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IDENTIFICATION OF ELASTIC PROPERTIES OF MATERIALS OF LARGER BODIES.

IDENTIFIKACE ELASTICKÝCH VLASTNOSTÍ MATERIÁLU ROZMĚRNĚJŠÍCH TĚLES.

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Abstract

The problem of stress propagation in the steel bar which is supported by a wood block is studied. First of all the numerical simulation has been performed using of LS DYNA 3D finite element code. The wood has been taken as an orthotropic continuum . The face of the block which is in contact with the bar has been subsequently chosen to be normal to L,R and T . The main attention has been focused on the evaluation of the reflection coefficient of the stress pulse at the interface between the rod and the wood block. Six different woods has been considered. These coefficients have been compared with the coefficients determined for the two semi - infinite rods . The results of numerical computation have been strengthened by the experiment performed with the blocks made from spruce wood. The influence of the block geometry on the reflection coefficient has been also studied.

Keywords:
stress pulse, reflection, wood blocks, anisotropy, acoustic impedance

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Introduction

The measurement of the dynamic elastic properties of solids is mostly based on the use of the specimen in the form of rods. The production of such specimens is sometimes difficult. At the same time there is also a number of events when it is necessary to measure the properties of materials forming a part of structures like buildings, etc.

In this paper, the possibility of the measuring of elastic constants of a large wood block is studied. The problem is outlined in Fig.1.

The steel rod , 400 mm in length and 15 mm in diameter is in a contact with the surface of a wood block. The axis of the rod is taken to be perpendicular to the block surface and its flat end to be in frictionless contact with this surface. The normal vector to contact surface of the wood block is oriented in L,R and T direction. The opposite surface of the block is in a contact with a rigid wall. It means the particle displacement on this surface in normal direction is zero. The stress pulse in elastic

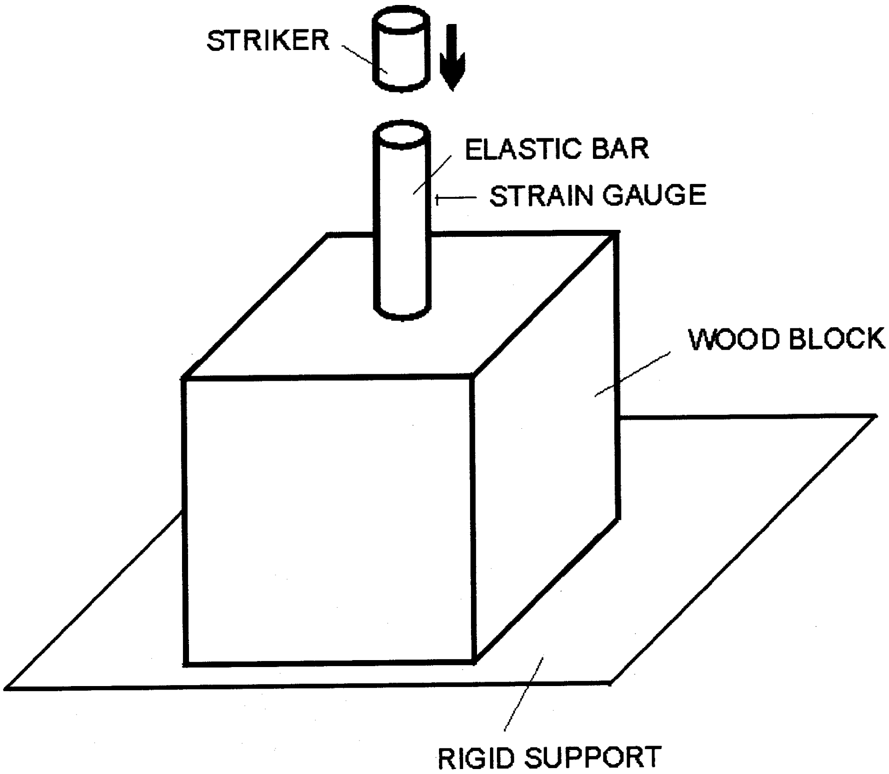

Fig.1. Schematic of the problem to be solved numerically.

rod is initiated by the impact of a striker made from the same material as the rod. At some position on the rod the incident and reflected stress pulses are detected using standard gauges like strain gauges etc. The similar problem has been solved by Boucher (1971) for a block made from an isotropic material. Even if this block was taken as a half - space the resulting relations for the reflection coefficient at the interface between rod and half - space were very complicated, namely from the point of a practical use. The propagation of elastic waves in wood , which is represented by the orthotropic continuum , is much more complicated than that in a isotropic continuum , see e.g. Bucur (1995) for a review. From this point of view it is probably impossible to solve the problem shown in Fig.1 analytically . This is a reason that we have used a numerical simulation by LS DYNA 3D finite element code. The computational results are compared with some experimental data obtained for blocks made from the spruce wood.

Numerical simulations

The basic numerical simulation has been performed for steel bar described in Fig.1 and wood blocks 150 x 150 x 150 mm. The six different woods have been selected for numerical simulation. Their elastic properties are given in Table 1.

Table 1.
ELASTIC PROPERTIES OF USED WOODS.(E is the Young modulus, G is the shear modulus, ν is the Poisson ratio and ρ is the material density. The parameters given in this table have been obtained mostly from the ultrasonic experiments at the frequency about 1 MHz)

Elastic constants	Spruce	Balsa	Poplar	Birch	Beech	Pine
E_a (10^8MPa)	95.64	63.00	97.00	163.00	137.00	163.00
E_b (10^8MPa)	10.37	3.00	8,90	11.1	22.40	11.00
E_c (10^8MPa)	4.87	1.10	4.10	6.2	11.40	5.70
G_{ab} (10^8MPa)	7.5	3.10	7.20	11.50	16.10	11.60
G_{bc} (10^8MPa)	0.39	0.30	1.10	1.90	4.60	0.66
G_{ca} (10^8MPa)	7.2	2.00	6.70	9.20	10.60	6.80
ν_{ba}	0.029	0.018	0.030	0.034	0.073	0.038
ν_{ca}	0.020	0.009	0.019	0.018	0.044	0.015
ν_{cb}	0.250	0.240	0.330	0.380	0.360	0.310
ρ (kg/m^3)	429	200	380	620	750	550

The notation used in Table 1 is explained in Fig.2. The striker, which is made from the same steel as the rod, has length 20 mm. The elastic properties of steel are : Young modulus E = 2.01x 10^5MPa, Poisson ratio ν = 0.31 and density ρ = 7 750 kg/m^3.
These elastic properties have been used for the computation of the stress pulse propagation in the system rod -block , which is shown in Fig.1. The impact velocity of the striker has been chosen as : 10, 20 ,30 , 40 and 50 m/s.

In Fig.3 the example of the computed axial stress (zz normal stress component) in the rod is plotted.

The block has been made from the spruce wood, the normal vector to the surface which is in the contact with the rod is in L direction. The impact velocity has been 50 m/s. It is clear that the initial pressure stress pulse is reflected as a tensile one. This reflection is well described for the two semi - infinite rods in contact . The theory assumes that the rods are thin enough in order to guarantee the validity of one dimensional theory of the stress wave propagation. In the framework of this theory, see e.g. Achenbach (1973) , the reflected stress pulse can be expressed as :

$$\sigma_R = \frac{Z_2 - Z_1}{Z_1 + Z_2}\sigma_I \qquad (1)$$

Where σ_I is the incident stress pulse , Z is the acoustic impedance (density times the longitudinal wave velocity), indices 1 and 2 denote the first and the second bar. If we change the arrangement shown in Fig.1 to system of steel rod in contact with the wood rod of the same diameter, the Eq.(1) leads to values of coefficient of reflection R given in Table 2 (1D solution). The acoustic impedance of the steel is 40.84 MPas/m. The acoustic impedance of the wood rod for the orientation of its axis in L,R and T directions are also given in Table 2. The acoustic impedance of the steel is 40.84 MPas/m.

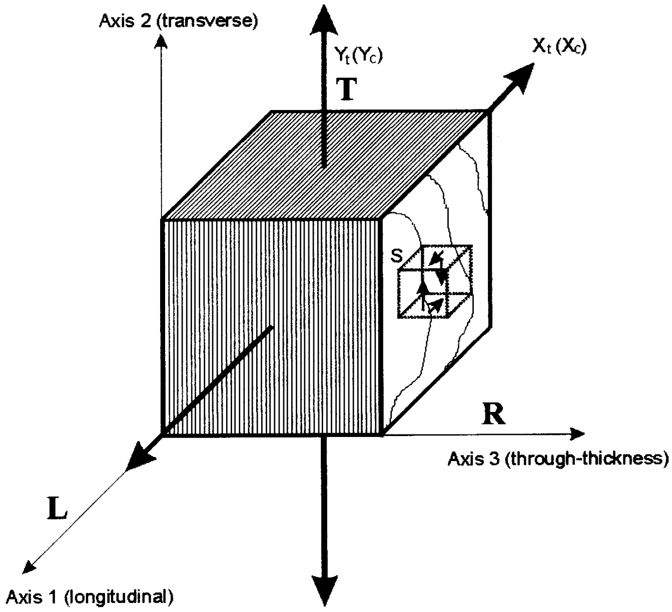

Fig.2. Coordinate system and principal strengths.

The coefficient of the reflection decreases with the wood density as it is shown in Fig.4. The form of these dependence is different for the different block face orientation.

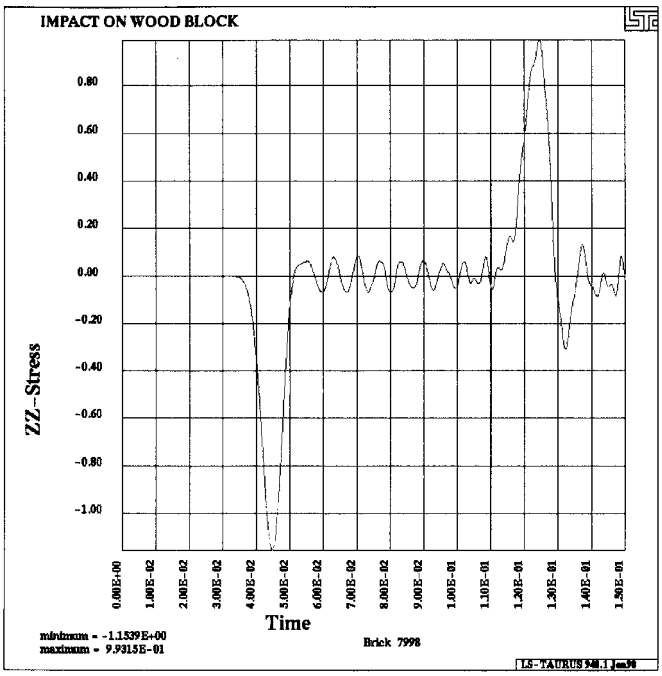

Fig.3. The computed axial stress component in the elastic rod (negative values corresponds to the pressure and positive values to the tension).

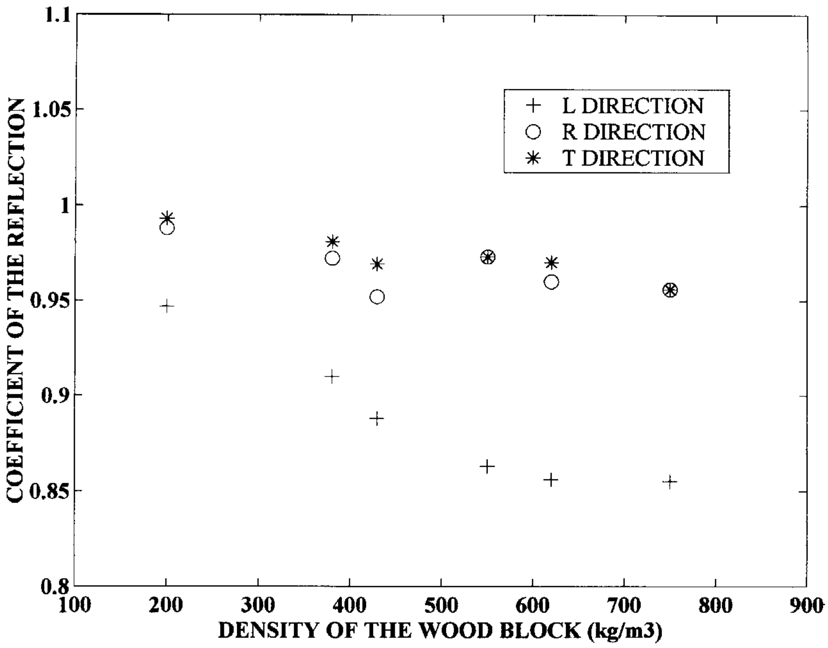

Fig.4. The dependence of the absolute value of the coefficient of the reflection on the wood density. The coefficients are computed using of the Eq.(1).

The values of coefficients of the reflection of the stress pulse at the interface between elastic rod and wood block have been evaluated from the numerical results, see example in Fig. 3. The values of these coefficients are given in Table2 together with the values of R obtained using of Eq.(1)

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Table 2
COEFFICIENTS OF THE REFLECTION OF THE STRESS PULSE AT THE INTERFACE BETWEEN ELASTIC ROD AND WOOD BLOCK.

	Spruce	Balsa	Poplar	Birch	Beech	Pine
$(R_L)_{1D}$	-0.888	-0.947	-0.910	-0.856	-0.855	-0.863
$(R_L)_{numer}$	-0.845	-0.883	-0.845	-0.812	-0.767	-0.821
$(R_R)_{1D}$	-0.952	-0.988	-0.972	-0.960	-0.938	-0.963
$(R_R)_{numer}$	-0.845	-0.892	-0.863	-0.833	-0.806	-0.844
$(R_T)_{1D}$	-0.969	-0.993	-0.981	-0.970	-0.956	-0.973
$(R_T)_{numer}$	-0.863	-0.911	-0.885	-0.856	-0.828	-0.866

The reflection coefficients at the interface between rod and block are in absolute value lower than the coefficients reflection at the interface between rods of the same diameter. The values of computed coefficients are also decreasing functions of the wood density. With the exception of the L direction the reflection coefficient at the interface rod - block is more sensitive on the wood density than the reflection coefficient at the rod - rod interface . The next computation performed indicates that the reflection coefficients are independent on the magnitude of the incident stress pulse σ_I .

In the next step the experiments have been performed. The blocks have been made from the Spruce wood. The normal of the block face which is in contact with the elastic rod has been chosen in L and R direction. The experimental recorded incident stress pulses have been nearly identical with the computed ones. The F - test revealed that the reflection coefficients are independent on the striker impact velocity, i.e. on the amplitude of the incident stress pulse.

The experiments also approved the conclusion from the numerical simulation on the identity of the wave reflection in L and R direction.

Conclusions

The performed numerical simulation of the stress pulse reflection at the interface between rod and wood block suggest that the corresponding reflection coefficient is probably unique function of the wood density. This coefficient is lower than that obtained from the one - dimensional theory of the stress pulse propagation through the connection of two thin elastic rods. The numerical results have been confirmed by the experiments. It seem that the use of the elastic bar made from an isotropic material can be successfully used for the determination of the elastic constants of the large wood beams or of similar wood members. The next numerical simulation as well as appropriate experimental effort is needed. The results of this research will be content of the forthcoming papers.

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