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TECHNICAL ASPECTS REGARDING THE MANUFACTURING OF TUBULAR PARTS USING COLD REVERSE EXTRUSION

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Abstract: *Processing of metals by cold pressing acquires an increasingly wide application, because of its proved benefits: low metal and energy consumption, high productivity, low costs and the possibility to achieve high precision products. In this context, cold metal extrusion can be considered as a leading process which offers the possibilities that a few years ago were unimaginable.*
This paper presents design problems with practical character, the execution problems of the extrusion dies and considerations regarding the technical equipment, which contribute to the product realization. In comparison with other procedures, the reverse extrusion assures high productivity, very efficient material utilization and reduced workload.
Also due to the hardening of extruded material, the finished parts have superior mechanical characteristics. The high complexity of the process required extensive theoretical and experimental research over the years, resulting in widening the range of products manufactured.
Obtaining a good quality of the extruded products requires a good knowledge of the properties that characterize the formability of metallic materials, plasticity and their resistance to straining, and also their dependence on the conditions in which the extrusion takes place. Most of the parts obtained by reverse extrusion have axial symmetry, but under certain conditions, irregular parts can be also extruded. In this case, the center of the technological forces should be placed on the tool axis. Theoretically, all metals and their alloys can be processed by cold extrusion; however, in practice, using different metals and alloys is conditioned by their formability. The specific pressure required for extrusion should not exceed (2000 ... 2500) N/mm^2, a value that provides good durability for the tools and a load of the equipment within acceptable limits.
Key words: *extrusion, reverse extrusion, extrusion technology.*

1. INTRODUCTION

Extrusion is a bulk forming operation which can be performed at different temperatures. Through this operation, parts with simple or complex geometrical configurations are made, by exploiting the plastic flow of the material into the space between the punch and the extrusion die or through the orifice of the extrusion die.

Reverse extrusion is a process characterized by the fact that the flow of the deformed material flowing is in the opposite direction to the punch motion. The technological process of cold reverse extrusion of ferrous and nonferrous alloys is applied with maximum economic efficiency for small parts, with certain configurations, on a large batch or mass production. Worldwide, it was found that through this process, parts with good quality are obtained at a lowest price as compared to other conventional manufacturing processes.

The extrusion process had an evolution of about two centuries. The documents prove that in 1797 Braman patented the design of an extrusion press that could be used for processing lead tubes. In 1909 L.E. Hooker also patented a "Method and device for manufacturing tubes of metal", with a direct application to the extrusion of cartridge brass body [2].

Since 1909 the cold extrusion has found a wide field of application in the weapon industry. Due to this applicability, the spread of the information referring to the cold extrusion has been drastically restricted. A public reappearance of the process is found during 1930-1935, with the explosion of consumer products for the cosmetics, aeronautics, automobile, etc.

From 1930 to 1940, the research on cold extrusion of steels was made in the greatest secrecy, the main objective being the replacement of the brass from ammunition body with cold extruded steel. A decisive step was made by creating a coating of the raw parts with a chemical compound of the metal itself.

In this way, a porous thin coat of mixed iron and zinc phosphate was made on the extruded steel surface. By impregnating this layer with oil or solid soap, it will withstand the high pressure that arises during the extrusion process. The phosphate layer should be (5 ... 15) μm, uniform, thin and adherent.

The process is currently in full development and the research works are numerous, with upgraded industrial applications, economic, technical, quality of parts, materials for cold extrusion, tools, equipment, etc. In our country, the cold extrusion of the steel began to be sporadically applied, this relatively new technology being considered very promising.

2. ADVANTAGES, DISADVANTAGES AND EXPECTATIONS

The applicability of the extrusion process in general and of the cold steel extrusion, in particular, is justified by the technical and economic advantages as compared with other technological processes. The industrial applications are limited only by the batch size. The following advantages can be mentioned:

- Material economy. In comparison with the cutting process 25 ... 75% of the raw material can be saved;
- Dimensional accuracy: very good (10...11 precision class according to STAS 8101);
- Quality of surface: average roughness is 0.1...0.4 μm;
- Improved material properties (increased hardness, yield strength, tensile strength);
- The ability to be combined with other technological processes;
- Labor savings;
- Energy savings, etc.

The main disadvantages are:

- Cold extrusion involves high value investments;
- The material submitted to the extrusion must support high extrusion strains;
- Expensive equipment and tools.

The extrusion improving and the necessity to reach new performances make the scientific research of the process to take an increasingly widespread.

3. SPECIFIC PARAMETERS OF THE EXTRUSION PROCESS

The main parameters specific to the cold extrusion process are: the straining degree, the flow curve of the deformed material, the forming speed, the friction between the material and the active elements of the tool, the shape and dimensions of the die, the size of the extruded profile, shape and dimensions of the blank, mechanical properties of the blank.

The straining degree gives information on the maximum extrusion force and either on the maximum permissible deformation, thus helping to establish the stages of the extrusion process.

Figure 1 shows the design of a part that will be achieved by reverse extrusion using a cylindrical blank. Table 1 shows some relations used to calculate the straining degree [2], [9].

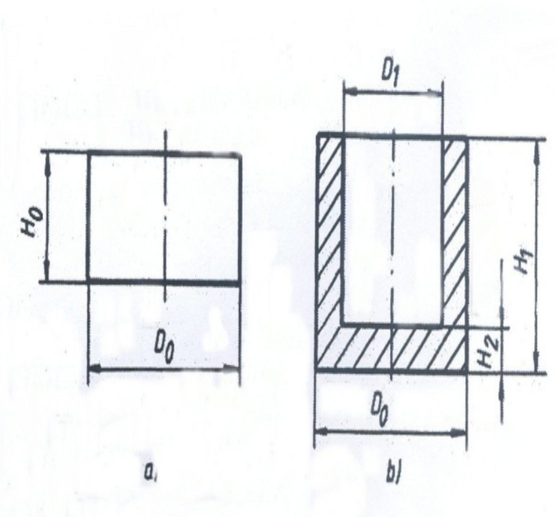

Fig. 1. Reverse extrusion of a part: a) blank, b) extruded product.

Table 1.
Relations for calculating the straining degree of the blank

Geometric elements	Conventional strain, ε [%]	Logarithmic strain, φ [%]
Height	$\varepsilon_H = \frac{H_0 -}{H}$ (1)	$\varphi_H = \left(l_n \frac{H_0}{H_2} \right)$ (2)
	H_o - initial height of the blank; H_2 – Height of the part bottom region	
Sectional dimension	$\varepsilon_F = \frac{F_0 -}{F}$ (3)	$\varphi_F = \left(l_n \frac{F_0}{F_1} \right) \cdot 1$ (4)
	F_0 – cross section of the blank; F_1 –annular section of the extruded part.	

Table 2 shows some maximum values of the strains achievable in a single operation for steel with a carbon content up to 0.20 %.

Table nr. 2
Maximum strains achievable in a single operation. [2]

Material	Conventional strain, ε [%]	Logarithmic strain, φ [%]
Steel with %C < 0,10	$\varepsilon_F = 90 \div 95$	$\varepsilon_F = 230 \div 300$
Steel with 0,10 ≤%C≤0,20	$\varepsilon_F = 75 \div 80$	$\varepsilon_F = 140 \div 190$

The strain determined on the basis of an idealized model of the reverse extrusion process can be expressed as follows: [2]:

- By E. Siebel,

$$\varphi_g = \left(l_n \frac{D_0}{D_o - D_1} - 0{,}16 \right) \cdot 100[\%] \quad (5)$$

- By M. Dipper, the process is considered to be formed by two homogeneous upsettings:

a) An axial upsetting under the punch;

$$\varphi_{g1} = \left(l_n \frac{H_0}{H_2} \right) \cdot 100[\%] \quad (6)$$

b) A radial upsetting between the vertical wall of the punch and the wall of the cup.

$$\varphi_{g2} = \varphi_{g1} \left[1 + \frac{D_1}{8(D_0 - D_1)} \right] [\%] \quad (7)$$

- By T. Altan and E. G. Thomsen [2]:

$$\varphi_{g2} = \varphi_{g1} \left[1 + \frac{D_1}{2\sqrt{3}(D_0 - D_1)} \right] *100, [\%] \quad (8)$$

The conventional strain „ε” and logarithmic strain „φ” are related as follows:

$$\varphi = \ln(1 + \varepsilon). \quad (9)$$

The flow curve describes the behavior of a metallic material subjected to plastic straining; this is shown by the existing relation between tensile flow (resistance to deformation) σ or K_f and the conventional strain ε or logarithmic strain φ.

The strain rate $\dot{\varepsilon}(\dot{\varphi})$ is a parameter that influences the deformation resistance [8], [9].

The friction between the material and active elements of the die is a parameter with great influence on the resistance to deformation. Due to friction, the value of the resistance may increase up to 50 ... 80% [8] [9].

The dies used in cold extrusion processing have different configurations, depending on the type of extrusion operation and production volume. Thus for mass production are recommended dies with high durability and productivity. Figure 2 shows a schematic diagram of a reverse extrusion die for metallic materials [9]. The upper part of the tool includes the a punch and the pressure plate b, while the lower package includes both the die c, and the external bandage of the die d, counter-punch e, the pressure plate f, the pin of the press bolster g and h the part ejector, all placed on the lower plate of the tool.

Punches and dies are submitted to dynamic loads, so it is necessary to use for these, materials with high strength and tenacity.

Figure 3 shows the construction of a punch, and Figure 4 – the die construction for reverse extrusion. Both constructions are proposed by K. Siegert [2].

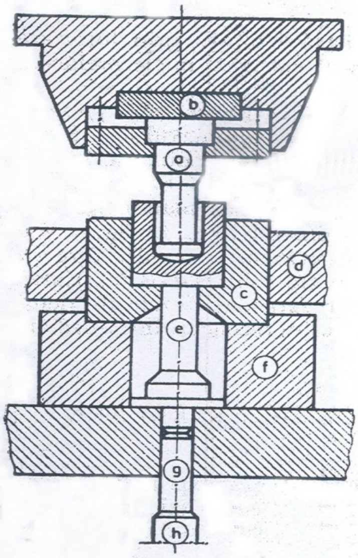

Fig. 2. Schematic drawing of a reverse extrusion die

Cold extruded parts are usually symmetric, but under certain conditions non-symmetric parts can be also produced.

The concentration in carbon of the extruded steels is from 0.02% to 0.6%, practically, the carbon content should not exceed 0.45%. Because of the above constraint, steels that are used for cold extrusion are unalloyed or low alloyed steels with low content of carbon; sometimes austenitic steels, medium or high alloyed steels are used [9].

4. THE TECHNOLOGICAL PROCESS OF COLD EXTRUSION

The technological process of cold extrusion comprises the following operations:

- blank cutting;
- heat treatment;
- surface preparation;
- lubrication;
- extrusion and final processing of the products.

The most important advantage of cold extrusion as compared with other processing technologies is the material and energy saving. Figure 5 shows a comparison between the costs of achieving a part by cutting and cold extrusion [9].

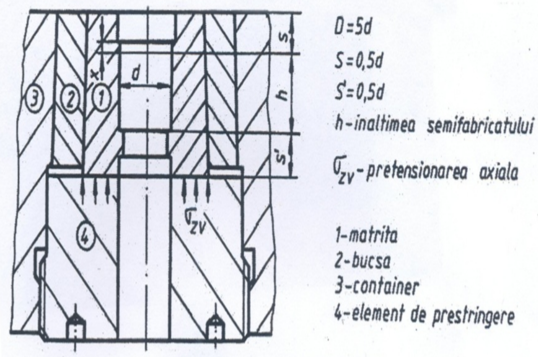

Fig. 4. Die construction for reverse extrusion

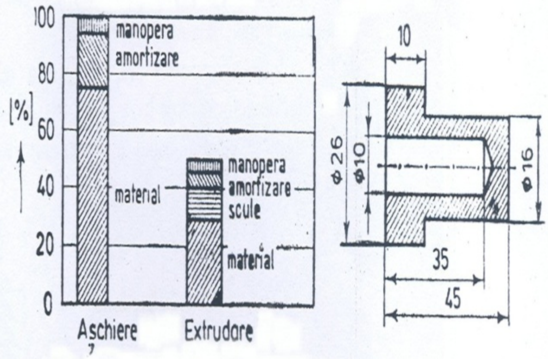

Fig. 5. Comparison of the production costs of components made by cutting and cold extrusion

The stages of the cold extrusion technology to achieve a product are:

- ✓ Developing an extruded part drawing;
- ✓ Determining the necessary amount of metal;
- ✓ Initial blank shape and size;
- ✓ Plan of operations (the number of pressing operations and their sequence).

Regarding the establishment of the minimum number of parts for which the extrusion is economical, there is not a general rule. This is determined on a case by case, depending on the economy of material, labor, energy, etc.

5. PARAMETERS OF THE EXTRUDED PART

Wall thickness for reverse extrusion, varies depending on the shape and material of the part, between 0.5 and 15 mm for steel and between 0.05 and 5 mm for non-ferrous alloys. In case of tubes, because of the tensile that occurs in the active elements, the ratio of tube length and diameter can not exceed l/d < (3...10).

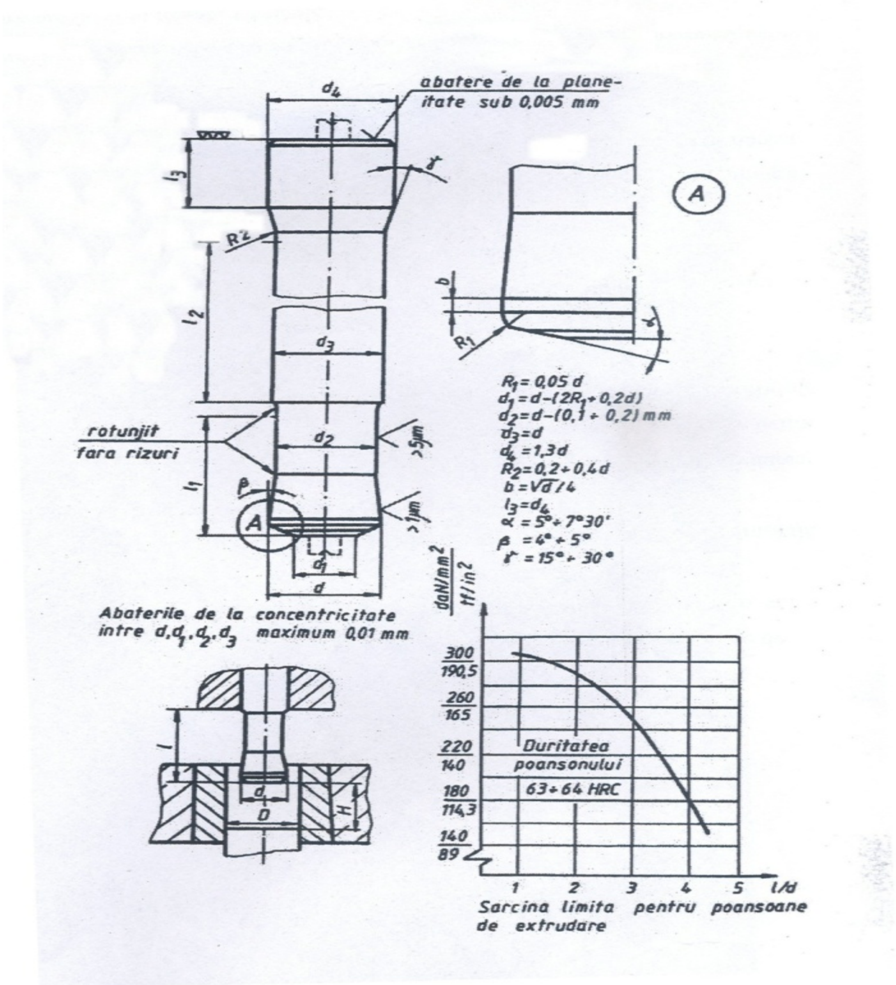

Fig. 3. Punch construction for reverse extrusion

The surface quality of the extruded parts is superior to fine turning (about 12 μm) and it is situated very close to fine grinding (0.05 ... 0.2 μm). By cold extrusion it is obtained a roughness of 0.1 ... 0.4 μm which is determined by surface preparation blank (phosphate and lubrication), the quality of active elements surface, material grain size and section variations.

In case of hollow parts, the exterior surface is generally less rough than the interior one.

One of the advantages of cold extrusion process is either the high precision of obtained parts with tolerances, which in many cases, can exclude the need for finishing operations. The dimensional deviations place the extruded parts in the precision classes 10 ... 11 [9].

During the forming process of the part by cold extrusion there is a hardening of the material, which increases the hardness, yield strength and fracture resistance, while the elongation and necking at break decrease.

6. CONCLUSIONS

Cold extrusion processing, as compared with other processing methods, shows clear advantages. The main advantages that stand out are: material saving, dimensional accuracy, surface quality, improving the mechanical characteristics of the material, labor savings, energy savings, the possibility of combining the process with other manufacturing methods, etc.

Due to the technical and economic efficiency of the cold extrusion, the process gains an increasingly higher applicability. The continuous improvement and the need to achieve new performances, makes the scientific research of this process to be interesting.

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ASPECTE TEHNOLOGICE PRIVIND REALIZAREA PIESELOR TUBULARE PRIN EXTRUDARE INVERSĂ LA RECE

Rezumat: Procedeele de prelucrare a metalelor prin presare la rece dobandesc, tot mai mult, o larga aplicabilitate, ca urmare a avantajelor ce le prezinta: consumuri reduse de metal si energie, productivitate ridicata, costuri reduse si posibilitatea realizarii unor produse de precizie ridicata. In acest context, extrudarea metalelor la rece se inscrie ca un procedeu de varf ce ofera astazi posibilitati care in urma cu cativa ani erau greu de imaginat. Lucrarea prezinta probleme cu caracter aplicativ de proiectare, executie a matritelor de extrudare inversa asigura o productivitate ridicata, un grad inalt de utilizare a materialului si reducerea volumului de munca. De asemenea, datorita ecruisarii materialului extrudat piesele realizate prezinta caracteristici mecanice superioare. Eficienta ridicata a procedeului a impus cercetari teoretice si experimentale intense de-a lungul anilor, avand ca rezultat largirea gamei de produse realizate. Obtinerea unor produse extrudate de calitate, necesita o buna cunoastere a proprietatilor ce caracterizeaza deformabilitatea materialelor metalice, plasticitatea si rezistenta lor la deformare, precum si modul de variatie a acestora in functie de conditiile in care are loc extrudarea. Domeniul cel mai larg il formeaza piesele simetrice, dar in anumite conditii pot fi extrudate si piese asimetrice aexial. In acest caz se impune conditia ca, centrul de greutate al piesei sa fie plasat pe axa sculei. Teoretic toate metalele si aliajele lor pot fi prelucrate prin extrudare la rece, in practica insa, folosirea diverselor metale si aliaje este conditionata de deformabilitatea lor. Presiunea specifica necesara extrudarii, nu trebuie sa depaseasca (200…250) daN/mm^2, valoare care asigura o durabilitate buna pentru elementele active ale matritei si o solicitare a utilajului in limite admisibile.

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