ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LIX 16 Number 5, 2011

THE POSSIBILITIES FOR MEASUREMENT OF SAW BLADES WEARING

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Received: April 12, 2011

Abstract

KOVÁČ, J., KRILEK, J.: *The possibilities for measurement of saw blades wearing.* Acta univ. agric. et silvic. Mendel. Brun., 2011, LIX, No. 5, pp. 137–144

Some effects come into the practice because of decreasing quality of a cutting knife. These effects then influence the whole cutting process. The paper deals with analysis of methods for evaluation of a chain saw wearing. It is necessary to know the methods for measurement of a chain saw wearing because the tool wearing has significant influence on the whole system acting i.e. machine-tool-work piece. The measurement of wearing rate was realized to obtain knowledge about the wearing rate of cutting knives on chain saws. The goal of measurement was to design suitable methods for evaluation of wearing and definition of exactness for used methods. The exactness of used methods is evaluated according to the range of variance. The cutting knife wearing was analyzed by two methods; the results of both methods were compared. In the future it would be very effective to generalize mentioned methodology for measurement of a cutting knife wearing.

cutting process, measurement methods, wear, saw blades, wood cutting

The woodcutting is the basic technological production process and has significant influence on production organization, efficiency, occupational safety, quality of products and volume of consumed energy. This is the reason why complex cognition of woodcutting process is very important for designers of working machines and their tools.

The one of the difficult tasks of the production-felling process is to optimize technical and technological parameters of cutting mechanisms in felling machines. These machines have to offer high cutting property, toughness, durability, operational reliability, good service, maintenance, low energetic consumption, weight and appropriate cutting quality. There are two ways how to solve this task. The first way consists of innovation and adjustment of chain and circular saws to new working conditions. The second way consists of looking for utilization possibilities of unusual principles of chip and chipless cutting process (Kováč, J., Mikleš, M., 2009).

Secondary output of cutting edge wearing

Some effects come into the practice because of decreasing quality of a cutting knife. These effects then influence the whole cutting process. These effects produce deformation of a processed material by a cutting knife creating tension in it, i.e. friction between processed material and a cutting knife (Nováček, E., Novák, V., 2006).

Tension and friction arise in the cutting knife at the process of woodcutting. The certain effects are created by the influence of decreasing quality of a cutting knife and they influence the whole cutting process.

The technological goal of cutting process – new surfaces formation on the machined material, is obtained by mechanical disturbances of a solid body – work piece (Rousek, M., 2004). When the wood layer is removed, tension arises in the wood, which creates deformation of this layer. The tension and deformation areas come behind the limits of normal cutting surface and it finally influences the quality of real machined surface. The course of woodcutting process by a cutting edge with curvature radius r_n is possible to define using following stages at the low cutting speed (Lisičan, J., 1996):

- Initial bending deformation of a cell-wall within the range of elasticity limits;

- Cells deformation and pressing cell-walls to each other;
- Compressive gradual deformation (elastic → plastic) of neighboring cell walls with final degradation of a cell wall.

The real condition of a cutting knife can be obtained by following conditions created by springing of a material (Lisičan, J., 1996):

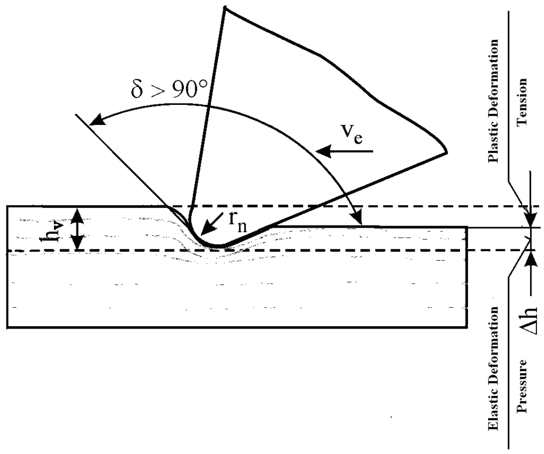
- If the radius of a fillet r_n is bigger than theoretical thickness of a chip $r_n \geq h_v$, then the chip is not produced and the cutting knife works with the cutting angle $\delta > 90°$. The tool presses the material under the cutting knife and processed material presses forward for the thickness Δ_h (Fig. 1).
- When there is adequate difference $h_v > r_n$ the real chip is produced with the thickness $h_D = h_v - r_n$ (Fig. 2).

The difference between $r_n - \Delta_h$ defines the rate of plastic deformation of a cutting surface by a cutting knife depending on value r_n, wood species, its humidity and a cutting model ($\Delta_{h\perp} > \Delta_{h||}$).

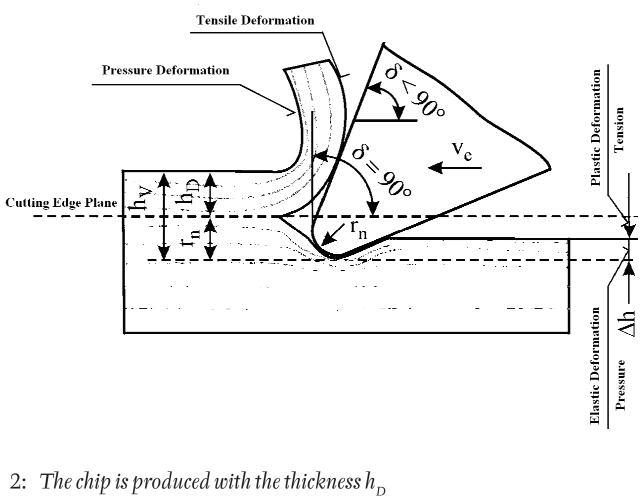
In the cutting process there are worn all active surfaces of a cutting knife touching a processed material. Regarding to working conditions the intensity of wearing on individual surfaces varies. The cutting knife is worn very quickly only on some surfaces and the wearing on other surfaces is very negligible. The character of a cutting knife wearing is analyzed according to the most worn parts (Buda, J., Souček, J., Vasilko, K., 1983). There are following shapes of wearing (Fig. 3).

On the basis of many studies there is defined an external expression of wearing on a cutting knife in the process of machining wood as following:

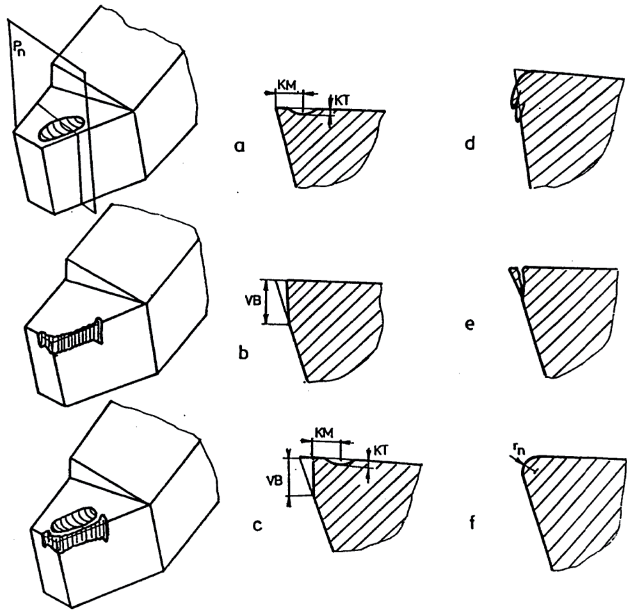
- fillet of a cutting edge by increasing radius of fillet,
- change of real cutting edge,
- curve (fillet of a cutting edge) with increasing radius from a cutting face to a back of a cutting knife
- eccentricity of a cutting edge, which is shifted due to the cutting face of a tool,
- increased abrasion on a back surface of a tool.



1: *The chip is not produced in the cutting process*



2: *The chip is produced with the thickness h_D*



3: *Various manifestations of the cutting knife wearing*
a – formation of a crack on a cutting face, b – formation of an abrasion surface on the back of a cutting tool, c – concurrent wearing on a cutting face and back of a cutting tool, d – plastic deformation of a cutting knife, e – brittle failure of a cutting knife, f – increasing the radius of cutting edge fillet

Methods of evaluation for a cutting knife wearing

There are used following methods for evaluation of wearing:

- indirect methods,
- direct methods.

The indirect methods are used for definition of wearing using measurement of another value connected to a tool wearing and having similar course e.g. cutting force, cutting power, cutting length, cutting speed, etc. The indirect methods do not inform about change of a cutting edge profile (Rousek, M., Kopecký, Z., Novák, V., 2009).

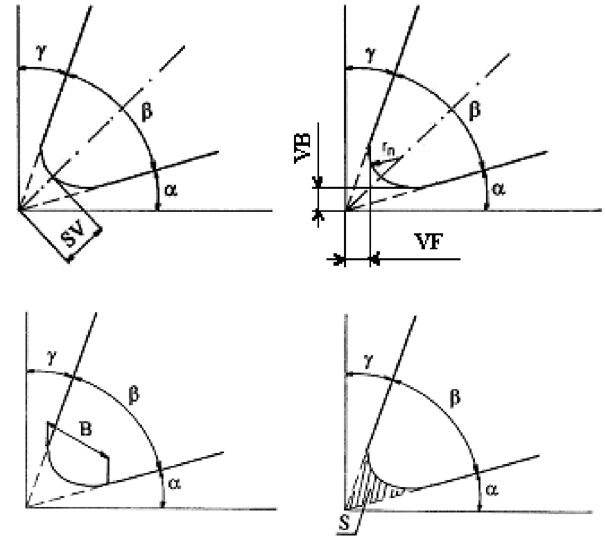
The direct methods are divided into two groups as following:

1st group of direct methods – there are methods based on measurement of removed material (weighting method, the method of stamps). The methods of this group do not describe completely the cutting knife wearing because they do not define its geometry.

2nd group of direct methods – there are microscopic methods based on measurement of linear dimensions chosen characteristics of a cutting knife wearing. The methods of this group describe changes in geometry of a cutting knife (Prokeš, S., 1980) e.g. decrease of a cutting edge SV, radius of a fillet on a cutting edge r_n, wearing along the cutting face VF, wearing along the back part VB, width of abrasion B, area of abrasion S, KT – depth of a slot on a cutting face, KV_s – dimensional wearing (Fig. 4).

There are many methods, which are used, e.g.:

- **Weighting method** – It consists of a measurement on very accurate scales. The weight of a tool is measured before and after machining. The weight difference is a tool wearing. The disadvantage of this method is that this method does not give information about real cause of wearing.
- **Using a scale beam** – The scale beam is given on a cutting knife, which is vertically divided into two parts. Deflecting a cutting knife about a certain angle changes the position of the gravity center from the supporting point. It deflects a scale beam about an angle γ. This way it is possible to define an angle of wearing.
- **Method of a cross section** – It is based on realization of some cross-sectional cuttings across a cutting edge. This method is destructive i.e. the cutting edge is destroyed. This method is not suitable for cutting difficulties. The cutting shall be realized to not destroy a cutting edge.
- **Method of a light beam** – The cutting edge is lite due to the plane $\beta/2$ and the light beam is measured by an eyepiece. The bigger wearing is, the bigger width of a light beam is.
- **Method of cutting quality change.**
- **Method of fuel consumption change.**
- **Method of change of tool temperature.**
- **Measurement of a profile by a profilograph and profiloprojector –** It uses a software NIS – Elements for measuring the value of wearing.



4: *The basic characteristics of a cutting knife wearing*

- **Contact way** – This method is based on measurement of a profile by a measurement needle. It analyses the signal and draws a shape of a cutting edge.
- **contactless way,**
- **using automatic profilometer.**

All these methods are very similar. On the basis of one parameter change we define the value of another parameter. A wood type and its properties, cutting model and so on can influence cutting quality.

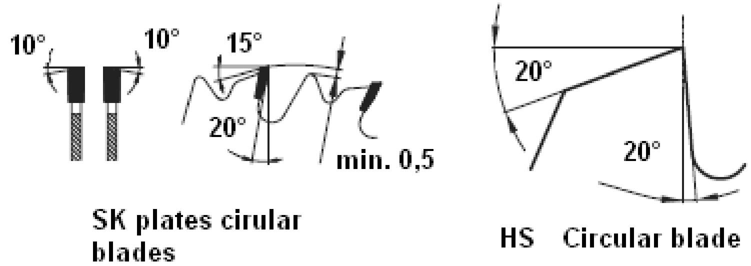
MATERIALS AND METHODS

Measurement of wearing rate was realized to obtain knowledge about the size of cutting knives wearing on circular saws, their technical parameters and material features are shown in Tab. I and Fig. 5. The value of wearing rate was measured on recorded samples of an area cut of cutting knives of a circular saw. The wearing was measured using software NIS – Elements and there were used three methods of measurements offered by the software.

The device used for this experiment consists of a microscope and a digital camera Canon Power Shot

I: *Basic dimensions and material of circular saws*

Basic dimensions	Diameter of a circular saw D (mm)	Thickness of a circular saw a (mm)	Cutting clearance angle α (°)	Cutting-edge side rake γ (°)	No. of teeth	Composition material
Circular saw made of high speed steel	600	3,5	20	20	56	**HS type 75 Cr 1** (0.74–0.8 % C; 0.25–0.4 % Si; 0.65–0.8 % P; 0.01 % S; 0.3–0.45 % Cr.)
Circular saw made with cemented carbide plates	600	3,5	15	20	54	70–97% weight Wolfram, binder Cobalt



5: *Technical parameters of teeth used on circular saws*

A520. The camera was controlled by PC software Zoom Browser EX 5.0. We recorded pictures of a cutting knife at fifty-fold increase. The picture was created in the highest quality, i.e. 3 megapixels. It enabled to analyze the picture in the software.

The wearing was measured in the software NIS – Elements. There were used three methods from the list offered by this software. The NIS-Elements Advanced Research offers recording pictures, archiving and picture analyzing. The software was developed for the most difficult systems, which require full control of all camera and microscope functions. The software is focused on high performance and fluent course of experiments. It is able to record and display multidimensional pictures in six dimensions (X, Y, Z, wave length, time, multipoint). It has many additional tools for repairs of recorded pictures, e.g. effective deconvolution, module for extended depth of focus (EDF) or a picture database.

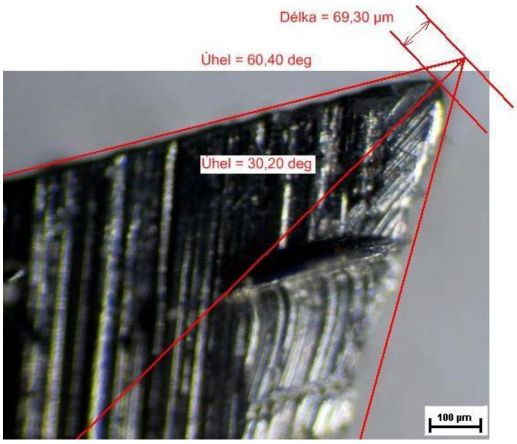
Three methods of indirect analysis for cutting knives of circular saws were used for experimental measurement of wearing:

1. analysis of the distance between measured profile and ideal profile of a cutting knife,
2. analysis of a circle radius r_0 described from an ideal cutting edge and touching the nearest point of a real cutting edge.

RESULTS AND DISCISSION

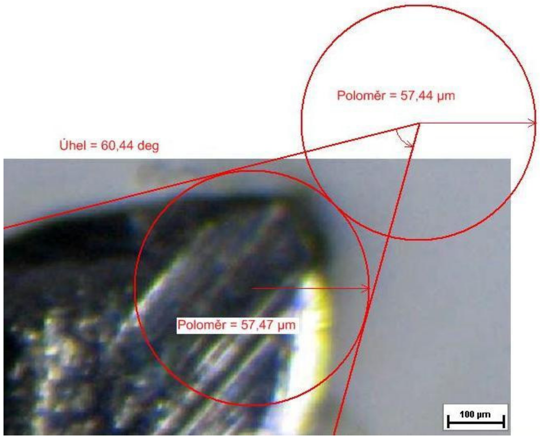
At present time there is not defined any indirect method for indirect measurement of wearing concerning cutting edge of circular saws as the most exact method. The paper deals with several methods of wearing analysis. It tries to define which method is the most exact. The exactness of used method will be defined according to the range of variance σ^2.

The calibration enables measurement of objects and structures in the pictures in the real units. The digital picture processed by a computer consists of huge number of small square elements called pixels. The calibration is addition of real sizes (in chosen units) to dimensions of one pixel (Fig. 6).



6: *High-speed steel – the analysis of wearing defined by the distance of an ideal cutting edge from a real cutting edge*

The cutting edge wearing was analyzed by two methods and these methods were compared to each other. The measurement for each tooth was realized twice (Fig. 7).



7: *High-speed steel – the analysis of wearing by the method of inscribed circle*

The first analysis of circular saws is defined by the distance of an ideal cutting edge from a real cutting edge measured in parallel with a cutting face of a cutting edge.

II: *HS wearing – according to the distance of a peak Δh*

Δh (µm)	107.43	69.30	115.04	86.58
σ^2	4.32	3.84	2.13	2.82

In the table II there are shown average values of distances of a peak of ideal cutting edge from the nearest point of a real cutting edge on circular saw teeth. The wearing on the teeth of a circular saw is not constant on the whole circular saw according to average values of radius Δh.

Then there was analyzed blunting defined by radius ρ of inscribed circle to the profile of a cutting edge. There were analyzed radius, diameter of inscribed circle by several points and variance among measured points Tab. III.

III: *HS wearing – according to inscribed circle Δρ*

Δρ (µm)	78.88	57.37	106.71	77.96
σ^2	4.53	1.11	3.90	4.40

In the table there are shown average values for radius of circles inscribed to the profile of a cutting edge on teeth of circular saws. There is also calculated the variance of measurements. The

IV: *Cemented carbide plates wearing - according to the distance of a peak Δh*

Δh (μm)	13.77	19.64	28.67	13.19
σ^2	0.67	0.84	0.87	0.42

V: *Cemented carbide plates wearing - according to inscribed circle Δρ*

Δρ (μm)	12.6	18.04	25.96	14.03
σ^2	0.22	0.53	0.87	0.68

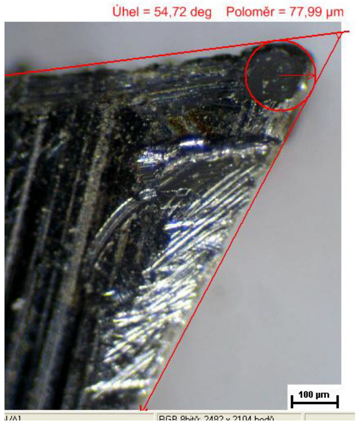
wearing on teeth of a circular saw is not constant according to average values of radius ρ.

In the Tab. IV and V there is little difference between analyzed average values of cutting edge wearing. It is not possible to eliminate the fact that methods were used unsuitably.

The goal of this method is analysis of a cutting knife wearing using the change of angle β on a cutting knife. In the Fig. 8 there is shown wearing on the cutting face and back of a cutting knife.

Used methods suit to definition of Δh and Δρ. They define cutting edge wearing with little differences.

Then, there was analyzed cutting edge wearing by the change of the shape on the cutting knife (fillet radius of a cutting edge, length and depth of wearing on the cutting face and back of the cutting knife) – measurement of length parameters „*x*" and „*y*".



8: *High-speed steel – the wearing caused by the change of angle β on a cutting knife*

The wearing was measured on the cutting face („*x*") and back („*y*") of a cutting knife. The measurement found out that distances „*x*" and „*y*" are the same as well as fillet radius „φ". It means that the cutting edge wearing on the cutting face and back are the same.

The best method for measurement of the cutting knife wearing is utilization of inscribed circle to the profile of a cutting edge. The variance of this measurement was the smallest.

SUMMARY

The goal of this paper was to analyze possibilities of the cutting knife wearing on the circular saws. According to Lisičan (1992) it is difficult to define when the tool is sharp or worn. At present, there is not defined any method of indirect measurement for a cutting knife wearing on the circular saws to be the most accurate. This is the reason why measurement of only one feature is not enough. There is necessary to measure more features, describe the peak of a cutting edge graphically before and after wearing.

Insufficient knowledge is used at the analysis of a tool. It is difficult to define whether the tool is sharp or not. It is not enough to measure only one feature for definition of a cutting knife wearing and it is necessary to measure several features or to describe peak of a tool graphically before and after wearing. The disadvantage of measurements of individual wearing features are also very small values, inexpressive passing from arch part to direct form, etc. (Nováček, E., Novák, V., 2006). It means that there is not only one method for measurement of a cutting knife wearing and it is a problem for comparison of experimental results.

In some works (Prokeš, S., 1980), the cutting force or necessary work, the power uses as the only tool for expression of cutting knife features. All influences acting on cutting force disenable comparing results. The source of mistakes is not only low stability of cutting material features but also polluting side surfaces of tools, different polluting gaps of teeth on a cutting knife, decreasing amount of chips on cutting surfaces, change of width of a cutting space caused by decreasing sharpness or change of side deviations of a circular saw in the cutting process. All circumstances causing increased friction act on increasing temperature of a cutting tool so the temperature cannot be the only criterion for analysis of a cutting knife.

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