PERFORMANCE MATERIALS USED IN THE MANUFACTURE OF CUTTING TOOLS

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Abstract *A technological system consists of four components (subsystems): machine tool, cutting tool, working piece and device. From the point of view of the technological system, are evident two concept: cutting tools capacity by efficient choice of their material and machine ability by cutting of the working piece. Efficient choice of the materials for manufacturing of cutting tools, is the most important link of any technological process. Their physical, mechanical and technological special they are to be used. cutting processing of all metallic and nonmetallic materials with superior cutting parameters*
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1. PRELIMINARY CONSIDERATIONS

Materials used for manufacturing of cutting tools must comply a series of conditions, out of which, most important are:

- high hardness, higher than that of the working material but being not brittle;
- to maintain the hardness at the corresponding cutting temperature, which means stability at high temperatures;
- strength to the efforts developed during cutting process;
- to be friction resistant
- reduced galling

It is recommended that the hardness of the tool's material to be at least two times more than that of the working material..

Materials complying with the above conditions might be grouped in three main categories:

a) steel materials,

b) strong materials,

c) extra-strong materials category includes :

- carbon steels and steel alloys category
- mixtures of metallic carbides and mineral-ceramic materials.

Category c includes diamond and cubic boron nitrate likeness mono or polycristals. A different category of materials, placed to the limit between strong and extra-strong materials is that of abrasive materials.

2. MATERIALS USED FOR MANUFACTURE OF CUTTING TOOLS

Metallic materials classification takes into consideration the followings: chemical composition, structure, manner of acquiring of materials, utilization range, and some others.

In industrial practice only rare are used pure metals, but are on large scale used, alloys of those metals having superior properties. So, metallic materials, are divided in two large categories: ferrous and nonferrous; ferrous materials are divided into cast irons and steels: these last ones are often used for manufacturing of cutting tools.

2.1. Steel materials . Carbon steels for tools.

These materials can be hardened only in a reduced measure and are recommended for tools with small areas and slow transitions; having high hardness they are recommended to be used for processing materials with medium cutting speeds, i.e. max. 20m/min. and developed temperatures during cutting process not to surpass 200 – 250 ^{0}C.

These steels have carbon content between 0.6 and 1.4 % and a reduced capability of hardening (having a hardening depth of 3 to 8 mm); therefore, the tools manufactured from these steels are hardening in water, with high cooling speed; this produces cracks and deformations of the tools with abrupt transitions from a cross section to the other. Therefore, the tools liable to shocks and vibrations and requiring a high tenacity are to be manufactured from carbon steel with reduced content of carbon (between 0.6 and 0.7 %) and those working without shocks are recommend steels with higher carbon content (between 0.8 and 1.4 %).

From the workability point of view, we can conclude that the carbon steel for tools are well sectile with tools of steel or metallic carbides, instead they are hard to be worked by grinding and therefore these steels are not recommended for manufacturing of profile tools or finishing tools (toothing tools, thread cutting tools, a.s.o.).

Alloy steels, additional to the high carbon content (0.8 – 1.7 %) comprise secondary ingredients like wolfram, vanadium, molybdenum, chromium,silicon and manganese. Due to these secondary ingredients, these alloy steels have a higher hardening capability and wear resistance than the carbon steels.

Low-alloy steel used for manufacturing some cutting tools, allows machining with a cutting speed of 30 - 35 m/min at which the cutting temperature not exceed 350^{0}C

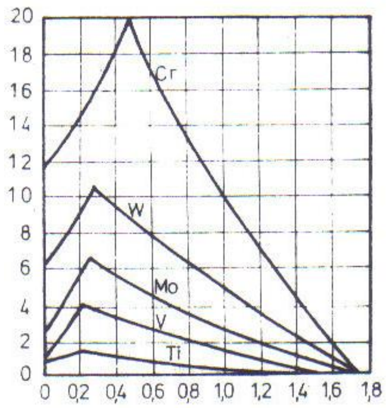
High-alloyed steels

These have a higher content of secondary ingredients giving high resistance to the steels at higher temperatures than the other steels. These materials having resistance

to heat up to 600 – 650 *C, allow a cutting speed of 2 – 3 times over that allowed by carbon tool steel.
Owing to high cutting speeds (60 – 75 m/min) of the tools of high-speed steel, comparable with those of high-alloyed steel tools, the high-speed steels are included in this category.
High-speed tool steel; depending of admissible brittleness (tenacity), distinguishes: high-speed steels for high working speeds, and high-speed steels for low working speeds. So, at high working speeds, appearing vibrations, are recommended high-speed steels with a higher tenacity (with low carbon content). In this case, tool's hardness and durability are assured by an increased content of wolfram.

- Tungsten steels containing 9 -18 % Wolfram have a good workability with cutting tools as well as grinding.
- Steel RP3 containing an average of 18% W is used for manufacturing tools with grounded profile for processing by finishing, embossing and others, like: profile cutter, threading tap, teeth cutters, profiled knifes and others.
- Steel Rp4 has a Wolfram average content of 9 % and as high Vanadium content as 2 – 2.6 %. Workability of this steel is lower (mainly by grinding) than that of steel Rp3 and that's why is less used for manufacturing of the tools necessitating grinding works. Generally it is used for drilling tools, enlarging bit, countersink bit, saw segments, cut tooth milling cutter, and others.
- High-speed steels alloyed with cobalt and wolfram are used for manufacturing tools of high productivity; this category includes steel Rp2 with 18% W and 5% Co and steel BK100with 18% W and 10% Co.
- Steels alloyed with Vanadium to an average of 2 – 6 % V as Rp1, Rp6, Rp7 having in composition also 9 – 12 % Wolfram. These steel have a good wear resistance, but a lower heat stability than those alloyed with cobalt; also these have a lower workability by grinding, being used for manufacture of light tools.

In most cases, the steels contain two ore more addition agents; these may have similar or perverse effects. Solubility of addition agents is influenced by allotropic state of the iron and also by the carbon content.
From Fig 1 results that in the austenite with less carbon, stability of addition agents increases and decreases once with increasing of carbon content in austenite.
These are produced by agglutination of a mixture of metallic carbides of wolfram, titanium, tantalum, niobium and others in a metallic binder such as cobalt (less used nickel); resulted material is delivered as small plates, used (in a removable or irremovable joining) for tools' outfitting.
After some experimental researches, was found that in case of small tools, the whole cutting tool may be manufactured by sintering this mixture. So, hardness characteristics (over 85 HRA), heat resistance and stability (over 900 *C) are superior of those of the other materials used for tools. The mixtures of metallic carbides are worked out beyond different recipe named according to the producer country or plant: Widia, Walter, Krupp, Harthn (Germany), Diadur (Czech), Durexit (Hungary), Fagesta, Coromat (Sweden), Carboloy, (USA) and others.



Carbon content [%]

Fig.1 Solubility of addition agents is influenced by the carbon content

2.2. Hard materials. Mixtures of metallic carbides

Particular physical properties of these materials make them to be used for machining by cutting of all metallic and nonmetallic materials with very big cutting speeds producing heavy cuts.
Also, unlike of other materials used for cutting tools manufacturing, these being nonferrous, need not heat treatments, cannot be forged and can be worked only by abrasion.
Considering the content of mixture of metallic carbides, these materials are divided in two main groups:

- mixtures containing wolfram and titan carbides sintered in cobalt binder, as are the Romanian ones symbolized by **P** and **M**, the Russian ones by **TK** Czech ones by **S.**
- mixtures containing wolfram carbides sintered in cobalt binder, as are the the Romanian ones symbolized by **K** Russians ones by **B** and some others.

Up-to-date, as result of some researches, are produced small plates made of metallic carbides covered by a high wear resistant lay (titanium carbide or titanium nitrite) or with a double lay (titanium carbide with aluminum overlay, or wolfram carbide and diamond overlay).

Mineral ceramic materials

These are obtained from pure oxide aluminum (Al^2O^3) or mixed with some metallic carbides (titanium carbide)). Are delivered as sintered small plates for outfitting working side of cutting tools.
Also, are characterized by a very high wear resistance, by a enough heat resistance (up to 1100 ^{0}C) and by a high hardness (90 – 92 HRA). These advanced characteristics led to their use for machining with cutting speed of 3 to 10 times over of those manufactured from high-speed steels being between 200 and 600 m/min;

In exchange, they have a big brittleness, their use being limited for finish machining only, without shocks.
*Hard mineral ceramic materials are produced in different countries under different names: T48, TM332 (Russia), Ceroc (French), Widalox (Germany), EBC (Romania) and so on. Small mineralo-ceramice plates are produced on two ways:

-sintered aluminum oxide

-sintered aluminum oxide mixed with other materials or metals; this material is named “cermets”

Cutting tools outfitted with mineral ceramic small sheets are used for machining of the parts made of cast iron, plastic materials; also may be used for machining light alloys – table 1.
*Although ceramic materials (manufactured by aluminium oxide) are well known in the field, cutting tools provided with mineral ceramic (sintered oxides) small sheets, met a fast development in the last years.

Ceramics used for accomplishment of active part of cutting tools have superior properties than metallic carbides, and therefore their use in processing operations by cutting is often met.
*Following of some laboratory tests, was found that carboxide ceramic materials (mixture of Al_2O_3 and TiC) or mixed ceramics have the highest hardness and therefore allow high quality processing of some heat treated steels with up to 64 HRC hardness, while ceramics based on the oxides, silicon nitrides are limited to processing of steels and cast irons with hardness bellow 38 HRC.
*Presently, is frequently met a big variety of assortments of small sheets of Al^2O^3 combined with titanium carbides, with titanium nitrides and carbonitrides as well as combination with Si^3N^4 and SiC (Wiskers) as filiform monocristals.

Table 1. Utilisation of mineral ceramic materials

Nr	Tool material and operation	Working material	Advance (mm/rev)	Cutting speed roughing [m/min]	Cutting speed finishing [m/min]	Angle settlement $\alpha[^0]$	Rake angle $\gamma[^0]$
1	-aluminium oxide -turning	-structural steel -silvery pig iron -bronze -hard.plastic	0,05-0,4 0,08-0,8 0,05-0,2 0,1-0,5	550-200 450-260 _ _	700-200 700-450 400-600 200-400	3.........8 5.........6 5.........8 5.........8	-3........12 -5..........0 0............1 0............4
2	-cermets -turning	-structural steel -chilled iron	0,05-0,4 0,08-0,6	100-30 250-50	100-30 350-50	5.........6 5.........6	-5..........0 -5
3	-cermets -milling	-steel and iron steel	0,25	_	190-200	5.........6	-6

2.3. Super hard materials

*** Diamond** is used for cutting tools manufacturing under monocristals form as well as powder form concealed in a binder mass (whetstone); is used in natural state as well as synthetic.
Synthetic diamond is obtained from pure graphite (min 99.8 %) at a pressure of $0,7.10^5...1,10^5$ daN/cm^2 and at temperature of 3000 ^{0}C; this has a intershot colour of grey and light green. After some laborious researches, was found that may be used for machining of very fine surfaces, assuring a high processing accuracy, at a high efficiency; having a high brittleness, is used in well defined conditions.
A characteristic of the tools wit concealed diamond powder is determined concentration of diamond content in the unit volume of the tool; is considered 100 concentration for a content of 4.4 karat per one cubic centimetre of abrasive tool.
*** Boron cubic nitride (NCB)** is a nitric acid salt crystallized in cubic system, following a heat treatment and high pressure (3500 ^{0}K and 10^5 daN/cm2).
Commercially is known as BORAZON (UAS) or ELBOR and CUBONIT (Russia). Obtaining process of NCB from boron nitride crystallized in hexagonal system is similar to that of synthetic diamond .
This material is used for manufacturing of abrasive tools.
NCB crystals with the size between 15 and 600 microns are delivered under simple metalled form or concealed by two or three crystals in a hard binder as resins, metallic carbides, glass a.s.o.
* **Diamond polycristals or of NCB.** Diamond or NCB use, in the monocristals
form, due to small dimensions is limited; it is economic with minor exceptions, for manufacturing abrasive tools only.
Polycristals on diamond base use natural or artificial diamond as granules of 0.1 to 0.02 mm. form either sintered in a metallic binder mass (Cobalt) or sintered as a lay of 0.5 – 0. 7 mm on a support of mixtures of metallic carbides as well as sintered under pills form. Sintering is produced at pressures of around $7x10^3$ daN/cm^2 and range temperatures 2000 – 2300 ^{0}C.
Polycristals of NCB are based on cubic crystals of Boron nitrite and are realised by industrially sinterise of hexagonal Boron nitrate using various metallic catalyser. Sintering conditions are similar of those based on diamond; to these materials’ category belongs:

Compacts, Hexanit-R, Ismit and PTNB. These are delivered as cylindrical or prismatic pills with base sizes of 3.5 – 5 mm. and 3 – 6 mm height . Properties of some polycristals types are shown in table 2.

Table 2. Polycristals properties

Nr. crt.	Trade mark	Density [g/cm^3]	hardness[HV] [dan/mm^2]	Strength in compression [daN/mm^2]	Thermal stability in air [^{0}C]
1	ASPK-Carbonado (diamant)	3,5 - 4	8.000 - 10.000	20 - 40	700 - 900
2	ASB-Balas (diamant)	3,5 - 4	8.000 - 10.000	40 - 80	700 - 800
3	Elbor – R (NCB)	3,4	8.000 – 10.000	150- 200	1.400 – 1.500

Analysing dates contained in Table 2, we can notice the hardness very close to that of diamond; also, an important characteristic of these materials, is their anisotropy due to homogenous granulated structure,
random oriented – without main directions; this fact offers wear resistance and tenacity.

3. TECHNOLOGY OF FOUR PIECES OF METALLIC POWDERS.

Thummler researcher Fritz sintering defined as a process of training and strengthening links between particle mass transfer print a heat activated, this leads to increased contact between particles, porosity change and pore geometry, as well as lowering the free energy
This process includes several steps that ensure the composition and structure directing various structural forms of metal powders and consequently, their properties .. Well, like powder metallurgy parts can be obtained from alloys of immiscible metals, liquid, using mixture dust or alloy.

Metal powders properties

Their properties so those physical, chemical, mechanical and technological properties determine obtained products from tissue powders.
The physical properties of powders consist of: the form of granules, their size and distribution of grain (grain loss characteristics grow with sintering;
the more grains are finer, the more they get better physical and mechanical properties, grain structure, surface quality and grain size.
This latter property depends on the process of getting the powder, the powder specific surface, expressed in [g/cm3] is even higher as the powder is fine.

Chemical properties directly influence the properties of parts from powders. Together with the grain chemical composition determine both the mechanical properties and the future of technological dust
Also, during the formation of dust is easing a high oxygen content in the form of oxides, which requires passage of powder through a thermal annealing in highly reducing atmosphere

Mechanical properties

Which depend on technological properties, are quite important, so that gives property distinguishes grain
Micro hardness, this, adverse influences compact ability powder compaction mold and durability.
Microhardness pote be reduced by a strong annealed in reducing atmosphere, thus eliminating the oxides formed on the surface granules
Blank form stability, strength characterized by its compactness and allow manipulation of the blank, in the technological process.
Irregularly shaped granules which have, or are porous, leading to higher raw-resistant
These types of chips are used mainly for parts di particulate compacted at lower pressures, , such as porous pieces are characterized by self-lubricating processing tools.

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