STUDY OF THE AIR VELOCITY FIELD IN THE COMBINE HARVESTING CLEANING SYSTEM

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Abstract

This paper describes how a stand for measuring the air flow generated by the fan of combine harvesters for cereals and technical plants was realised. The air flow velocity at the top of the sieve and the velocity profile over the entire sieve surface are important for the design and construction of a cleaning system fan fitted to combine harvesters. The experimental results show the velocity profile of the New Holland TC5050 combine measured with the anemometer at 52 points on the upper sieve surface for different fan rotations, fan deflector positions, upper sieve positions and lower sieve positions.

Key words: centrifugal fan, cleaning system, combine haresters, air flow

The cleaning process in a combine harvester is a complex process, which is influenced by a cumulation of parameters, such as, combine settings for different crops, crop condition, harvesting moisture, etc. (Craessaerts G. *et al*, 2007).

The air flow created by the fan of the cleaning system in combine with the oscillatory motions of the sieves realizes the separation of the grains from the total material mixture passing through the cleaning system (Wang L. *et al*, 2024; Craessaertsa G. *et al*, 2008).

The use of an anemometer in measuring the air flow velocity created by the combine harvester fan is a widespread method of determining the air flow velocity profile (Gebrehiwot M.G. *et al*, 2010; Adachi T. *et al*, 2004; Kergourlay G. *et al*, 2006).

As a result of the determination of the air flow velocity generated by centrifugal fans used in combine cleaning systems, it results that the maximum air flow velocity is obtained near the side walls of the outlet duct of the fan and is minimum at the center of the fan (Pustovaya O.A. *et al*, 2024).

Due to the uneven air flow velocity distribution created by the combine fan, it is difficult to achieve homogeneous cleaning over the entire surface of the upper sieve (Liang Z. *et al*, 2019; Badretdinov I. *et al*, 2021; Gebrehiwot M.G., 2010).

Much of the research on the velocity profile of the airflow created by the fan of the cleaning system for grain and technical plant combine harvester cleaning has been based on fluid dynamics simulations (Chai X. *et al*, 2020; Gebrehiwot M. G. *et al*, 2007; Li H. *et al*, 2013).

So far, the problem of obtaining a uniform airflow distribution on the surface of the upper screen of the cleaning system arises when using a centrifugal fan. In order to eliminate a number of drawbacks of centrifugal fans, some of the high-efficiency combusters are equipped with CFF-type fans (Liang Z. *et al*, 2023).

In research conducted on the NH combine on the velocity profile of the cleaning system fan, it was found that at the outlet of the air stream from the fan the velocity profile is unevenly distributed over the sieve surface (Badretdinov I. *et al*, 2019).

The disadvantage of centrifugal fans is the high static pressure in the type of cleaning process, which leads to the creation of an unevenly distributed air flow velocity profile, which influences the performance of the grain cleaning system and consequently the performance of the combine (Chai X.Y. *et al*, 2020).

In the paper, the construction of a stand for adjusting the flow rate of the New Holland TC 5050 combine fan by controlling its speed and determining the air flow velocity profile on the surface of the upper sieve of the combine cleaning system is presented. The determination of the velocity profile on the surface of the upper sieve was carried out at different air flow rates generated by the fan, at different positions of the fan deflectors and by adjusting the opening position of the air flaps of the upper and lower sieve of the combine cleaning system.

MATERIAL AND METHOD

In the paper, a stand for operating the combine fan at different speeds in order to regulate the air flow rate, and a stand for measuring the air flow velocity at the surface of the upper screen were realized.

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Construction of the stand for operating the combine fan

For the experimental part the New Holland TC5050 combine of USV Iași was used. The cleaning system of the combine consists of an grain pan, a centrifugal fan with six blades 1000 mm long and 500 mm in diameter, two deflectors (noted A and B) with two adjustment positions (up and down) and two screens: upper with a width of 1000 mm and a length of 1580 mm, lower with a width of 1000 mm and a length of 1350 mm. The screens of the combine are of Petersen type, adjustable, allowing the opening of the screen louvers to be changed.

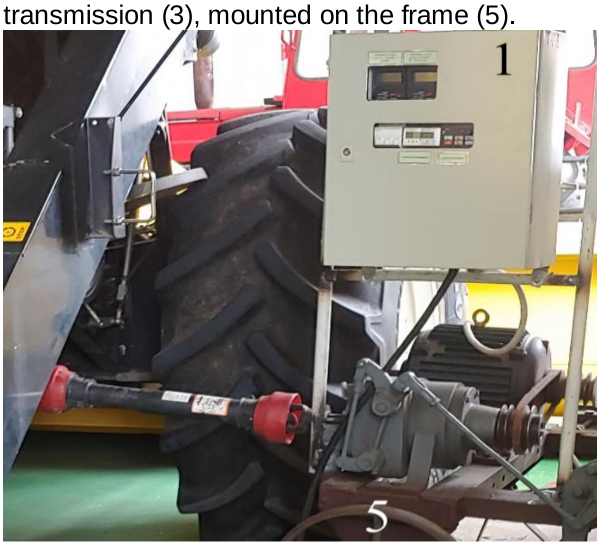
The baffles are part of the fan casing and are located at the airflow outlet of the fan to direct the airflow to the cleaning system screens.

The asynchronous electric motor was used to produce the rotational motion required to drive the combine fan. The electric motor is supplied at a voltage of 380V, with a maximum speed of 1430 RPM and power of 4.5 KW. The converter was used to change the speed of the electric motor by changing the frequency. The VFD type converter allows frequency change in the range of 0 - 60 Hz.

By using the intermediate transmission, which is driven by the electric motor through a belt drive, the speed transmission on the same axis as the axis of the fan of the combine fan was realized. The cardan coupling was used to transmit the rotational motion from the intermediate transmission to the fan shaft.

Combine fan speed measurement was performed with the DT-2234C tachometer. The tachometer uses laser technology for measurements and can measure in the range 2.5 - 99999 RPM with an accuracy of ±0.05%.

In order to start up the fan of the combination, a stand (figure 1) was realized, consisting of: frequency converter (1), asynchronous electric motor (2), intermediate transmission (3), mounted on the frame (5).



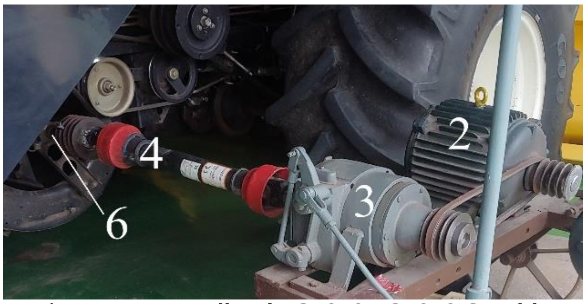


Figure 1 **New Holland TC5050 TC5050 Combine Combine Fan Drive Stand**
1 - converter; 2 - electric motor; 3 - intermediate transmission; 4 - cardan coupling; 5 - beat; 6 - combine fan shaft.

Combine cleaning system fan speeds for which the air flow velocity profile was determined were set according to the adjustments required for different crops. Using the tachometer (figure 2 a), the speed of the combine fan was measured. At speeds of 400, 500, 600, 800 RPM correlations were made between the fan speed and the electric current frequency (table 1) displayed on the converter screen (figure 2 b).

For the upper sieve, 5 positions were set in relation to the harvesting requirements of different crops (table 2): fully closed (0), open a quarter (¼), open half (½), open three quarters (¾), fully open (1), and for the lower sieve 3 positions were set: fully closed (0), open half (½), fully open (1) and for the two baffles 4 different positions were set (table 3).

Table 1
Combine fan speed and electric current frequency at the fan motor

Speed fan (RPM)	400	500	600	800
Converter frequency (Hz)	28	35	42	56

Figure 2 **Frequency setting versus fan speed**
a - fan speed measured with tachometer; b - electric current frequency displayed on the display of the converter

Table 2
Site position and site opening

Site position	0	1/4	1/2	3/4	1
Opening the site (mm)	0	6	12	18	24

Table 3 shows the four variants of positions corresponding to the two deflectors.

Table 3

Deflector positions

Positions/Variants	V1	V2	V3	V4
Deflector A	Sus	Sus	Jos	Jos
Deflector B	Sus	Jos	Jos	Sus

The stand for driving the combine fan was put into operation after the a combine belt drives through which the fan was driven were removed.

Construction of the stand for measuring the air flow velocity created by the combine fan

Four anemometric sensors, 25 cm apart, were used to measure the air flow velocity created by the combine fan. The sensors were calibrated to the testo 405i anemometer. The source supplying power to the entire stand is a 12v switching power supply, powering the stepper motor and the LM7805 type 5V voltage stabilizers to power the anemometer sensors.

The temperature difference between the ambient environment and the temperature of the air flow0 created by the combine fan was measured with two temperature sensors (NTC 100K).

The stepper motor (NEMA 17) was used to move the 4 anemometric sensors along the entire length of the upper screen of the combine by means of a belt. The driver type A4988 was used to control the stepper motor.

A computer was used to acquire the data while measuring the air flow created by the combine fan from an acquisition board (Arduino Uno). Through the Arduino Uno, anemometric sensors were connected to record the air flow velocity, two temperature sensors and the A4988 driver for controlling the stepper motor (figure 3). Arduino IDE programs for loading the microcontroller programming code and CoolTerm for data acquisition were installed on the data acquisition computer.

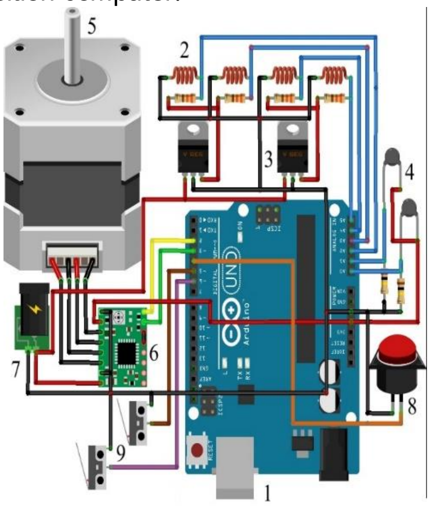


Figure 3 **Wiring diagram of the stand for measuring air flow velocity**

1 - Arduino Uno; 2 - anemometric sensor; 3 - voltage stabilizer; 4 - temperature sensors; 5 - stepper motor; 6 - motor driver; 7 - power supply; 8 - start button; 9 - limit swich 1 and 2.

Three switches were used to control the stepper motor. The first one called "start button" initializes the process of measuring the air flow created by the fan of the combine, the second one called "limit swich 1" initializes the movement of the stepper motor in the reverse direction once the process of measuring the air flow velocity over the entire working length of the combine screen is completed, and the third switch called "limit swich 2" allows the motor to be stopped and prepared for a new series of determinations.

In order to measure the air flow velocity over the entire surface of the screen, a stand (figure 4) was built, consisting of a frame positioned on the upper sieve, on which a sledge was mounted, which moved along the length of the frame by means of bearings.

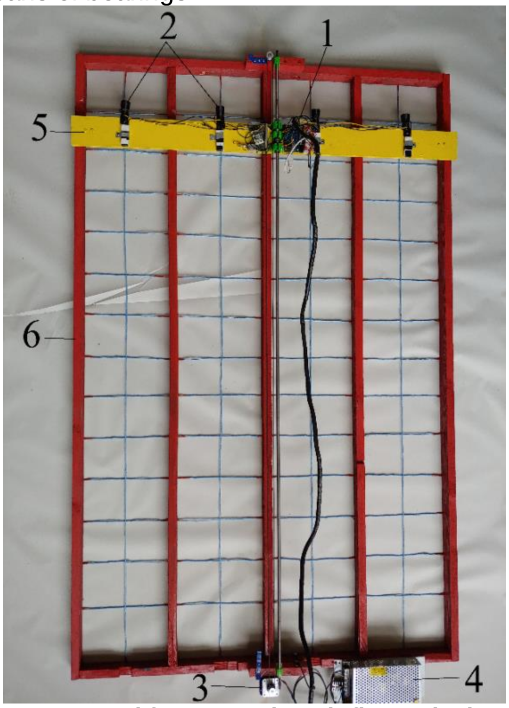


Figure 4 **Stand for measuring air flow velocity on the surface of the upper screen**

1 - Arduino Uno; 2 - anemometric sensor; 3 - stepper motor; 4 - power supply; 5 - sledge; 6 - frame.

Anemometer sensors, Adruino Uno, temperature measurement sensors, stepper motor driver and limit swich 1 and 2 were mounted on the sled (figure 5). The sled moves on the frame with the stepper motor.

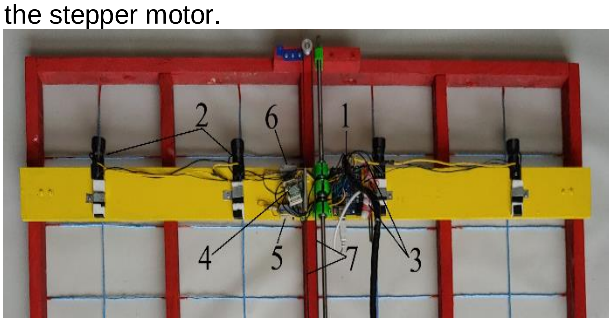


Figure 5 **Layout of components on the sled**

1 - Arduino Uno; 2 - anemometric sensors; 3 - temperature sensors; 4 - stepper motor driver; 5 - limit swich 1; 6 - limit swich 2; 7 - transmission belt.

Air flow velocity determinations were made perpendicular to the surface of the upper sieve of the combine cleaning system, with anemometer sensors mounted at an angle of 90° on the sled. The stand was placed on the surface of the upper sieve of the cleaning system (figure 6). The process of measuring the velocity profile of the air flow created by the fan, on the surface of the upper sieve of the cleaning system, started with the adjustment of the position of the deflectors and the blinds for opening the sieves, and by means of the converter, the frequency of the electric current corresponding to a certain speed of the fan was adjusted. The connection of the Arduino Uno to the acquisition computer was realized through the CoolTerm software, in the interface of which the following parameters are displayed: the air flow velocity measured by the four sensors and the temperatures acquired from the temperature sensors.

Once the fan of the combine was put into operation, through the CoolTerm program data acquisition began, after determining the first 10 values, by pressing the "start button" switch, the motor step by step moves the anemometric sensors 100 mm, after which it stops moving and starts measuring the velocity of the flow air created by the fan of the combine. 10 air flow velocity determinations are made for the four anemometric sensors, one determination every second, after which the stepper motor moves the anemometric sensors by another 100 mm following the determination of the new airflow values. In total, the stepper motor makes 12 movements over the entire surface of the upper sieve.

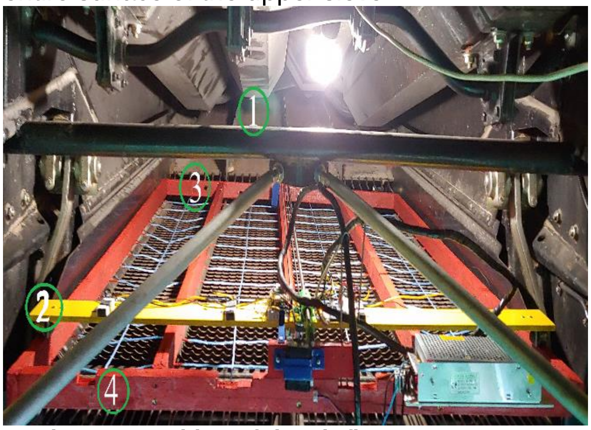


Figure 6 Position of the air flow measurement stand on the sieve surface
1 - grain pan; 2 - sled; 3 - front of upper sieve; 4 - rear of upper sieve

At limit swich 1 when the last air flow velocity measurement is performed, the stepper motor changes its direction of rotation and redirects the anemometer sensors to the starting point of the measurements, the stepper motor is stopped and the stand is prepared for a new measurement by operating limit swich 2.

In figure 7, the front side of the upper sieve, where the air flow velocity determinations started, is corresponding to number 1 and the rear side, where the last air flow velocity determination on the upper sieve surface was performed, is corresponding to number 13.

According to Figure 7 the intersection of the anemometric sensors (I, II, III, IV) and points 1, 2, 3, ..., 13, 10 cm apart, were used for the air flow velocity determinations.

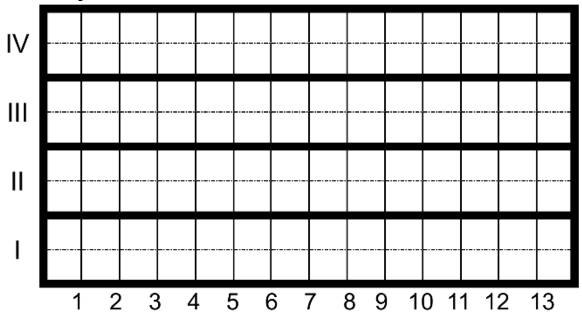


Figure 7 **Site area and points at which air flow velocity determinations were made**
I, II, III, IV - positions of the four anemometer sensors along the length of the upper sieve; 1, 2, 3, ...13 - points where air flow velocity determinations were made on the upper sieve surface.

Once the data acquisition from the anemometric sensors is done electronically on an acquisition computer, and the measurement of the air flow velocity along the entire length of the upper sieve is done automatically, the human involvement is reduced to initializing the measurement process by pressing a button and changing the parameters of fan speed, position of the deflector flaps and position of the opening flaps of the upper and lower sieve.

RESULTS AND DISCUSSIONS

The plot in Figure 8 shows the average values of the air flow velocity over the sieve surface obtained from the four anemometric sensors at a fan speed of 600RPM, with the baffles in position V1 and the air flaps opening at the upper sieve in position ¾ and at the lower sieve in position ½.

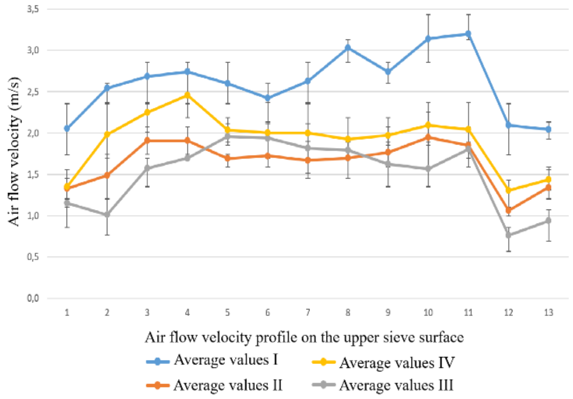


Figure 8 **Air flow velocity measured at 52 points on the surface of the upper sieve at 600 RPM fan speed, with baffles in V1 position, upper sieve ¾ and lower sieve ½.**

The red and grey velocity curves (figure 8) are the average values of the air flow velocity along the length of the upper sieve obtained from sensors II and III located in the middle of the sieve, and the blue and yellow velocity curves are the average values of the air flow velocity along the length of the sieve obtained from sensors I and IV located on the sides of the sieve.

The values of the air flow velocity generated by the fan of the combine cleaning system are higher on the sides of the upper sieve surface, as determined by sensors I and IV, than the values of the air flow velocity recorded in the middle of the upper sieve surface, as obtained from sensors II and III.

The obtained air flow velocity determinations show that the velocity profile is unevenly distributed over the surface of the upper sieve. The air flow velocity profile varies within wide limits from one anemometric sensor to another and from one measurement point to another.

During the cleaning process, the grains separate from the material mixture once they pass through the screen openings, and the air flow created by the fan, due to pneumatic transport forces, separates light particles (chaff, short straws, etc.) from the grains (Miu P., 2016).

If during the working process of the cleaning system of a combine harvester, the velocity of the air flow created by the fan is low, the grains will not be separated from the total mass of material, which leads to the appearance of impurities in the mass of clean grains.

If the air flow velocity is high, the grains will be removed along with the total mass of material (chaff, short straw, etc.), leading to grain losses (Khoshtaghaza M. H. *et al*, 2006).

The air flow velocities determined in the middle of the sieve by sensors II and III are lower than in the sides recorded by sensors I and IV which causes the grain cleaning process to be influenced due to the unevenness of the air flow velocity created by the fan.

In the case of the air flow velocities obtained at the sieve sensors I and IV, the air flow velocity is higher on the side of the sieve than in the middle of the sieve corresponding to sensors II and III, which leads either to higher grain losses on the sides of the sieve due to the grain floating velocity being exceeded or to the presence of impurities in the grain mass due to insufficient air flow velocity in the middle of the sieve.

The non-uniformity of the air flow on the surface of the upper sieve is determined by the construction characteristics of the centrifugal fan, but the non-uniformity of the air flow is also influenced by the position settings of the deflector flaps and the upper and lower sieve. The temperature at which air flow velocity determinations were made was approximately 23 ^{0}C. The temperature difference between the air stream sensor and the encapsulated sensor was approximately ±0.5 ^{0}C.

CONCLUSIONS

The determination of the air flow velocity profile created by the combine cleaning system fan, by modifying the fan speed, the position of the baffles and the flaps adjusting the position of the upper and lower sieve louver position, eliminates the involvement of the human factor in making these determinations.

Using the stand with the four anemometric sensors, the air flow velocity determinations were performed simultaneously over the entire working width of the upper screen, increasing the accuracy with which the experimental determinations were made.

The air flow velocity profile on the surface of the upper sieve is unevenly distributed. On the sides of the sieve corresponding to the mean air flow values determined by anemometer sensors I and IV, they were higher compared to the mean air flow values obtained in the middle of the sieve from anemometer sensors II and III.

The non-uniformity of the air flow velocity profile is related to the type and design parameters of the fan and the positions of the sieve adjustment flaps and baffles. Centrifugal fans are known to have high values of static pressure, which is manifested near the side walls of the fan.

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