolves in melted state, a big quantity of oxygen (until 22 times of its capacity), that is eliminated with violence at the solidification, throwing metallic drops, and that's why the pure silver can not be poured; presents the biggest electrical and thermal conductibility among the elements; the crystallization system is cubic; Seldom, it is presented under the shape crystals, frequent under the shape of twisted threads, dendrite, irregular plates, sometimes curved, nuggets, compact mass, thin papers etc.; crystals, when exists, have the shape of dodecahedron; the linear dilatation coefficient is 1,92 x 10^{-5} at the temperature of 40°C; it is diamagnetic; almost all the combinations of this metal are not toxic.

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The fine silver (according with STAS 3321 – 88) has the mark Ag999,6 with a 99,96% content. The examination of the chemical composition it is made according with STAS 8907/2 – 71.

4. THE PRESENTATION OF THE ATTEMPTING METHOD AT ROLLING

The rolling process is a deformation process of the precious metals semi-products, in the shape of ingots, wires, flower band etc. through there passing between two or more cylinders [1, 4, 6, 7, 17, 21, 27, 29, 30, 31, 37, 38, 39]. The rolling process is realized through plastic deformation at cold of the wire resulted through drawing, with a view to obtain a band of rectangular section.

The main parameters in the realisation of these processing operations are:

- The tolerance at the thickness of the laminated band must be as less as possible;
- The dimensional uniformity for all band length.

For the obtaining through rolling process of a certain thickness of a rectangular section band of wire, the wire diameter is reduced through successive crossing among the rolling mill cylinders. The reducing coefficient for the first operations is, in general, from 19 – 26% and for the last operations is comprised from 10 – 20%. The rolling speed has values of approximate 18m/min. at the first operations and can reach 24 – 26m/min at the last operations. Between the diameter of the drawn wire constrained to the rolling operation and the band section obtained through the rolling process there is an interdependence.

The adjustment at the rolling rate can be done with the help of the control micrometers or with the help of some holds (slips) of precision or spies.

5. THE DESCRIPTION OF THE STAND USED AT THE ATTEMPTING OF THE ROLLING PROCESS

The stand for the effectuation of the determinations at the micro-rolling is presented in fig. 1.a.b and fig. 2. This stand (fig. 1.a.b.) is composed of a micro-rolling mill (2) electrically turned over, the distance among the rolling mill cylinders can be adjusted with the help of two micrometers (1). The cylinders are electrical turned over through the cog wheels gearing 4, to assure a uniform speed. The measurement method of the required forces values at the rolling process is the tensiometer method. The deformations that appear during the processing of the semi-products are collected and transmitted by two dynamometers (elastic

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elements) (3). The signals are processed and registered at the inscriber (5). The obtained data at the inscriber are mathematically processed depending on the adjustment characteristics of the <u>tensiometer</u> deck (6), of the inscriber and the curve obtained at the standardization (calibration) of this stand (fig.3).

The obtained curve at the standardization of the stand establishes the mathematical dependence between the movements registered at the inscriber and the known forces applied to this one.

This stand allows, simultaneously with the processing of the semi-products through rolling process, the obtaining of a large range of typo dimensions of the material, the measurement of some rolling characteristic parameters (deformation forces, deformation grades), as well as the establishment of some interdependencies among the rolling parameters.

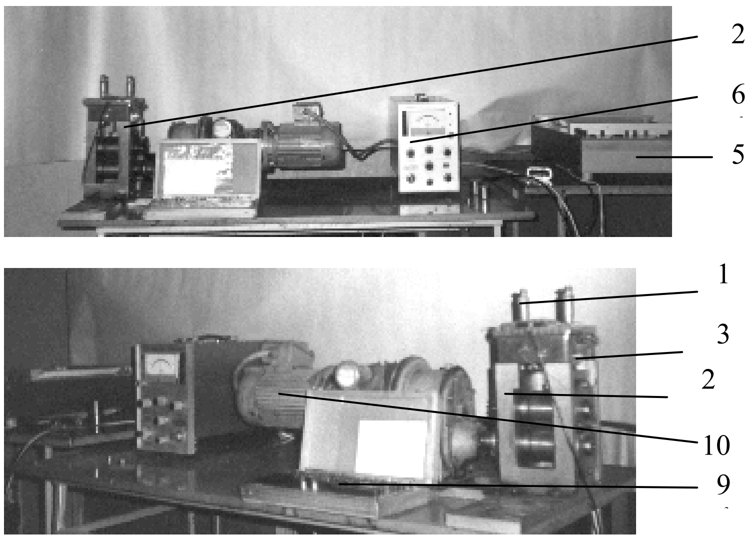

Fig.1.a,b. The stand for the effectuation of the determinations at the micro-rolling; 1.Micrometers (the adjustment of the distance among the rolling mill cylinders); 2.Rrolling frame; 3.The elastic element (2 pieces); 5.Inscriber; 6.The tensiometer deck; 9.Parallel plan holds and spies for the controlling of the distance among the rolling mill cylinders; 10.Engine electrical turned over by rolling grill.

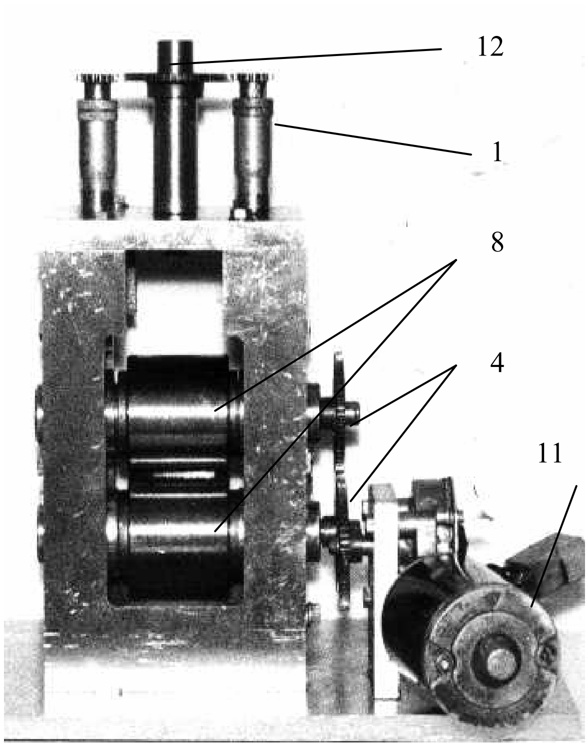

Fig.2. Rolling grill. 1. Adjustment micrometers for the distance among rolls; 4. Gearing for the movement transmission; 8 Rolls; 11.Engine; 12.Device for the adjustment of the distance among rolls.

6. EXPERIMENTAL DATA

The rolling operation is realized through plastic deformation of the wire, from the following materials: silver (Ag999,6), silver alloy (AgCu800), aluminium (Al199,7) and copper (Cu99,9). The purpose of this processing is to obtain a rectangular section band and, concomitantly, to establish the values of rolling specific parameters: the rolling forces; the deformation grades; deformation pressures; defects. [23] The obtained data at the standardization are presented in the graph nr.3. Analysing the specific graph of the stand standardization at the rolling we can figure that the dependence between the force and the movement to the inscriber is linear, and through a mathematical shaping, this one is expressed by a line that has the following equation:

$$Y = 1{,}7076X - 0{,}8707; \qquad R^2 = 0{,}9997 \qquad (1)$$

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Through these determinations, it has been tried, simultaneously with the rolling process the establishment of the dimensional values of the forces required for rolling process, of the rolling pressure and the establishment of some relations between these measures and reduction coefficients of the used sections, as well as the realization of a technological way of the rolling process in which, using a specific coefficient to reduce the material section, to make possible the rolling without using thermal treatments for roasting among the intermediary operations. So, the variations of the decrease of the section coefficient (δ), is constant, in general (δ≅20). To remember that this coefficient of the section reduction is different from the real one (obtain at the rolling process), because of the elastic properties of that analysed metals.

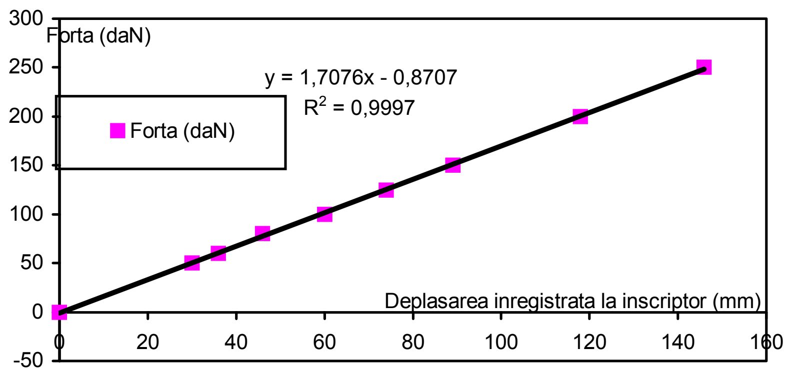

Fig.3. Stand standardization (calibration) form tolling process and the establishment of the dependence between the force and the movement registered at the inscriber

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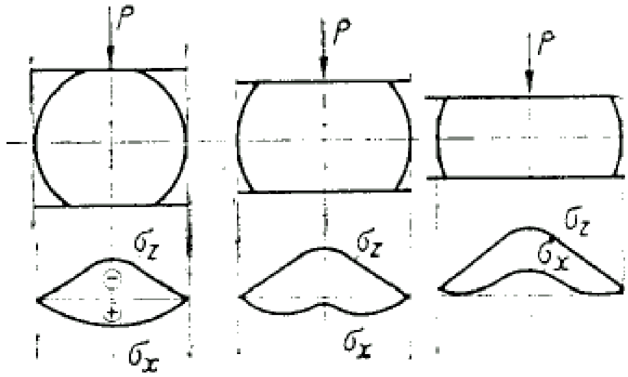

Fig.4. Efforts distribution scheme at the wire rolling [7]

The adjustment at the quota of the rolling mill cage (fig.1; fig.2) will be done with the help of the devices from the endowment and with the spies help, through the cogwheel device. Take care not to repeat a crossing, because this one can affect in a negative way the material deformation capacity. The semi-product state (of the wire before the rolling process) has a very important influence on the band's characteristics obtained through rolling process. It is imposed a checking of the drawn wire quality that must be rolled considering: dimensional deviations of the drawn wire diameter (no more than ±0,01 mm), the tensile strength and that of the extension, the drawn wire quality, the lack of the deficiencies, the pores flattening; the state of the cylinders surfaces of the rolling mill. The end of the wire, that follows to be rolled and that has to be inserted among the cylinders of the rolling mill, will be initially flattened and so ca be warmed up easily.

6.1. The rolling pressure

The speciality literature presents the entire pressure on the rolling cylinders $\mathbf{p_t}$ (fig. 4; fig.5) as being equal with product among the horizontal line projection of the contact surface between the semi-product and the $\mathbf{S_c}$ cylinders and the medium tolling pressure $\mathbf{p_m}$ [1, 6, 7, 39]:

$$P_t=S_c p_m \tag{2}$$

In which S_c represents the contact surface between the cylinders and the semi-product and it is calculated with the help of the formula (fig. 5)

$$S_c=[(b+B)/2]\cdot l_c \tag{3}$$

and p_m represents the medium rolling pressure. In the equation (3) **b** and **B** represents the semi-product width before and after the rolling process, and $\mathbf{l_c}$ represents the contact arc length between the rolling mill cylinders and the semi-product in horizontal projection. The length of the arc horizontal projection it is calculated with:

$$l_c \cong \sqrt{R \cdot \Delta h} \tag{4}$$

Knowing the values of the forces required for the rolling process, as well as the contact arc length between the material and the rolling mill cylinders, have been obtained the real rolling pressures values:

$$p_m = P_t / S_c = \frac{F}{[(b+B)/2]\sqrt{R\Delta h}} \tag{5}$$

in which: F is the measured force of rolling ; b, B are the semi-product dimensions before and after the rolling process; Δh the difference among these dimensions.

Considering that in the case of these determinations the test – pieces used in the rolling process are from wire of round section with the initial diameter ϕ (fig. 5.a), it is considered that for the first rolling H = ϕ and b = 0, because the initial contact between the rolling mill cylinders and the semi-product is tangent. In these conditions the (3), (4) and (5) are becoming: [1]

$$S_c = (B/2) \cdot l_c \tag{6}$$

$$l_c \cong \sqrt{R \cdot (\Phi - h)} \tag{7}$$

$$p_m = \frac{F}{\frac{B}{2}\sqrt{R \cdot (\Phi - h)}} \tag{8}$$

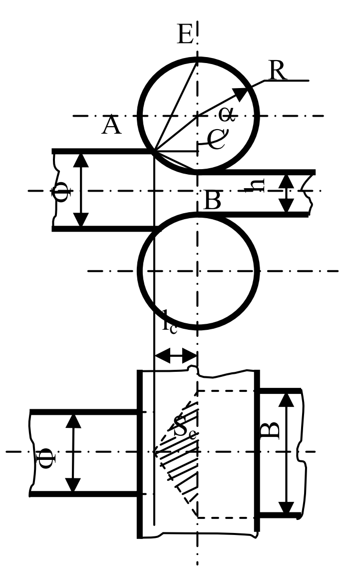

Fig. 5.a;b. The projection of the contact surface S_c between the semi – product and rolling mill cylinders: a. for the first rolling process; b. for the next rolling processes [1]

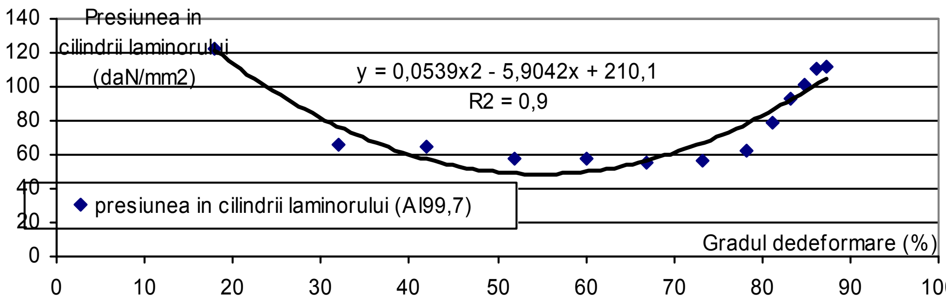

Fig.6. The variation of the pressure in the rolling mill cylinders during the Al99,7 rolling process

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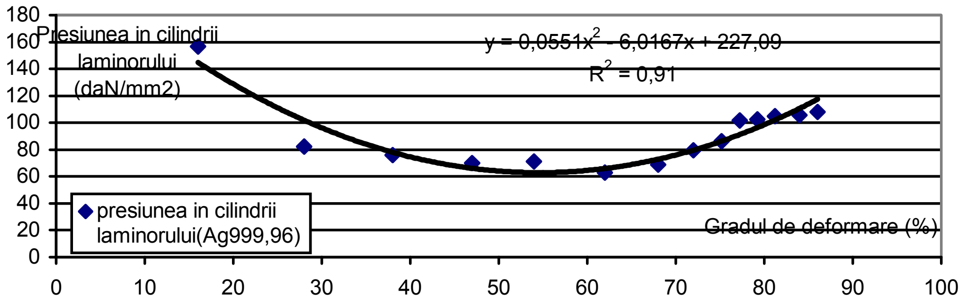

Fig.7. The variation of the pressure in the rolling mill cylinders during the Ag999,96 rolling process

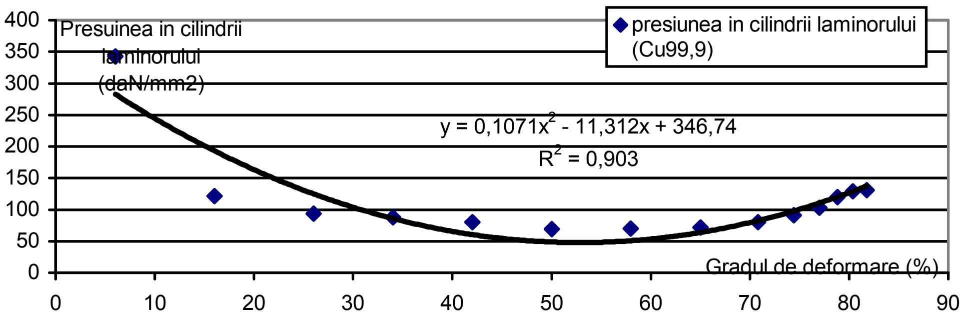

Fig.8. The variation of the pressure in the rolling mill cylinders during the Cu99,9 rolling process

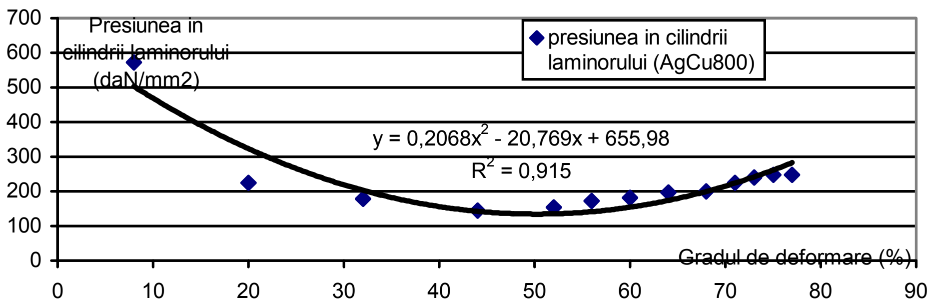

Fig.9. The variation of the pressure in the rolling mill cylinders during the AgCu800 rolling process

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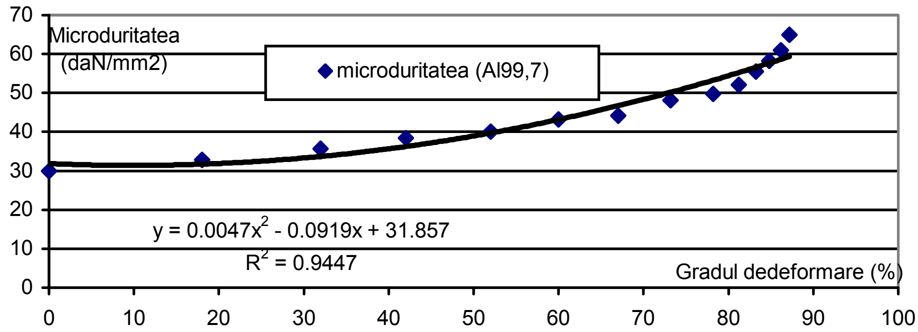

Fig.10. The variation of the micro hardness varying with the relative deformation level during the Al99,7 rolling process

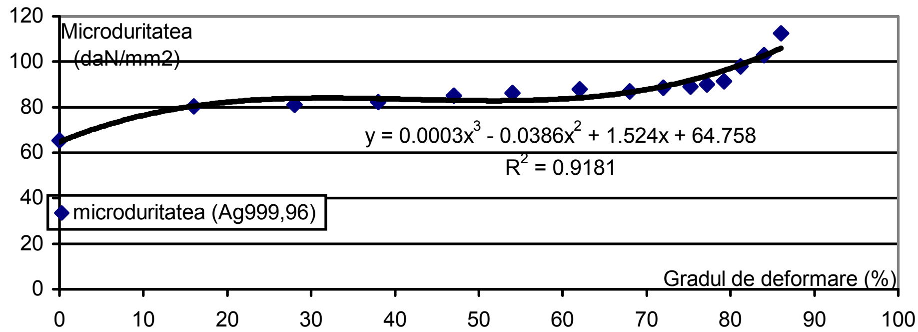

Fig.11. The variation of the micro hardness varying with the relative deformation level during the Ag999,96 rolling process

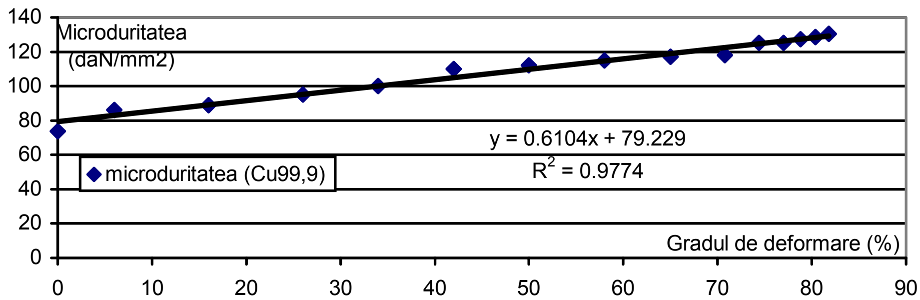

Fig.12. The variation of the micro hardness varying with the relative deformation level during the Cu99,9 rolling process

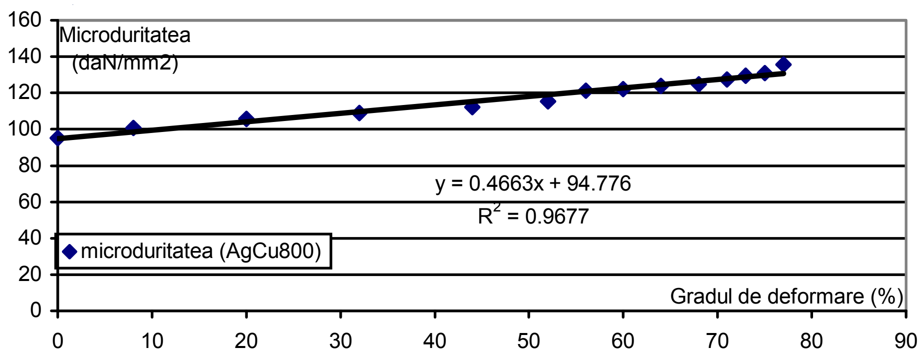

Fig.13. The variation of the micro hardness varying with the relative deformation level during the AgCu800 rolling process

Graphics from figures 6 – 9 presents the medium variations of the pressures in the rolling mill cylinders in accordance with the relative deformation level. Analysing these graphs results that these variations take place according with polynomial second grade laws, whose equations are written on the specific graphics. Variation curves present:

- A descendant section in which the medium pressure in the cylinders decreases according with the increasing of the entire relative level of the deformation, explained by the increase of the contact section between the semi-product and the rolling mill cylinders (this section increase takes place because of the expansion of the contact between the semi-product and cylinders, through the transformation by rolling process of the circular section in rectangular section);
- A minimum that corresponds to a maximum contact surface between the semi-product and cylinders.
- An ascendancy section in which the medium pressure in the rolling mill cylinders increases depending on the increase of the entire relative level of the deformation simultaneous with the decrease of the contact section between the semi-product and the rolling mill cylinders, because of the hardening phenomenon of the metal.

From the comparative study of these graphics results that the medium pressures form the rolling mill cylinders increase while the metals plastic properties decrease.

$$p_{m(Al99,95)} < p_{m(Ag999,96)} < p_{m(Cu)} < p_{m(AgCu800)}$$

6.2. The Micro hardness

In the case of the cold rolling process of the semi-products, under the recrystallization temperature, or in the case that the speed of rolling is smaller than the deforming speed, it takes place a hardening of metallic material and a growing of the deforming resistance follows it. This phenomenon is [23 27 30 31]:

- characteristic to the majority of metals (excepting Pb and Sn , these metals having the recrystallization temperature smaller than the rolling temperature, of the medium)
- depending on the flowing level of the metal, or of the semi-product section for rolling.
- depending on the purity level of the metal, so that on pure metals (Ag 999,96), the hardening is smaller than on alloys of respective metals (AgCu 800).

By analyzing the hardening variation curves, fig. 10-13, resulted at the rolling process it results the following :

- the variation of the micro hardness depending on the relative deformation grade takes place after variation laws: linear in case of AgCu800 and Cu99,9 , second grade polynomial in case of A199,7 and third grade polynomial in case of Ag 999,96:
- the appearance of these curves, no matter the variation law, is ascending in the way of the micro hardness growth with the deformation level;
- the variation of the hardness shows the hardening of the material, so the more plastically the material is the smaller the hardening is, so the hardness value is smaller:

$$HV_{100(Al99,95)} < HV_{100(Ag999,96)} < HV_{100(Cu)} < HV_{100(AgCu800)}$$

- the more plastically the material is, the higher the entire relative deformation level is, in the same trying conditions:

$$\varepsilon_{Al99,95} > \varepsilon_{Ag999,96} > \varepsilon_{Cu} > \varepsilon_{AgCu800}$$

- by choosing one optimal deformation grade, hardness of the materials used in the rolling process did not imposed thermal treatments for recreation of the plastic properties .

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7. CONCLUSIONS

The paper presents the results obtained according with the experimental researches regarding the fine silver and the silver alloy AgCu800 behavior, after rolling process attempts. Analyzing these results we can conclude the following: at the rolling process one must consider that the flow limit increases while the rolling section decreases; the obtained quality of the semi-product through the rolling process depends on the constructive variant of the device used for this operation; the material through its physical – mechanical properties influences directly the rolling process; the respect of the technological process specific for the rolling process has an important part in obtaining of the qualitative parameters of the rolled semi-product; the proper utilization of the technologic process is very important for the obtaining of the qualitative parameters of the rolled semi-product.

The conceived and realized stand for the effectuation of the experimental researches, allows simultaneously with the rolling process, the determination with precision of characteristic parameters of this operation: the deformation level, the deformation force, the pressure etc. The adjusting at the quota of the rolling mill can be done with a high precision. The used rolling mill in these experimental researches allows the rolling in a great dimensional range of many materials: aluminum, copper, silver, silver alloy. The comparative study of the metals used at the rolling process: AgCu999,96; AgCu800; Cu99,9; Al99,7 aim at the establishment of the values of the main characteristic dimensions of the rolling process and also, considering the offered dates by the specialty literature (regarding the copper and the aluminum) and knowing that these materials have the same behavior from the workability properties point of view, the checking of the obtained dates at these measurements.

In conclusion:

- Medium pressures form the rolling mill cylinders increase with the decrease of the plastic properties of metals.
- In the case of the semi-products rolling at cold takes place a hardening of the metallic material and so the deformation resistance increases.
- The micro-hardness is dependent of the purity level of the metal, so at pure metals, this one is smaller than the one from respective metal's alloys.
- The variation of the micro-hardness considering the relative deformation level takes place regardless of the material nature, while the micro-hardness increases the deformation level decreases.

- Values of the micro-hardness demonstrate the material hardening, so as plastic the material is as smaller the hardening is, so the micro-hardening value is smaller.
- By choosing an optimal deformation coefficient, the materials hardening from the rolling mill attempting doesn't require thermal treatments for plastic properties recover.

By respecting the literature of specialty recommendations, the choosing of some technological parameters, the obtained semi-products at the rolling process attempt, do not present deficiencies from witch the rejection of the proofs result.

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