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APPLICATIONS OF THE EDM WITH MASSIVE AND WIRE ELECTRODE AT PROCESSING OF THE DIE ACTIVE PARTS

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Abstract: this paper presents theoretical research concerning the processing of dies active parts by means of working on CNC milling machines, combining the chipping coarse grinding with the massive electrode EDM finishing, as well as the wire electrode EDM; next is presented a case study about the realization of a die cut active part and the technological itinerary, by means of wire electrode EDM.

1. INTRODUCTION

Nowadays, EDM is successfully used in almost every industrial branch to process hard and extra-hard materials, in order to manufacture dies for hot and cold pressing, dies for plastic materials, wiredrawing dies, metal carbide chipping tools etc.

Lately, the wire EDM cutting is widely used for cutting of punch plates and dies, burr-removing molds, profiled knives etc. The cutting can be achieved with very high accuracy, at least ±2 μm, for the most complex shapes, on programmable numerical command machines. The cut width depends on the wire diameter, which can be chosen in such manner that, after the cutting of the plate, the resulted part should be the die itself. This procedure is used mainly for small and complex-shaped parts. A special application of this technique consists of the realization of molds and punches for electrical micro-motors cores [2, 3, 5].

There are more possibilities for making the mold active parts, for which one can use the wire EDM or the massive electrode EDM as they are or combined with working on NC milling machines. Some common cases are shown next [3].

Case 1: working of complex through-hole surfaces

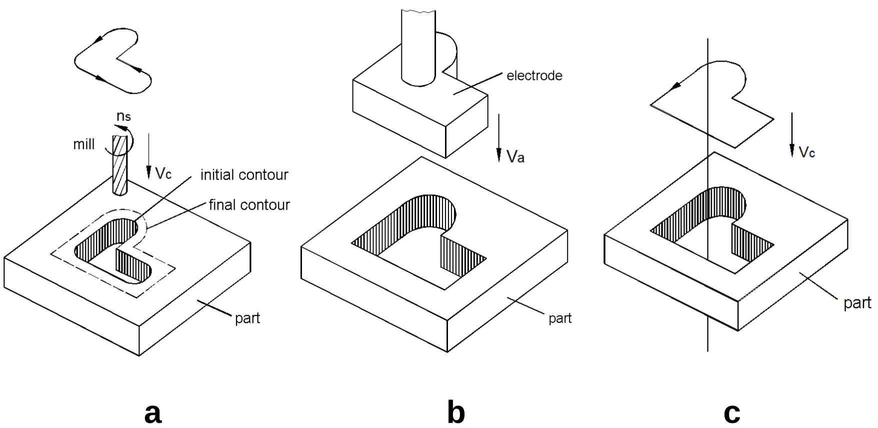

Fig.1. Working of complex through-hole surfaces:
a – milling, b – massive electrode EDM, c – wire EDM.

Fig.1.a shows the working by means of a cylindrical-frontal mill on a NC milling machine, which makes the coarse grinding. The finishing operation will be made by means of massive electrode EDM (fig.1.b). Fig.1.c shows the wire EDM. In this case also, the optimal working is achieved by wire EDM.

Case 2: working of blind-end complex surfaces

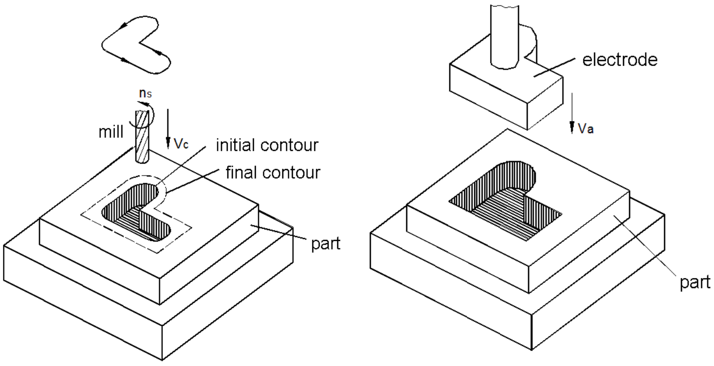

Fig.2. Working of blind-end complex surfaces: a – by milling, b – by EDM.

No wire electrode can be used in this case (fig.2). In order to increase productivity and because of the complex surface, only the coarse grinding may be achieved by milling, but the finishing is made by massive electrode EDM. This procedure is often used in the working of plastic mass injection molds active parts.

2. PRINCIPLE OF WIRE EDM AND USAGE POSSIBILITIES

Because of the increase in the parts complexity, the programmable NC wire EDM installations are built and used. These can be classified as follows:

- programmable NC EDM installations for working of complex shapes (bores, profiled cavities etc);
- programmable NC EDM installations for cutting (punch plates, cams, gears etc).

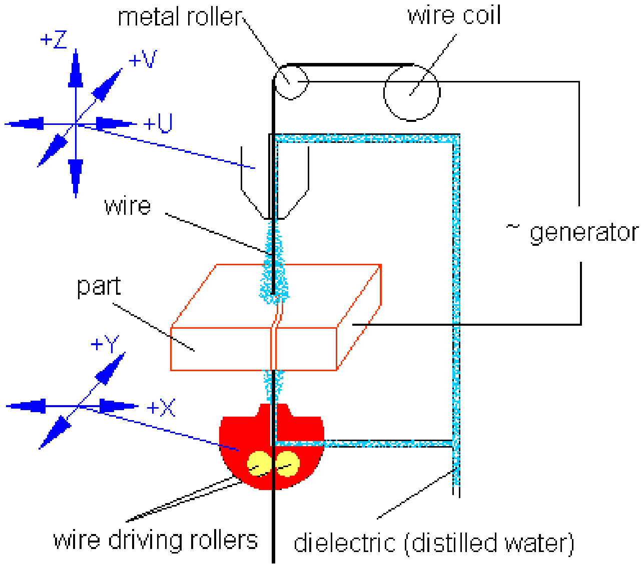

Fig.3. Working principle of wire EDM installation.

First were made wire-cutting machines with templates, which had the shapes of the parts to be made, and the tracking was achieved by:

- direct tracking, when the wire-electrode follows the template contour;

- indirect tracking, when the template contour is followed by a sensing head, and the movement is transmitted to the part fixing device by means of a pantograph-type device.

These methods yield low quality and working precision, which require further adjusting operations.

Many wire EDM installations are made by renowned companies: Charmilles, Agie, Ona etc. These machines can perform movements on 5 axes: the inferior head on X and Y, and the superior head on U, V and Z (fig.3) [7].

The wire can be tilted by means of special devices, thus tilted cuts or different profiles from top to bottom become possible. The wire diameter is very important for the accuracy of working on programmable NC machines. The wire has 0.05 ÷ 0.2 mm in diameter, and it is made of wolfram, copper or molybdenum.

3. CASE STUDY CONCERNING THE TECHNOLOGY OF WIRE EDM REALIZATION FOR THE ACTIVE PART OF A DIE

Fig.4.a shows the execution drawing for the active part of a die, which will be used to punch metal sheet in order to produce hinges, and fig.4.b shows the die after milling and boring, prior wire electrode EDM.

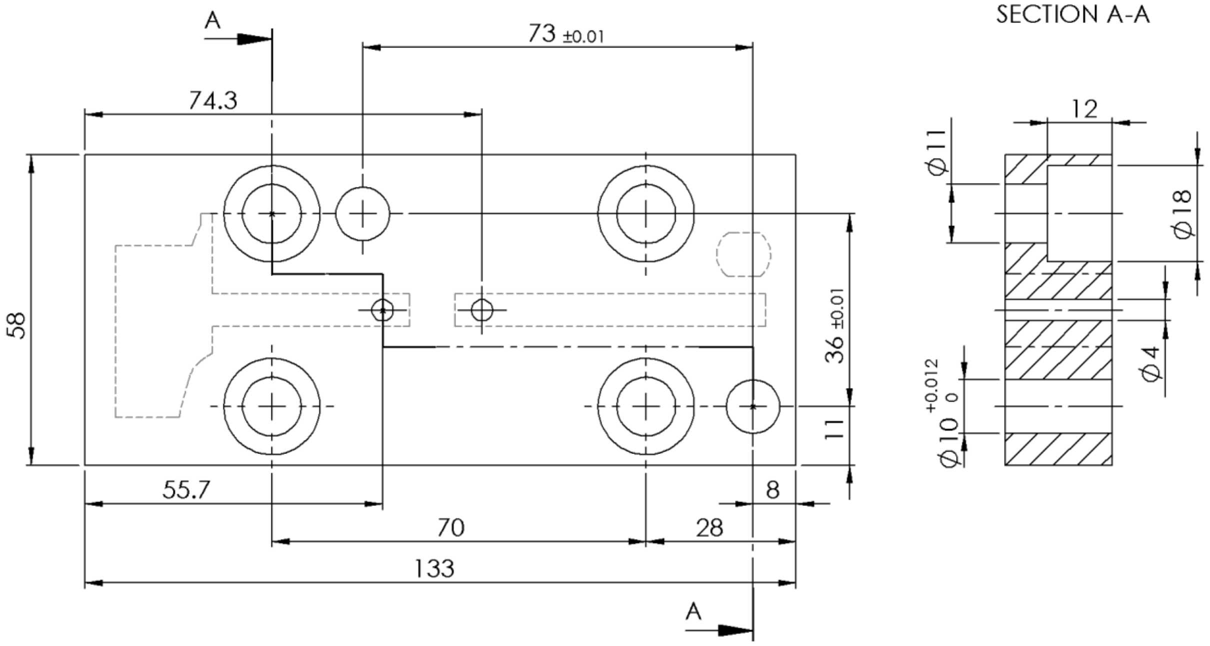

Fig.4.a. Execution drawing of the die active part.

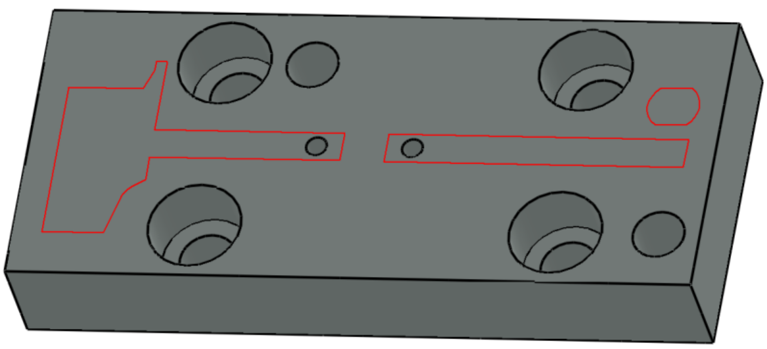

Fig.4.b. Die active part, after milling and boring.

First the CNC machine operations are carried out, with respect to the dimensions of the execution drawing, and then two technological bores are made and a thermal treatment is applied. The technological bores are made in an unused zone of the finite part (fig.4.b), and the wire electrode will be introduced through them. The machining parameters are set according to the ROBOFIL handbook and to the notions above mentioned [1, 6].

When working different parts by means of EDM, the setting of the parameters is achieved according to each particular case, taking into account the diameter of the wire-electrode and the dimensions of the part to be done (height, material).

The tensile force *P* of the wire-electrode is set according to its diameter. After choosing the diameter of the wire-electrode diameter to be used, the other working parameters are set: capacity of the discharge circuit, wire winding speed, working voltage and current. Once the working parameters are set, according to the wire-electrode diameter and the part thickness, the characteristic elements of the cutting process result: the cutting capacity V_s [mm^2/min], cut width *S* [mm], maximum roughness of the worked surface R_{max} [μm].

Working parameters

The wire-electrode diameter is chosen according to the admissible rounding radius (tab.1) and then it is checked if it complies with the corresponding values for the part height (tab.2).

Tab.1. Admissible rounding radius according to the wire diameter.

Admissible rounding radius r_a [mm]	Wire diameter *d* [mm]
> 0.12	0.20
0.08 - 0.16	0.15
0.06 - 0.12	0.10
0.04 - 0.08	0.08
0.03 - 0.06	0.05

Tab.2. Material thickness according to the wire diameter.

Material thickness *H* [mm]	Wire diameter *d* [mm]
< 2	0.05
2 – 4	0.08
4 – 10	0.10
10 – 20	0.15
20 – 80	0.20
80 – 400	0.25

It is recommended to use the maximum possible wire diameter for each part to be made, because the cutting capacity depends on the wire diameter. In practice, in order to avoid frequent changes of the wire, it is recommended to use a single 0.2mm diameter wire-electrode.

The tensile force is chosen according to the material of the wire-electrode (hard copper or soft copper) and to the chosen diameters (fig.5).

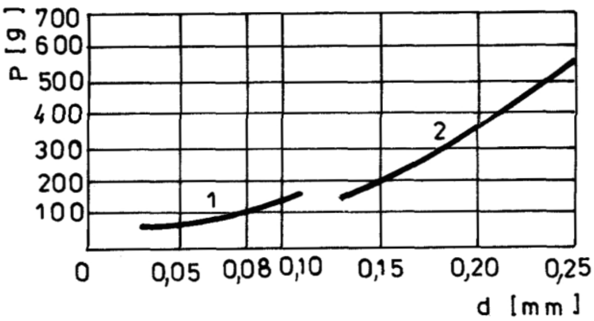

Fig.5. Tensile force P versus wire-electrode diameter d; 1 – hard copper, 2 – soft copper.

In order to obtain a better dimensional precision, it is recommended that the wire tensile force should be as high as possible. However, this parameter is limited by the wire mechanical strength.

The capacity of the discharge circuit is set according to diameter of the wire-electrode and to the material to be worked, and its rough guide values are shown in tab.3. These combinations yield a large capacity of material removal, corresponding to a certain roughness of the resulted surface. The attainment of a better roughness implies the decrease of the capacity, but also of the working efficiency. Thus, the optimal value of the capacity is set always by means of test cuts.

Tab.3. Capacity of the discharge circuit according to the wire diameter.

Material to be worked	Capacity of the discharge circuit *C* [nF]						
steel	2 - 6	6 - 10	10 - 25	25 - 50	75 - 100	100 - 120	120 - 130
metal carbides	-	-	-	30 - 40	45 - 60	70 - 90	-
Wire-electrode diameter *d* [mm]	0.05	0.08	0.10	0.15	0.20	0.25	0.30

The electrode rolling speed v_r is proportional to the thickness of the worked part, up to 20mm (fig.6)

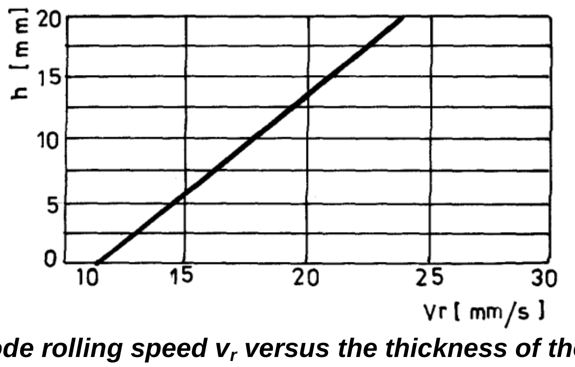

Fig.6. The electrode rolling speed v_r *versus the thickness of the worked part h.*

For thickness greater than 20 mm, the rolling speed is determined experimentally, by means of test cuts: on a test part is performed a test cut, with maximum rolling speed, and the diameter of the worn-out wire is measured; then the rolling speed is reduced until the diameter of the worn-out wire is 10% smaller than the initial value.

At lower rolling speed, the same wire portion is submitted to a larger number of discharges, so its wearing increases and its mechanical strength decreases considerably. Also, at very high rolling speed, the stability of the machining and the slot accuracy decrease.

For different materials, the choice of the rolling speed is made according to a diagram similar to the one that is presented in fig.7.

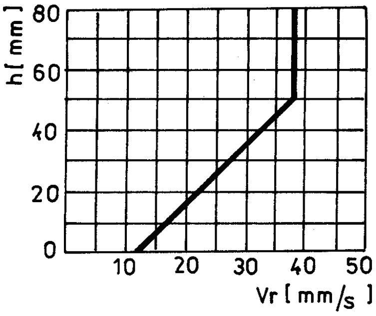

Fig.7. Choice of the rolling speed according to the material to be worked; copper wire-electrode, steel part-electrode.

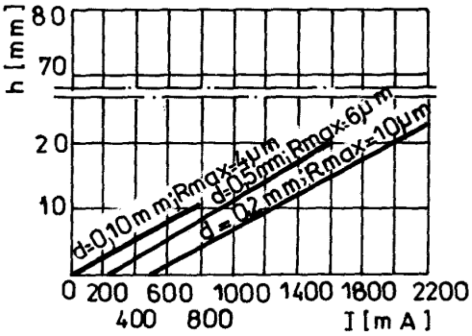

Fig.8. Choice of working current according to the material to be worked; copper wire-electrode, steel part-electrode.

The working voltage is constant and automatically maintained around a medium value of U = 200 V at the ROBOFIL machines. *The working current I* is set according to the thickness and material of the part and to the diameter of the wire-electrode, so that a certain roughness of the worked surface is obtained. The current determines directly the frequency of the discharges, so it influences the working efficiency. The increase of the working current is limited by the wired diameter, and its optimal values are set also by test cuts. When the part has variable thickness, then the current value for the medium thickness must be determined. If at the minimum thickness of the part the wire breaks, then the current knob must be backed with at least one unit. The values of the working current for various materials are chosen from diagrams as the ones shown in fig.8.

The cutting capacity is the surface cut on the part contour in time unit, according to the material to be worked:

$$V_s = \frac{S}{t_p}\left[\mathrm{mm}^2/\mathrm{min}\right] \qquad \textbf{(1)}$$

where V_S is the cutting capacity, S the cut surface on the part contour [mm^2] and t_p is the working time [min]. Some rough guide values are shown in fig.9.

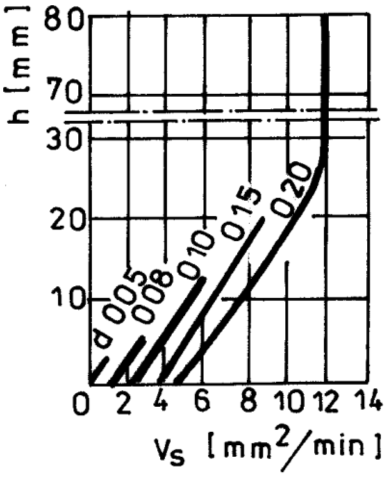

Fig.9. Cutting capacity according to the material to be worked; copper wire-electrode, steel part-electrode.

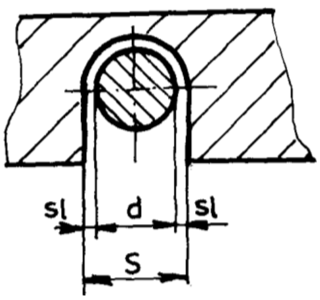

Fig.10. The cut width.

The cut width S is determined according to the wire-electrode diameter, and it is equal to this diameter plus twice the lateral interstice s_l (fig.10) $S = d + 2 \cdot s_l [\mathrm{mm}]$.

The working interstice is influenced directly by the electric conductibility of the dielectric (water), which is recommended to be of 12 ÷ 25 μS/cm in the case of steel and metal carbide working, and of 12 ÷ 20 μS/cm in the case of non-ferrous metals working (Cu, Al).

The worked surface of the part contour, cut by means of wire EDM, is clean and does not feature the usual signs of the chipping. The unsatisfactory aspect of the surfaces is caused by faults during machining, such as insufficient dielectric washing of the work zone, wire breaking, great wear of wire guiding rollers, wrong setting of the wire versus the work table, as well as the wrong setting of the electro-technological parameters.

The maximum roughness of the cut surface depends on: the capacity of the discharge circuit, the working current and the material of the part to be worked. Currently, roughness values of R_a = 1.6 - 3 μm are obtained by wire EDM. As other working characteristics, the surface roughness is set according to experimental diagrams, to part thickness and to the diameter of the wire-electrode. Such diagrams are shown in fig.11.

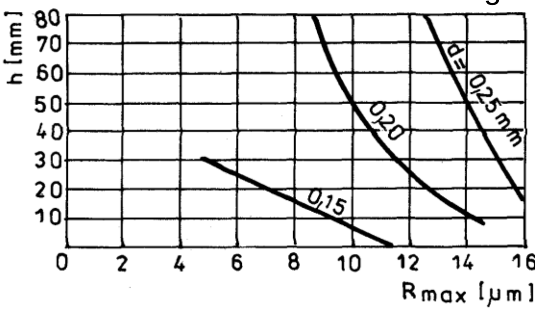

Fig.11. Roughness of worked surface; copper wire-electrode, steel part-electrode.

The correlation between values R_{max} and R_a (written on the execution drawing) is shown in tab.4:

Tab.4.

R_a [μm]	0.2	0.315	0.5	0.8	1.25	2	3.15
R_{max} [μm]	1 - 1.6	1.6 - 2.5	2.5 - 4	4 - 6.3	6.3 - 10	10 - 16	16 - 25

After all previous mentioned conditions are met, the program is realized and the execution of the part is launched, which can be made automatically or semi-automatically. Next are shown some lines of the program used for the part shown in fig.6, made on ROBOFIL500 machine.

```
%
O1111 (pxy_1.0)
N1 G77 P0
N2 G92 X0 Y0
N3 G90
N4 M15 P1
N5 G00 X55.7 Y-29.
N6 M00
N7 Z52.
N8 G11 W1 I25 K6 Z25 E2 P1
N9 G92 I-45. J45.
N10 S1
N11 G01 G42 G52 T2. D0 X55.7 Y-32.
N12 X23.8
N13 Y-37.
N14 X21.639 Y-38.507
N15 G03 X19.67 Y-41.314 I2.861 J-4.101
N16 G01 X17.611 Y-49.
N17 X5.8
N18 Y-17.
N19 X20.1
N20 X21.8 Y-13.
N21 Y-11.
N22 X23.8
N23 Y-26.
N24 X60.7
……………………………………..
N166 G11 W1 I25 K6 Z25 C1 P1
N167 S101
N168 G01 G42 D0 X47. Y-11.
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N169 G02 X47. Y-11. I5. J0.
N170 M00
N171 G00 G40 X52.
N172 G00 Z66.
N173 S102
N174 G01 G42 D0 X47. Y-11.
N175 G02 X47. Y-11. I5. J0.
N176 G00 G40 X52.
N177 G00 Z251.
N178 M30
%
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Fig.12 shows the finished die active part, after wire electrode EDM.

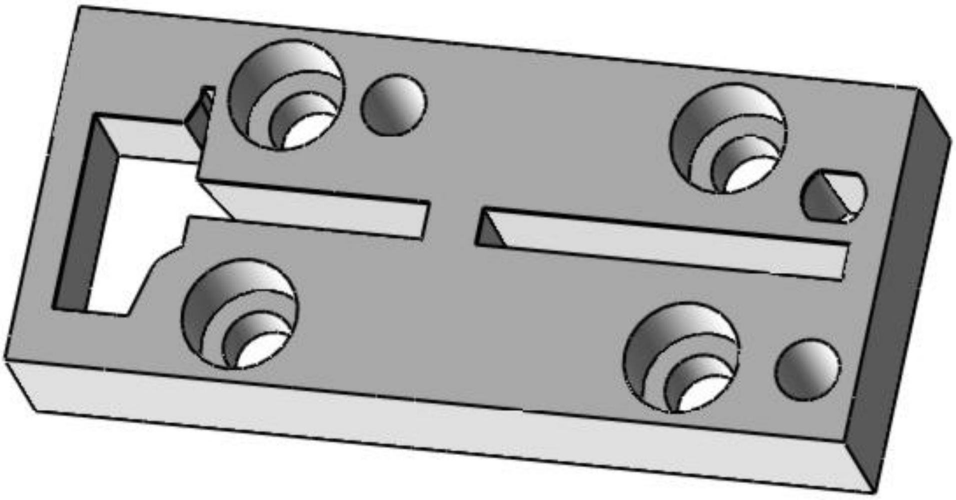

Fig.12. Finished die active part, after wire-electrode EDM.

4. CONCLUSIONS

The wire EDM of active plates of punches and molds is more and more used, due to its advantages concerning the working precision and the quality of the worked surfaces. The use of brass or wolfram wire with diameter under 0.1mm allows the attainment of both the active part and the die from the same plate, when this is allowed by the clearance mentioned in the project. One slight disadvantage of the wire-electrode EDM consists of the limitation to make only through holes.

Another advantage of wire EDM consists of the possibility of cone-shaped cuts in order to obtain cutting surfaces slightly cone-shaped instead of prismatic, in order to ensure the back rake angle for molds and for tools.

The appearance of CVD and PVD chipping tools makes it possible to turn and mill thermally treated steel up to HRC65 on CNC machines, and the finishing will be carried out by means of massive-electrode or wire-electrode EDM, according to the complexity of the active part to be made, which leads to significant increases in productivity and quality.

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