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ABOUT FLANK SURFACE QUALITY IN HIGH PRECISION PUNCHING OF TOOTHED GEARS

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Abstract: *The high precision punching is a modern procedure in order to obtain high quality cylindrical gears. During the process, the prominent plastic deformation and the superior tensions produce a flank surface with low roughness. The smooth zone proportion from the processed surface is bigger in high precision punching (about 80-90%) than in ordinary punching (about 30-40%). If the influence factors - quality: material, thickness, clearance and friction - have optimal values, and the proceeding technology is correct, the flank roughness arrived to* $R_a = 0.2 \ldots 0.4\ \mu m$ *and the toothed gear has a precision in IT 6 – 8 ISO.*
Key words: *high precision punching, influence factors, flank surface.*

1. INTRODUCTION

The high precision punching is a modern, high-tech and productive manufacturing procedure, which is applied with success for various pieces forms.

The high precision punching can be used with success for the obtaining of external or internal cylindrical gears on final size, starting from table semi-product. The gears must be with straight teeth, low thickness (maximum 16...20 mm) and with high precision requirements, used especially in fine mechanics mechanisms and which have varied tooth flank form.

The gears are made of punching steel if their width (table thickness - g) is

$$g \leq (1{,}9...2{,}25) \bullet m_n \qquad (1)$$

where m_n is the normal module.

The principle of high precision punching consists in decreasing the clearance j between the punch-active plate clearance trough negative values or previous pressing with pressures next to the flow limit. The punch and the active plate are teeth contour, of course.

$$j = \frac{g^2}{8 \cdot b} \cong (0{,}05...0{,}2) \cdot g \qquad (2)$$

where b is the breadth of deformed zone of material.

In the end of process, the punch not penetrate trough the active plate orifice. The punch movie is arrested at a distance h_0 from frontal surface of the active plate

$$h_0 \le \frac{\mu_S \cdot q_S \cdot g}{\sigma_f + \mu_S \cdot q_S} \tag{3}$$

where q_S is the normal tension, σ_f - the shearing tension of material, μ_S - the friction coefficient punch-material.

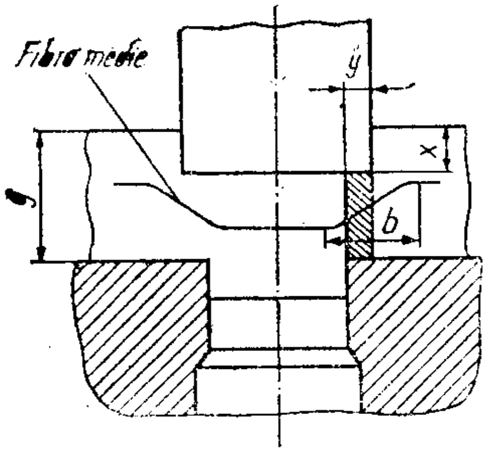

Fig. 1. *The principle of high precision punching.*

2. THE CUTTING PROCEDURE. THE SMOOTH – SHINY ZONES

The cutting procedure has 3 successive stages, like in ordinary punching, which can be identify in cut section: *the elastic state strain stage*, *the plastic state strain stage* (the cut section is a shine surface with low roughness and the width h_f) and *the shearing stage*.

The shearing model by high precision punching with negative clearance (figure 2) presents the same 3 structures like in ordinary punching: SB - basic material has crystalline and normal granules and isotropic proprieties, SP - of cool strained material has oblong granules, orientated thru the flow direction, SSa - which is characteristic for intense strained material in elastic-plastic area, with cold-hammering. Also, the mechanism of deformation-shearing as in ordinary punching the same, but there are some important *distinctions*:

– tensions growing inside the plastic zone SP;

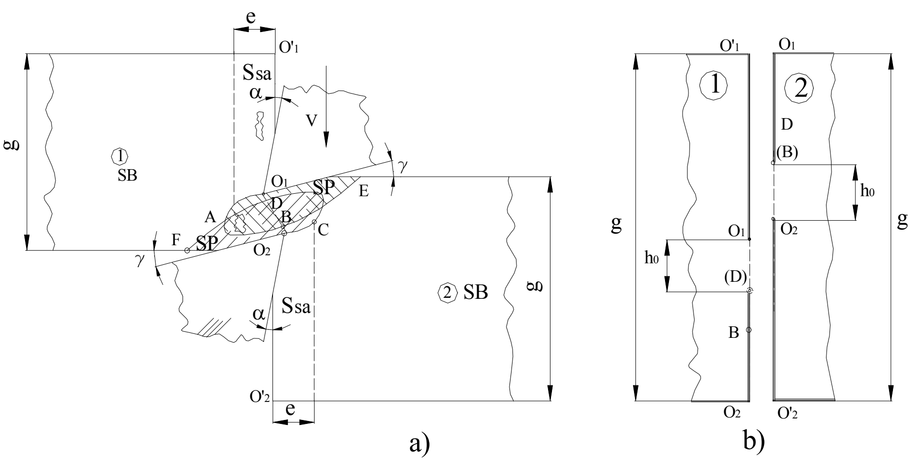

Fig. 2. *The deformation-shearing structures in high precision punching with negative clearance: a) the deformation model; b) the cut zones surface.*

- the plastic zones extension SP, which intersect in the end of process;
- the material between the edges goes in the super-plasticity state, permitting the pure shearing.

In the cut section, there are two smooth-shiny zones h_f which includes mostly section. There are separated by a rugged-sheared but narrow zone h_0:

- the first part of material, where $h_0 \in (O_1D, O_1B)$ is near by the O_1 edge;
- the second part of material, where $h_0 \in (O_2B, O_2D)$ is near by the O_2 edge.

In high precision punching, the dimensional precision, the surface perpendicularity and roughness growing is attended by thickness and hardness growing of the cold-hammering stratum *"e"*.

That is why ***the width of plastic zone*** h_f and ***its percentage*** h_f / g are indexes of flank surface quality of punching gear. In high precision punching the smooth plastic zone width h_f grows and decreases the cut zone with roughness. Also decreases the median roughness of cut section and grows its perpendicularity on the frontal faces of gear.

3. THE TEETH FLANK SURFACE QUALITY. THE INFLUENCE FACTORS.

Using the previous models in cutting out for toothed gear with external teeth (2), in perforating for toothed gear with internal teeth (1) there is observing the aspect, contour, and the disposition of smooth-shiny and rugged zones - figure 3.

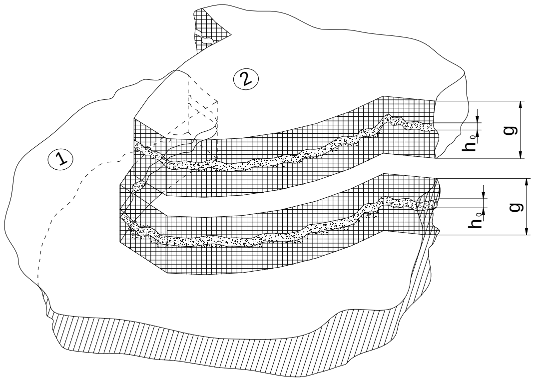

Fig. 3. *The deformation-cutting zones in high precision punching*: *(1) internal gear perforated contour*; *(2) cutting out external gear.*

The principal factors that influence the size of smooth surface h_f, the percentage of smooth surface in punched surface h_f/g, the punched flank quality, the dimensional and form precision of the gear tooth are:

- the punch-active plate clearance size and its contour un-uniformity;
- the punched material structure and physical-mechanical proprieties;
- the size (thickness) of punched piece;
- the wear state of cutting edges;
- the tensions state that is generated in the material;
- the punch-material and active plate-material friction level;
- the operational process parameters.

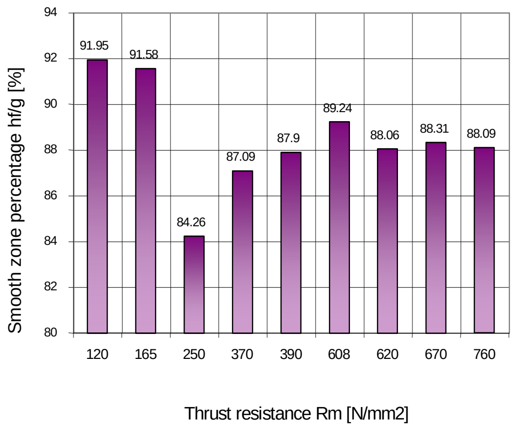

Fig.4. *Material influence on the smooth zone percentage in high precision punching, g=0...12mm, μ=0.25, j=jopt.*

The thorough analysis on the influence of these factors on the punched flank surface quality took finally to global influence chart drawing for the high precision punching figure 4 and 5.

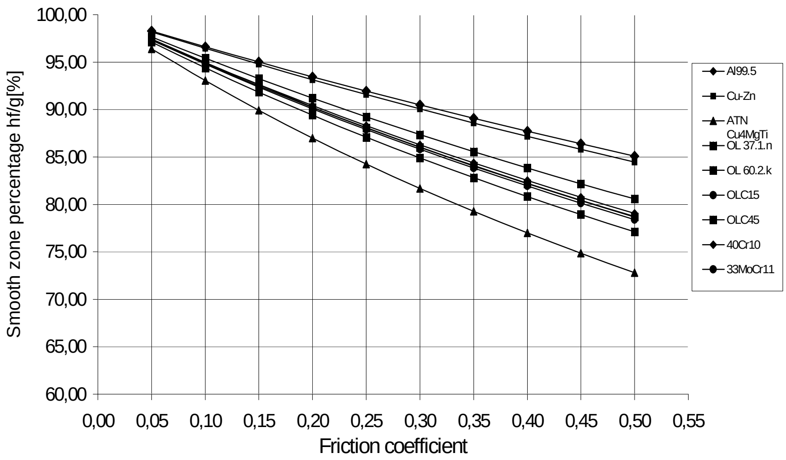

Fig.5. *Friction level influence on the smooth zone percentage.*

4. CONCLUSIONS

Studying the chart 4 and 5, there are observing:

- the smooth zone h_f measured in absolute values, grows continuous as the thickness of the semi-product and the obtained flank quality is more superior;
- in the cut section, there are two smooth-shiny zones h_f;
- the thick tables (10 ÷ 12 mm) assure smooth zone with h_f = 8,5 ÷ 11mm;
- the smooth zone percentage h_f/g is much superior as in ordinary punching. It represents 84 ÷ 92 % from the cut section, depending on material – about 50% in ordinary punching;
- the growing of tool-material friction coefficient worsens the gear flank quality thru 25%;
- in limit friction (μ = 0,1 ÷ 0,2), the flank smooth zone percentage h_f/g is 97-98%, coming in dry friction (μ = 0,5) at about 77-78 %;

In high precision punching, the punch and the active plate must be manufactured with all the active surfaces by R_a= 0,8…0,4 μm roughness, by grinding procedure until in level IT 5-6 ISO.

In these case, for steel, it can be obtained a toothed gear in level IT 9 – 10 ISO and a flank roughness R_a= 3,2…1,6 μm by ordinary punching and a toothed gear in level IT 6 – 8 ISO and the roughness R_a= 0,8…0,2 μm by high precision punching.

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