Studying the Trajectory of Moving Particles in the Air-Screw Separator

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Abstract. When cleaning the heap of grain, the impurities reducing the grain value and affecting its safety, in particular, possible self-heating effect and further deterioration are to be released. For grain cleaning an air-screw separator is developed to separate particles moving along it helically. Computer simulation and experimental studies made it possible to detect the trajectory of moving particles and determine the optimal air flow rate.

Introduction

Cereals cultivation is one of the primary directions for agriculture. However, climatic conditions have a significant impact on the efficiency of grain harvesting and cleaning [1, 2]. When the agrotechnical period of grain harvesting exceeds, the grain quality and yield are significantly reduced [4, 5]. Choosing crops and varieties according to their maturing rates makes it possible to increase the agrotechnical period of grain harvesting and post-harvesting cleaning and involve fewer technical means [6, 7]. The most important stages in grain processing affecting its final quality and cost are pre-cleaning and drying [8]. When cleaning, the impurities reducing the grain value and affecting its safety, in particular, possible self-heating effect and further deterioration of grain are released from the grain heap. For separating light impurities such as parts of stems, husk, chaff, broken grain, dust the principle of mixture separation in the air flow is used according to the difference in aerodynamic properties and mass of particles [9, 10]. The heap for cleaning has non-uniform moisture; therefore, the particles have different terminal velocities. In the end, this leads to either the presence of whole grains in the waste, or the presence of trash in the grain after cleaning. It is possible to change the situation for the better by introducing another force into the system by complicating the motion trajectory of particles. A similar principle is used in the air-screw separator (Figure 1) where particles move along helically. However, at the moment, the motion trajectory of particles with different mass is not defined. In modern science there are a large number of mathematical methods and models for separating impurities due to centrifugal forces. ANSYS CFX is a high-performance tool for computational hydrodynamics, a combination of theoretical, experimental and numerical methods designed to simulate the flow of liquids and gases, heat and mass transfer processes, reactive flows, etc.
Figure 1 – The operation principle of the air-screw separator

Materials and Methods
To simulate the movement of particles in the air-screw separator, the boundary conditions for simulation were set and a part of the separator was modeled, representing one turn of a screw in a cylindrical body (Figure 2), the separator diameter being 300 mm, the screw pitch being 300 mm, the screw axis being 80 mm. An ideal gas at the temperature of 20°C was chosen as the main medium. As a result of computer simulation, the trajectory of the air flow moving helically was determined.

For successful separation, all light impurities should be removed from the initial grain heap, and whole grains in the waste should not exceed 1.5%. As broken grain is the fraction to be most difficult separated, its damage exceeds 50%. The operating mode of the separator, when the particles are removed by flowing air, is optimal. When the air flow rate in the modeled air-screw separator is 7.5 m/s, impurities are to be carried away by flowing air, while whole grains remain in the separator. The trajectory of moving impurities is presented in Figure 3.
Figure 3 – The trajectory of moving impurities

To confirm the theory and studies on the trajectory of particles in the air-screw separator, a laboratory installation was made (Figure 4). The most part of the installation was made of translucent PET material (polyethylene terephthalate) to fix the experiment with the help of a camera.

To create the air flow, a 1.2 kW centrifugal fan with a regulating damper was used to change the air flow rate.

Figure 4 – Laboratory installation

Photo and video shooting was carried out with the camera in two directions: in the frontal and side ones. The video shooting frequency was 30 frames per second. Grain and light impurities were used for the experiments. The air flow rate was chosen according to the recommendations for wheat with 18% moisture. As a result of the experiment, according to the video analyzed, the location points of particles were marked to detect the trajectory of their movement.

Results and Discussion

The experimental studies showed that when the air flow rate is $V=7.5$ m/s, light particles are easily carried along by the air flow and removed from the separator, while the force of the air flow is not enough for whole grains to make a full turn in the screw channel of the separator (Figure 5).
Figure 5 – The trajectory of moving impurities in the experimental installation

For further comparing the obtained results, the dependency graphs for the particles locating on the Y-axis and the experiment timing were constructed (Figure 6).

Figure 6 – The dependency graphs for the particles locating on the Y-axis and the experiment timing

**Conclusion**

Thus, the analysis of the data obtained makes it possible to say with confidence that the theoretical data on the air flow rate necessary for the separation process in the screw channel are confirmed by the experimental studies.
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