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INCREASING THE PERFORMANCE OF HIGH SPEED STEELS CUTTING TOOLS

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The performance of cutting tools is indissolubly linked to the metallurgical, design and manufacturing factors; it is influenced also by their exploiting regime. Among the metallurgical factors, those related to the material - chemical composition: carbides type, size, content and distribution, bulk phases composition (by heat treatment) and the composition of active superficial zones (by surface hardening processes) have particular importance and determine the performance level of cutting tools. The paper aimed at highlighting the increasing the performance of cutting tools (replaceable plates) executed from Rp3 (HS18-0-1) - (steel with ~ 18%W) and Rp5 (HS6-5-2) - (steel with ~ 6%W and 5%Mo) high speed steels by change of the carbides size and distribution and hardening of the active zones by thermochemical treatment.

Keywords: carbides size and distribution, replaceable plates, ion nitriding, processing by cutting

1. Introduction

The high speed tools are mainly used for cutting tools. Their performance during exploiting is determined by series of material factors (chemical composition), metallurgical processing conditions, design quality, manufacturing precision and also by exploiting regime.

Depending on the productivity assured during processing by cutting, the high speed steels are classified in two categories - normal and high productivity steels; those of normal productivity - Rp3 (HS18-0-1)- have a hot work stability up to 600°- 610^{o}C, being assigned to the processing of the metallic materials with hardness of about 260 - 280 HB and those of high productivity - Rp5 (HS6-5-2) - have a hot work stability up to 630°- 650^{o}C, being assigned to the processing of the metallic materials with hardness of about 280 - 320 HB.

To assure these levels of characteristics it is necessary to provide the most finer and uniform distribution of the primary ledeburitic carbides in a base matrix

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of tempered martensite containing low contents of residual austenite (below 5%) and secondary carbides.

Besides their high stability, the primary carbides are characterized by large sizes and rugged shapes which influence directly the cutting tools performance (Fig.1).

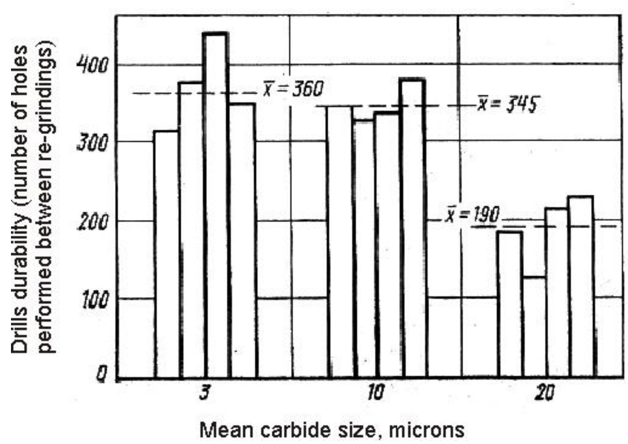


Fig. 1. The influence of mean primary carbides size on durability of cutting tools (drills) manufactured from Rp5 (HS6-5-2) steel [1]

The decreasing of the primary carbides sizes and ensuring their uniform distribution in the base matrix can be realized by hot plastic deformation, the forging with successive rotation of semi-product with +/-90° being the most suitable deformation variant which provides the most advanced refining and uniformizing level of the carbides repartition [2, 3].

Other particular variant of diminishing the non - uniformity of primary carbides distribution is the increasing of the crystallization rate of liquid steel [4]; thus, a significant decreasing of the size of the eutectic network takes place, or, in certain conditions, its occurrence is not possible and therefore the steel structure is close to that obtained in the steels processed by powders obtained by spraying of the liquid steel [4].

The advanced plastic deformation of semi - products which are in the optimal temperature range for the steels taken into analysis, up to the attaining high reduction ratio of area of initial section led to an important diminishing of the carbides sizes and distribution non-uniformity (Fig.2) and thus creates the premises of realizing of considerable increasing of the cutting tools durability by applying subsequent bulk heat treatments and superficial hardenings (in situ or extra situ).

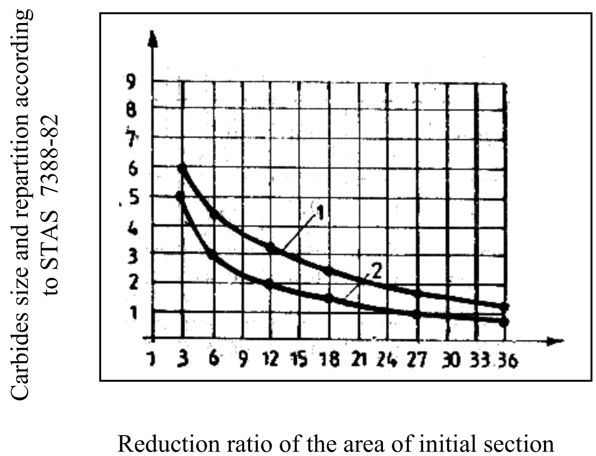


Fig. 2.The variation of the carbides sizes and repartition uniformity level (reference standard scales according to STAS 7382-88) depending on the reduction ratio of area of initial section, during forging with (curve 2) and without (curve 1) successive rotation of the initial semi-product of square section with +/-90°

2. Research methodology, equipment and materials

The cutting tools used in the research were replaceable plates of triangular shape (Fig.3), manufactured from Rp3 (HS18-0-1) and Rp5 (HS6-5-2) high speed steels; their chemical composition and the heat processing conditions are specified in the SR EN ISO 4957-02 standard. The replaceable plates were processed from bars with square section and advanced plastic deformation as to attain the highest possible reduction ratio of area of initial section; thus, levels of ~27 were achieved for this indicator, starting from a section of 100 x 100 mm and through permanent rotation of the semi-product with +/-90°.The purpose was to provide the most advanced refining level of the primary ledeburitic carbides and their most uniform distribution in the base matrix. Using the reference standard scales mentioned in the STAS 7382-88 standard with a view to appreciate the carbides sizes and repartition uniformity level, values of the 1-2 of these indicators have been realized.

As indicators of the performance level determined experimentally have been chosen the maximum admissible cutting speed, respectively the maximum cutting length.

To estimate the maximum admissible cutting speed, the frontal cylindrical turning of 18MnCr11 (16MnCr5) steel semi-products (chemical composition and heat processing conditions in accordance with EN 10084-2008- hot rolled and annealed bar with sizes of ϕ200mm x 500mm and average hardness of 198 HB) has been approached during experimental researches; by movement of the cutting tool from the peripheral area to the center of the bar, the change of the cutting speed in large range was possible.

The parameters of the cutting regimes used in the experimental researches were those related to the finishing turning with cutting speeds in the range of 60 ÷ 215m/min, advance on pass of 0.07 mm/rotation, cutting depth of 1.5 mm, running angle of 45^o, in regime without cooling.

The measurement of the effects of linear wear of the cutting tool (plate) active geometry has been performed by means of an optic microscope with magnification x10 (measurement accuracy of +/- 0.01mm), mounted on the lathe port-cutting tool sleigh. The measurement of the maximum possible cutting length (the length until the moment when the plate edge wear occurs) for different cutting speeds has been performed by cutting on sides of the same semi-product of 18MnCr11 (16MnCr5) steel in identical cutting conditions with those used during frontal cutting and with cutting speeds which have varied in the limits of 70 ÷ 140 m/min.

The cutting plates with triangular geometry (Fig.3) manufactured from the two steels and subsequently were heat treated according to the corresponding standards, were ion nitrided in a laboratory installation of 3KW, using an argon diluted ammonia atmosphere, at a total pressure of the gaseous mixture of 1.5torr.

The ion nitriding has been performed at different thermal (between 350° and 550^oC) and temporal (between 0.5 and 1.5 hours) parameters, the effects of the dimensional variation of the ion nitrided layer on the durability of the cutting plates manufactured from the two steels being observed.

The aspect of carbides distribution and morphology together with the structure, after the applying of the corresponding heat treatments and different ion nitridings has been highlighted by optical microscopy using a Neophot II type microscope.

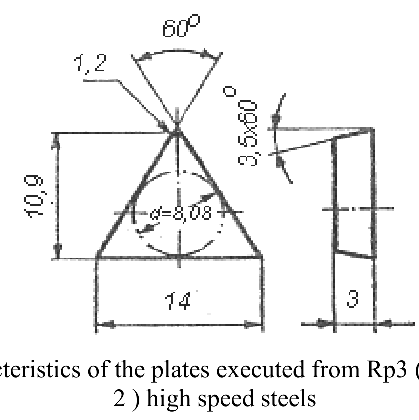


Fig. 3. The geometry characteristics of the plates executed from Rp3 (HS18-0-1) and Rp5 (HS6-5-2) high speed steels

3. The results of the experimental researches

The structure of samples at the end of processing cycle (Fig. 4) has revealed an appropriate repartition of the carbides in a matrix of tempered martensite and a relatively uniform ion nitrided layer without ε phase or nitrides in excess under network.

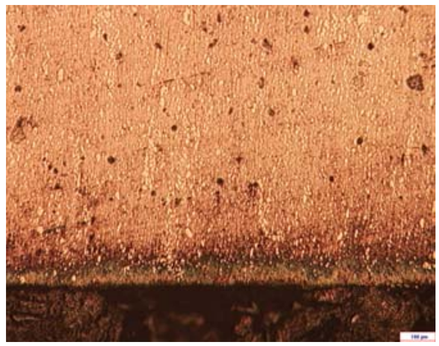
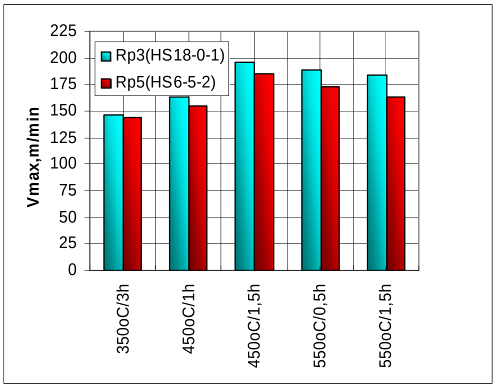


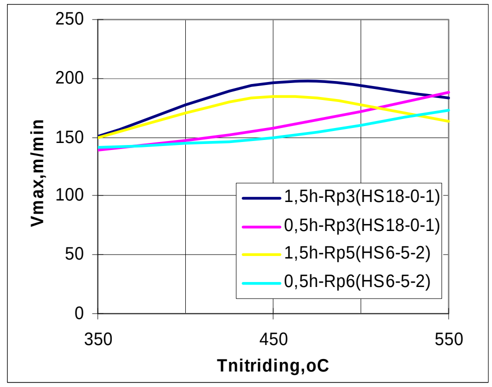
Fig. 4. The microstrucure of the ion nitrided layer and of neighboured zone. Rp3 (HS18-0-1) steel, after advanced plastic deformation, heat treatment (quenched and triple tempered) and ion nitriding (450^{o}C/1.5h; δ~150μm) Nital 5%

The analysis of the effects of this kind of carbides distribution and also of the presence of the nitrogen enriched layer on the maximum admissible cutting speed (Fig. 5 a, b) and on the maximum possible cutting length (Fig. 6) until the moment when the plate wear occurs - the two performance indicators taken into analysis - highlights the following:

- the combination of the two ensures an considerable increasing of the cutting tools performance during exploitation;
- the maximum effect on the performance level, taking into account the maximum admissible cutting speed, is assured by the tools which were nitrided at temperature lower than the tempering temperature of the steels taken into analysis (450^{o}C/1.5 hours);
- at lower nitriding time, the high levels of performance, taking into account the maximum admissible cutting speed, can be obtained even for higher nitriding temperatures (equal with the tempering temperature).

Note. The high microhardness of the nitrided layer is determined by the presence of tungsten, chromium and other nitrides and of $M_{23}(C,N)_6$; $M_3(C,N)$ type carbonitrides, its hardness being about 1300-1350 HV(in the core 62-65 HRC); the excessive increasing of the nitriding time can lead to the layer brittleness by occurrence of the ε phase or of the nitrides networks (the use of the high quenching temperature in the case of high speed steels and especially in the case of Rp3 (HS18-0-1) steel, amplifies the susceptibility of the appearance of the ε phase).





a) b)

Fig.5. Dependence of the maximum admissible cutting speed on the parameters of the ion nitriding regime and on type of high speed steel (a and b)

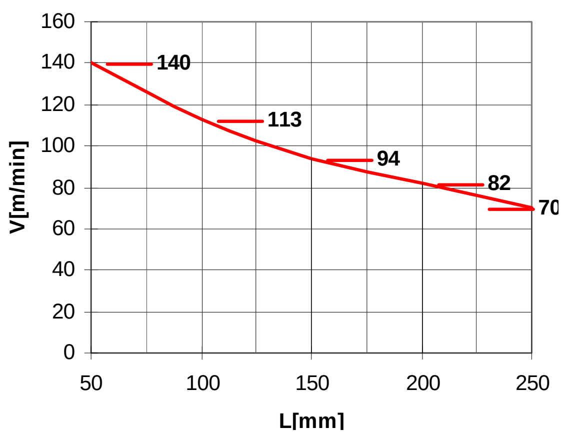


Fig.6. Dependence of the maximum admissible length on the cutting speed tool of Rp3 (HS18-0-1) steel

The wear phenomenon of the plates processed by advanced plastic deformation and thermochemical treatment takes place at cutting speeds which are much higher than those speeds at which the mono block knives executed from these steels are meant for working: 50 – 60 m/min in the case of Rp3 (HS18-0-1) steel.

Note: The increasing of the cutting speed (Fig. 6), in the case of a processing without cooling, is diminishing the maximum cutting length; the decreasing of the cutting length is intensified with the speed increasing.

The level of performance of the cutting tools is changing considerably, both by point of view of maximum admissible cutting speed and also of maximum cutting length if the cutting is realized with appropriate cooling in the media composed of, for example, 25% ricine oil + 13% soy oil + 17% mineral oil + 13% natrium hydroxide, of concentration 20% + 31% water, or exclusively mineral oil, vegetal oil, solutions of oleic acid and oil and lamp oil, etc.

In these situations, the maximum cutting speeds can attain values of about 250 m/min, in the case of plates executed from ion nitrided high speed steel with an appropriate carbides distribution in the base matrix.

In the absence of nitriding, but after advanced plastic deformation of the semi-products until obtaining of a carbides sizes and distribution in the limits 1-2 (according to reference standard scales included in the STAS 7382-88 standard), the performances of the cutting tools – replaceable plates, executed from the two high speed steels, is remaining high, but is ~1.5 times (50%) lower than that of nitrided tools and considerably higher than that of tools with a higher carbides sizes and distribution (in the limits 5 - 6 or upper of the same standard), this aspect determines a possible premature failure of the tools due to the brittleness of their active parts.

6. Conclusions

The providing smaller primary ledeburitic carbides sizes in the high alloyed steel (high speed steels) used for tools together with their uniform distribution in the base matrix of the semi-products, allows an increasing of the exploiting performance of the cutting tools; in the presence of the layers hardened by nitriding the microhardness is significantly increased and implicitly the wear resistance.

The highest cutting speeds have been realized by cutting tools which were ion nitrided at 450^{o}C/1.5h; cutting speeds of about 200m/min were attained (the cutting parameters were those corresponding to the finishing processing) in the case of cutting without cooling and this performance can be higher in the presence of an appropriate cooling.

The literature information taken into analysis through comparison with those resulted from the own researches, led to the conclusion that the manufacturing of the cutting tools from powders with ***particles sizes below 40µm,*** should allow a finer and uniform repartition of the carbides in bulk in the semi-products even up to higher diameters of these (100-200 mm) with keeping of the most finer and uniform carbides distribution.

The advantages of using of the powder metallurgy for execution of the semi - products of high alloy tool steels are numerous (besides those mentioned previously) such as: higher resistance and toughness (with 30-50% for smaller sections and higher for higher sections), hot stability (with minimum 5°C higher) and final hardness with 0.5-1 HRC higher (due to a more uniform saturation of the solid solution, absence of the anisotropy of deformations after quenching.

The application of superficial hardening processes at the end piece (any of these) can improve considerable the level of performance of the tools as compared to the performance of tools which were not hardened and with that of tools obtained through conventional methods.

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