Evaluation of the influence of inhomogeneous inclusions on the stems bend of agricultural plants

D. Alijanov* and Y. K. Jumatov
Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (National Research University), Tashkent, Uzbekistan

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 $E_J$ 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 can’t 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].

* Corresponding author: yakubbay1963@gmail.com

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).
2 Materials and methods

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]:

\[
f = \frac{P l^3}{3EJ},
\]

where \( P \) is the bending force;
1 - 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 (Figure 1), but having different lengths and numbers, leads to the need to refine dependence (1) or obtain new models.

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

\[\text{Fig. 1. Scheme of a rod bend with inclusions "in".}\]

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

\[F_1 = bc \sin \alpha,\]

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

\[
\frac{dt}{dl} = t g \alpha = \frac{P l^2}{EJ}.
\]
which determines the position of the tangent to the rod in section 1-1, i.e. corner:

\[ \alpha = \arctg \left( \frac{p_1^2}{EJ} \right), \]

and the value of the additional bend:

\[ f_1 = b \sin \left[ \arctg \left( \frac{p_1^2}{EJ} \right) \right]. \]  \(2\)

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:

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

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 \( b = 5, 10, 15, 20 \text{ sm} \). 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 \( EJ = 1.67 \times 105 \text{ kg} \times \text{sm}^2 \), it is possible to obtain the equation \( F = \varphi (l) \) in the form of a second-order polynomial. What we use the MatLAB file and systems for:

\[ PA = \text{Pol: fit} \left( l, F, n \right), \]  \(4\)

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

\[ F_m = a_2l^2 + a_1l + a_0. \]  \(5\)

So, at \( b = 5 \text{ sm} \), the adequate model of the bend has the form:

\[ (F_1) \text{ m } = 0.0047*l^2 - 0.4326*l + 13.0056; \]  \(6\)

Similarly, for \( b = 20 \text{ sm} \):

\[ (F_2) \text{ m } = 0.004*l^2 - 0.4296*l + 13.625. \]  \(7\)

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 \((F_1) \text{ m} \) and \((F_2) \text{ m} \).

| Table 1. Results of calculation of bar bends. |
|---|---|---|---|
| Rod length l, sm | 50 | 100 | 150 | 200 |
| Bend size, f sm at \( EJ = 1.67 \times 105 \) | 1.25 | 10 | 33.75 | 80 |
| Angle of contact between a straight line and a curved rod along sections \( \alpha \), rad | 0.07 | 0.25 | 0.59 | 0.87 |
| Bend size, cm | At \( b = 5 \text{ sm} \) | f1 | 0.3739 | 1.4367 | 2.7974 | 3.8411 |
| | | f2 | 0.3739 | 1.81 | 4.61 | 8.45 |
At \( b = 20 \text{ sm} \)  
\[
\begin{array}{cccccc}
\text{f3} & 1.4958 & 5.747 & 11.1895 & 15.3644 \\
\text{f4} & 1.4958 & 7.24 & 18.43 & 33.79 \\
\end{array}
\]

Full bend at \( b = 5 \text{ sm} \)  
\[ F_1 = f + f_2, \text{ sm} \]
\[
\begin{array}{cccccc}
1.8239 & 11.81 & 38.36 & 88.45 \\
\end{array}
\]

Full bend at \( b = 20 \text{ sm} \)  
\[ F_2 = f + f_4, \text{ sm} \]
\[
\begin{array}{cccccc}
2.7458 & 17.24 & 52.18 & 113.31 \\
\end{array}
\]

Rigidity \( E_J, \text{ kg cm}^2 \times 10^5 \)  
\[
\begin{array}{cccccc}
\text{At} & 1.3839 & 1.4112 & 1.4664 & 1.5074 \\
\text{b=5 sm} & & & & \\
\text{At} & 0.7587 & 0.9667 & 1.078 & 1.1767 \\
\text{b=20 sm} & & & & \\
\end{array}
\]

Note: total bends \( f_2 \) and \( f_4 \) correspond to inclusions \( b = 5, 20 \text{ sm} \)

Fig. 3. Bends of the rod.

1- \( f \) at \( E_J = 1.67 \times 10^5 \); 2 - \( f_2 \) at \( b = 5 \text{ sm} \); 3 – \( f_3 \) at \( b = 20 \text{ sm} \); 4 - \( F_1 = f + f_2 \) at \( b = 5 \text{ sm} \); 5 - \( F_2 = f + f_4 \) at \( b = 20 \text{ sm} \); (\( F_1 \)) m – bend approximation according to equation (6); (\( F_2 \)) m – bend approximation according to equation (7)

4 Conclusion

Based on studies, it has been observed that the presence of heterogeneous inclusions in a console has a significant effect on its bends and stiffness. The console's heterogeneous nature refers to the existence of different types of materials with varying properties, such as composition, shape, size, and location, which can impact the console's structural behavior. Therefore, it becomes essential to consider these inclusions while designing consoles to avoid structural failure.

However, in cases where it is impossible to use equation (1) for designing the console, an analytical technique can be used to obtain models of bends. This technique involves considering the physical properties of the materials and their arrangement in the console, and using analytical methods to obtain a mathematical model of the console's behavior. This technique can help to predict the console's behavior accurately and enable designers to make
informed decisions on how to optimize console design, ensuring that it meets the required specifications and standards.

References

1. D. Alijanov, Ya.K. Jumatov, Agro iIm 70, 75 (2020)