THEORETICAL ANALYSIS OF CUTTING CONDITIONS OF A SAW BELT WITH THE SPECIAL GEOMETRY OF TEETH

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Abstract
The paper presents the theoretical analysis of cutting conditions in the course of wood sawing by a thin saw belt with the special geometry of teeth. The principle of sawing is combined, viz. in the first stage, a chip is separated and in the second stage, the plastic deformations of wood are used. A supposed contribution of the study consists in reducing the saw kerf, achieving the smaller roughness of wood surface and strengthening the cutting surface. At modelling energy elements, the saw belt thickness up to 1 mm is supposed and the saw belt cutting speed should be 35-100 ms^{-1}. A basic condition for the realization of the given principle is using dynamic effects of a proposed tool, which produce elastic and plastic deformations in the zone of the tool action on wood.

Keywords: *saw belt, tooth geometry, energy elements of cutting*

INTRODUCTION

The production of sawn timber by traditional technologies of sawing is theoretically well described and methods for the determination of energy elements are proved by long-term experience and practice. At these technologies, a chip originates and the tooled surface shows certain roughness. At present, improving the parameters of sawmill technologies is particularly aimed at increasing the quality of cutting tool materials, increasing cutting and feed speed and at the field of partial adjustments of the geometry of teeth with an endeavour to achieve higher technological parameters.

The aim of the paper is to present quite another view of the technology of sawn timber production – to replace the chip-forming principle of sawing by a combined principle. A basic idea is to use properties of rough timber, particularly its ability of plastic and elastic deformation. Under these conditions, a special geometry of the cutting tool tooth presented on the saw belt of a mobile band saw is designed (Fig. 1). A condition for the implementation of the cutting process is to design the theoretical model of determining energy elements at this method of sawing, which is presented in the paper. Testing the theoretical model by an experiment is included in another paper.

In the previous period, experiments were carried out with the knife-shaped geometry of teeth. Results are given, eg in [3], [4], [5].

A PRINCIPLE OF THE SPECIAL GEOMETRY OF A CUTTING TOOL

Geometry of the saw belt tool is based on the conventional tooth system of a thin saw belt. The tool is designed in such a way all teeth to cut and, at the same time, the teeth to carry out smoothing the material. All teeth are set. To simplify calculations, it is possible to suppose that every tooth cuts out just one half of material from the saw kerf. A scheme is evident in Fig. 1.

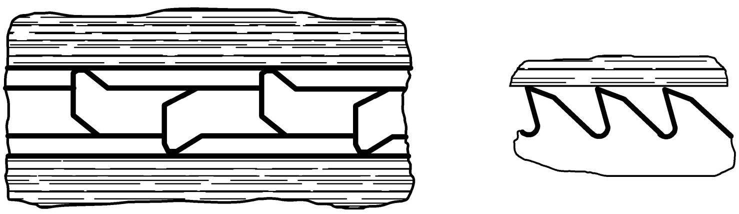

Fig. 1 The designed principle of the special geometry of teeth of a band saw

THEORETICAL ANALYSIS OF THE DETERMINATION OF ENERGY ELEMENTS

The theoretical analysis results from an analytical method described, eg in [1]. Known relationships are valid for the cutting part of a tooth. For the part of a tooth, which uses plastic deformations of the saw kerf surface the model of the surface deformation by smoothing teeth can be derived from known relationships for mechanical phenomena of the process of sawing. The greatest pressure deformation occurs in the nearest layers of particles to areas of operation under smoothing teeth gradually decreasing in farther layers. We start from findings on compression and shear stress on parts of edge under the plane of shear and on the cutting wedge back.

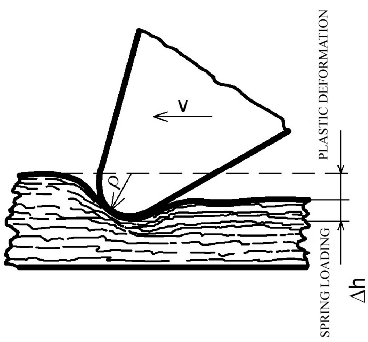

Fig. 2 Effects of the edge blunting radius on the deformation of wood

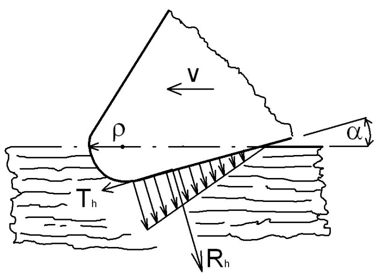

Fig. 3 The distribution of pressure on the back area of a cutting tool

The rate of compression deformation on the back side of a cutting edge depends upon the radius $\boldsymbol{\rho}$ of the edge blunting and the chip thickness $\boldsymbol{h}$. At $\boldsymbol{h} \leq \boldsymbol{\rho}$, the chip does not originate. A layer deformed by pressure to a depth = $\boldsymbol{\rho}$ springs backward by thickness Δ, see Fig. 2.

Through the difference ***ρ* -*Δh*,** the rate is expressed of the plastic deformation of a cutting area by a cutting wedge dependent except ***ρ*** on the species of wood, its moisture and model of sawing (***Δh⊥*** > ***Δhll***). Approximate values of spring loading (***Δh***) given by literature are (for basic models of sawing) as follows: according to [1]: ll: 0.01 ÷ 0.06 mm, ⊥ 0.05 ÷ 0.12 mm.

Force conditions on the back area of a cutting wedge (see Fig. 3) can be characterized as a resultant force of the wood compression perpendicular to the cutting wedge back. Its size is expressed by the relation (1) according to [1]:

$$R_h \cong \frac{m\rho^2\left(1-\sin^2\alpha\right)}{2\sin\alpha} \tag{1}$$

where ***m*** is the coefficient of wood elasticity in compression.

Thus, a frictional force on the back will be as follows:

$$T_h = f \cdot R_h = f \cdot \frac{m\rho^2\left(1-\sin^2\alpha\right)}{2\sin\alpha} \tag{2}$$

Through adjustment in the direction of the band movement we can obtain the resultant force equation acting on the cutting wedge back:

$$F_h = T_h \cdot \cos\alpha = f \cdot \frac{m\rho^2 \cdot \cos^3\alpha}{2\sin\alpha} \tag{3}$$

The coefficient of wood elasticity ***m*** is dependent on the species and moisture of wood (≈14÷85 Nmm^{-3}). The coefficient of friction ***f*** is dependent on the species of wood, model of sawing, radius of the edge curvature ***ρ*** and cutting velocity. The coefficient of friction between the tool and wood has not been exactly studied yet. There are only too little experimentally measured values (for conditions h=0.1 mm, w=9% and T=20°C, model of the elementary ll sawing) given in [1].

For our case, a situation given on Fig. 4 holds good. Because pressure conditions on the tool back have not been exactly explored yet a following condition is selected.

In order the surface to be treated it is necessary to overcome at least the material bruising limit. The area ***S*** of bruising in mm^2 is evident in Fig. 4. Bruising is the permanent change of the wood surface caused by external forces. Bruising takes place at that time if the actual contact pressure overcomes the characteristic stress of the surface layer material.

If the smoothing tooth is to create surface changes it is necessary to add friction force caused by bruising to force $\boldsymbol{F_h}$. The total force acting on the smoothing tooth in the direction of movement is as follows:

$$F_c = F_h + f \cdot \sigma_o \cdot S = f \cdot \frac{m\rho^2 \cdot \cos^3\alpha}{2\sin\alpha} + f \cdot \sigma_o \cdot S = f \cdot \left(\frac{m\rho^2 \cdot \cos^3\alpha}{2\sin\alpha} + \sigma_o \cdot S\right) \tag{4}$$

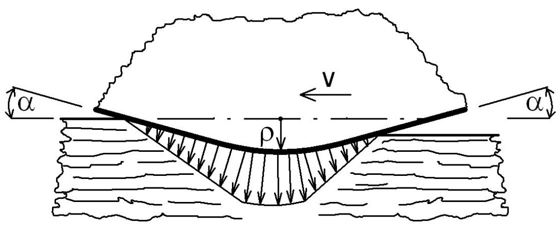

Fig. 4 Distribution of pressure on the area of a smoothing tooth

Necessary power per one smoothing tooth is given by the product of force $\boldsymbol{F_c}$ and cutting speed $\boldsymbol{v}$:

$$P_c = F_c \, . \, v \tag{5}$$

To determine cutting power for cutting teeth an analytical method is used. Thus, the total power for smoothing teeth is then directly proportional to the number of smoothing teeth in the saw kerf. It is important for the geometry designed that all teeth smooth the material. Every tooth cuts one half of the material in the saw kerf. Generally, the cut is carried out by one half of the total number of teeth:

$$P_k = P_c \cdot \frac{e}{t_z} \tag{6}$$

Based on the condition mentioned above it is necessary to adjust the number of teeth, which act in the cutting process in one cycle of the saw belt according to relation (7), where $\boldsymbol{D}$ is the moving wheel diameter, $\boldsymbol{A}$ is clear width between the wheels and $\boldsymbol{t_z}$ is tooth pitch (spacing).

$$z = \frac{\pi \cdot D + 2D + A}{t_z} \cdot \frac{1}{2} \tag{7}$$

Other relations already correspond to the standard theory. Total cutting power is determined as the sum of cutting and smoothing power.

$$P = K \, . \, b \, . \, e \, . \, u + P_k \tag{8}$$

CONCLUSION

The proposed methodology of determining energy elements results from a generally known analytical method, which was modified for the designed combined geometry of teeth of a saw belt. At experiments with this geometry of teeth and their possible modifications consistency of measured results with theoretical calculations was proved. Results of experiments are presented in another paper. The methodology of measurements is the same as at monitoring phenomena in knife-shaped geometry of teeth, see, eg [5].

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