UDC 674

ANALYSIS OF THE TENSE STATE WHEN THE TIMBER IS BENDED, CONSIDERING KNOTS

O. Malakhova, Ph.D., associate professor of wood technology

National University of Bioresources and Environmental Sciences of Ukraine

The article contains theoretical analysis of the impact of knots' size and location at the timber on the tense state under bending at seams and at the edge. Shown on the model of a block with cylindrical inhomogeneity.

Keywords: timber, knots, bending, elasticity.

Mechanical properties, which are inherent in the wood of different species without defects, have been well studied [1, 4]. However, the presence of defects in lumber breakes structural patterns [1]. If there is a knot, the part which is occupied with perceives stress during deformation differently than solid wood.

The study of the relationship between the structural parameters and mechanical properties of lumber was conducted to establish normative foundations of rational use of specific timber.

Let us analyze the effects of the presence, size and location of the defect in the form of a knot in lumber in bending at seams and at the edge. Consider a mechanical model of timber in a beam that has a heterogeneity in the form of a cylinder which diameter is equal to 15% of the width, which roughly corresponds to the average size of the knot, according to the experiment, and the axis is perpendicular to the layer.

When bending the timber without defects at seams, the inertia moment ($J_{пл}$) is calculated by a commonly known [3, 5] formula:

$$J_{пл} = \frac{bh^3}{12},$$

and if there is a knot (Fig. 1), the inertia moment of the section, which has the properties of defect-free wood ($J_{пл.с}$) will be:

$$J_{пл.с} = \frac{(b - 0.15b)h^3}{12} = 0.85J_{пл}$$

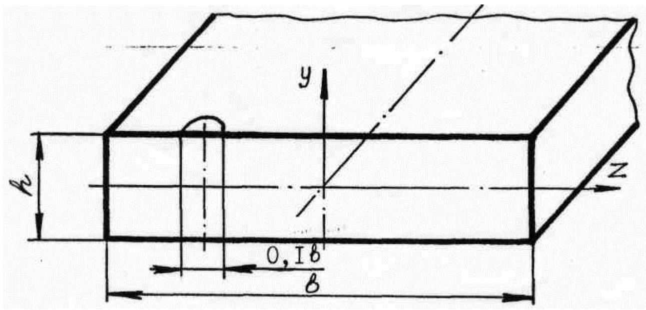

Fig. 1. – Analysis of the influence of knot under bending at seams stimulation

Note that the knot's width appears here as a constant, and the knot's coordinates along the axis Z are irrelevant.

If we mark the coefficient that corrects with K, we get:

$$J_{пл.с} = K_{пл} J_{пл}. \qquad (1)$$

Moments of section's resistance under such bending are accordingly equal:

$$W_{пл} = \frac{J}{h/2} = \frac{1}{6} bh^2; \qquad W_{пл} = \frac{0,85}{6} bh^2; \qquad (2)$$

Similarly, the inertia moment under bending the timber without defects on the edge is:

$$J_{пл} = \frac{hb^3}{12},$$

and an inertia moment of section with a knot (Fig. 2) :

$$J_{кр.с} = \frac{0,85^3 hb^3}{12} + 0.075^2 hb = \frac{0.614hb^3}{12} + 0.0056hb;$$

or $$J_{кр.с} = K_{кр} J_{кр}. \qquad (3)$$

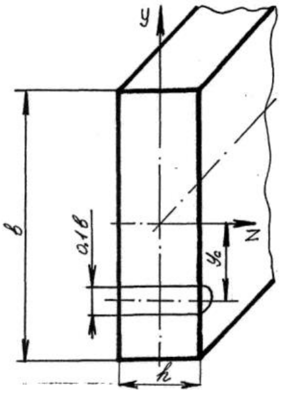

Fig. 2. – Analysis of the influence of knot under bending at the edge

Moments of resistance under such bending are accordingly equal:

$$W_{кр} = \frac{1}{6} hb^2; \qquad W_{кр} = \frac{0,722}{6} hb^2 \qquad (4)$$

Comparison between the expressions (2) and (4) indicates that there is a significant impact of knots in timber on the rigidity. Obviously, the load on an edge will give greater effect than the load at seams.

Now let us consider the effect of knot on the deformation process of timber depending on the test circuit.

The equation of the elastic line's curvature, which corresponds diagrams of moments from the application of force (P) at one point in the middle of the length of the sample, has the form:

$$E_и = \frac{PL^3}{48} hb^2,$$

now knowing the size of deflection (f), we can determine the module of elasticity under bending:

$$E_и = \frac{PL^3}{48} Jf,$$

When the load is applied at two points, the value of moments in between load elements will be constant, and the equation of the elastic line will be:

$$EJf_{max} = \frac{P(L - L_1)}{96} [3L^3 - (L - L_1)^2].$$

Then

$$E = \frac{P(L - L_1)[3L^3 - (L - L_1)^2]}{96Jf_{max}}. \qquad (5)$$

Let us consider the influence of knot location along the length of timber in case of bending with application of the load at mid length. As seen at Fig. 3, the moment that bends in the section located at a distance X from the the support in the presence of knot is equal to M_p=0,5 P X, and under the unitary load (P = 1), M_p= 0,5 X.

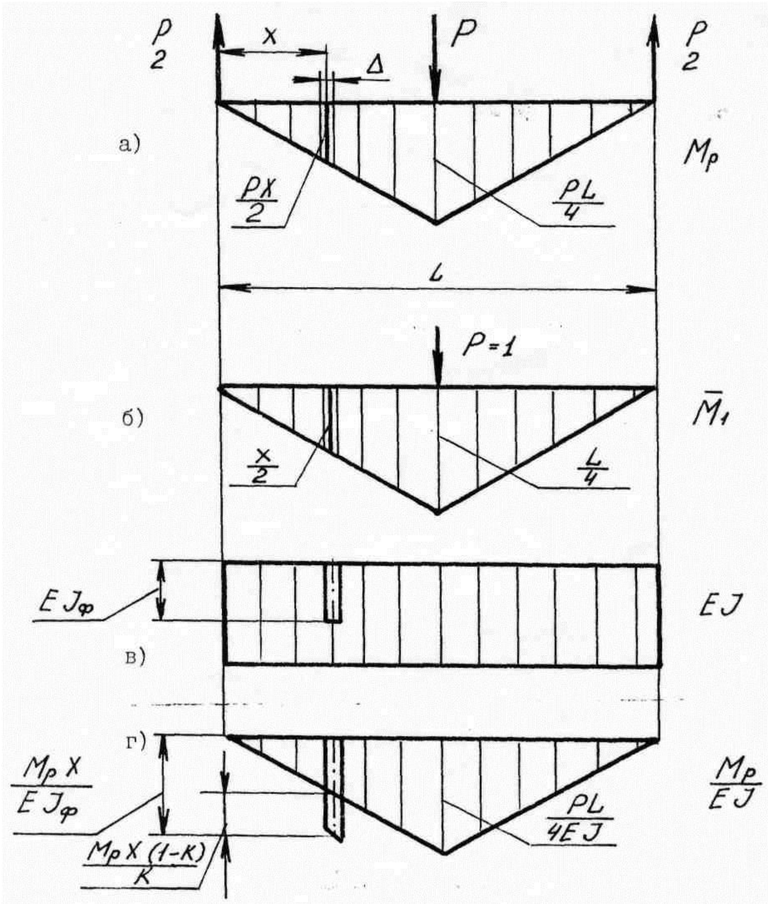

Fig. 3. - Diagrams of moments, which bend (a) and moments from the unitary load (b), stiffness (a) and troughs (d) under bending timber with a knot

As noted above (formulas 1, 2), the presence of a knot of an average size reduces the inertia moment of the section, which has the properties of a solid wood, under bending at seams by 85%, while under bending at the edge (at the edge-position of the knot) – by 61%, that accordingly adjusts the stiffness of timber in this section. In consequence the curvature diagram, obtained by dividing the moments on the stiffness, shows a tendency to the local changes of the deflection at this section. Thus, in the section with a knot the elastic line’s curvature tends to the form:

$$\frac{M_P X}{EJ_{пл.с.}} = \frac{M_p X}{EJ_{пл} K} = \frac{M_P X}{EJ_{пл}} + \frac{M_P X(1-K)}{EJ_{пл} K}. \qquad (6)$$

If there is one knot of the d_c size along the sample, located at a distance X from the support

$$EJf_{max} = \frac{PL^3}{48} + \frac{PX}{2}\frac{(1-K)}{K} + \frac{d_c}{2},$$

And when the number of knots is n:

$$EJf_{max} = \frac{PL^3}{48} + \sum_{n=1}^{n} \frac{PX^2{}_i(1-K_i)d_{ci}}{4K_i}$$

Thus, on the basis of theoretical analysis of the deformation process of the timber with knots we can assume that the bending at seams not only the number and the size of knots is important, but also their position along the length of the area, which is bended. And under bending at the edge important issues are the number of knots, their size and location across the timber’s width at the area of stretching.

Discovery of the significant impact knots’ presence on the elastic properties gives basis to apply the method of structural timber’s quality evaluation by determining the magnitude of their elastic properties regarding the similar characteristics of the defect-free patterns.

Bibliography:

1. Ашкенази Е.К. Анизотропия древесины и древесных материалов / Е.К. Ашкенази. – М.: Лесная пром-сть. – 1978.- 224с.

2. Боровиков А.М., Лохов В.Н., Копчевская М. Р., О показателях качества пиломатериалов/ А.М. Боровиков, В.Н. Лохов, М.Р Копчевская.; - Изв. ВУЗов. Лесн. ж. – 1987. - № 3 с. 127-133.

3. Михайлов А. М. Сопротивление материалов/ А.М. Михайлов – М. Изд.: Академия Высшее профессиональное образование, 1992. – 448 с.

4. Перелыгин Л.М. Влияние пороков на технические свойства древесины / Л.М. Перелыгин – М. – Л.: Госбумиздат, 1949. - 160 с.

5. 4 Сопротивление материалов: Учебник для вузов / Под общ. ред. акад. АН УССР Г. С. Писаренко. — 4-е изд., перераб. и доп. — Киев: Высшая школа. Главное изд-во, 1979. — 696 с.