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THE ANALYSE ACTIVITY OF CUTTING FORCES FOR THE CHIPLESS CUTTING WOOD

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Abstract

On the score of largeness energic slope and value delimbing (expurgation xylem stuff trunk from limb) is very important analysis cutting forces in process delimbing. The paper shows investigation and influence on chosen technological parameters machine delimbing to improve the process of the cutting of bough and increase of qualities machine delimbing during tree processing. This paper is intent on evalutionof influence on individual aspects at cutting force with keep to the terms of delimbing that are tobe used at machine delimbing. The analyse of the cutting forces in the process of delimbing is important with aspect to energy losses and the quality of delimbing (delimbing of tree trunk).

Key words: *cutting force, cutting speed, chipless cutting*

INTRODUCTION

The part of felling machines is technological or manipulation device, which does main operations like cutting, delimbing, shortening and other manipulation of a tree. The most important task in this area is optimization of technical and technological parameters of cutting mechanisms (KOVÁČ J., 2005). The general requirements for cutting mechanisms are high cutting property, operational reliability, durability of a tool, low requirements for operation and maintenance, weight and suitable quality of work (Kováč J., 2004).

The process of chipless wood cutting looking like operation of tree delimbing, which is used in all sorts of multifunctional machines is characteristic by quantity parameters. There are realized theoretical and experimental works in the area of chipless transverse separation of wood with delimbing and at barked wooden assortments, with analysis of dynamic and kinematic parameters (Marko J., 2008). There is paid attention to the score of most often used technologies at multifunctional machines. A lot of factors deal with main qualitative indicators e.g. cutting force, quality of section, wearing resistance of a cutting edge, etc (Lisičan J., Siklienka M., Zemiarová B., 1994).

Power necessary on transposition tree near breaking down limb in branch chaplet must overcome cut and grinding resistance.. Specification of these forces will permit to determine the power of drive e.i. energetic intensity of delimbing process. It is necessary to do force analysis of forces which works in parallel with an axis of wooden tunk (Marko J., Holík J., 1994). The base for this analysis is investigation of force arangement, which are produced at cutting by the knife with its shape of wedge and with the dorsal angle $\alpha = 0°$ (Fig. 1). At the same time we get a picture about character of sawing, which takes part in

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the area of non - chips producing process through the medium of knives in the direction which is discordant with the direction of fibres on sawing wood (Mikleš M., 1994).

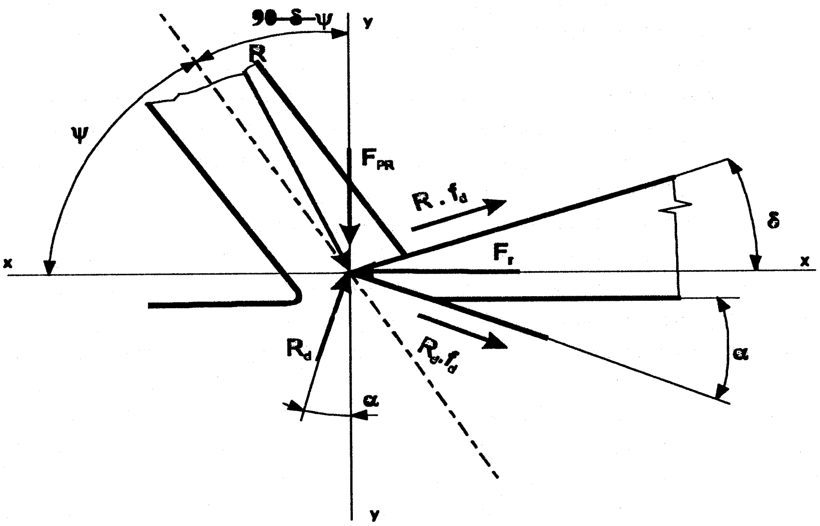

Fig. 1 Application cutting forces in the delimbing

Formation of balance formula of forces in the direction of axis x, y:

$$\sum F_X = 0; \; -F_{PR} + R_d.(\cos\alpha - f_d \sin\alpha) - R.(\cos\delta - f_d \sin\delta) = 0 \qquad (1)$$

$$\sum F_Y = 0; \quad F_R - R_d(f_d \cos\alpha + \sin\alpha) - R(f_d \cos\delta + \sin\delta) = 0 \qquad (2)$$

On base of knowledge from theory of elasticity and hardness we form the formula, which defines the violence of limbs at local deformations of combined stress (from the knife) on tension and bend. After the reform we get:

$$R.\sin(\delta + \psi) - \frac{\sigma.S.W}{(W + eS)} = 0 \qquad (3)$$

where:

F_{PR}– compressive force of knife toward the trunk, (N)
R_d – reaction of trunk on the back of the knife, (N)
R – reaction of a branch on the forehead of knife, (N)
f_d – coefficient of friction between the surface of knife and wood of a limb, (-)
s – stronghold limit of limbs on the tension along (in the direction of) fibres, (Mpa)
S – area of a part of the branch which is not cut, (mm)
W – three-dimensional modulus in bend, to z-axis, (mm3)
e – elentricity of a branch cross-section, (mm)
δ – cutting angle, (°)
a – dorsal angle of a knife, (°)
ψ – growth angle of the branch, (°)

When we project all forces to axis y, we get:

$$F_{PR} = R.\cos\delta - R.f_d.\sin\delta - R_d \quad (4)$$

The study of authors (Koceragov, Mensikov) demonstrated and our study has certified (Jandel, Mikles, Koren, Marko) that reaction of forces on a knife from ability of elastic reversibility of fibers we can omit. According to general law of wood sawing, compression of fibers will take a part at constant tension on the dorsal and frontal surface where the wood elasticity is characterized at bending and compression of fibers by numerical data. In that case the general pressure on the surfaces of a knife can be simplified and it is proportional to the perimeter of penetrated part of a knife. Frictional force $R_d.f_d$ at big thickness of a chip (over the 5 mm) generates 1,0 - 1,5 % from the whole cutting force. Collapsing length of limbs, where the creation of chips is turned off, is equal to 40 - 50 mm. It follows that forces R_d and $R_d.f_d$ we can omit like minimal. Then mentioned formula gains pattern:

$$F_{PR} = R.\cos\delta - R.f_d \sin\delta \quad (5)$$

The fulfilled condition refers for the quality of delimbing that comprehensive force F_{PR} has to be bigger than reaction force of knives, which reacts opposite the force of comprehension.

MATERIAL AND METHODS

At the production of experiments as the main roll is comparison of cutting force with the magnitude of cutting resistance with reference to quality of cutting process according to the changing parameters which limbs cutting defines. The goal of measurements was comparison of cutting speed according to the magnitude of cutting resistance with the reference to the quality of delimbing process. The tests were made on the machine for cutting of wood by high speed with reversible movement of cutting mechanism. The power of cutting mechanism was performed by pneumatic cylinder. It was designed by professor Mikleš and made at VDL TU in Zvolene.

At laboratory experiment of delimbing measurements there was studied maximum cutting force characterized by the rest and by the rip of a limb at the speeds of 1,5 $m.s^{-1}$, 2,0 $m.s^{-1}$ and 2,5 $m.s^{-1}$. The technical parameters of tested knives are shown in Tab. 1. The individual speeds of knife movement result from the scale of the pressure magnitude which was justified in a pneumatic engine at the pressure of 0,8 MPa. There was measured 3,12 $m.s^{-1}$ by a sensing device of acceleration a maximum speed of piston motion and it was produced in program NEXT WIEV 2.5, at the speed of 2,48 $m.s^{-1}$.

Tab. 1 Technical parameters of tested knives

No.	δ(°)	α(°)	h(mm)	s(mm)	ρ- radius of a cutting edge
1	20	7	2	15	0,012-0,025
2	15	4	2	15	0,012-0,025
3	20	4	2	15	0,012-0,025

The character of a cutting force depends on works along the movement of a knife in the process of cutting. The cutting force increases linear and the speed of cutting decreases linear at increasing penetration depth by penetration of a knife. The linear dependency of the cutting force (Fig. 3) changes at penetration depth of a tool approximately at 0,5. d_0, or something less than the half of a limb diameter.

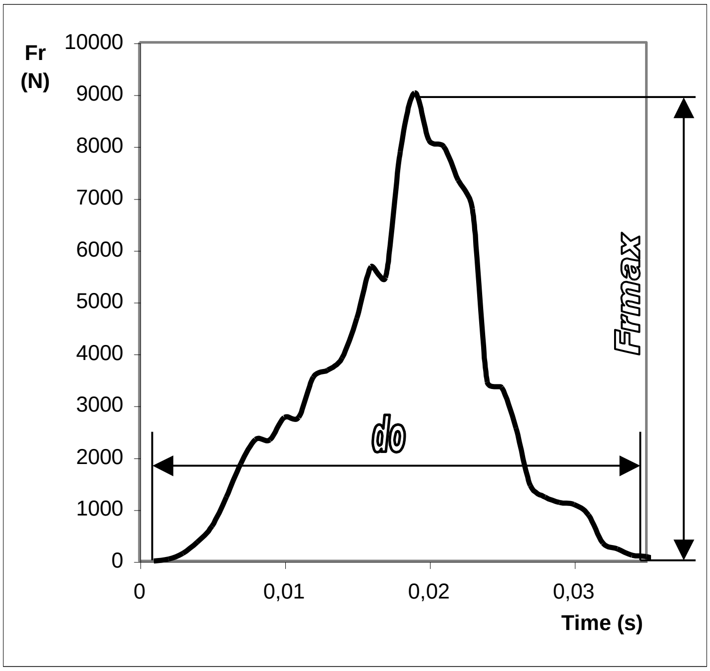

Fig. 2 Course cut force near grained branches

For a spruce the character of dependency changes at cutting by knives with different geometrical parameters and it does not change with increasing limb thickness and also it does not vary with the change of growing angle of a limb in the limits characteristic for given wooden species.

RESULTS AND DISCUSSION

The individual laboratory results of measurements handled in a table form we handled for limpidity in graphical form by MS Excel (e.g. Figures 4,5 and 6). The flows of individual investigated values e.g. the maximum cutting force, the maximum cutting force on $1mm^2$ of the limb surface, the index of low energetic severity and also a qualitative index, at specification of dependent parameters give better scheme at appraisal mentioned parameters from the quality and energetic severity point of view of chipless cutting process.

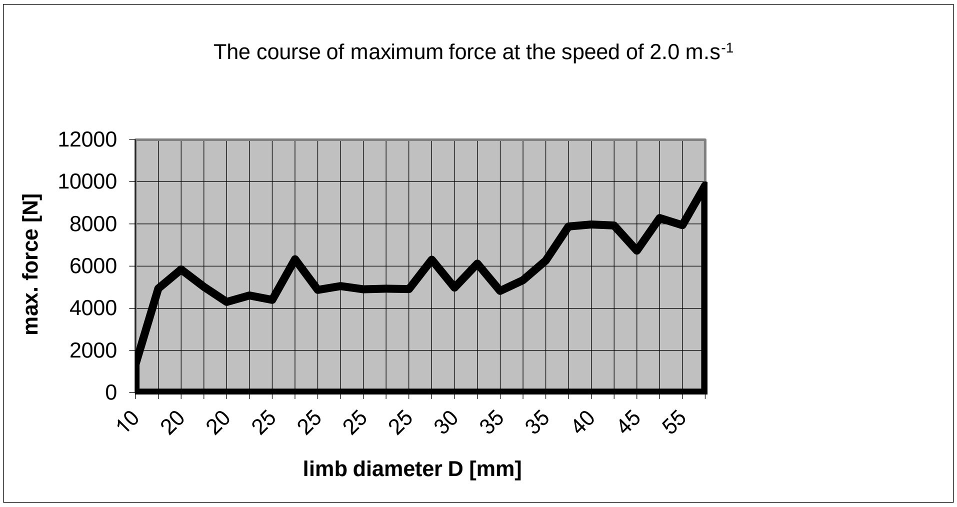

Fig. 4 The course of max. cutting force at the speed of 2.0 $m.s^{-1}$ and knife No.1

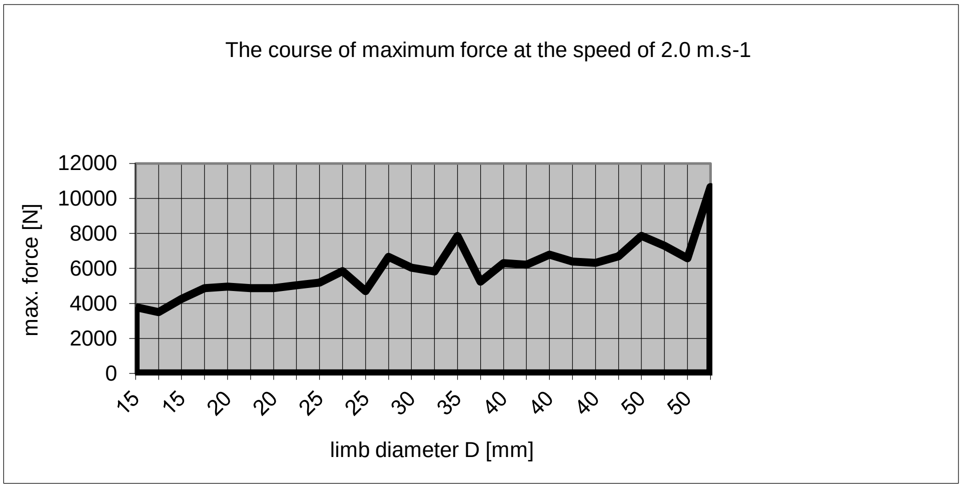

Fig. 5 The course of maximum cutting force at the speed of 2.0 $m.s^{-1}$ and knife No.3

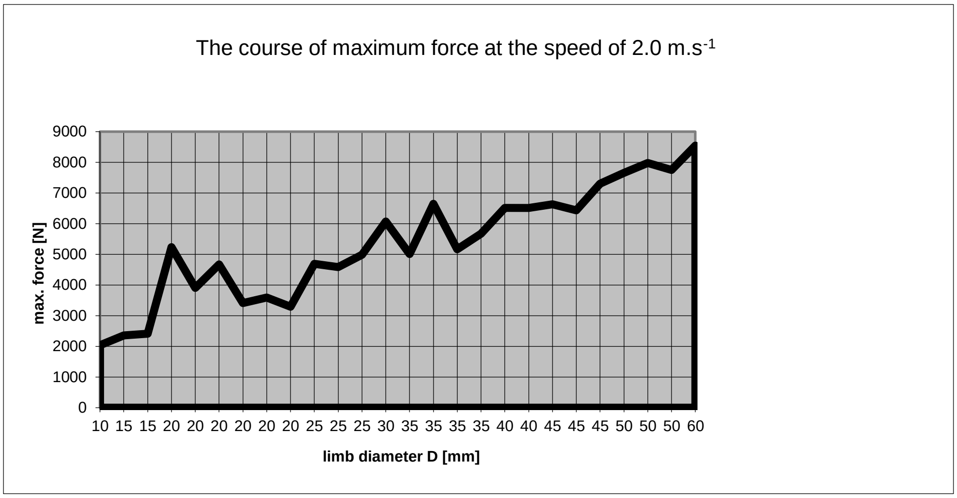

Fig. 6 The course of maximum cutting force at the speed of 2.0 $m.s^{-1}$ and knife No.2

The meaning is in statistical knowledge. The processes have relative comparison with an individual selected pack at studying properties of chosen packs. For investigation of relative dependency on multiple factors in maximum cutting force of delimbing there was used covariance of multi-factorial analysis called ANOVA.

The results of statistical features are shown in Table 2 for the dependency among maximum cutting speed (2), type of a knife (1) and limb diameter (3). There were shared to two classes DP1 – limbs at diameter of 0 to 35 mm; DP2 – limbs at diameter of 35 to 55 mm; the majority of diameters occur in these two classes.

Tab. 2 Attributes statistical characterization dependencies max. cut strength on diameter limb, cut speed, unmarried husband knives, Summary of all Effects; 1-NOZ, 2-VUU, 3-DUP

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	3	21033206	283	1533050,63	13,720	0,000
2	2	5998744,5	283	1533050,63	3,913	0,021
3	1	332425824	283	1533050,63	216,839	0,000
12	6	436176,34	283	1533050,63	0,285	0,944
13	3	468428,94	283	1533050,63	0,306	0,821
23	2	681868,19	283	1533050,63	0,445	0,641
123	6	1639006,4	283	1533050,63	1,069	0,381

df effect - degree of freedom for factor,
MS effect - scatter (average square) for input,
df error - residual degree of freedom for accidental anomalies,
MS error - scatter (average square) for accidental anomalies,
F - Fischerov F-test, share scatter infliction input and scatter infliction adventitious effect,
p-lion - significance level test

From the results it is evident that the biggest statistical effect has the type of a knife and there is a cutting speed of small statistical account, diameter of a limb has also very important statistical effect on maximum cutting force, it confirms assumptions acquired throughout measurements (so the diameter of a limb has the biggest effect on the maximum cutting force, then the type of a knife and the cutting speed has small statistical effect). All three factors work independently without interaction. The differences among knives vary at different speeds and different diameters of limbs.
The smallest maximum cutting force is at the knife No. 3, i.e. verification of correctness of geometry selection of a knife mentioned in methodology of work of the academic dissertation. For more accurate statistical interpretation we made multi-regression, where we got following mathematical model expressed by a pattern of regression in the second grade of dependency between maximum cutting force and mentioned independent parameters (Kováč J., 2004).

When the effect of speed is not significant then formulas for specification of maximum cutting force depend on significant factors (diameter of limbs and type of a knife) as following:

a.) at the cutting speed of 1,5 m.s^{-1}

$$F_{R,\max} = -38{,}125 + 207{,}487d + 601{,}91 n\hat{o}\check{z} - 1{,}388d^2 + 6{,}573d \cdot n\hat{o}\check{z} - 185{,}212 n\hat{o}\check{z}^2 \qquad (6)$$

b.) at the cutting speed of 2,0 m.s^{-1}

$$F_{R,\max} = 693{,}16 + 173{,}732d + 545{,}401 n\hat{o}\check{z} - 0{,}728d^2 + 0{,}767d \cdot n\hat{o}\check{z} - 146{,}447 n\hat{o}\check{z}^2 \qquad (7)$$

c.) at the cutting speed of 2,5 m.s^{-1}

$$F_{R,\max} = -647{,}936 + 277{,}969d + 719{,}312 n\hat{o}\check{z} - 2{,}378d^2 + 3{,}512d \cdot n\hat{o}\check{z} - 199{,}326 n\hat{o}\check{z}^2 \qquad (8)$$

CONCLUSION

The results of experiments always have relationship to exact cutting conditions. The cutting force as one of main parameters establishes material quality, shape dimensions and energetic consumption of a cutting tool (Marko J., 1993).
Discovered values of cutting forces, designed parameters of cutting tools, knowledge about decreasing defected area of wood at delimbing process make exact results for projection of cutting tools, dimensioning operational parts and estimation of asked power consumption of harvesters and processor heads of felling machines. Obtained results and knowledge can be applied at projection of working mechanisms in the harvester heads, respectively also at the development of cutting mechanisms and process parameters of chipless cutting for some working machines in forest depots in the commercial forestry of the Slovak Republic (KOVÁČ J., 2005).

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