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Abrasive wear resistance of selected woods

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Abstract

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In this contribution, the results of the wear resistance study of 10 sorts of wood (apple, aspen, beech, hornbeam, horse-chestnut, London plane, mahogany, silver fir, sour cherry and sweet cherry) are published. The laboratory tests were carried out using the pin-on-disk machine when the abrasive clothes of three different grits (240, 120 and 60) were used. The wear intensity was assessed by the volume, weight and length losses of the tested samples. From the results of the carried out tests it follows that the wear resistance of different woods is different. It was proved that the wear resistance of different woods depends on the abrasive particles size, too. Also the technical-economical evaluation was part of the carried out tests. It was univocally proved that at the intensive abrasive wear using the abrasive cloth the best results were shown by hard woods, e.g. apple, beech or mahogany. Soft woods, e.g. horse-chestnut, silver fir or sweet cherry, are cheap, but their wear is bigger compared to hard woods.

Keywords: bonded abrasive particles; abrasive cloth; laboratory tests; technical-economical evaluation

Wood is a natural material, which our ancestors had learned to utilize very early. The first use of wood was evidently energy utilization with the aim to gain heat by its combustion. Later, wood has been utilized to construction of buildings and fortifications, building of means of transport (ships and wagons) and tools.

In contrast to other used materials (metals, plastics, aggregate, limestone, glass, ceramics, …) wood has one exceptional property – it is a renewable material. From statistical sources it follows that in the long term the one-year wood growth in the Czech Republic is higher than logging. Hence, the wood supplies increase.

Compared to other materials the properties of wood are different (Kafka 1989; Pluhař et al. 1989; Peschel 2002; Kettunen 2006). Some differences can be seen at first sight, e.g., colour, gleam or texture. In contrast to many other materials wood has a specific aroma. From physical properties, let us specify e.g. density, moisture (shrinkage, swelling) and thermal, electric and acoustic properties. From mechanical properties let us specify at least elasticity, strength (tensile, pressure, bending, shear, torsion), hardness, toughness. Technological properties of wood are also exceptional, e.g. machinability, bendability, loading capacity of metallic binders, wear resistance or various defects. For some applications, e.g. floors and staircases, the wear resistance is very important (Ohtani et al. 2001, 2002, 2003; Král, Hrázský 2008; Liu et al. 2012) (Czech National Standards: ČSN 01 5050:1969; ČSN 49 0134:1984; ČSN EN 13696:2009; ČSN 91 0276:1989).

Today, wood is still considered as a very good building material. The greatest consumer of wood is therefore building industry, followed by cellulosic-paper industry (Tsoumis 1991; Faherty, Williamson 1995; Zahradníček, Horák 2007; Slavid 2009). Production of furniture, musical instruments, works of art, sports equipment or of toys for children represents an interesting utilization of wood. A part of wood is consumed in the form of firewood.

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In the contribution, the results of abrasive wear resistance study of 10 sorts of wood (apple, aspen, beech, hornbeam, horse-chestnut, London plane, mahogany, silver fir, sour cherry and sweet cherry) are published. The laboratory tests were carried out using the pin-on-disk machine with abrasive cloth, when the abrasive clothes of 3 different grits (240, 120 and 60) were used. The wear intensity of all test samples was assessed by volume, weight and length losses at different conditions.

The part of the carried out tests was the technical-economical evaluation, too. The prices of wood used in calculations are the average prices in the Czech Republic calculated from the offer of 13 sellers.

MATERIAL AND METHODS

For the materials, wear resistance determination of single wear types (ČSN 01 5050:1969) in principle field tests, pilot tests and laboratory tests are used. Each of the mentioned tests has advantages as well as disadvantages. Therefore, each of the test types is suitable for another field of application. The wear resistance test type is always necessary to be chosen with regard to the in-wear process dominant conditions and to the demanded test results (Brožek 2007).

The wear intensity can be expressed by the directly measured values or by the relative values. The directly measured value can be abrasion specified in length (cm), weight (g) or volume (cm^3). The other possible way is to express the dimensionless quantity, when wear intensity of the tested sample is compared to the wear intensity of the standard (Vocel, Dufek et al. 1976; Vocel 1983).

In literature, a sufficient number of wear resistance testers for various types of wear is mentioned (Lever, Rhys 1968; Vocel 1983; Friction and Wear Testing 1987; Blau 1992). Testing equipment for abrasive wear resistance determination is usually classified according to the contact mode of the sample with free or bonded abrasives. In practice, the testing machines with abrasives bonded to cloth (Fig. 1) are used most often. They are simple and reliable, with small variance in results. Their disadvantage is the variable quality of abrasive cloth. In the Czech Republic this testing method is standardised according to ČSN 01 5084:1974 (similar foreign standards: STN 01 5084, ASTM G 132).

The principle of the abrasive wear test using the pin-on-disk machine with abrasive cloth (ČSN 01 5084:1974; Fig. 1) is to wear the sample under predetermined conditions. Using the apparatus with abrasive cloth the samples were of 10 mm diameter and 70 mm length. The test sample was pressed against the abrasive surface using the prescribed normal force. The wear path was a spiral on the disk, caused by the disk rotation and the radial feed of the sample, so the sample progressively moved over the unused abrasive along the prescribed track length.

As abrasive cloth the corundum twill type A 99 – G, S 25, trademark Globus, grit 120, was used. In addition tests using grits 60 and 240 were carried out, too. It corresponds to the average abrasive grain sizes of 44.5 (grit 240), 115.5 (grit 120) and 275 μm (grit 60) (Brožek et al. 2010). During the test, the test sample was pressed to the abrasive cloth by the pressure of 0.1 MPa.

The above-mentioned pin-on-disk machine with abrasive cloth (bonded abrasive) is primarily destined for the determination of abrasive wear resistance of metallic materials (Brožek, Nováková 2008; Brožek 2012; Cieslar et al. 2013). By the

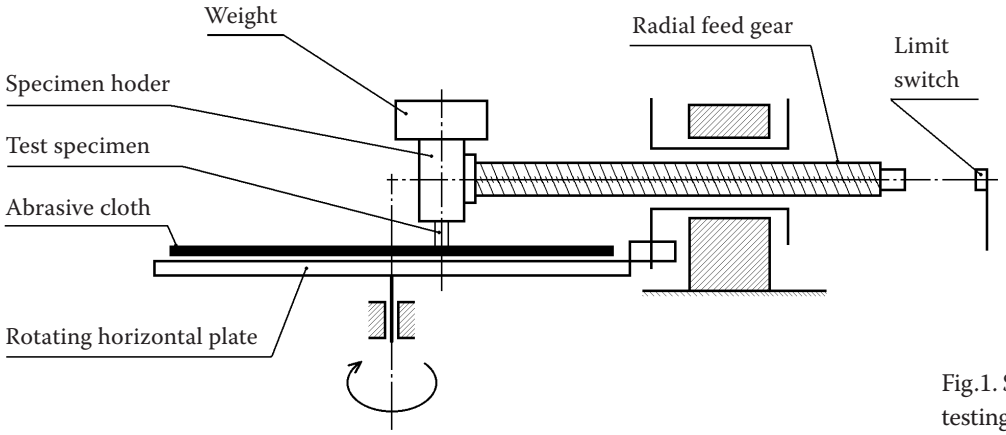

Fig.1. Scheme of the abrasion testing machine (pin-on-disk)

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Table 1. Summary of tested materials

Tested material		Density (g/cm^3)	Price of sample material (CZK)
Horse-chestnut	*Aesculus hippocastanum*	0.50	0.06
Silver fir	*Abies alba*	0.40	0.09
Sweet cherry	*Prunus avium*	0.56	0.13
Aspen	*Populus tremula*	0.47	0.24
London plane	*Platanus acerifolia*	0.68	0.20
Hornbeam	*Carpinus betulus*	0.69	0.08
Sour cherry	*Prunus cerasus*	0.76	0.14
Apple	*Malus domestica*	0.80	0.44
Beech	*Fagus silvatica*	0.76	0.07
Mahogany	*Swietenia mahagoni*	1.23	0.24

1 EUR = 27.030 CZK (November 6, 2015)

carried out tests it was proved that this machine is suitable and applicable for wear resistance tests of plastics (Brožek 2014) and wood, too.

In practice, also machines of other design are used, e.g. machine with rubber cylinder. In this case, the test sample is worn out by free abrasive, which is poured between the sample surface and the slowly rotating cylinder, which touches the sample surface. The rubber cylinder pushes the free abrasive grains against the tested sample surface. The used grains fall in a container (Budinski 1997).

The summary of the used materials is in Table 1. From semi-products (boards, planks, squared timber logs) the test samples of the desired shape and dimensions were cut out in the direction of their length.

Before the abrasive wear test the density (ρ) of all tested materials was determined. Using a dial balance the sample weight (g) before (m_1) and after (m_2) the test was determined with accuracy of 0.0001 g. The wear path length was 50 m.

The weight loss Δm (g) is calculated using the equation:

$$\Delta m = m_1 - m_2 \quad (1)$$

The volume loss ΔV (cm^3) is calculated from the weight loss Δm (g) and the density ρ (g/cm^3) (Table 1) from the equation:

$$\Delta V = \Delta m/\rho \quad (2)$$

The length loss Δl (cm) is calculated from the volume loss ΔV (cm^3) and from the worn out sample front surface characterized by its diameter d (cm) from the equation:

$$\Delta l = (4 \times \Delta V)/(\pi \times d^2) \quad (3)$$

RESULTS AND DISCUSSION

In next figures the woods are arranged according to the decreasing weight loss using the abrasive cloth of grit 240 (the average abrasive grain size 44.5 μm).

From the test results shown in Fig. 2 (weight loss) and in Fig. 3 (volume loss/length loss) it follows that different woods have different abrasive wear resistance. The order of the tested woods arranged according to the decreasing weight/volume loss is identical. It is logical owing to the same worn out front surface diameter of all tested samples.

At the test using the pin-on-disk machine the highest wear using the abrasive cloth of grit 240 (44.5 μm) was determined at horse-chestnut. The wear intensity of next woods decreased in order: silver fir, sweet cherry, aspen, London plane, hornbeam, sour cherry, apple and beech. The minimum wear was determined at mahogany. At the wear using the abrasive cloth of grit 120 (abrasive grain size is 115.5 μm) the woods ranking changed. The highest wear was determined at horse-chestnut. The next ranked in descending order aspen, silver fir, sweet cherry, apple, sour cherry, hornbeam, London plane, beech and mahogany. At the wear using the abrasive cloth of grit 60 (275 μm) the woods ranked in ascending order as: horse-chestnut, sweet cherry, aspen, London plane, hornbeam, sour cherry, silver fir, beech, apple and mahogany.

From the results of the carried out tests it follows that for a majority of woods the trend of the course of wear expressed by the weight loss is identical. The wear using the cloth of grit 120 is higher at all samples than using the cloth of grit 240. At the

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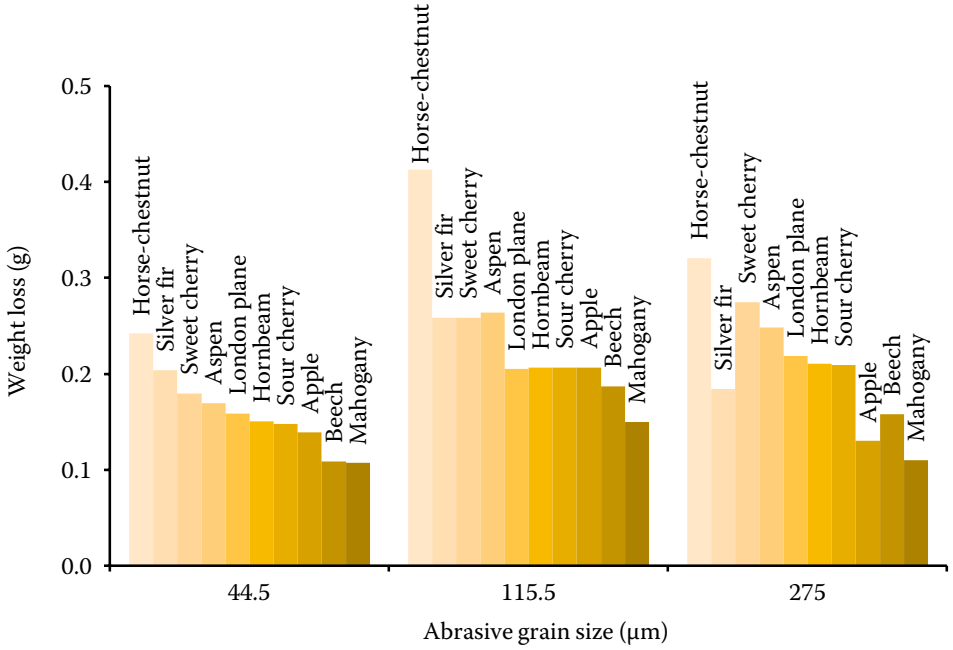
Fig. 2. Weight loss



majority of woods, namely at 6 from the 10 tested samples, the wear using the cloth of grit 60 is minor than using the cloth of grit 120. At four woods, namely at sweet cherry, London plane, hornbeam and sour cherry, the wear using the cloth of grit 60 was higher than using the cloth of grit 120.

From the results of the carried out tests it follows that for a majority of wood the trend of the course of wear expressed by the volume/length loss (Fig. 3) is similar. The wear using the cloth of grit 120 (115.5 μm) is higher at all samples than using the cloth of grit 240 (44.5 μm). At the majority of woods, namely at 6 from the 10 tested samples, the wear using the cloth of grit 60 (275 μm) is minor that using the cloth of grit 120. At four woods, namely at sweet cherry, London plane, hornbeam and sour cherry, the wear using the cloth of grit 60 is higher than using the cloth of grit 120.

The graphical illustration of the technical-economical evaluation of the carried out tests is evi-

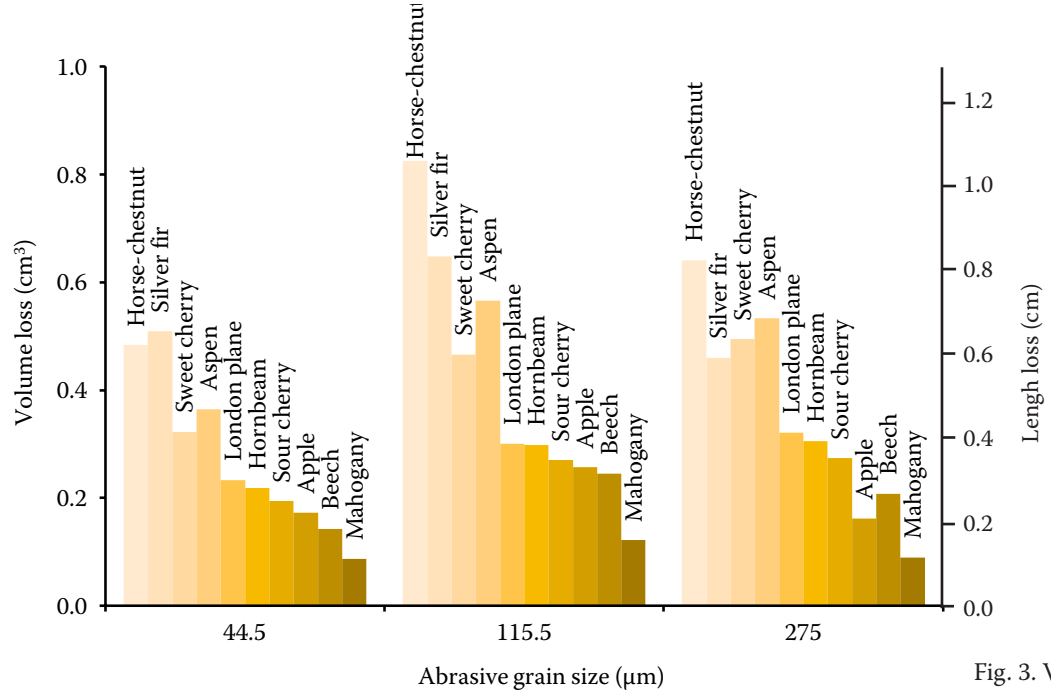


Fig. 3. Volume/length loss

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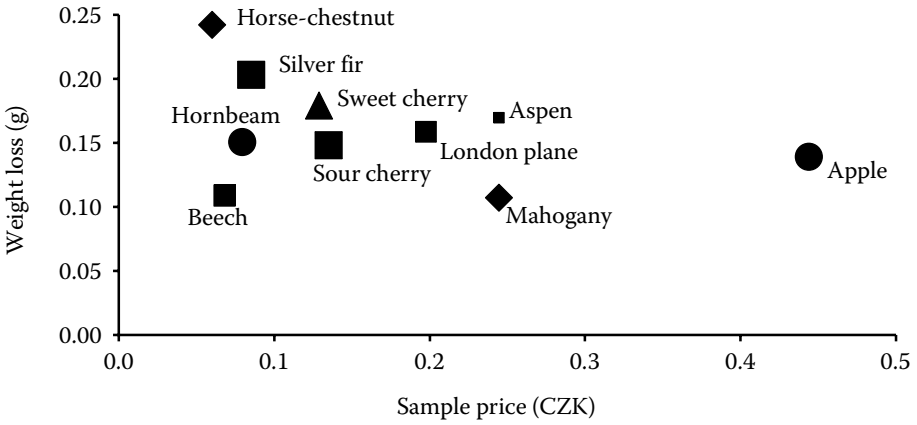

Fig. 4. Relationship between weight loss and sample price

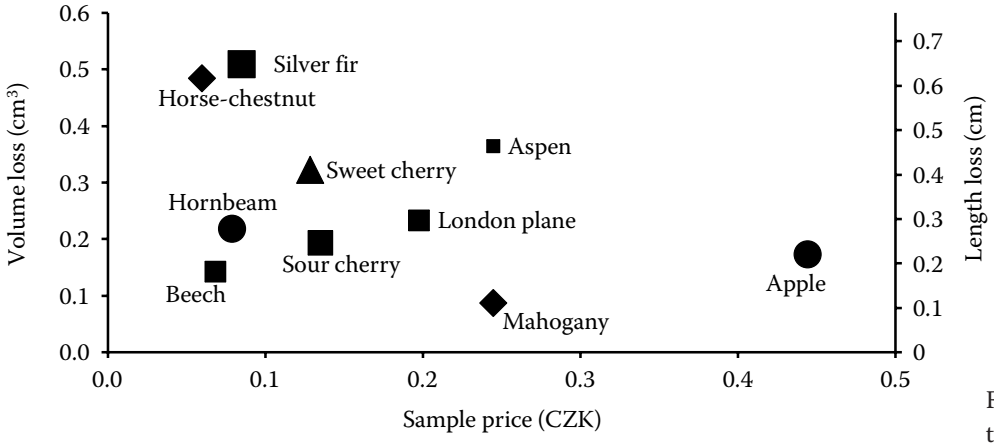

Fig. 5. Relationship between volume/length loss and sample price

dent from Fig. 4 (according to weight loss) and Fig. 5 (according to volume/length loss).

In Figs. 4 (weight loss) and 5 (volume/length loss) the results of the woods most suitable for practice from the technical-economical point of view are located left at the bottom. It is a case of keenly priced materials of relatively small wear. On the contrary, the results of woods located right on the top are not suitable for use in conditions of abrasive wear. It is a case of material low wear resistance and high price.

As it is evident from Figs. 4 and 5, the cheapest sample was the wood of horse-chestnut. The price of next samples increases in order beech, hornbeam, silver fir, sweet cherry, sour cherry, London plane, aspen and mahogany. The most expensive samples was the wood of apple.

The results of the laboratory tests show that the woods from beech and mahogany have small wear at an acceptable price.

However, because different woods have different density, it depends on the circumstances, if the wear is obtained as weight loss or by volume/length.

From the summarization of the results of wear resistance evaluation it follows that at different materials it is necessary to give the parameter of loss. As it is showed in the above mentioned figures, the results expressed by volume or length loss (Fig. 3) are identical at the same size of test samples, while the results expressed by weight loss (Fig. 2) differ.

CONCLUSION

The contribution contains the laboratory tests results of abrasive wear resistance of selected wood using the pin-on-disk machine with abrasive cloth carried out according to the standard CSN 01 5084:1974. In total, 10 sorts of wood (apple, aspen, beech, hornbeam, horse-chestnut, London plane, mahogany, silver fir, sour cherry and sweet cherry) were tested. The aim of the carried out tests was to assess the possibility of their use for products,

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which are intensively worn out, e.g. terraces or staircases.

All samples were of cylindrical shape of 10 mm diameter and 70 mm length. For the test samples wear three abrasive clothes of different grit, namely 240 (mean abrasive grain size 44.5 μm), 120 (mean abrasive grain size 115.5 μm) and 60 (mean abrasive grain size 275 μm) were used. The wear intensity was evaluated by volume loss, weight loss and length loss at all the tested samples. The technical-economical evaluation was the part of the carried out tests.

From the evaluation of the carried out tests it follows that the greatest difference between the most and the least wear-resistant woods (mahogany/horse-chestnut) was determined at the use of the abrasive cloth of grit 240 having the smallest abrasive particles. The difference is put by the ratio of 0.44. With the increasing size of abrasive particles this ratio decreases. Using the abrasive cloth of grit 120 it is 0.36 and of grit 60 having the greatest abrasive particles it is 0.34. It was also found that the greatest wear regardless to the sort of wood is caused by the particles of the medium size (grit 120, mean abrasive grain size 115.5 μm, weight loss 0.235 ± 0.068 g), the minor wear by the great particles (grit 60, mean abrasive grain size 275 μm, weight loss 0.206 ± 0.061 g) and the smallest wear by the small particles (grit 240, mean abrasive grain size 44.5 μm, weight loss 0.161 ± 0.039 g).

The technical-economical evaluation was the part of the carried out tests. At the same time, it was proved that at the Czech market the price of wood is very different. The samples of horse-chestnut, beech and hornbeam were the cheapest; the samples of mahogany and apple were the most expensive.

From the point of view of wear resistance, the most favourable results were determined at the samples of mahogany and beech. Mahogany, regardless of the evaluation criteria (weight loss, volume loss, length loss) and of the used abrasive cloth grit (240, 120 and 60) had always the smallest wear.

The very good results were determined at the samples of beech, which is cheaper than the mahogany samples.

From the results of the carried out tests it follows that for applications where wood is intensively abrasively worn out, it is possible to recommend beech. The other tested woods are either not so wear-resistant (horse-chestnut, silver fir, sweet cherry) or they are more expensive (aspen, mahogany, apple).

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