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WOOD STRENGTH EVALUATION UNDER IMPACT LOADING

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The paper deals with the evaluation of the strength of the wood at impact loading. The experimental method of the plate impact on the specimen has been used. The preliminary experiments performed on the specimens of Spruce and Beech suggested that there is a great influence on the strength of the wood. Numerical study revealed the stress state in the specimen. The stress development for the different orientation of the wood specimens has been obtained.

Wood, plate impact, numerical analysis, strength, specimen orientation

INTRODUCTION.

The use of timber in structures like guard – rail systems requires knowledge about the behaviour at high loading rates. There are many experimental techniques for the study of the impact behaviour of wood – see e.g. Leiten, 2000 for a review. Generally it is accepted that the strength of the wood at the impact increases of 20 % about its value at static loading. In order to give some insight on this statement let us follow the values of the wood strength at the different loadings. In table 1 the strength data for the spruce wood and for the beech wood are given.

Table 1. Strength of the wood.

WOOD	LOADING	DIRECTION OF LOADING	STRENGTH (MPa)	STRAIN RATE (s^{-1})	REFERENCE
SPRUCE	STATIC IN TENSION	L	143.5	10^{-4}	Bodig and Jayne, 1982
		R	6.3		
BEECH		L	128		
		R	3.3		
SPRUCE	STATIC IN COMPRESSION	L	43.5	10^{-4}	Bodig and Jayne, 1982
		R	5.9		
BEECH		L	69		
		R	14.5		

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SPRUCE	DYNAMIC IN COMPRESSION (TAYLOR TEST)	L	122	10^4	Buchar et al, 2000
		R	38		
BEECH		L	136		
		R	45		

SPRUCE	DYNAMIC IN COMPRESSION (HOPKINSON SPLIT BAR)	R	101		Bragov and Lomunov, 1997
BEECH		R	133	10^3	

It may be seen that the increase in the wood strength with the increase of the loading rate is much more pronounced that is generally assumed. The given values of the strength at the strain rates corresponding to the impact loading have been obtained by different methods and in the pressure.

The aim of this paper consists in the verification of the results reported in Table 1 in tension and at the higher strain rates. This loading may be realized by the experiments where the specimens of the tested mateial, usually in the form of cylinders, are loaded by the impact of a flat plate with some incident velocity. This experiment, so called “Plate impact test” is widely used for the study of the behaviour of materials at very high strain rates. The present paper involves some preliminary results on the wood behaviour under this loading and namely the detail numerical analysis of the given method.

EXPERIMENTAL METHOD AND RESULTS.

The used experimental method is shown in Fig.1. The specimen of the tested material is loaded by the impact of a projectile at the normal incidence.

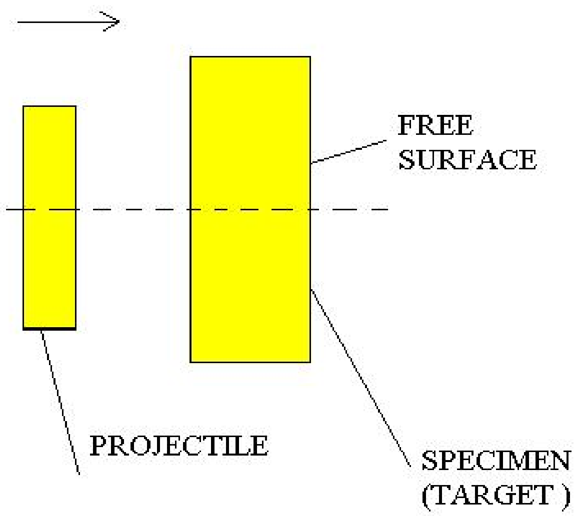

Fig.1. Schematic of the experimental method.

The details on he given experimental arrangements can be found e.g. in paper (Rajendran and Grove, 1996). This test provide a loading path that is very different from Split Hopkinson bar test as well as from conventional Taylor test. The deformation is that of one – dimensional strain, and the mean stress is generally very high compared to that in the tests mentioned above . Strain rates are 105 s-1 or higher. The material undergoes compression followed by the tension (this a consequence of the loading pressure pulse reflection on the free surface of the specimen) . In general, plate impact experiments are essential for calibrating and validating high strain rate material models that aspire to general applicability. The time dependence of the stress in the material is strongly affected by the thickness and material of the projectile as well as by the thickness of the specimen.

For the experiments the specimens of the Spruce and Beech wood have been used. The specimen have been cylindrically shaped with diameter of 15 mm. The same shape has been used for the projectile (diameter 20 mm) . The projectile has been made from the tool steel (strength about 1500 MPa). The normal of the loaded specimen surface has been choosen in Longitudinal (L) and in the Radial (R) directions. The survay of the experiments is given in Table 2.

Table 2. Plate impact experimental details

WOOD	DIRECTION OF IMPACT	IMPACT VELOCITY (m/s)	SPECIMEN THICKNESS (mm)	PROJECTILE THICKNESS
SPRUCE	L	219.8	6.98	2
	R	206.6	7.02	2
	L	222.2	7.05	4
	R	208.1	7.02	4
BEECH	L	220.5	7.05	2
	R	207.3	6.97	2
	L	222.8	9.95	4
	R	210.6	7.02	4

After the loading ,the specimens did not exhibit any damage. Their deformation has been purely elastic. It means the numerical analysis of the given experiments is relatively very easy.

NUMERICAL ANALYSIS.

Numerical analysis of the experiments reported in Table 2 has been performed by the use of the finite element code LS DYNA 3D. The model of the orthotropic elastic material has been used. The elastic moduli have been evaluated fro the ultrasonic tests (Buchar and Slonek,1994). They are collected in Table 3. Owing to a relative small scatter in the specimen thickness a model specimen 7 mm in thickness has been used for the computation.

Table 3.Elastic properties of the tested wood.(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, $a \equiv L$, $b \equiv R$, $c \equiv T$)

Elastic constants	Spruce	Beech
E_a (10^8MPa)	95.64	137.00
E_b	10.37	22.40

(10^8MPa)		
E_c (10^8MPa)	4.87	11.40
G_{ab} (10^8MPa)	7.5	16.10
G_{bc} (10^8MPa)	0.39	4.60
G_{ca} (10^8MPa)	7.2	10.60
ν_{ba}	0.029	0.073
ν_{ca}	0.020	0.044
ν_{cb}	0.250	0.360
ρ (kg/m^3)	429	750

In Fig.2 the axial stress at the axis of the Spruce specimen (projectile thickness 2 mm) is plotted as function of the time. It may be seen that the loading changes from the pressure to the tension. The values of stress in the R direction are significantly lower as it can be seen in Fig.3.

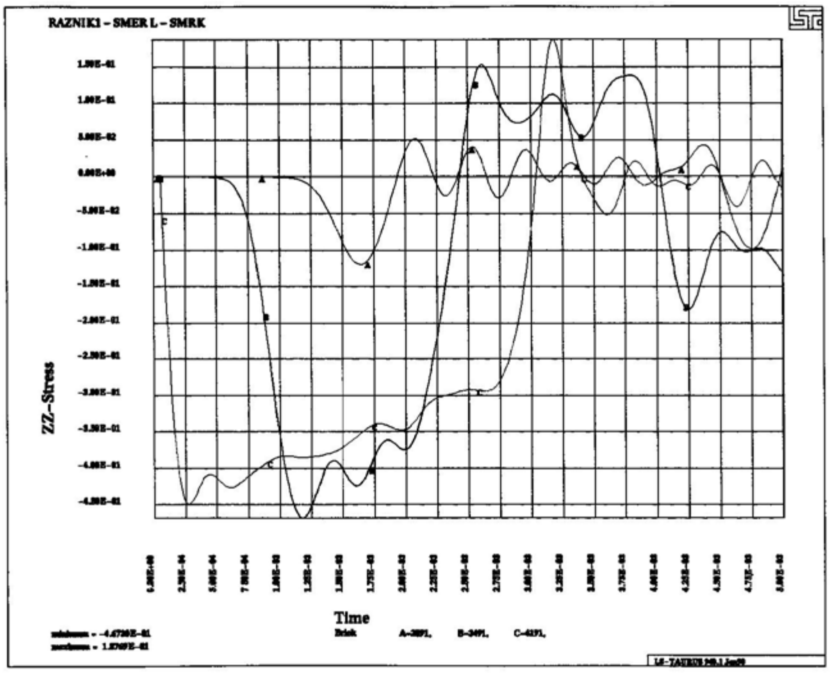

Fig.2. The axial stress component at the specimen axis. Impact velocity V = 220 m/s in the L direction. Projectile thickness has been 2 mm. C denotes the point at 0.25 mm from the loading surface, B denotes the point at 3.75 mm from the loaded surface and A is at 0.25 mm from the free surface.

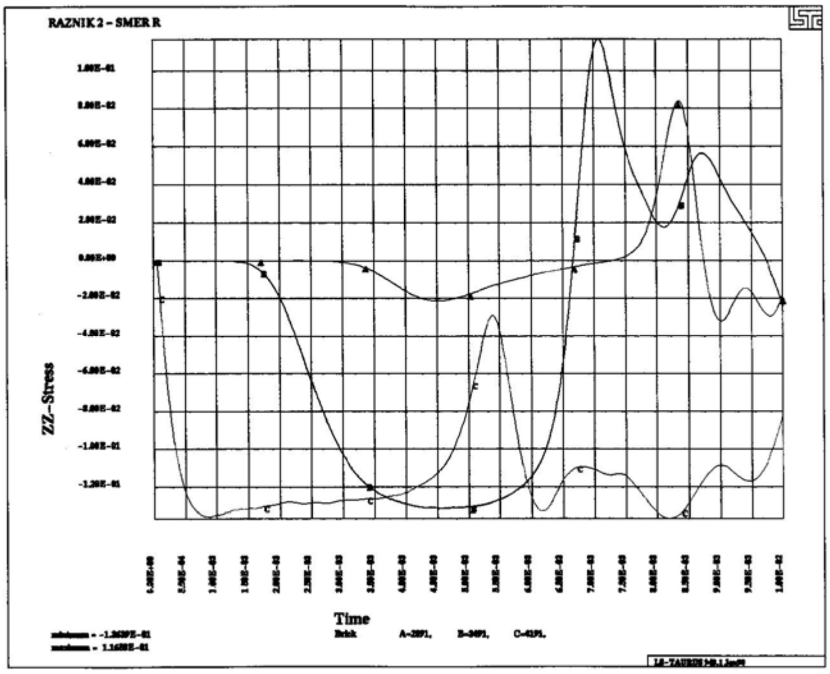

Fig.2. The axial stress component at the specimen axis. Impact velocity V = 220 m/s in the R direction. Projectile thickness has been 2 mm. C denotes the point at 0.25 mm from the loading surface, B denotes the point at 3.75 mm from the loaded surface and A is at 0.25 mm from the free surface.

Very similar results have been obtained for all experiments. The main results of the numerical simulations are given in Table 4.

Table 4. Main results of the numerical simulations – maximum values of the tensile stresses (+ sign) and pressure stresses (- sign)

Spruce. Impact velocity 220 m/s . Loading in the L direction. Projectile thickness = 2 mm.

DISTANCE	z= 0,25 mm		z = 3.75 mm		z = 6.75 mm	
STRESS (MPA)	-450	+150	-467	+190	-120	+50

Beech. Impact velocity 220 m/s . Loading in the L direction. Projectile thickness = 2 mm.

DISTANCE	z= 0,25 mm		z = 3.75 mm		z = 6.75 mm	
STRESS (MPA)	-710	+290	-753	+336	-190	+90

Spruce. Impact velocity 205 m/s . Loading in the R direction. Projectile thickness = 4 mm.

DISTANCE	z= 0,25 mm		z = 3.75 mm		z = 6.75 mm	
STRESS (MPA)	-137	N/A	-128	+116	-22	+83

Spruce. Impact velocity 220 m/s . Loading in the R direction. Projectile thickness = 2 mm.

DISTANCE	z= 0,25 mm		z = 3.75 mm		z = 6.75 mm	
STRESS (MPA)	-142	N/A	-135	+121	-22	+84

Beech. Impact velocity 220 m/s . Loading in the R direction. Projectile thickness = 2 mm.

DISTANCE	z= 0,25 mm		z = 3.75 mm		z = 6.75 mm	
STRESS (MPA)	-320	+61	-275	+80	-50	+80

Beech. Impact velocity 205 m/s . Loading in the R direction. Projectile thickness = 4 mm.

DISTANCE	z= 0,25 mm		z = 3.75 mm		z = 6.75 mm	
STRESS (MPA)	-300	+58	-265	+45	-50	+80

From these results it follows that the dynamic strength of the wood at high rates of strain may reach very high values which cannot be predicted from the results obtained from the experiments at lower strain rates. The more detail investigation of this unexpected results will be subject of our forthcoming papers.

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