Numerical Simulation of the Working Bodies of the Machine for Removing the Tops of Vegetable Crops

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Abstract. This article is devoted to the analysis of the kinematic and aerodynamic characteristics of the model of the working bodies of the haulm topper. The problem of removal of lodged tops of vegetable crops was investigated on the basis of finite element analysis of the model. Obtaining data on the density and air flow rates inside the casing of the topper is an urgent task. The aim of the work was to analyze the air flow rates and air pressure during the operation of the topper. The Solidworks FlowSimulation package was used to build and simulate a numerical model of the working bodies. Numerical modeling of the haulm-removing organ obtained maps of the distribution of velocities and pressures in the cutting zone of the haulm. Average values of air flow velocity (12-30 m/s) and pressures inside the casing (1.5-2 kPa) ensure the rise of the haulm to the cutting zone of the knives.

1. Introduction

Weediness of fields of vegetable crops reaches 65% by the beginning of harvest [1]. This circumstance is associated with a break in the treatment with herbicides before harvesting. In turn, this period of time makes it possible for a noticeable growth of weeds [2].

The unsatisfactory condition of the field necessitates the removal of weeds and tops [3]. Therefore, a topping machine is used to remove weeds and tops [4]. Figure 1 shows the block of working bodies of the haulm topper.

Previously, the analysis of the influence of aerodynamic forces on plants during harvesting was carried out, as well as strength calculations of the working body [5]. The purpose of this work was to analyze the air flow rates and air pressure during the operation of the topper.

Figure 1. The block of the working bodies of the haulm topper without cover.
2. Materials and methods
The package of gas-hydrodynamic analysis SolidWorks FlowSimulation was used for numerical modeling and simulation of air movement [6]. Flow functions for a moving medium and other aerodynamic characteristics are determined in FlowSimulation based on the continuity equations [7].

The three rotating bodies are modeled using a rotating area. The initial conditions are shown in Table 1. Static pressure in the gap between the casing and the surface of the field, as well as in the opening of the defoliating window.

| Parameter name            | Value                                      |
|---------------------------|--------------------------------------------|
| Thermodynamic parameters  | Static Pressure: 101325.00 Pa             |
|                           | Temperature: 20.05 °C                     |
| Velocity parameters       | Velocity vector                           |
|                           | Velocity in X direction: 0 m/s            |
|                           | Velocity in Y direction: 0 m/s            |
|                           | Velocity in Z direction: 0 m/s            |
| Turbulence parameters     | Turbulence intensity and length           |
|                           | Intensity: 2.00 %                         |
|                           | Length: 0.004 m                           |

The goals for calculating the convergence of calculations were set: global goals - the average value of the velocity (m/s) and the average value of the total pressure on the field surface (Pa).

The simulation took into account the air flow factors, excluding the cut off haulm.

Design data of the model for calculation: knife width - 120 mm; knife length - 267 mm; knife installation angle - 45 degrees; distance from the surface of the field to the casing - 100 mm; the distance between the shafts of adjacent working bodies - 572 mm; angular speed of rotation - 210 rad/s (2000 rpm); the width of the defoliating window is 92 mm [8]. The general view of the model is shown in Figure 2. Computational grid: all cells - 72572, cells in a fluid - 72572.

![Figure 2. General view of the model: 1 - working body; 2 - knife blade; 3 - casing.](image)

3. The results of numerical research
The results of the kinematic and dynamic characteristics of the air flow are presented in Table 2. The results obtained generally correspond to experimental studies of a real sample of the working body.

From among the obtained characteristics of the air flow, velocity and pressure were selected for further analysis.
Table 2. Results of kinematic and dynamic characteristics of the air flow inside the casing.

| Parameter name | Minimum | Maximum |
|----------------|---------|---------|
| Density (Fluid) [kg/m^3] | 1.13 | 1.32 |
| Pressure [Pa] | 95096.66 | 111745.18 |
| Velocity [m/s] | 0 | 88.042 |
| Vorticity [1/s] | 3.84 | 27972.45 |
| Acoustic Power Level [dB] | 0 | 83.11 |

The results of modeling the trajectories of air particles during the rotation of knives with a frequency of 2000 rpm are presented in Figures 3 and 4. Figure 3 shows the distribution of air flow velocities in the form of trajectories. The average air speed was in the range of 12-30 m/s.

Figure 3. Distribution of trajectories and air velocities inside the machine casing.

The pressure distribution in the form of air flow trajectories is shown in Figure 4. The pressure under the implements was low on the ground and increased above the knife blades. This circumstance shows that pressure plays a role in raising the tops of the plants. The pressure difference on the surface of the field and in the area of the ejection window is 1.5-2 kPa.

Figure 4. Distribution of trajectories and pressures inside the machine casing.

Measurements of speed and pressure were made for a detailed study of the air flow in the area of each working body. Measurements were taken using 3D Sketch offset1-3 segments with the beginning
at point (a) and ending at point (b) (Figure 2). The distributions of the speed and pressure of the air flow near the working elements are shown in Figures 5 and 6.

![Graph of air flow velocity near working bodies](image1)

**Figure 5.** Distribution of air flow velocity near working bodies.

Analysis of the graph in Figure 5 shows a jump in the air flow rate from the soil surface to the level of the height of the knife blades, and above the speed decreases. The increased air flow rate under the working bodies leads to a decrease in pressure in the area of the knives.

![Graph of air flow pressure near working bodies](image2)

**Figure 6.** Distribution of air flow pressure near working bodies.

Pressure fluctuations are shown in Figure 6. Lowering the pressure under the working bodies helps to raise the plant stems and bring them into the cutting zone of the knives.

4. **Conclusion**

Numerical modeling of the haulm-removing organ obtained maps of the distribution of velocities and pressures in the cutting zone of the haulm. Average values of air flow velocity (12-30 m/s) and pressures inside the casing (1.5-2 kPa) ensure the rise of the haulm to the cutting zone of the knives. Raising the plant stems and bringing them into the cutting zone of the knives is facilitated by an increase in speed and a decrease in pressure under the working bodies. It can be concluded that the machine is operable with these design and operating parameters of the working bodies.
5. References

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