Simulation of a tubular cultivator rack of tillage machines under static and dynamic loads

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Abstract. Curved tubes of non-circular cross section are widely used in various fields of technology. The change in the planned operating modes of various technological processes is associated with the wear of the executing mechanisms, which is caused by unstable frequencies and amplitudes of oscillations. Thus, the issue of determining the oscillation parameters of these elements becomes more significant. The technique and results of tests for stresses, displacements and frequencies of natural oscillations of a tubular cultivator tine made in the form of a curved tube of various sections (mainly flat-oval with an inverse ratio of semiaxes) in the ANSYS software package are presented, the maximum allowable loads and the effect of a rigid tip on oscillation frequencies are determined.

1 Introduction

In works [1-8], the use of bent flexible tube (BFT) as power elements of various mechanisms, in particular, as a working body of tillage and sowing machines, was considered.

The cultivator (Figure 1) consists of the following structural elements: 1 - loosening paw; 2 – cultivator stand made of a bent flexible tube; 3 - fitting that provides the flow of working fluid to change the pressure inside the rack; 4 – cultivator frame; 5 - a mechanism designed for fastening 2 to 4. To increase rigidity, the tubular element is made with an inverse ratio of the semiaxes.

The working fluid supplied with variable pressure (pressure pulsations) after 3 causes vibration of the cultivator rack with certain frequencies and amplitudes. By changing the frequencies and values of pressure pulsations, it is possible to control the oscillatory movement of the loosening paw.

To reduce the traction resistance of the unit on various types of soil, it is necessary, by changing the parameters of the variable pressure, to set certain oscillation modes, which in frequency will coincide with the oscillations arising from the soil resistance forces.

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2 Statement of the problem

The use of a flexible tubular element as a stand in a cultivator can significantly reduce the power of tillage machines, as traction resistance is reduced due to the vibration effect on the cultivated soil. In addition, the vibration effect makes it possible to improve the quality indicators of tillage by selecting the optimal frequency and amplitude of oscillations of the loosening paw [9, 10].

In the ANSYS software package, using the numerical finite element method, the stresses and displacements that occur in the BFT are determined, taking into account the variable internal pressure (constant and pulsating) and external force, as well as the natural frequency.

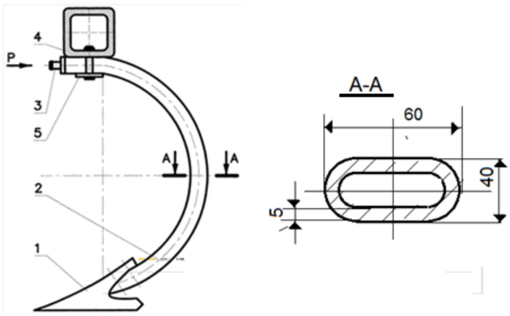

Fig. 1. Cultivator design.

3 Methods

BFT is made of steel, main geometric characteristics: angle - 180 degrees; radius -180 mm; wall thickness, constant along the entire length of the BFT - 5 mm, horizontal axis of the flat oval section - 60 mm, vertical axis of the flat oval section - 40 mm.

To assess the convergence of calculations, a study of the grid model was carried out. The movement of the free end of the BFT was estimated with various methods of meshing and element sizes, the results are shown in Figure 2.

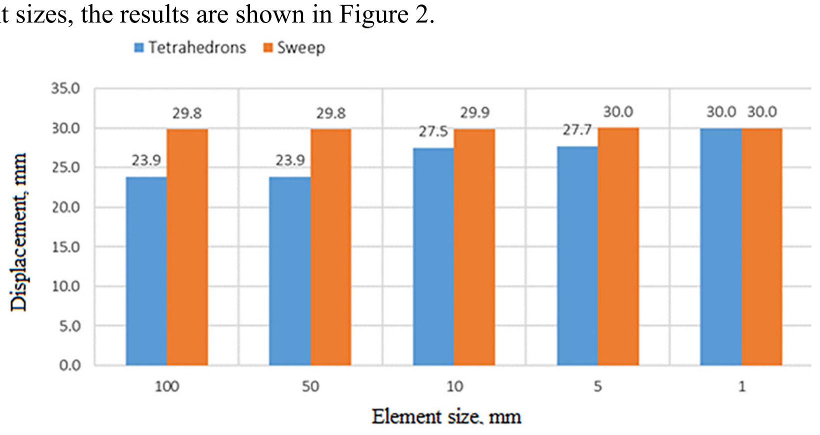

Fig. 2. Free end movement evaluation results.

The results of evaluating the methods for constructing the grid and the dimensions of the element showed that with a decrease in the size of the elements for both methods, the movement of the loosening share becomes a constant value. For further research, the element size was adopted - 5 mm, the method - sweep, since these parameters provide the necessary accuracy of calculations.

4 Results

The influence of the acting force on the free end of the FTE (the place of attachment of the tip) is shown in Figure 3.

In Table 1 numerical results are given. They showed that with an increase in the force acting on the free end of the FTE, the stresses also increase proportionally. The maximum load at which the stresses are close to the allowable ones is 6 kN, while the displacement is about 3 mm.

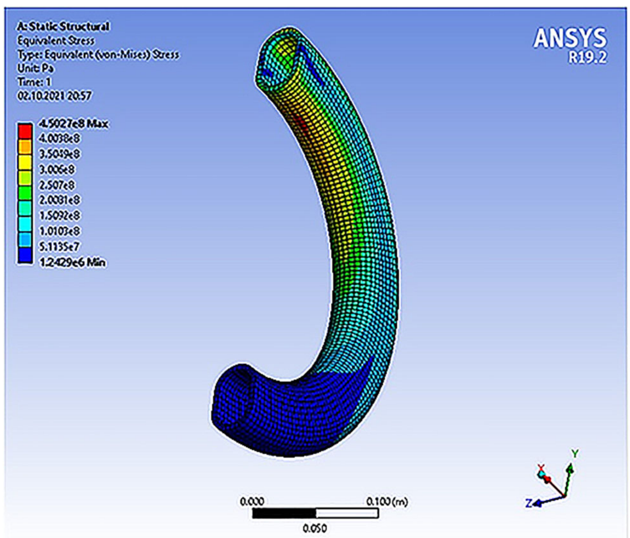

Fig. 3. Stress distribution under force.

Table 1. Stresses and displacements in FTE from the impact of force.

Force, kN	Stresses, MPa		Δ, %	Displacements, mm		Δ, %
	Without tip	With tip		Without tip	With tip	
2	45.0	45.0	-	0.43	0.53	23.3
4	135.1	135.1	-	1.29	1.59	23.3
6	225.1	225.1	-	2.15	2.65	23.3
8	360.2	360.2	-	3.43	3.43	23.3
10	450.3	450.3	-	4.29	5.29	23.3

The results of pressure assessment in BFT for stresses and displacements is presented in Table 2. The maximum internal pressure at which the stresses are close to the allowable ones is 5 MPa, while the displacement is 3 mm.

Table 2. Stresses and displacements in FTE due to internal pressure.

Force, kN	Stresses, MPa		Δ, %	Displacements, mm		Δ, %
	Without tip	With tip		Without tip	With tip	
2	102.9	104.0	1.1	0.96	1.17	21.8
4	205.9	207.9	1.0	1.91	2.34	22.5
6	306.8	311.9	1.6	2.87	3.51	22.2

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8	405.8	415.8	2.5	3.83	4.68	22.1
10	515.5	519.8	0.8	4.79	5.85	22.1

In Table 3 shows the results of calculating the first 5 free frequencies of the FTE with and without the tip. The results show a significant effect on the frequencies of the rigid tip, which plays the role of the attached mass, while the frequencies in the presence of the tip are significantly reduced.

Table 3. Free frequencies of the FTE, Hz.

N frequency	**1**	**2**	**3**	**4**	**5**
Without tip	195.2	262.3	571.1	774.3	1671.7
With tip	53.7	73.9	203.5	239.4	498.1

The results of the assessment of the effect of internal pressure pulsations from 2 to 6 MPa on the stresses arising in the FTE. studies are presented in Figure 4.

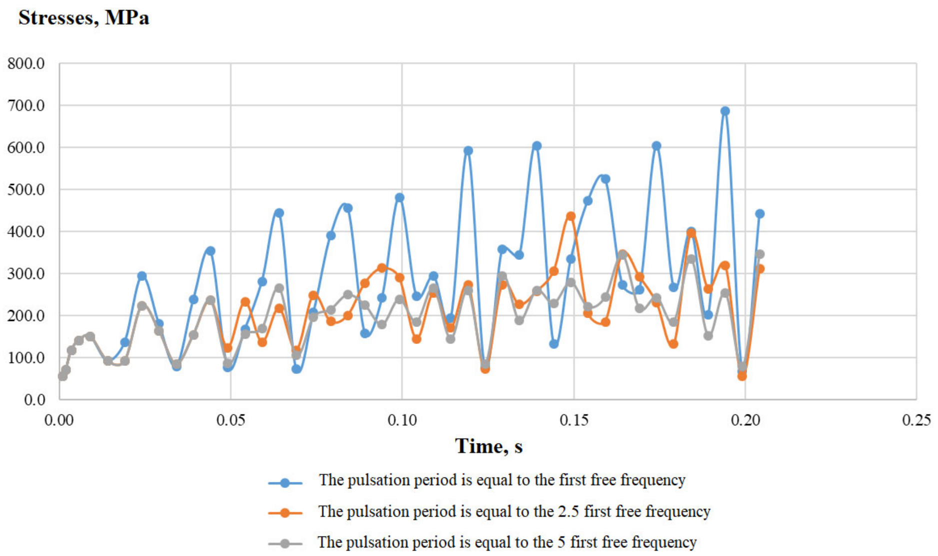

Fig. 4. Stresses arising from pressure pulsations.

As can be seen from these graphs, with a vibration period greater than the BFT oscillation period, the resulting stresses do not exceed the value given in Table 2. If the frequency of internal pressure pulsations and the frequency of free oscillations of the BFT corresponding to the first harmonic, a resonance phenomenon will be observed and a significant increase in stresses in the BFT.

5 Discussion

To model the cultivator rack as a BFT in ANSYS, the optimal finite element sizes were determined - 5 mm, and methods for constructing a grid model - sweep. The influence of BFT internal pressure pulsations, as well as the values of the horizontal component of the force acting on the free end of the BFT, was evaluated.

The critical values of force and pressure are determined. The increase in stresses caused by the resonance is estimated.

6 Conclusion

Pulsations of the working fluid in the cultivator tine at frequencies different from the BFT oscillation frequencies will create a sufficient vibrational effect on the soil. Thus, the conducted studies confirm the performance of this unit and it can be successfully used in tillage.

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