IOP Conf. Series: Materials Science and Engineering **448** (2018) 012024 doi:10.1088/1757-899X/448/1/012024

FEM analysis of saw blade

O Bílek[1] and J Baďurová[2]

[1] Department of Production Engineering, Faculty of Technology, TBU in Zlín, Vavrečkova 275, 76001 Zlín, Czech Republic
[2] Department of Physics and Material Engineering, Faculty of Technology, TBU in Zlín, Vavrečkova 275, 76001 Zlín, Czech Republic

E-mail: bilek@utb.cz

Abstract. Article deals with identification of the critical points of the saw blade designed for wood cutting which teeth are made from stellite material. Cutting parameters and shape of blade were under investigation. FEM analysed the influence of cutting speed, size of cutting forces, clamping and geometry of saw blade. Factors that significantly affect the strength of the saw blade have been identified and can contribute to identification of critical conditions leading to the destruction of the saw blade. The results can also be applied when sawing wood with a band saw.

1. Introduction

Machining processes generally and particularly wood machining processes are complicated by many factors influencing each other. Unlike artificial materials wood is inhomogeneous biological material with significantly changeable mechanical qualities. Therefore; observing interaction between material and machining tool in conditions of different technological parameters is inevitable to understand the whole process and leads to higher quality of final product, improves effectiveness of production and machining process. In this article the saw blade made from tool steel 75Cr1 with the stellite tool tip, two dilatation slots and two ejecting slots is analysed.

Cutting tool plays the main role in cutting process [1-2]. It affects process productivity, cutting stability, and machining accuracy. It must also meet the safety requirements [3-6]. Thin cutting saw blades are preferred for its smaller cut and smaller waste. On the other hand, thin saw tools are less tolerant to changing cutting conditions and are more difficult to maintain. [7-10]

The preload of the blade is the result of effect of an external force through a hammer or rolling roller on the surface of the saw blade. In the experimental part it is determined as a rolled groove. It is a volumetric deformation that results in a local shape change resulting in a flat groove and the introduction of residual pressure stresses.

If the saw blade is used without preload, friction forces that occur during machining cause the edge of the blade to expand. The circuit thus becomes loose and machining is not straight. This phenomenon is also referred to as circling the wheel. On the other hand, the saw blade with a pronounced preload gets a plate shape, but it balances at certain speeds.

Preload compensates adverse thermal state of stress which occur as a result of friction of teeth during cutting process. Higher preload allows the blade to machine with higher speed. Preload effects on the smooth running and hence the quality of the cut. The preload allows reducing the thickness of the saw blade, while the other cutting conditions (circumferential speed and feed rate) remain unchanged.

Cutting tool with radial grooves can compensate thermal expansion of the blade edge resulting in machining, thus maintaining their flatness. Radial grooves also reduce the noise level by interrupting the peripheral part of the disc. However; the conditions generally are: the length of the grooves is at least 0.1 × ØD and the number of grooves (for SC blades) 3-4. Radial grooves are also recommended for saw blades with smaller tooth pitch and in case of thick blade.

The knowledge of lateral stiffness contributes to the choice of the appropriate thickness of the blade. According to GOST 980-80, lateral stiffness should be greater than 40 N / mm in sweep and greater than 25 Nmm^{-1} in cross-cutting. If the values are lower, it is necessary to use the guide pins. [11-14]

Von Mises' stress σ is judged in this article. They are defined as the equivalent tensile stress (reduced stress), used in resistant materials such as steel to predict multiaxial load using the results of simple tensile tests. In this paper this parameter is used as a benchmark for the strength of the saw blade.

2. Methodology

The finite element calculation method (FEM) was chosen for this research project. A static analysis is considered when a 3D saw blade model is used. The shape and geometry of the disc are shown in figure 1. The geometry of the tool and its description presents table 1.

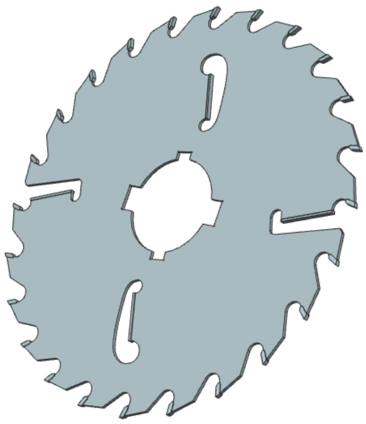

Figure 1. The basic shape of saw blade

Table 1. Description of geometry of saw blade

Geometric feature	Value
Diameter of the saw blade	350 mm
Number of teeth	24
Diameter of the clamping hole	80 mm
Thickness of the wheel body	2.6 mm
Width of the tooth	4 mm
Tooth height	4 mm
Radial compensating slots	2
Clearing slots	2
Compensating rolling	0.66R
Clearance angle	14°
Rake angle	18°
Wedge angle	58°
Tooth shape	FZ

The material of the saw blade was tool steel 75Cr1 with the mechanical properties presented in table 2. The material is considered homogeneous even in the area of teeth, although they are made of stellite. This material has greater strength and hardness than the saw blade material. This is a simplification for FEM analysis and is considered in the discussion of the results, but it does not affect the results of the experiment.

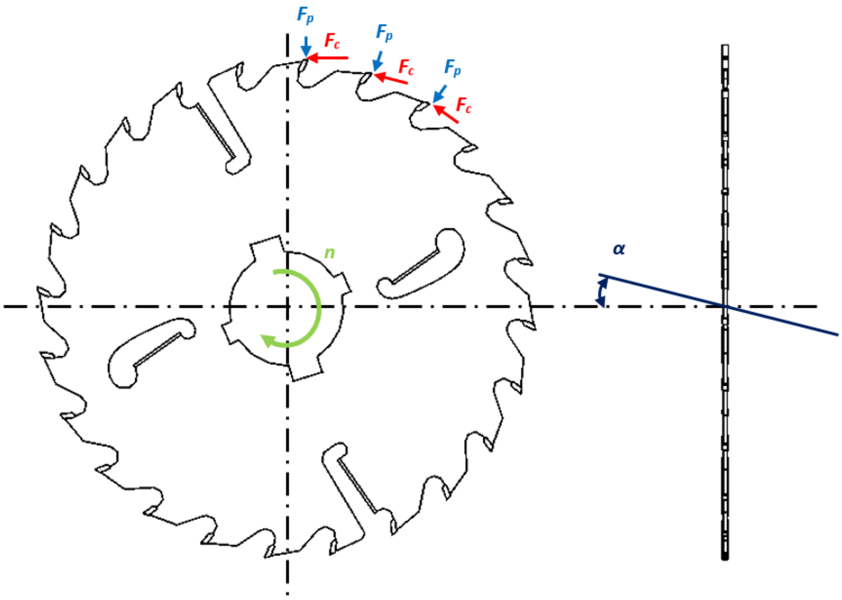

Figure 2. Scheme of loading of the model by the cutting forces F_c, F_p, revolutions per minute n and axis deviation α

Table 2. Mechanical properties of tool steel 75Cr1 (1.2003)

Property	Value
Density	7850 kg/m^3
Poisson's number	0.28
Modulus of elasticity	200 GPa
Tensile strength σ_p	650-880 MPa
Yield strength σ_k	350-550 MPa
Fatigue strength	275 MPa

Table 3. Experiment input conditions

Property	Value
Clamping	Key
Revolutions n	3500 min^{-1}
Tangential force F_c	110 N
Passive force F_p	55 N
Axis deviation α	1°
Thickness of the saw blade body	2.6 mm

IOP Conf. Series: Materials Science and Engineering **448** (2018) 012024 doi:10.1088/1757-899X/448/1/012024

3. Results

The experiments serve to clarify the behavior of the saw blade, depending on the different technological conditions. The following chapter presents variants of static analyzes of the basic shape of blade compared to blade with a rolled-out groove. The influence of clamping on the flange and the strap is monitored. Moreover; dependence of cutting forces and gears on the overall distribution of the Von Mises tension in the blade together with the feed size is expressed in the graph. In addition to the strength of the blade and its critical areas, stiffness for lateral force is determined in individual variants.

3.1. The strength of the saw blade in basic shape in case of clamping on a key

Technological conditions are displayed in table 3 and input constrains in the figure2. Circular saw blade model was clamped on a key, where the revolution speed *n* was 3500 min^{-1}, the size of cutting forces F_c = 110 N and F_p = 55 N, while axis deviation was $\alpha = 1°$

Result of FEM analyses showed that maximal stress according the scale on the right reach 450 MPa close to the place of clamping key way (see figure 3). Generally, the saw blade keeps low stress except weak spots between the clearing slots and the key way hole.

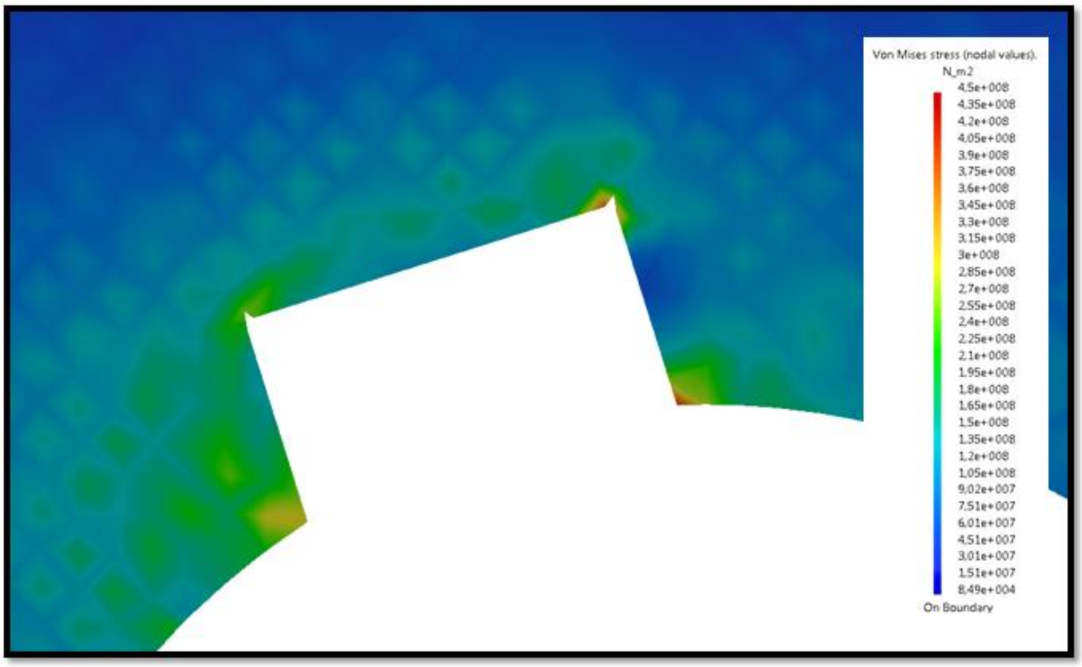

Figure 3. Detail of the area of the key way in the saw blade

Furthermore, the wheel displacement size was evaluated - figure 4. The maximum values of 5.44 mm are achieved in the marginal areas of the blade by deflecting the saw teeth and the entire blade body. Due to the character of the clamp, this maximum is asymmetrically oriented to the opposite side of the clamping strap.

In addition, aggregate characteristics have been determined. They influence the strength of the saw blade and thus the Von Mises stress. Similar to previous results, the higher the value, the more likely the critical limits may be exceeded. Either a permanent deformation may occur at the yield strength, or breakage of the disk can occur within the strength limits of the material. The results are presented in the following chapters.

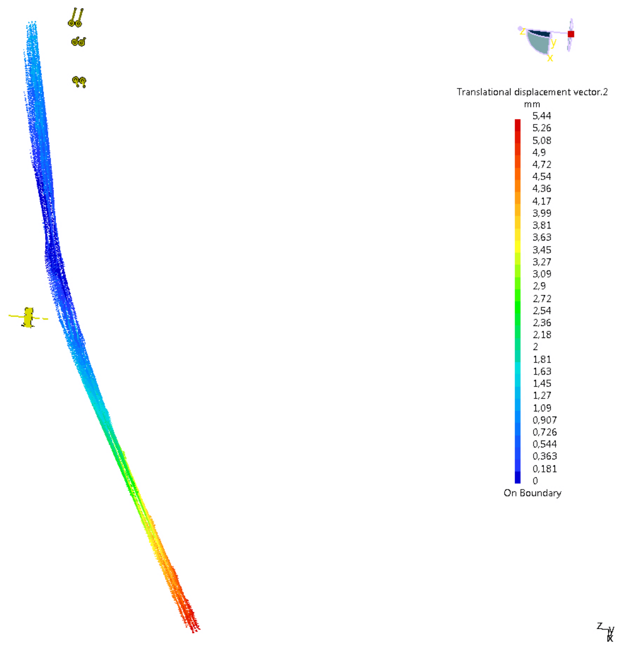

Figure 4. Deformation and circular saw blade displacement

3.2. Determination of the influence of revolution on the strength of the saw blade

Experiment was done in same input conditions. The effect of rotational speed on the strength of the saw blade as the Von Mises stress is examined. According to figure 5, it can be assumed that increasing gears evoke quadratic increase of Von Mises stress in the saw blade. Above lower yield point σ_k a permanent deformation of the saw blade may occur. Considering the equation; a permanent deformation may occur at a speed above 2900 min^{-1}.

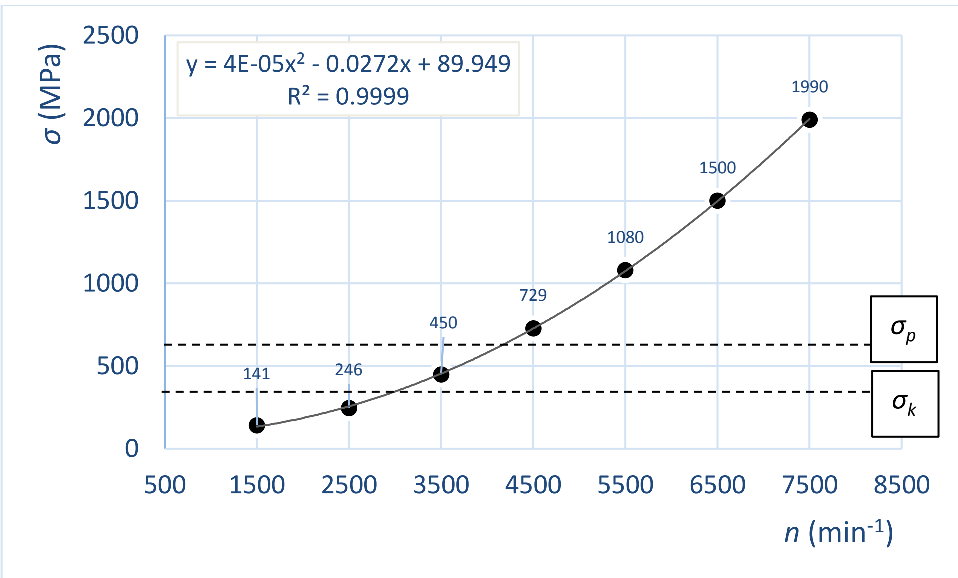

Figure 5. The effect of rotational speed on the strength of the saw blade (α = 1°, F_c = const.)

The following figure 6 shows the size of displacement - blade deformation depending on the speed. Its trend is comparable to the Von Mises stress. According to figure 5 the largest size of the deformation is at the opposite ends from the clamp strap hole of the saw blade. Its size in units of tens of millimetres is determined by the method of clamping the blade and deflecting it in the axial direction. Compared to reality, it is possible to evaluate the trend of deformation, but in practice the clamp of blade is not only a strap but also a clamping on flange which, in the axial direction significantly prevents deformations and thus undesirable cutting of the material.

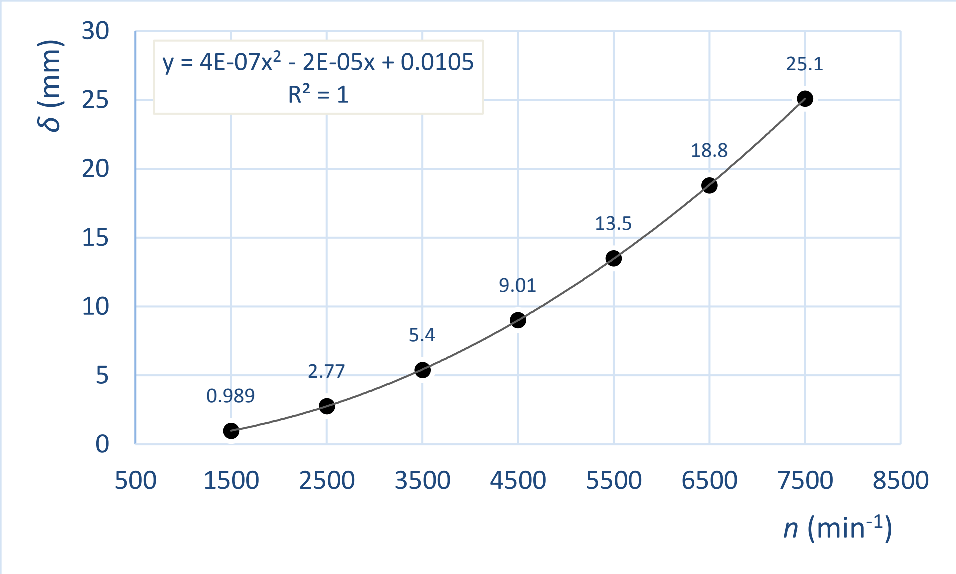

Figure 6. Effect of rotational speed on size of displacement of the saw blade (α = 1°, F_c = const.)

3.3. Determination of the effect of the cutting forces to the saw blade strength

Results of rotating saw blade (n = cons. = 3500 min^{-1}) and its dependence on size of cutting forces are important. They simulate effect of cutting process and may serve to predict result of cutting process in dependence of machined material (hard wood etc.) Linear dependence was determined between Von Mises stress and tangential force F_c and has mathematical interpretation:

$$\sigma = 0.7326 \times F_C + 340.12 \quad (1)$$

as demonstrated in the figure 7.

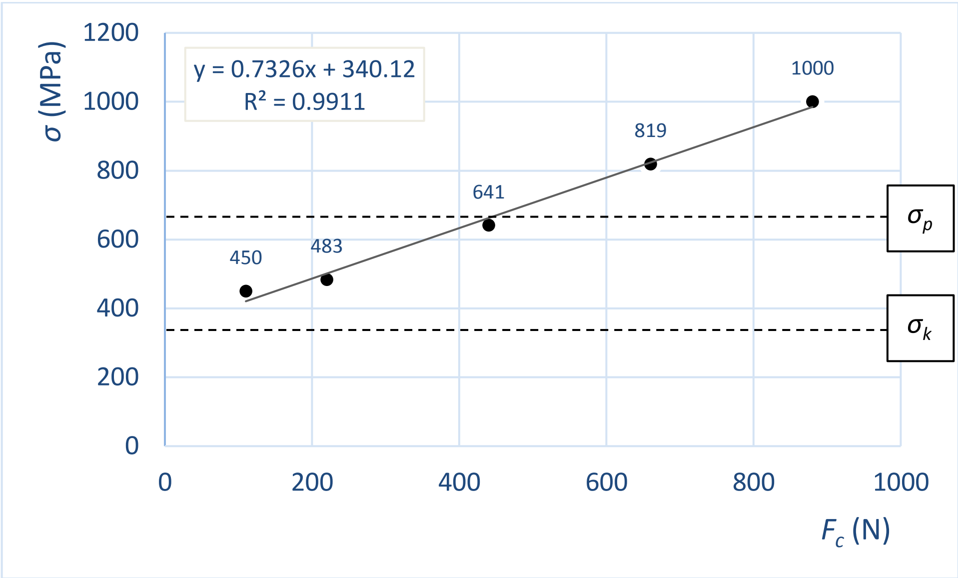

Figure 7. Effect of tangential force F_c on Von Mises stress
(n = 3500 min^{-1}, α = 1°, $F_c : F_p$ = 2 : 1)

4. Conclusion

At a certain moment, with the simultaneous effects of both cutting and rotating forces, a significant tool deflection may occur, which may cause the disc to break. This extreme deflection was observed in the FEM analysis of the rotating saw blade. In the case of the circular saw blade, the tool continues to permanently deform above 2900 min^{-1}. Clamping is the significant factor influencing stability and strength of the saw blade. In the case of clamping on the key is then the critical area of weakening in the key way of the saw blade.

References

[1] Cristovao L 2013 *Machining properties of wood, tool wear, cutting force and tensioning of blades* (Luleå : Luleå tekniska universitet) p 144
[2] Csanády E and Magoss E 2013 *Mechanics of Wood Machining* (Berlin: Springer) p 202
[3] Echeverri R 2003 *Modeling of static and dynamic components of cutting force in sawing*. B.m. (Colombia : Universidad de Norte) p 191
[4] Fritz K 2011 *Manufacturing Processes 1: Cutting* (Wien : Springer) p 506
[5] Kováč J and Mikleš M 2010 *J. For. Sci*. **56**, 271–7
[6] Markopoulos A P 2013 *Finite Element Method in Machining Processes* (London : SpringerBriefs in Applied Sciences and Technology) p 92
[7] Stakhiev Y M 2003 *Holz als Roh- und Werkst* **61**, 13–22
[8] Wojtowicki J, Beslin O and Nicolas J 1994 *Can. Acoust.* **1**, 105–6
[9] Mikó B, Szegh I and Kutrovácz L 1999 *Period. Polytech. Mech. Eng.* **43** 97–106
[10] Otko T and Zębala W 2016 *Precision Machining VIII* **686** 33–8
[11] Kandráč L, Maňková I, Vrabeľ M and Beňo J 2014 *Appl. Mech. Mater.* **474**, 192–9
[12] Kandráč L, Maňková I, Vrabeľ M, Beňo J, Stahovec J, Durakbasa M N, Bas G 2014 *Appl. Mech. Mater*. **693**, 358–63
[13] Matras A. 2017 *Proc. SPIE 10445, Photonics Applications in Astronomy, Communications, Industry, and High Energy Physics Experiments 2017* (Wilga : SPIE) 1044515
[14] Oravcová J, Košťál P, Delgado Sobrino D R and Holubek R 2013 *Appl. Mech. Mater*. **309** 20–6