EVALUATION OF SINTERED CARBIDES WEAR RESISTANCE

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Abstract. The paper contains the laboratory test results of selected metal materials abrasive wear resistance using the apparatus with abrasive cloth. The wear rate comparison of cast iron, selected steel types, selected overlay types and sintered carbides have been the aim of carried out tests. The results show that the wear values of overlays and especially of sintered carbides are expressively lower than these ones of cast iron or constructional steels. Therefore they can be considered for perspective materials for the use for agricultural machines active parts.

Key words: wear, wear intensity, laboratory tests, pin-on-disk machine, sintered carbides.

Introduction

The often cause of agricultural machine parts premature outage is their excessive wear. Namely it concerns parts which come in contact with soil, which hard particles evoke the intensive wear of their surfaces. For the present and especially in the future exacting task expects designers of modern and always more heavy-duty machines – to lower the wear and in this way to extend the service life of these parts. It is possible to do it using several ways, e.g. by change of used material (and by its suitable heat treatment), by more suitable design (and in this way to decrease the surface stress), by use of overlay on functional surfaces etc [7]. Lately agricultural tools appear, where sintered carbides are used in the most stressed points [4]. For many years tools with sintered carbides are known and successfully used in mining and building industry [6, 8 – 13]. Fig. 1 shows several types of such tools.

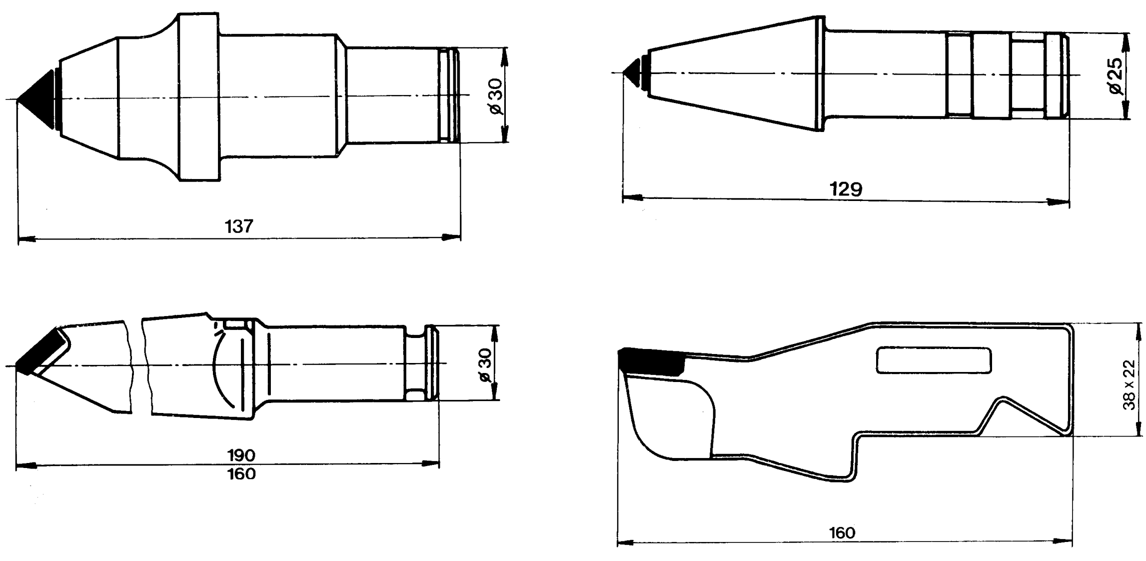

Fig. 1. **Tools used in mining and building industry**

Sintered carbides are manufactured by a special method, so-called powder metallurgy, in several stages. The first is powder production. Then pressing of compacts, sintering and semi-product treatment follow. The resultant properties are affected not only by size and form of powder grains, their homogeneity, impurities content etc., but by chemical composition of the concrete carbide, too.

The name "sintered carbides" is the name of the whole material class, analogously as "cast irons", "steels" or "plastics". The basis of all types of sintered carbides is tungsten carbide (WC), which is bound by a metal binder, most often by cobalt (Co). From the chemical composition standpoint the more complex types can contain next carbides, e.g. titanium carbide (TiC), tantalum carbide (TaC), niobium carbide (NbC), chromium carbide (Cr_2C_2), molybdenum carbide (Mo_2C) or so-called mixed carbides, e.g. tantalum-niobium carbide (Ta,Nb)C, titanium-tungsten carbide (Ti,W)C etc. Detailed classification and recommended application fields of single types can be found in standards or in literature.

With respect to the above hinted course of manufacture and used raw materials it is evident that sintered carbides and from them made products are very expensive. E.g. exchangeable inserts for turning or milling from sintered carbides can be today bought in Czech Republic for the price from 3 to 12 Euro. Test samples of 10 mm diameter and 70 mm length were bought for 33.5 Euro each.

Materials and methods

The aim of experiments published in this paper was to compare the wear resistance of selected materials. One type of cast iron, three types of steels, three types of overlays and three types of sintered carbides were tested. Detailed information is presented in Table 1.

Table 1

Overview of tested materials

Material	Specification of tested samples
Cast iron	Cast iron according to CSN 42 2415 (corresponds e.g. to GJL-100 according to EN 1561, SČ 10 according to GOST 1412-85 or Class 20B according to ASTM A48), chemical composition: 3.93 % C, 0.38 % Mn, 3.74 % Si; microstructure: ferritic-pearlitic matrix, laminated pearlite, flake graphite distributed evenly, sporadically mixed
Steel (etalon)	Steel 12 014 according to CSN 41 2014 (corresponds e.g. to 10880 according to GOST 3836-83 or ELFE 100 according to MSZ 8628), chemical composition: 0.009 % c, 0.27 % Mn, 0.002 % Si, 0.066 % Al, 0.009 % P, 0.010 % S; microstructure: ferrite
Steel 1	Steel 15 230 according to CSN 41 5230 (corresponds e.g. to C 4738 according to JUS C.B9.021-89), chemical composition: 0.30 % C, 0.58 % Mn, 0.18 % Si, 2.31 % Cr, 0.13 % V, 0.015 % P, 0/017 % S; heat treated, microstructure: weakly heterogeneous sorbite
Steel 2	Steel 15 142 according to CSN 41 5142 (corresponds e.g. to 42CrMo4 according to EN 10083-1, TYPE 3 according to ISO or 38ChM according to GOST 4543-71), chemical composition: 0.41 % C, 0.71 % Mn, 0.28 % Si, 0.94 % Cr, 0.18 % Ni, 0.20 % Mo, 0.019 % P, 0.012 % S; heat treated, microstructure: heterogeneous sorbite
Steel 3	Steel 15 341 according to CSN 41 5341 (corresponds e.g. to 42CrMo4 according to DIN 1654, 4142 according to ASTM A 752 or SMC 4 according to JIS G4105-73), chemical composition: 0.38 % c, 1.30 % Mn, 0,25 % Si, 0.97 % Cr, 0.21 % Mo, 0.17 % V, 0.04 % P, 0.04 % S; hardened, microstructure: martensite
Overlay 1	Chemical composition: 0.14 % C, 1.6 % Mn, 0.7 % Si, 0.5 % Cr, 0.25 % Ni, 0.25 % Mo, 0.025 % P, 0.01 % S; microstructure: martensite
Overlay 2	Chemical composition: 2.51 % C, 0.25 % Mn, 1.76 % Si, 9.12 % Cr, 0.031 % Mo, 3.48 % V, 0.007 % P, 0.003 % S; microstructure: fine needlelike martensite with Cr, V and Ti carbides
Overlay 3	Chemical composition: 3.45 % C, 0.14 % Mn, 1.94 % Si, 18.45 % Cr, 0.11 % Ni, 4.42 % Mo, 1.34 % V, 0.013 % P, 0.006 % S; microstructure: fine martensite, Cr, Ti, Mo, Nb and V carbides
Sintered carbide 1	Type P 20, chemical composition: 75.5 % WC + 14 % TiC + 0.5 % Mo_2C + 10 % Co
Sintered carbide 2	Type M 10, chemical composition: 84 % WC + 4 % TiC + 6 % (Ta,Nb)C 60/40 + 6 % Co
Sintered carbide 3	Type K 05, chemical composition: 93 % WC + 2 % TiC + 5 % Co

Laboratory tests were carried out using the machine with abrasive cloth, which is used in practice most often. Its design is relatively simple (Fig. 2), therefore these machines are reliable. Results scattering is relatively small. In Czech Republic it is standardized in CSN 01 5084 [15]. Similar machines are standardized e.g. in STN 01 5084 or ASTM G 132 [5].

This machine is used in laboratories of Department of Material Science and Manufacturing Technology already for 25 years for wear resistance determination of metal materials, especially of overlays on agricultural machines parts and on parts working under intensive abrasion conditions [1, 2, 3].

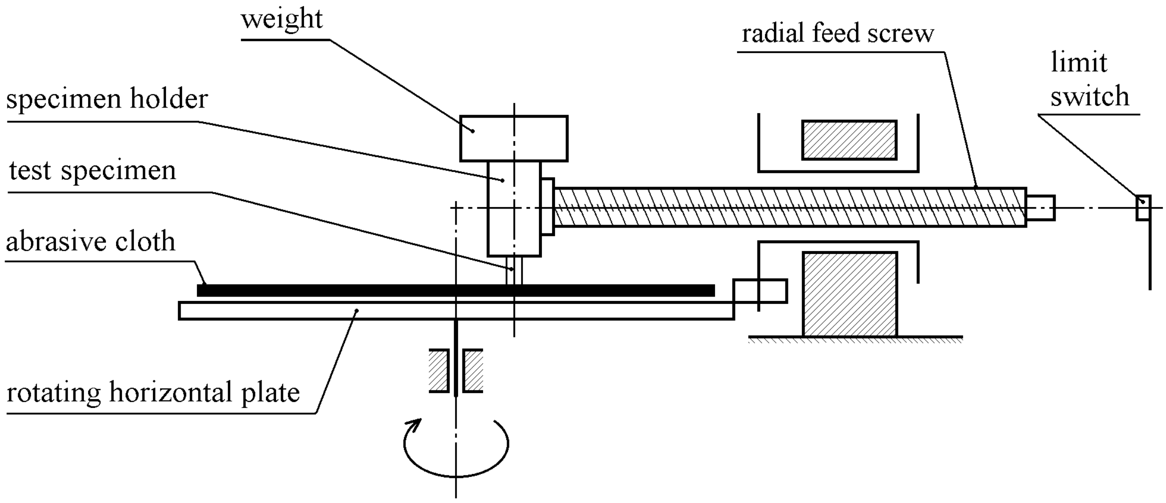

Fig. 2. **Operating principle of the pin-on-disk machine**

The substance of the abrasive wear [14] testing machine according to CSN 01 5084 is the wear of the test specimen by abrasive cloth under in advance defined conditions. The machine consists of the uniform rotating disk whereon the abrasive cloth is fixed. The test specimen is fixed in the holder and pressed against the abrasive cloth by the weight. Further it consists of the screw which makes possible the radial feed and of the limit switch. During the test the specimen moves from the outer edge to the centre of the abrasive cloth and a part of the specimen comes in contact with the unused abrasive cloth.

The specimens are weighed before and after the tests with an accuracy of 10^{-3} g. The HV hardness of all specimens is measured, too.

With regard to the variable quality of used abrasive cloth the relative wear value RW_{abr} of the tested material to the etalon is calculated using the equation (1)

$$RW_{abr} = \frac{W_{hZ}}{W_{hPZ}} \cdot 100, \tag{1}$$

where W_{hZ} – mean mass lost of tested specimen, g;
W_{hPZ} – mean mass lost of reference specimen, g.

Results and discussion

Test results are graphically presented in Fig. 3.

From test results it is evident that the maximum wear (of about 93 % greater compared with etalon) was determined at specimens made from grey cast iron. All three tested steels showed smaller wear than etalon, namely of about 30 to 35 %. Relatively considerable differences were determined at three tested overlays. It is evident that their wear resistance depends expressively on their different microstructure. While the relative wear value of the overlay 1 (about 71 %) approximated itself to tested steels, the wear of next two overlays (containing e.g. chromium, vanadium, titanium, molybdenum and niobium carbides) was expressively lower (about 14 % at overlay 2 and 3 % at overlay 3). Very high wear resistance values were determined at all three types of tested sintered carbides. Their relative wear RW_{abr} varied under about 0.7 %. The wear resistance of tested sintered carbides increases in the sequence K 05 – M 10 – P 20.

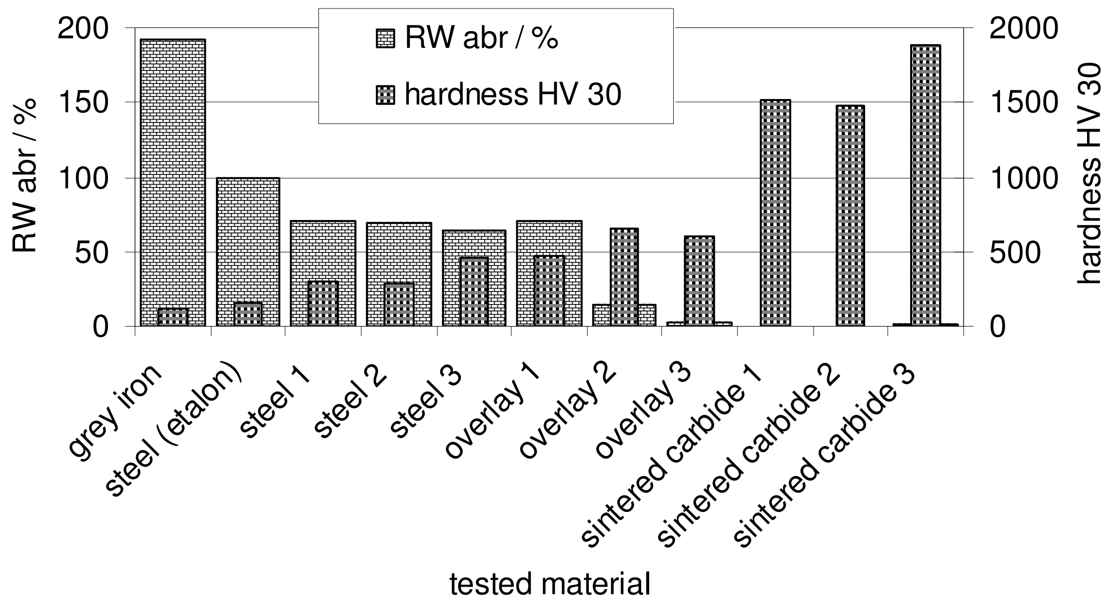

Fig. 3. **Test results**

The part of the test results evaluation was the study of the relative wear – hardness dependence (Fig. 4).

From the results it follows that between the wear intensity and the overlay hardness a low dependence exists (R = 0.54).

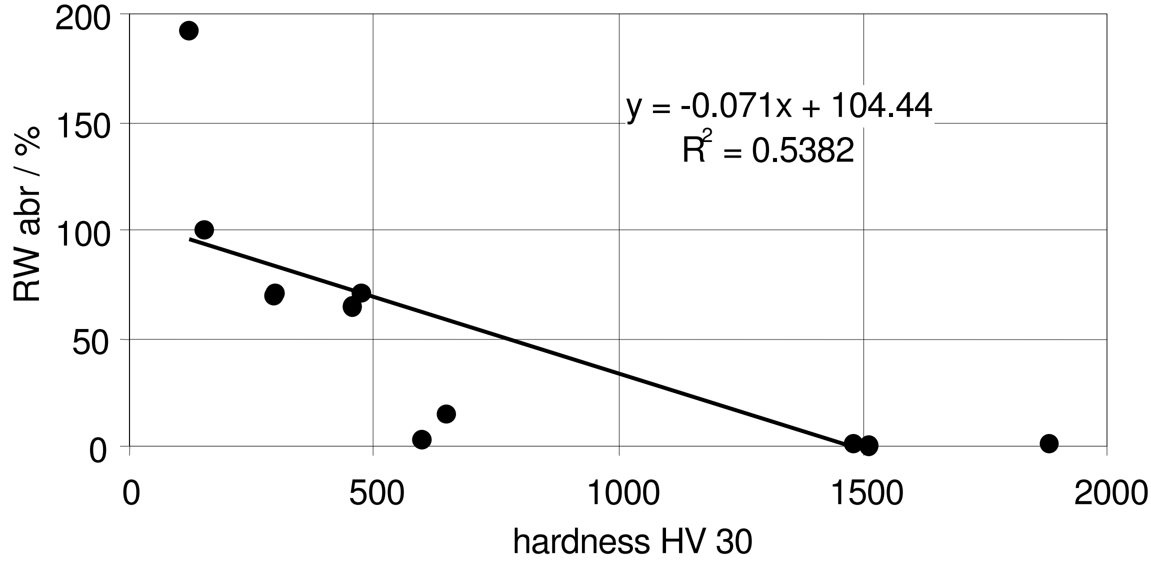

Fig. 4. **The RW_{abr} – HV 30 dependence**

From Fig. 4 the evident, but only orientation dependence can be seen. With the increasing material hardness the wear resistance increases, too. But it is necessary to keep in mind that this fact cannot be accepted always and generally. E.g. at the overlay 2 the hardness is of HV 30 = 648 and RW_{abr} = 14.4 %, at the overlay 3 it is a lower hardness of HV = 599 but the expressively lower wear of RW_{abr} = 2.7 %.

Wear resistance of the concrete material depends except other factors on its microstructure, too. Therefore it is impossible to presume its wear resistance with guarantee.

Conclusions

In fine it is possible to state that the use of sintered carbides for the extremely stressed parts of agricultural machines could become the perspective way to their service life extension (or to their decrease in wear). But it is necessary to use their application carefully. It is necessary to consider some negative properties of sintered carbides, namely their relatively high price and lower mechanical properties at impact stress (brittleness).

Before the mass use in some concrete application it is suitable to carry out verification field tests and to complete it by technical-economical evaluation. For instance the three times service life extension at the five times costs increase does not mean savings in its result and therefore it is not economical substantiated.

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