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# ON THE STRAIN GAUGES MEASURING OF NOTCHED WOOD IN TENSION
# TENZOMETRICKÁ MĚŘENÍ NA DŘEVĚNÝCH VZORCÍCH S VRUBEM

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*Series of tensile test experiments on notched spruce wood specimens have been performed. The relative strain of wood in different distances from notch tip has been monitored by diverse methods (specimen displacement and strain gauges method). A three-dimensional numerical simulation of experiments was additionally carried out by use of ANSYS 6.1 programme. The comparison of experimental and computed results confirmed satisfactory accordance.*

## Keywords

**Wood, notch, strain gauge, finite element, ANSYS, strength, tensile test**

### Introduction

The spruce wood specimens with V notch have been chosen to perform the tensile test. The tested material was Norway spruce (*Picea abies*) from the eastern part of Bohemia. All specimens were fabricated from a single, radially sawn, straight-grained board. The moisture content and density of the tested material were 12 % and 430 kg.m$^{-3}$. The specimen dimensions were in accordance with valid standards and parameters of V notch were: angle – 45°, depth – 2, 4, 5 and 6mm.
The following procedure was performed. The strain gauges have been glued on the specimen surface. The 3/120LY11 type strain gauges were used and placed to the position in front of the notch tip (2 mm from the notch tip). The specimens were then fitted into testing machine ZWICK Z050/TH3A.

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Conventional tensile test followed these procedures and several values were monitored during the experiment.
Geometry of specimen was formed in accordance with Czech/Europe standard specification (CSN/ISO). A one-half model was used because of symmetry. Model script was parametric according to variable shape of notch.

The problem is solved using 3-D solid (SOLID95) and 3-D solid (SOLID45) elements. Due to problem of singularity the crack tip was formed by SOLID95 elements and replaced with SOLID45 using mid-side node position (quarter point location). In the 3-D analysis, the plane strain condition was achieved by constraining UZ degrees of freedom of all the nodes (displacements in the Z-direction). Plane of symmetry on one-half of model was constrained by symmetry boundary conditions. Process of loading was realized by definition of non-zero value of displacement on the top of the specimen, the same as occurred during the experiment.

Mesh of finite element at crack tip was formed by set of prismatic elements, which can tolerate singular point of notch vertex without as much loss of accuracy due to twelve mid-side nodes, six nodes on one element of crack tip and summary twenty nodes per element (Figure 1a).

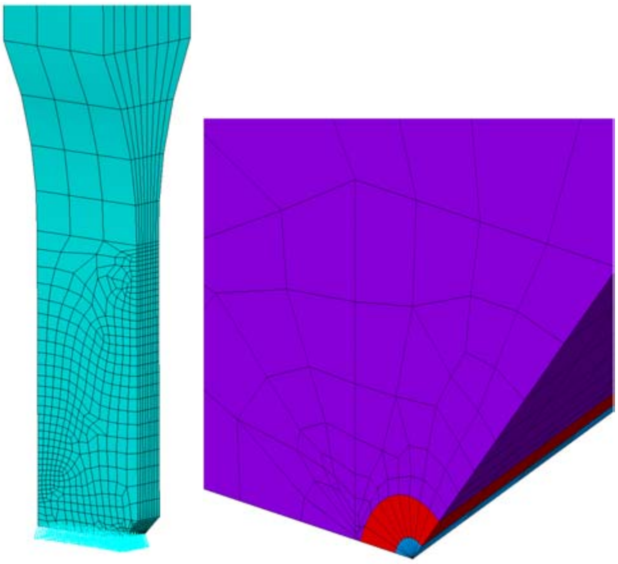

Figure 1 a) FE model of specimen b) Detail of notch tip

Next the space near the crack tip (Figure 1b) was divided by regular, map shaped mesh with an appropriate size of element. Due to smaller significance parts of geometry in farther regions were meshed by SOLID45 finite elements. They support displacement as type of degrees of freedom and differ only in count of nodes per element. Thus, less CPU time is required for element stiffness formation and stress-strain calculation.

## RESULTS

In Figure 2 relationship between strain of strain gauges, ZWICK measurement and notch depth is given. Strain gauge was placed in a distance of 2 mm from notch tip, where the strain or strain alternatively, is of the greatest value.

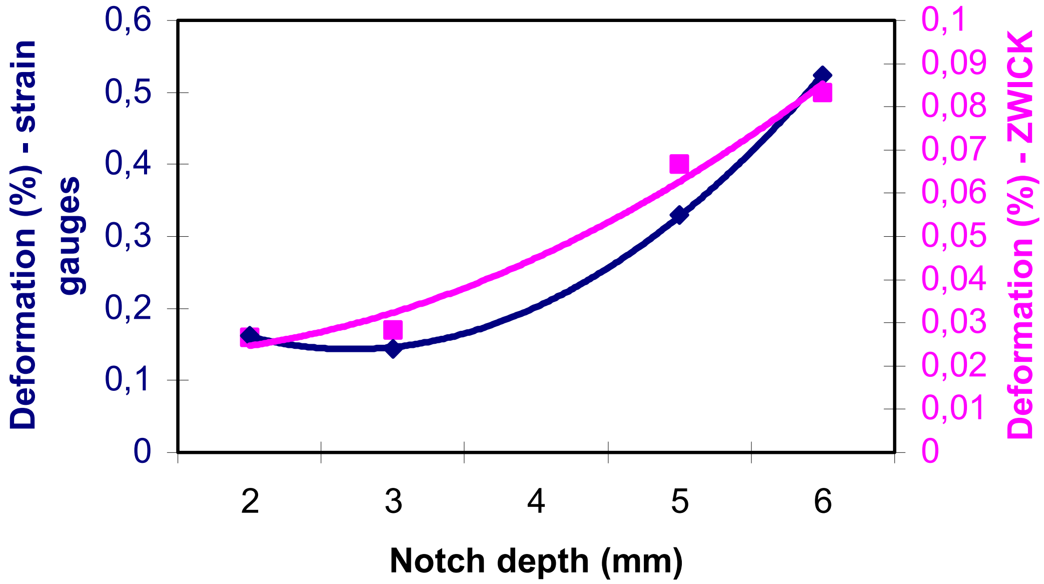


Figure 2 Relationship between strain of strain gauges, ZWICK measurement and notch depth

The values of strain obtained from Zwick machine represent the strain of a specimen part situated between the pulling jaws and recorded by extensometer (80 mm). It is obvious that strain (strain) value changes with increasing distance from notch tip. The average values of these quantities are given in Table I.

These values represent an average from 3 measuring for each notch depth and measuring method. The values of strain around the notch tip (measured by strain gauge) during initial part of loading are generally 3 times greater then values of strain of a whole specimen. Unlike the values during initial loading, the values received during final parts of loading (under greater stress) were approximately 6 times greater. Another type of experiment has been performed in order to complete the concept of behaviour of notched wood loaded in tension. The general layout of experiment was the same as in the last test, but an extra strain gauge was glued on the surface of the specimen (6 mm from the notch tip). This extra strain gauge offers another completion dates about specimen strain in the other area and enables the imaging of a whole process.

| | Notch – 2 mm – strain (%) | | Notch – 3 mm - strain (%) | | Notch – 5 mm - strain (%) | | Notch – 6mm - strain (%) | |
|---|---|---|---|---|---|---|---|---|
| Time (s) | Strain gauge | Zwick | Strain gauge | Zwick | Strain gauge | Zwick | Strain gauge | Zwick |
| 5 | 0,01 | 0,004 | 0,005 | 0,002 | 0,01 | 0,002 | 0,01 | 0,003 |
| 10 | 0,03 | 0,008 | 0,03 | 0,008 | 0,04 | 0,015 | 0,05 | 0,012 |
| 15 | 0,04 | 0,011 | 0,05 | 0,012 | 0,11 | 0,025 | 0,11 | 0,030 |
| 20 | 0,08 | 0,016 | 0,07 | 0,014 | 0,19 | 0,035 | 0,17 | 0,053 |
| 25 | 0,11 | 0,018 | 0,12 | 0,018 | 0,32 | 0,045 | 0,25 | 0,058 |
| 30 | 0,16 | 0,027 | 0,17 | 0,024 | 0,40 | 0,055 | 0,50 | 0,072 |

Table I Values of strain for different notch depths and areas of measuring

The values of strain obtained from strain gauge glued in a distance of 6 mm from notch tip were approximately 30% lower then values from the first strain gauge. The experiment has been performed with a notch depth 5 mm and repeated several times. The approximate difference (decrease) 30% occurred relatively regularly.

Due to consistent matrix of stiffness reduced analyse (with Guyan reduction) was used.

Output distribution of stress and strain near the crack tip was used for evaluation of appropriate equivalent of strain gauge reaction and appreciation of stress/strain gradient.

Evaluated isolines of strain components showed (Figure 3) that strain gauge take into account mainly part at very small distance from crack tip. Due to high anisotropic properties of wood we observed large amount of probable stress/strain distributions that can be integrated by strain gauge. Experiment also emphasized significance of more detailed description of inner structure of wood and difficulties which have to be solved in calibration of strain gauge on this scale of material.

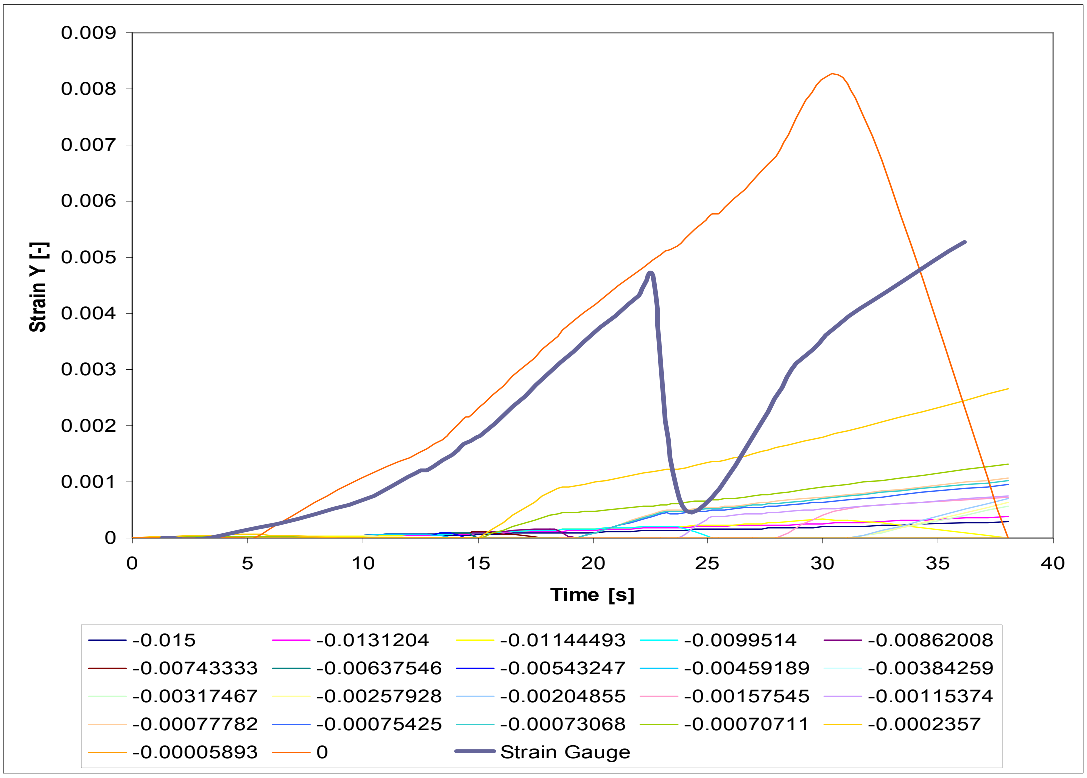


Figure 3 Isolines of strain inY direction with size of notch=5mm

## CONCLUSIONS AND DISCUSSIONS

The data presented in this work suggest that strain in notched wood specimens loaded in tension is approximately 6 times higher in the area directly surrounding the notch then strain of a whole specimen. The strain measured by means of second strain gauge placed 6 mm from the notch tip showed about 30% decrease against strain measured before.

The statistical processing of strain quantities does not enable the clear definition of correlation between the notch depth, stress and size of strain. Such conclusions would require more experiments performed with wider range of notch depths and will be offered and discussed in our forthcoming paper. The distribution of strain and material strain could also differentiate with changes of notch shape. This problematic is also the topic of our forthcoming paper.

But above mentioned results give us an idea about performing of notched wood specimen during the tensile test and numerical simulation offers even closer view into this problem. Nevertheless more detailed explanation of discussed phenomena requires further numerical simulations.

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