# NEW TOOL STEELS PRODUCED FROM POWDERS

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## NOVÉ RÝCHLOREZNÉ OCELE VYROBENÉ Z PRÁŠKOV

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**Abstrakt**

Článok pojednáva o nových rýchlorezných oceliach, vyrobených cestou práškovej metalurgie. Východiskové, chemicky modifikované práškové rýchlorezné ocele typu STN 19830 (M2), boli vyrobené rozprašovaním dusíkom do dusíka v podmienkach rýchlej solidifikácie a zhutnené jednak pretlačným lisovaním za tepla a jednak izostatickým lisovaním za tepla. Zhutnené vzorky boli tepelne spracované.

Analyzovali sme rýchlosť ochladzovania, mikroštruktúru a fázové zloženie východiskových práškov, ako aj mikroštruktúru a základné vlastnosti zhutnených polotovarov.

Zistili sme, že mikroštruktúra nových PM rýchlorezných ocelí bola homogénna, izotrópna, jemnozrnná a priemerná veľkosť karbidov činila 0,5μm. Výmenné rezné doštičky, vyrobené z najlepších novovyvinutých rýchlorezných ocelí, vykázali pri krátkodobej skúške rezivosti viac ako 2-krát vyššiu životnosť v porovnaní so zodpovedajúcimi rýchloreznými oceľami, vyrobenými tavnou metalurgiou.

Novovyvinuté PM rýchlorezné ocele sú vhodné na výrobu rôznych nástrojov, a to najmä pre také aplikácie, kde sa vyžaduje vysoká húževnatosť. Okrem toho, tieto materiály sa môžu využiť aj na výrobu špeciálnych súčiastok a ložísk.

**Abstract**

This article is devoted to the new high speed steels prepared by powder technology. The starting, chemically modified high speed steel powders of the M2 (STN 19830) grade, were produced by atomization with nitrogen into nitrogen under rapid solidification conditions, then consolidated by powder hot extrusion or powder hot isostatic pressing, and finally thermally treated.

We have analyzed the cooling rate, microstructure and phase composition of started powders, as well the microstructure and basic properties of consolidated semiproducts. We have found that the microstructure of the new PM high speed steels was homogenous, isotropic, fine grained, and the average carbides diameter was 0,5μm. The cutting inserts made from the best of new developed high speed steels have shown more then twice higher cutting edge life when comparing with corresponding high speed steel prepared by melt metallurgy.

## 1. Introduction

Powder metallurgy (PM) plays an important role in the development of new metalic materials particularly due to the fact that it is capable of producing metallic materials, with a high variability of chemical composition and offers a whole range of production techniques. Economically advantageous methods can be used to produce materials with an unconventional microstructure and excellent properties and mainly those with such a combination of service properties that cannot be achieved by melt metallurgy (MM). Important savings of raw materials and energy can be achieved practically without any unfavourable influence on the environment and humans health.

Technologies of PM are well suited to the production of tool materials, namely high speed steels (HSS). With regard to considerable segregation in the process of production of tool steels by MM, only inhomogeneous coarse-grained microstructure with non-uniform distribution of relatively coarse carbides can be obtained. After hot forming, the carbidic particles concentrate in bands and networks, which results in considerable anisotropy of properties. Very high reduction, even as high as 94%, is needed to achieve fine and uniform distribution of carbides. Moreover, the utilization of materials is only about 50%. The main advantages offered by PM in comparison with MM when producing tool materials are:

- better mechanical properties and service characteristics resulting from high chemical and structural homogeneity, finer grains, high dispersity and higher quantity of carbides and their uniform distribution,
- better utilization of material.

Microstructures of a high speed steel produced via melt metallurgy and via powder metallurgy are compared on Fig.1. The following tools or parts can be manufactured economically from PM HSS :

- cutting tools ( cutters, cutting inserts, drills),
- shaping tools for hot and cold forming (dies, pressing and forging punches, tools for glass industry and for plastic materials forming),
- wear resistant structural materials (valve seat inserts and valve rocker arm tips for automobile engines, aircraft engines bearings).

a) b) Fig.1

Comparison of the microstructure of a high speed steel produced by melt metallurgy (a) and powder metallurgy (b)

## 2. Experimental

For our experiments we used with addition of niobium, or titanium, or cobalt modified high speed steel powders of the M2 grade (STN 19830). High speed steel powders were produced by atomization with nitrogen into nitrogen under conditions of rapid solidification. This technology enables one to produce HSS powders with a considerably higher content of alloying additions than is the case of MM by which, due to sever marked segregation, the possibilities of further increase of the content of alloying additions are practically exhausted. Owing to the fact that the segregation in PM HSS is only limited to the volume of individual particles of the HSS starting powders, we can achieve, even in the case of highly alloyed PM materials, an isotropic, fine-grained microstructure with uniform distribution of very fine carbides and in this way also substantially better service properties.

The starting HSS powders were subjected to microstructural analysis and their basic physical - technological properties were determined. The starting powders were compacted using progressive PM technologies, powder hot extrusion and powder hot isostatic pressing (HIP) in evacuated steel containers. From the compacted semiproducts we prepared cutting inserts for short-term cutting tests. These tests we have performed in accordance with the standard ISO 3685; at the same time we measured the critical wear at the tool flank $VB_{krit}$= 0,8mm. Machining was done on a SUI 50 lathe. The cutting conditions were as follows: Cutting speed *v* = 50 $m.min^{-1}$, feed *f* = 0.210$mm.rev^{-1}$, cutting depth *t* = 1 mm. Standard material STN 12050.1 was used for machining in accordance with the above mentioned standard.

## 3. Results and discussion

The particles of the starting HSS powders were predominantly spherical and the microstructures of differently alloyed HSS powders showed no significant differences. Using X-ray diffractography we found that the microstructure was composed of difficult to etch martensite, austenite and primary carbides. By the evaluation of the dependence of integral reflection intensities of $\alpha$ and phases (in the form I /I +I$\alpha$ ) on the particle size it has been found that, with decreasing particle size, hence with increasing cooling rate, the proportion of $\alpha$ phase significantly increased. The content of $\alpha$ phase is the sum of martensite content and content of $\delta$-ferrite, that was kept due to the modification of the crystallization mechanism, particularly incomplete course of peritectic reaction. The addition of the alloying elements resulted in an increase of untransformed austenite content. The greatest influence of niobium has been demonstrated [3]. The cooling rates of individual particles were determined by the measurement of distances between second dendrite arms [4]. The dependences of cooling rate on the particle size for various PM HSS are shown in Figure 2.

For the powder hot extrusion or powder hot isostatic pressing, chemically modified HSS powders with various content of microcrystalline powders were used. The microstructure of consolidated PM HSS before and after heat treatment was homogeneous, formed by martensite, austenite and very fine uniformly distributed carbides, see Figure 3. The carbides were of an average mean size cca 0.5 μm, with the largest not exceeding 2μm. This is a substantial difference, in comparison with HSS produced via MM.

The applicability of a compacting method depends mainly on the shape, size and series size of the respective product. An unambiguous advantage of PM extrusion consists in combining the process of compacting with the process of deformation as a result of which, already after the compacting, i.e. in the state without thermal treatment, we can obtain materials with high service properties.

Fig.2 Dependence of cooling rate on particle size for various HSS powders

Fig.3 Microstructure PM - Nb HSS after HIP-ing and thermal treatment

The via HIP consolidated samples, were subjected to cutting life tests. The evaluation of the tests, carried out on the new PM HSS, revealed that the cutting life of cutting inserts produced from unconventional HSS powders, obtained by atomization of chemically modified melts, was excellent. We found that niobium-modified PM HSS exhibited an optimum microstructure and properties. The service life of the best newly developed materials, determined at short-term tests, was at least two-times higher than the service life of corresponding HSS produced by melt metallurgy, see Figure 4. An additional increase in cutting life can be reached by modification of surface properties, namely via PVD or laser treatment.

Fig.4 Cutting life of tools made from PM HSS in comparison with HSS, produced by MM

On the basis of results obtained we can assume that the use of these materials appears realistic, mainly in those applications where, along with long cutting life, a sufficient toughness of the materials is also required. Analysis of relevant regularities will be the subject of an additional investigation.

## 4. Conclusion

New high speed steels, modified with addition of Nb, or Ti, or Co, having an optimalized granulometry, have been developed by using powder metallurgy techniques. The starting high speed steel powders were produced by atomization and consolidated by powder hot extrusion or powder hot isostatic pressing.

By the investigation of the influence of additional alloying on the microstructure and properties of newly developed high speed steel powders and consolidated products, the following has been found:

a) The particles of chemically modified high speed steel powders cooled during atomization more rapidly than the particles of referenced powder high speed steel. Due to the higher cooling rate these materials contained a higher portion of untransformed δ-ferrite and residual austenite.

b) The microstructure of high speed steels produced by powder metallurgy was homogeneous, and the very fine carbides were distributed uniformly.

c) New materials have shown substantially better cutting edge life than corresponding materials produced by melt metallurgy. The cutting life of the best of these materials was more then twice higher when comparing with referenced high speed steel produced via melt metallurgy.

d) New developed PM high speed steels are suitable for those applications, where along with long cutting life a sufficient toughness is required.

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## Literature

[1] Martinez V. and all.: Metal Powder Report, 44, (1989), 11, p.751

[2] Froes F.H. : The International Journal of Powder Metallurgy, 24, (1988), 3, p.279

[3] Miškovičová M.: New Materials Produced via Powder Metallurgy. In.: Proceedings from Int. Conf. East-West 1993, High Tatras, Slovakia. Publisher: Slovak Metallurgical Association, Košice, 1993, p.157

[4] Takigawa H. and all.: Powder Metallurgy, 23, (1981), 4, p.196