Evaluation of the influence of inhomogeneous inclusions on the rod bend

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Abstract. The work is devoted to the study of the bending of cantilever rods in the presence of inclusions leading to a significant increase in the angles of rotation of the rod sections. The presence in the structure of the rod of sections that are inhomogeneous in stiffness and are not subject to bending, but having different lengths and numbers, leads to the need to develop models of bends, in contrast to the simplified equations known in the literature. An example of the calculation of bends and stiffness of the rod in the presence of inclusions of various lengths is given. The calculation was carried out in the direct calculation mode in the PC MatLAB system. The initial data were taken for corn stalks based on field and laboratory studies of limbs within elastic deformations. Analytical models for the rigidity of the rod are obtained, calculations and graphs of the bends of the rod are given.

1. Introduction

The physical and mechanical properties of plants are fundamental when choosing the technology and technical means of their processing. For the stems of agricultural plants, when they are bent, the stiffness EJ is not observed. This is due to the complexity of the internal structure of the material. A corn stalk, for example, in its cross section has a large shell filled with a parenchymal mass, in which there are bundles of thinner strength comparable to that of steel. Significantly enhances the design of stem nodes with high strength. However, the strength of the stem with different directions of deformation is significantly different. This applies primarily to the elastic moduli of compression and tension both along and across the stem fibers in the internodes. When the stem is bent, a signify cant difference in the moduli of elasticity leads to a shift of the neutral axis towards the stretched fiber, a change in the moments of inertia of the section, an uneven increase in maximum stresses, if they reach destructive values, the stem is broken either due to rupture of the fibers or due to their crushing [1]-[5].

2. Materials and methods of research.

When the rod is bent within the limits of elastic deformations with the same stiffness value for the stretched and compressed parts of the section, the bending value is determined from the well-known equation [6]-[8]:

$$f = \frac{Pl^3}{3EJ}, \quad (1)$$

where P is the bending force;

l - console length;

EJ - rod stiffness.

The presence in the structure of the rod of sections “b” that are inhomogeneous in stiffness and are not subject to bending (Fig. 1), but having different lengths and numbers, leads to the need to refine dependence (1) or obtain new models.

Fig. 1 shows a diagram of a rod bend with inclusions of length "b" located in the considered sections of length l.

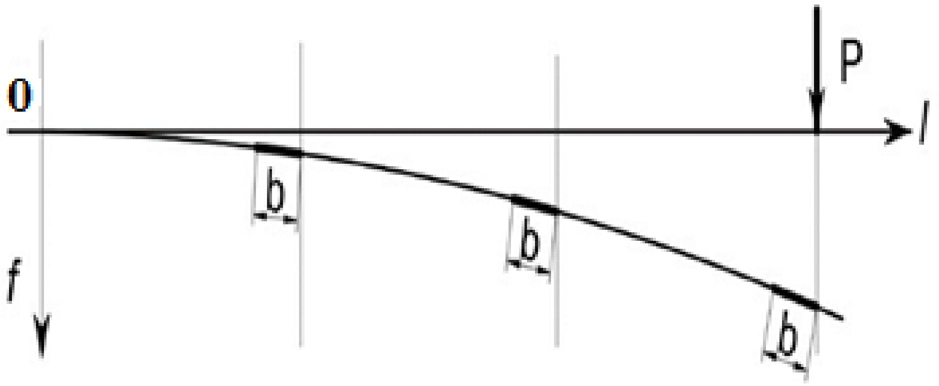

Fig.1. Scheme of a rod bend with inclusions "in".

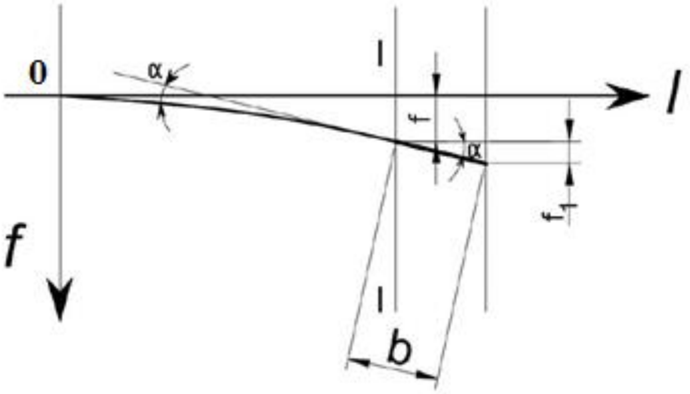

Fig. 2. To the definition of an additional bend f1.

From fig. 2 it can be seen that in the presence of an inclusion with a length of "c", an additional bend arises:.

F_1= b*sinα,

where α is the angle of the tangent to the bent axis of the rod in section I-I. From equation (1) we have:

$$\frac{dt}{dl} = tg\alpha = \frac{Pl^2}{EJ},$$

which determines the position of the tangent to the rod in section I-I, i.e. corner:

$$\alpha = arctg\,(\frac{Pl^2}{EJ}),$$

and the value of the additional bend:

$$f_1 = \text{в}\, sin[arctg\ (\frac{Pl^2}{EJ})]. \qquad (2)$$

Because the value f_1 changes in the section and increases as the length of the rod increases, then the actual value of the bend can be represented as a vector:

$$f_1 = [f_{11}; (f_{11} + f_{12}); (f_{11} + f_{12} + f_{13}); \ldots.], \qquad (3)$$

where $f_{11} + f_{12} + f_{13} \ldots$ is the value of bends on the corresponding sections of the rod length.

Below is an example of calculating the bends and stiffness of the rod in the presence of inclusions with a length of b=5, 10, 15, 20 sm. The calculation was carried out in the direct calculation mode in the PC MatLAB system [9]-[11]. The initial data were taken for corn stalks based on field and laboratory studies of limbs within elastic deformations [1].

3. Results and discussion.

The results obtained are shown in Table 1. Figure 1 shows the nature of the bends in the presence and absence of inclusions "b", as well as the rigidity of the rod. As can be seen from Table. 1, the presence of inclusions leads to additional and total bends in all considered sections, and depends on the length and number of these inclusions. The rigidity of the rod also decreases significantly.

Since the nature of the bends f_2 and f_4 does not allow to obtain the total bends F_1 and F_2 in accordance with equation (1) at EJ = 1.67 * 105 kg * sm^2, it is possible to obtain the equation F = φ (l) in the form of a second-order polynomial. What we use the MatLAB file and systems for:

$$PA=Pol:\ fit\ (l, F, n), \qquad (4)$$

where, when specifying the required degree n of the algebraic equation, we obtain the vector of the desired coefficients, for example, for n=2:

$$PA = [a_2, a_1, a_0];$$

and the bend model

$$Fm = a_2 l^2 + a_1 l + a_0. \qquad (5)$$

So, at b=5 sm, the adequate model of the bend has the form:

$$(F_1)\ m = 0{,}0047 * l^2 - 0{,}4326 l + 13{,}0056; \qquad (6)$$

Similarly, for b=20 sm:

$$(F_2)\ m = 0{,}004 * l^2 - 0{,}4296 l + 13{,}625. \qquad (7)$$

Analytical models for bar stiffness can also be easily obtained. At the same time, the file (4) provides a minimum of the root-mean-square error of the numerical values of the bends (Table 1) for sections and analytical models.

Figure 3 shows the values of bends on the bar sections in the form of broken lines and solid lines for models (F_1) m and (F_2) m.

Table 1. Results of calculation of bar bends

Rod length l, sm			50	100	150	200
Bend size, f sm at EJ=1.67*105			1,25	10	33,75	80
Angle of contact between a straight line and a curved rod along sections α, rad			0,07	0,25	0,59	0,87
Bend size, cm	At *b*=5 sm	f_1	0,3739	1,4367	2,7974	3,8411
		f_2	0,3739	1,81	4,61	8,45
	At *b*=20 sm	f_3	1,4958	5,747	11,1895	15,3644
		f_4	1,4958	7,24	18,43	33,79
Full bend at *b* = 5 sm $F_1 = f + f_2$, *sm*			1,8239	11,81	38,36	88,45
Full bend at *b = 20 sm* $F_2 = f + f_4$, *sm*			2,7458	17,24	52,18	113,31
Rigidity EJ, *кг см*^{2} *x 10*^{5}	At *b*=5 sm		1,3839	1,4112	1,4664	1,5074
	At *b*=20 sm		0,7587	0,9667	1,078	1,1767

Note: total bends f_2 and f_4 correspond to inclusions b=5, 20 sm

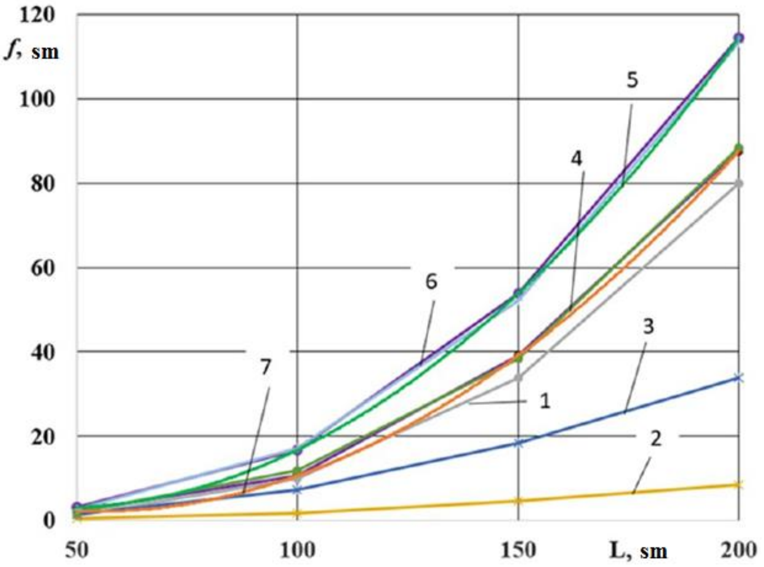

Fig. 3. Bends of the rod.

1- f at EJ = 1.67 * 105; 2 - f_2 at b = 5 sm; 3 – f_3 at b = 20 sm; 4 - $F_1 = f + f_2$ at b = 5 sm; 5 - $F_2 = f + f_4$ at b = 20 sm; (F_1) m – bend approximation according to equation (6); (F_2) m – bend approximation according to equation (7)

4. Conclusions

Studies show a significant dependence of the bends and stiffness of the console in the presence of heterogeneous inclusions in it. A technique is given for obtaining analytical models of bends when it is impossible to use equation (1).

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