Dawid ROMEK, Dariusz ULBRICH, Konrad WŁODARCZYK
Jarosław SELECH, Jakub KOWALCZYK, Jakub ADAMKIEWICZ
Politechnika Poznańska, Instytut Maszyn Roboczych i Pojazdów Samochodowych
ul. Piotrowo 3, 60-965 Poznań, Poland
e-mail: jaroslaw.selech@put.poznan.pl
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LABORATORY STUDIES OF PNEUMATIC TRANSPORT OF GRAIN WITH THE USE OF AIR STREAM AMPLIFIER KW

Summary

The main goal of the research was to design and build a prototype of device used for pneumatic transport, which will increase the difference of pressure in the pipeline and will increase velocity of the airflow during the transport of materials over different distances. During design process of the device using graphics software assumes that the system of separation of grain and air should be eliminated. The device is applicable in systems that need additional air amplifier, without the cyclone-filter system. The results confirmed that in the rearmost point of the pipeline dynamic pressure was lower than the pressure at the nearer measuring points. In addition, analysis of the transported grain did not show his deformation. During the test of the device only a slight increase in the temperature of the transported material was noted.
***Key words**: pneumatic transport, grain, air stream*

BADANIA LABORATORYJNE PNEUMATYCZNEGO TRANSPORTU ZIARNA Z WYKORZYSTANIEM WZMACNIACZA STRUMIENIA POWIETRZA KW

Streszczenie

Celem wykonanych badań było zaprojektowanie i wykonanie prototypu urządzenia do transportu pneumatycznego, które pozwoli na zwiększenie różnicy ciśnień w rurociągu oraz umożliwi wzrost prędkości strumienia powietrza podczas transportu materiałów na różnych odległościach. Podczas projektowania urządzenia z wykorzystaniem programów graficznych założono, że należy wyeliminować system separacji ziarna i powietrza. Urządzenie znajduje zastosowanie w układach potrzebujących dodatkowego wzmocnienie strumienia powietrza, bez zbędniej konieczności użycia filtrocyklonów. Wyniki badań potwierdziły, że w najodleglejszym miejscu rurociągu ciśnienie dynamiczne było niższe od ciśnienia panującego w punktach pomiarowych położonych bliżej. Ponadto analiza stanu transportowanego ziarna nie wykazała jego deformacji, a zauważono jedynie niewielki wzrost temperatury materiału, który był transportowany.
***Słowa kluczowe**: transport pneumatyczny, ziarno, strumień powietrza*

1. Introduction

Pneumatic transport is widely used in the industry for transfer of bulk materials over specific distances. During pneumatic transport of materials the difference of pressure at the ends of the arrangement for transport is used. Mainly used transport systems consist of source which generates air, material supply devices, conveying line and system which receives the transported material (Fig. 1) [4–6].

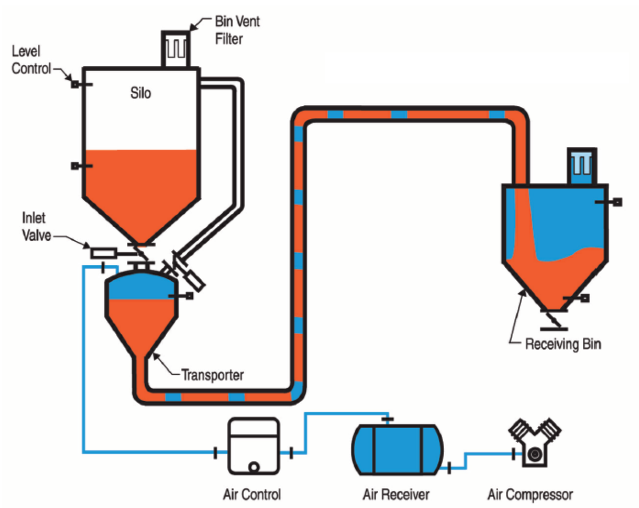


Fig. 1. Scheme of pneumatic conveying system [2]
Rys. 1. Schemat pneumatycznego systemu transportowego [2]

2. Construction of the device

The prototype of the device was designed based on the electric motor with a rotor (10) of vacuum cleaner which was placed in the sleeve (12). These elements are base of the devices. Machine was built and designed as two cones (5, 15) connected to a cylindrical sleeve (14), so it acts as diffuser. The purpose of the nozzle is to provide an adequate flow of air and increase dynamic pressure, which is directly related to the increased velocity. A sleeve with cone is inside the case. The sleeve (12) is used as the engine installation. Cone (13) shapes the air stream which is generated by the engine. The outer part of the casing comprises a beam (4) shaped in the wing section, which results in better aerodynamic flow around. In the middle part of the beam a bearing support is placed. Another bearing is mounted on the rotor. The bearings are connected by a shaft (2). On the shaft regulated cone (6) with openings is installed. Openings must be smaller than the diameter of transported grain, and are designed to increase the amount of intake air. This combination of external and internal elements is connected by screws (11). A channel is the result of all joined elements. This channel was created because the grain should move through the entire cross-section of the tested model. The channel has selected dimensions to maximize the velocity of the stream and pressure differences, so thus increase the maximum expense of mass flow. The model of the air flow amplifier with description of the elements is shown in Fig. 2 and in Fig. 3 the prototype of the device is presented.

Fig. 2. The model of air flow amplifier [1]: 1 – nut, 2 – shaft, 3 – bearing, 4 – the upper support of bearing, 5 – outer cone, 6 – inner cone, 7 – bearing, 8 –bearing support, 9 – support fixing, 10 – engine, 11 – screw fixing, 12 – inner sleeve, 13 – inner cone, 14 – outer sleeve, 15 – outer cone

Rys. 2. Projekt modelu wzmacniacza strumienia powietrza [1]: 1 – nakrętka, 2- wałek, 3 – łożysko, 4 – podpora górna łożyska, 5 – stożek zewnętrzny, 6 – stożek wewnętrzny, 7 – łożysko, 8 – podpora łożyska, 9 – mocowanie podpory, 10 – silnik, 11 – śruby mocujące, 12 – tuleja wewnętrzna, 13 – stożek wewnętrzny, 14 – tuleja zewnętrzna, 15 – stożek zewnętrzny

Additionally it has been designed and constructed special rack (Fig. 2).

Fig. 3. The prototype of air amplifier [1]

Rys. 3. Prototyp wzmacniacza strumienia powietrza [1]

The device has a switch and voltage regulator 1613C produced by AVT. Due to use of this system the pressure, speed and motion of the particles in selected areas of the engine speed can be tested. To pressure measurements the U-tubes and Prantl tube were used [6]. To verify the correctness of the calculated air velocity Testo 440 device was used.

3. Scheme of measurement

Points of airflow test was presented in Fig. 4. Points No. 0, 1, 2, and KN show the most sensitive and the most important places in the conceptual model. Point No. 2 was placed at the end of the measurement section with a length of 2 meters. Other research was carried out at the measuring points at the height of 0,5 m, 0,8 m and 1 m (Fig. 3). 0 point is located at the beginning of the model. In this point it took place the study of pressure and gravity feed. Point KN is a characteristic in the study of pressure and velocity test of air stream.

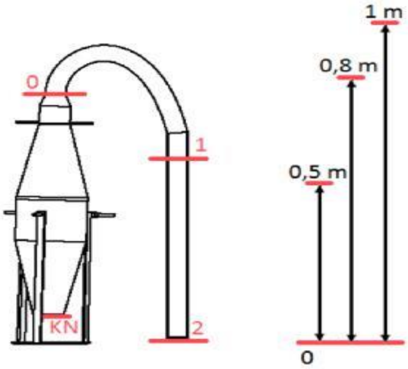


Fig. 4. Measurement diagram used during the test of device [1]

Rys. 4. Schemat pomiarowy wykorzystany podczas badania urządzenia [1]

4. Results of research

At the start of the study measure of the air stream velocity by the U-tube was performed. To calculate the air velocity equation (1) was used:

$$w = \sqrt{\frac{2 p_d}{\rho}}, \tag{1}$$

where:

p_d – dynamic pressure [Pa],

ρ – air density [kg⋅m^{-3}].

All measurements according to the setting of a motor controller (lowest setting was 0.5, whereas the biggest 1) were performed. The measuring points are distributed depending on the length of the pipe. Point marked as No. 2 (2 meters) is the highest value, while 0 is the point of the beginning of the gravity fall, the KN is the outlet from the device. The measurement results are shown in Tab. 1 and in Fig. 5.

It can be seen that in the farthest point of the pipeline the velocity of the airflow was the lowest, and at the point KN it was the highest. In order to validate the study, measurements by direct method were examined. This test was performed using the unit Tesla Model 440. Also it can be observed that the results of measurements using the indirect and direct method are different. The results at the point of the KN are reliable because the airflow completely powered measuring gauge.

Tab. 1. The results of measurements of the air flow using the direct and indirect method for the 0.5 engine range [1]
Tab. 1. Wyniki pomiarów strumienia powietrza metodą bezpośrednią i pośrednią dla 0,5 zakresu regulacji silnika [1]

Method	Measurement point			
	2	1	0	KN
	$m \cdot s^{-1}$	$m \cdot s^{-1}$	$m \cdot s^{-1}$	$m \cdot s^{-1}$
Indirect	8.09	9.04	10.70	14.01
Direct	9.00	9.50	9.80	13.60
Incertitude limits	0.91	0.46	0.90	0.41

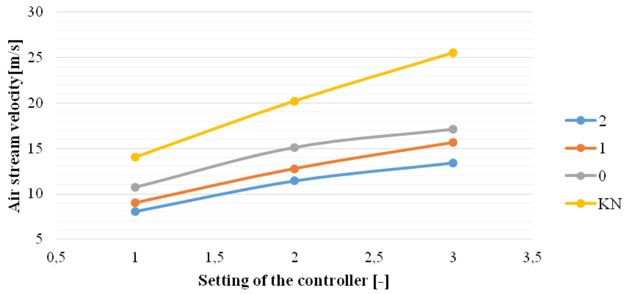


Fig. 5. The dependence of flow speed of the air and controller setting at certain points of measurement [1]
Rys. 5. Zależność prędkości strumienia powietrza od nastawy regulatora w określonych punktach pomiaru [1]

5. Examination of stream amplifier using grains

Tests on the grains of barley and wheat, depending on the distance from the suction device and its speed were performed. Research in the distance 0 m on the sample of 50 g of grain (wheat and barley) were performed. It was checked whether the prototype device can suck the corn with a 2 meter long pipe, 30 mm in diameter. The measurements lasted 60 s, and the results are presented in Tab. 2. The results obtained in this test confirm theory that the velocity is too low for the demand for transportation. The particles were sucked only up to a certain distance and were levitated.

Tab. 2. Measurements at point 0 m through a 2- meter pipe for barley and wheat [1]
Tab. 2. Pomiary w punkcie 0 m przez rurę 2 metrową dla jęczmienia i pszenicy[1]

Point	2					
	Grain type					
Controller settings	Barley			Wheat		
	g	g	$g \cdot min^{-1}$	g	g	$g \cdot min^{-1}$
0,5	0	50	0	0	50	0
0,75	0	50	0	0	50	0
1	2	48	2	4	46	4

In tests performed in point 0,5 the grain was sucked in 2 ways. The first was a 2- meter long pipe, and in a second case the pipe was 1 meter long. Both pipes had a diameter of 30 mm. The results of obtained measurements are shown in Table. 3 and Fig. 6.

The next step of the experiment was to test the efficiency of the device for a height of 0,8 m for the pipe of 1 m and 2 m in length. In this case, the experiment was performed only with grains of wheat. The results are presented in Tab. 4. For comparison of the data obtained during the research, graph of the amount of suction and efficiency for the length of tube 1 and 2 was prepared (Fig. 7).

The aim of the last part of the experiment was to test random sample of 5 grains that have been identified under a microscope. Grains, shown in Fig. 8 were not damaged, so transportation can be accepted as safe for the transported material.

Tab. 3. The measurements at the point of 1 m through the pipe of 1 and 2 meters in length for wheat grains [1]
Tab. 3. Pomiary w punkcie 1 m przez rurę 1- i 2-metrową dla pszenicy [1]

Grain type	Wheat					
	Measuring point					
Controller settings	1			2		
	Test sample	Remain	Efficiency	Test sample	Remain	Efficiency
	g	g	$g \cdot min^{-1}$	g	g	$g \cdot min^{-1}$
0,5	16	34	16	0	0	0
0,75	50 g/56 s	0	56	14	36	14
1	50 g/18 s	0	167	20	30	20

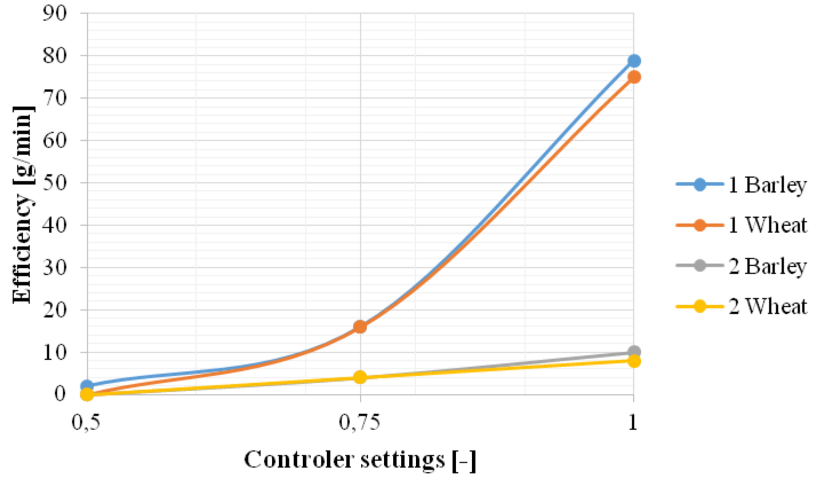


Fig. 6. The dependence of the performance of the controller settings for barley and wheat at a measuring height of 0,5 m [1]
Rys. 6. Zależność wydajności od nastawy regulatora dla jęczmienia i pszenicy na wysokości pomiarowej 0,5 m [1]

Tab. 4. The measurements at the point of 0,8 m through the pipe of 1 and 2 m for wheat [1]
Tab. 4. Pomiary w punkcie 0,8 m przez rurę 1- i 2-metrową dla pszenicy [1]

Grain type			Wheat			
			Measuring point			
Controller settings		1			2	
	Test sample	Remain	Efficiency	Test sample	Remain	Efficiency
	g	g	g⊙min^{-1}	g	g	g⊙min^{-1}
0,5	4	46	4	0	0	0
0,75	28	22	28	10	40	10
1	50 / 28 s	0	107	12	38	12

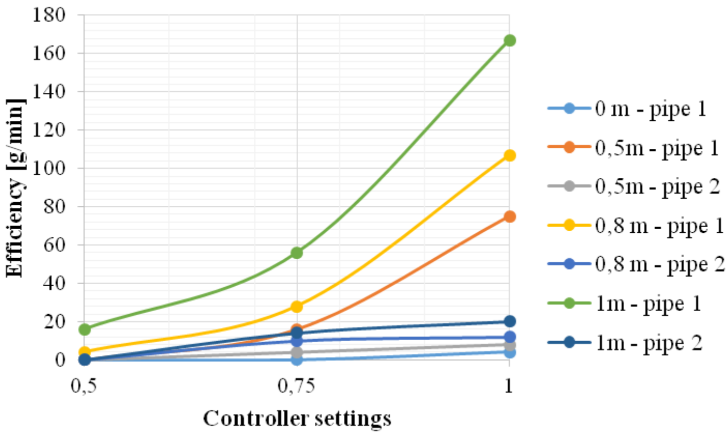
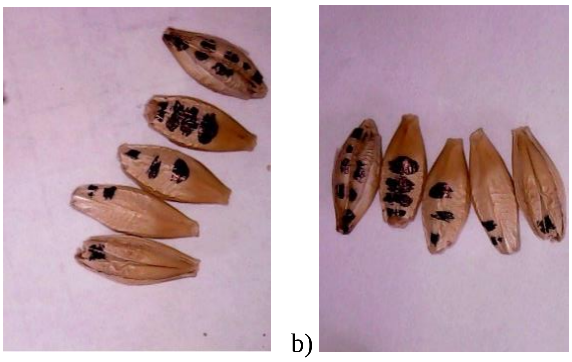


Fig. 7. The dependence of the performance of the controller settings for wheat at different heights [1]
Rys. 7. Zależność wydajności od nastawy regulatora dla pszenicy na różnych wysokościach [1]



a) b)

Fig. 8. Random seed: a) before transportation in a pipeline using a prototype, b) after transportation process [1]
Rys. 8. Losowo wybrane nasiona: a) przed transportem w rurociągu z wykorzystaniem prototypu urządzenia, b) po procesie transportu [1]

Research on innovative stream amplifier confirmed its usefulness during the transportation process. The velocity obtained at individual measuring points shows that the farthest measuring point has dynamic pressure less than the points that are closer. Research shows that the best effects are achieved by setting the engine at least at 0,75% of the maximum speed. At maximum engine speed suction of the grain runs most efficiently. Analyzing the results of the experiment it can be said that the greatest efficiency is directly proportional to engine speed. Taking into account test of the model in a continuous manner, it can be concluded that the highest efficiency occurs at maximum engine speed, however, there is a possibility of excessive loss in the stream. Studies of deformation of grains confirm the idea that the pneumatic transport does not deform the material. During the experiment observed temperature of grains rises. it was caused by the engine running.

6. Conclusion

Designed and built model fully met the assumptions that were given at the first step of the conceptual stage, and the results were satisfactory. In the future, tests should be extended to the measurement of the wet beans. The device can replace Cyclone Filter systems and other air devices used in the transport of bulk materials.

7. References

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