NUMERICAL INVESTIGATION OF DISC TOOL PENETRATION FOR DIFFERENT VALUES OF TOOL CUTTING EDGE ANGLE

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Abstract

The paper contains nonlinear numerical analysis of 20 mm diameter disc tool caving into wooden roll for different tool cutting edge angles (in the range from 10^o to 31^o). Earlier numerical models of knife and wooden roll were used to create models of successive calculation variants of cooperating elements. The obtained data which were the result of conducted analysis are patterns of normal stresses perpendicular to wood fibres. Courses of the highest values of stresses in the function of cutting edge angle of a tool to machined material was presented.

Key words: *FE-nonlinear analysis, contact analysis, wood, disc tool, stress patterns, normal stresses perpendicular to fibres*

INTRODUCTION

The modern lathes are equipped in classical turning tools [PN-64 D-55000][12], which practical uses are limited. The methods of turning determine the choice of a tool (Fig.1). The construction of edge of a given tool settles the it name and usage like for example knives for external or internal usage, from flat knifes, flat slanting, reversible slanting to. All the above mentioned are homogenous ones.

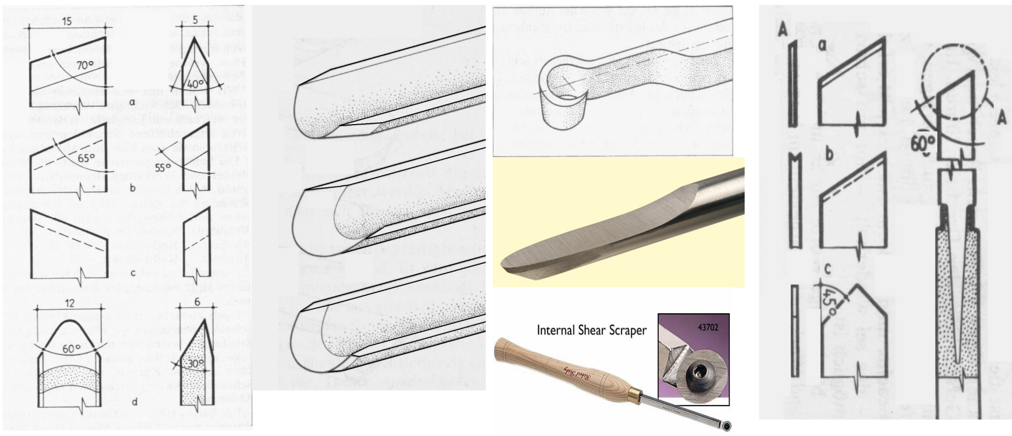

Fig.1 Different shapes of knives for turning wood

Currently used turning tools should be complemented with such tools which could be used in more and more difficult machining conditions. Such knives could be folding knives in which replaceable edges are fixed mechanically like in the knives used for turning metal. They have already been used to turn wood products modified by styrene [1,3,8].

Growing demand for production of turned wood for garden and playing grounds for children equipment as well as usage of wood of small diameters resulted in the interest of disc tool containing round shape of cutting edge and stable rounding radius. They are used in different forms and are similar in shape to "hook" type of knife which have been known for very long time[12].

MATERIAL AND METHODS

The introductory numerical research conducted earlier for cutting edge angles of 10°, 20° and 30° have shown the fall of normal stresses perpendicular to fibres for angles of 20° [6]. It was decided to conduct more detailed research of this phenomenon.

Numerical analysis

For the construction of calculation models the knife model (diameter 20mm) and wooden roll (diameter 150mm and length 60 mm) from earlier investigation were used (Fig.2) [6].

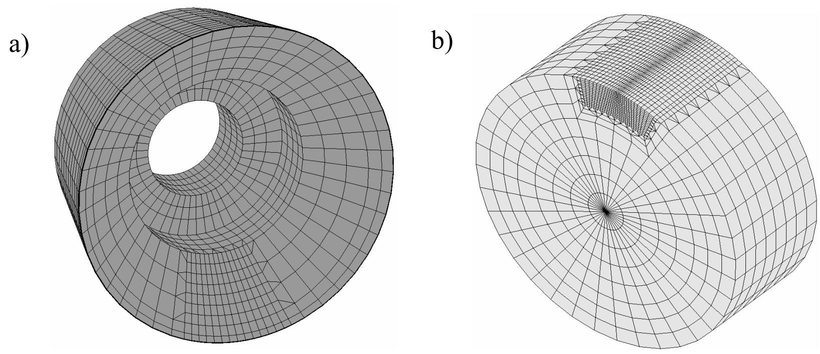

Fig.2 FE-models: a) knife; b) pine roller

The variants of calculation models were generated for the following cutting angles of the tool χ: 10°, 12°, 14°, 15°, 15.25°, 15.4°, 15.45°, 15.5°, 16°, 17°, 18°, 19°, 20°, 21°, 22°, 23°, 24°, 26°, 28°, 29° and 31° (Fig.3a).

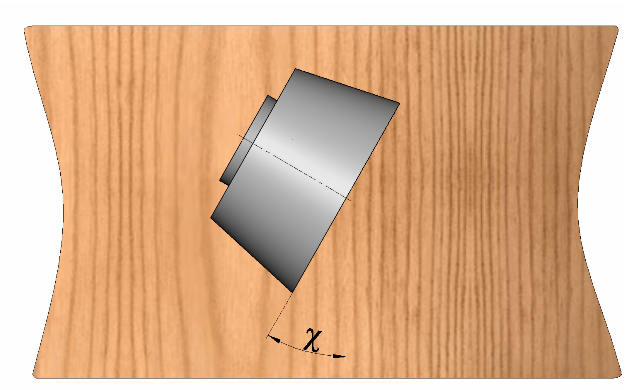

Fig.3a The variant cutting edge angle χ

In the contact area of cooperating elements the net of finite elements was compressed (Fig.3b) and surfaces and contact pairs were defined. Between the knife and the wooden roll friction coefficient of μ=0.1was assumed.

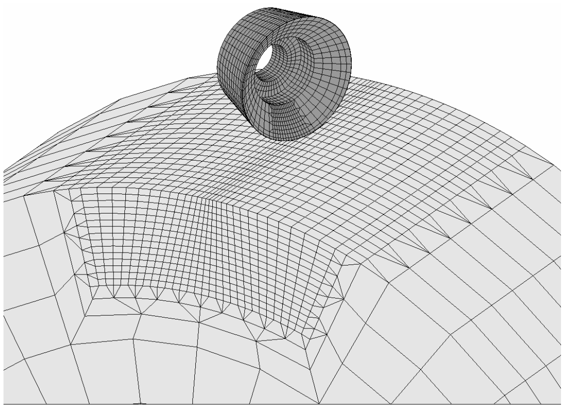

Fig. 3b The nets of finite elements in the area of contact of cooperating elements

The edge conditions fit the assumed conditions in earlier research [6]. The material models, isotropic for the knife and orthotropic for wood were assumed analogically to the earlier research [4,5,6,7,11].
Nonlinear static analysis were accomplished for two displacement values (0.01, 0.05 mm) for each of cutting edge angles.

THE OBTAINED DATA OF NUMERICAL ANALYSIS

The conducted numerical analysis resulted in obtaining stress patterns and displacements. The stress patterns presented in the latter part of the paper (Fig.4) are limited to normal, perpendicular to fibres and obtained for knife replacement of 0.01 mm [4, 5, 6, 7].

The stress patterns presented in Fig.4 were chosen for cutting edge angles accordingly 15^{o} and 16^{o}. The patterns show as it was noticed in earlier investigations [6] an insignificant asymmetry. The sudden fall of analyzed stresses for cutting edge angle of 16^{o} needs special attention.

The data analysis
The data analysis contains determination of investigated stress patterns on the surface of the wooden roll in longitudinal and perpendicular directions (Fig.5) in the surfaces illustrated in Fig.4a and 4b. Fig. 5 (below) shows graphic dependences for different cutting edge angles from Fig. 4. Additionally on the basis of the given stress patterns, the highest value of the analyzed stresses depending on cutting edge angle, were shown graphically (Fig.6). It was assumed for the transverse section, that for the highest values are average from nodes distant from cutting edge of the knife of accordingly - 0,5595 and -1,207 (compare Fig.5). These nodes are situated under the tool flank.

Values of tool cutting edge angle

$\chi=15^{o}$ $\chi=16^{o}$

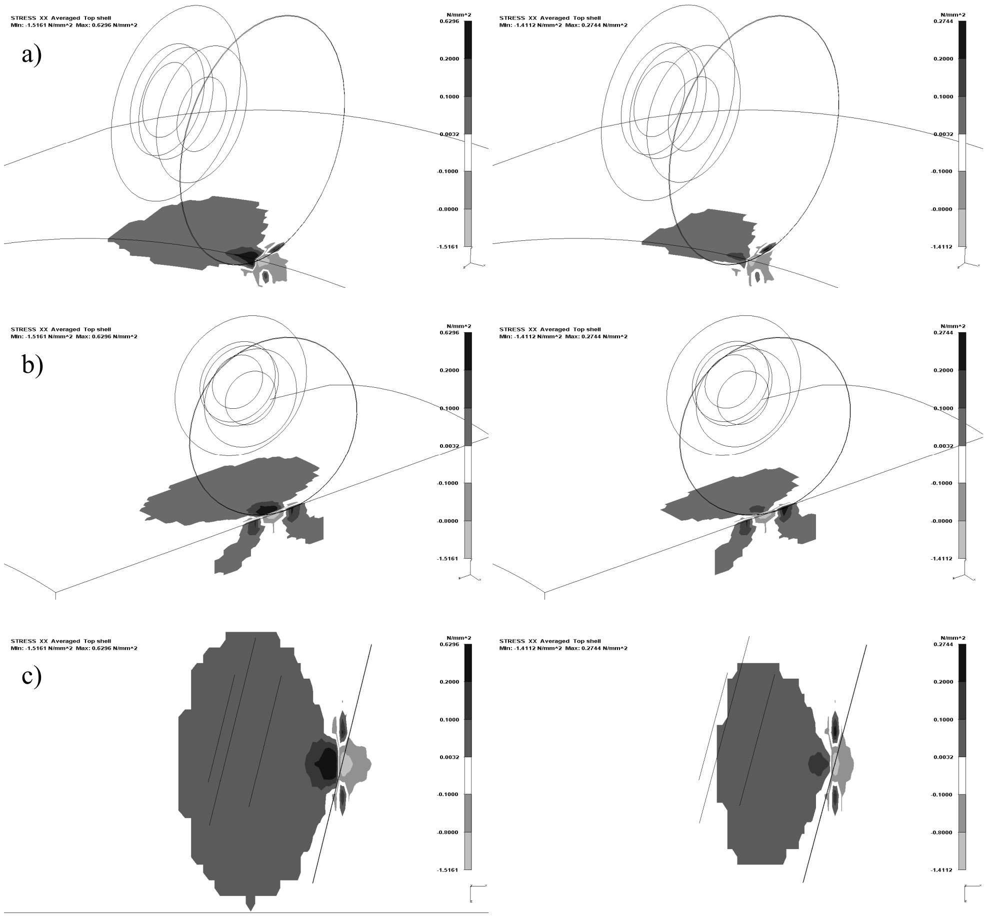

Fig.4 Normal stress patterns perpendicular to grain for cutting edge angle of 15^{o}:
a) on the surface of the roll and in transverse section in the point of contact with the tool
b) on the surface of the roll and in longitudinal section in the symmetry plane of the roll
c) overview

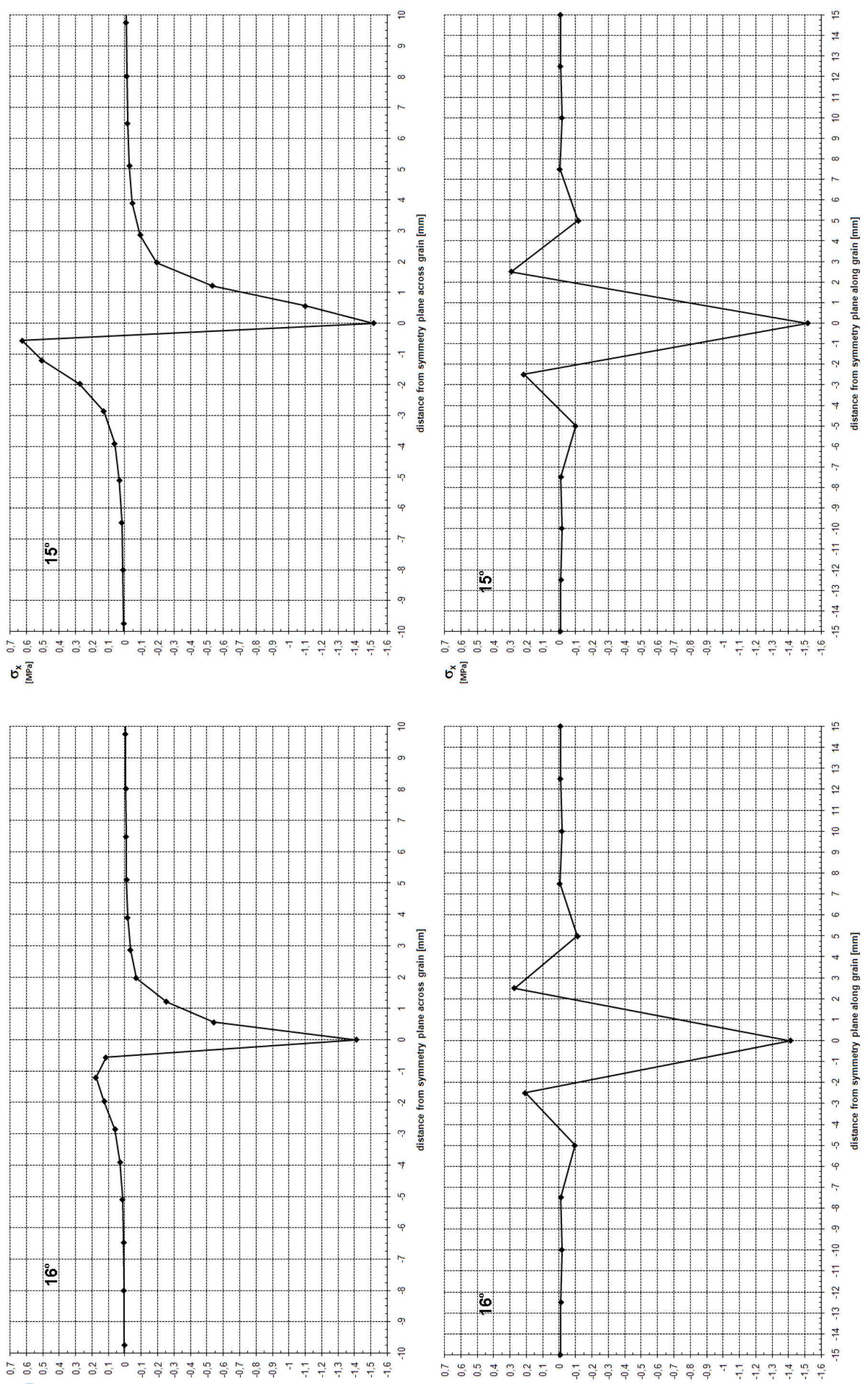

Fig. 5 The graphic representation of normal stresses perpendicular to grain on the surface of wooden roll in transverse and longitudinal section

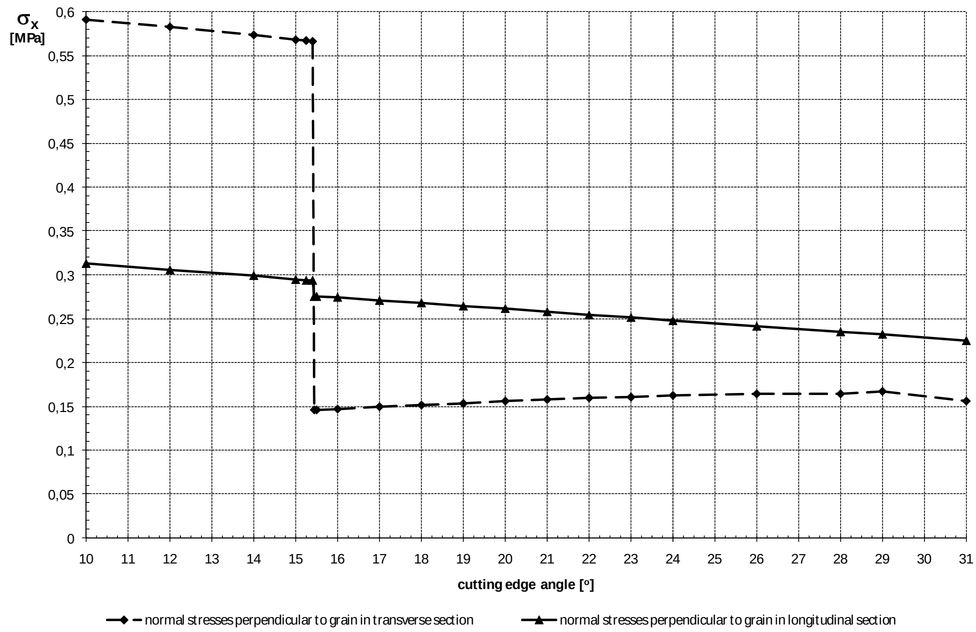

Fig. 6 The graphic representations of the highest values of normal stresses perpendicular to grain in transverse and longitudinal sections of wooden roll in the function of a tool cutting edge angle

CONCLUSIONS

Because of problem connected with numerical modeling of wood [9,10] the analysis and presented data is limited to displacement of 0,01 mm. The significant observation resulting from the conducted calculations is sudden fall of stresses observed on the surface of the roll in transverse section in the point of contact with the tool. The fall for the given data is between 15.4^{o} and 15.45^{o}. For higher angle values cutting edge angle oscillates slightly. It should be stressed that this phenomenon occurs in the beginning phase of tool penetration in wood. Probably the observed fall of stresses is connected with interaction between tool flank and the wooden material possessing orthotropic properties. Additionally the influence on the obtained data has the density of the net -MES (mesh density) in the area of contact of cooperating elements. Further penetration of the knife needs consideration of the phenomenon of consolidation of the material and cracking of wood. That is why further investigation of knife penetration is useless for assumed material model of wood [2, 5, 7 and 10].

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