IMPROVING THE CHARACTERISTICS OF PNEUMATIC TRANSPORT OF GRAIN

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Pneumatic transport is the most commonly performed transport of fine-grained and powder materials to manufacturing plants. It is considered that this is the most applicable transport within the manufacturing companies for the processing of grain and powder materials. The need for this kind of transport to be more sustainable, improved and to perfect encouraged the authors of this paper to address this issue. It is assumed that at a certain point transport system choked due to unforeseen circumstances so it is necessary to make urgent additional works to be returned to the operating mode of the system. Tendency is to make the system predictable and downtime to a minimum.

Key words: Pneumatic transport, Granular materials, Oilseeds, Damaged grains, Pipe system

INTRODUCTION

The basic tendency of pneumatic transport is to be the most economical and more flexible with the use of a high level of process automation in compare to other types of transport like screw or belt conveyors [01, 09]. The environmental demands that are presumed today just favor this kind of transport in relation to others and make it the only possible thing in a particular technological process, since the transport is carried out by pipes and there is no waste of material and therefore environmental pollution.

In comparison of the pneumatic transport with mechanical, numerous advantages can be seen. Pneumatic transport can be carried out in all directions, adapting to the available space and other conditions. It requires less space and provides ability to connect different segments in process due to technological requirements (drying or moistening of materials during transport, simultaneous heating or cooling air, sorting material by size of grain based on deposition rate, etc.). Applying the vacuum process the environmental requirements are meet (less air pollution). Pneumatic transport provides a high degree of automation of the process and it can be positioned in numerous places simultaneously and thereby enabling transport of large amount

of material in short time.

Pneumatic transport within the factory, which is engaged in processing oilseeds, is faced with many problems. By conducting oil seeds from the silo to the production line comes to significant damage to the piping system because of the shock of grain on the walls of the pipe. The worst damage can be seen on elbow pipes, since the wiring system is combined with the movement of the grains in the horizontal and in the vertical direction. Speed of impact and the amount of grain in a given time interval are the causes of deformation and failure within the transport system. Experience has proven to overhaul this system must be carried out over a period of 6 to 8 months and constantly have to combine materials to pipe installations withstood high speed shocks of grain for a longer period of time. The process rebuilds due to failure lasts up to several days, which represents a high cost for producers. It is necessary to predict system failures and reduce them to a minimum during a longer time interval. It is believed this problem can be successfully solved by the introduction of new technologies, which would reduced the number of failures to minimize in the medium-term production planning (1-5 years of exploitation). This would practically overhaul of the transport system reduced to a regular (annual) period with

significantly lower total cost of production.

The need for the system to the introduction of grains into the transport system and flow through a system (discontinuous and turbulent) is reduced to continuous, to give a more balanced effect of the shock on the walls of the tube system. The grain is irregular in shape with certain impurities (skinned), and each attack creates the effect of a bullet strikes causing major damage to a small area. In order to mitigate this effect, it is necessary to group the grains in the cross section of the pipe system and reduce the speed of impact of the crossing points (elbows) and thus achieved the effect of superficial attack with minor consequences. To achieve this effect in the transport system should be controlled and synchronized multiple parameters in a short time interval. Using the Venturi injector, at the beginning of the pneumatic lines, can significantly improve and speed up the flow and thereby improve the dosing grains with significant control the speed of movement of grain.

TECHNICAL CONDITIONS OF PNEUMATIC TRANSPORT IN FACTORY FOR PRODUCTION OF EDIBLE OILS

Pneumatic transport of granular materials, sunflower and soya, is organized so that the silo granular material leads to the central doser, and then the method of free fall granular material falls into the dispenser thrusters air-blowers (compressors), as shown in (Figure 1) [07]. Blowers uppresses the granular material through a pneumatic system to a processing plant peeling. Working pressure blowers is 0.35 bar and the capacity of 30 tons of sunflower or 25 tons of soy per hour. The compressor products operating pressure of 1.5 bar that reduce the required 0.5 bar. The compressor is from a group of rotary compressor with profile rotary pistons. The microprocessor is configured to exclude the compressor at a pressure of 0.7 bar, in order to avoid overloading and heating. Through the installation of pneumatic granular material flows at high speed flow in order to provide the required capacity of the materials.

Pipe installation of pneumatic system consists of seamless pipe diameter ø 176 mm, a length of about 70 meters, with multiple crossings of the horizontal to the vertical part of the transport system. Transitions (knee) pipe systems are made of curved pipe with flanges on both ends

and made an angle of 90 and crossing radius of 1800 mm. The system extends from the blower to plant for peeling grains and partly exposed to the outside temperature and weather influences [07].

Figure 1: Knee reinforced with PE 1000

TECHNICAL CHARACTERISTICS OF THE BLOWERS

Aggregate from the manufacturer of blowers is designed to provide air flow high capacity at low differential pressure. The unit is supplied as a pusher air (blower) with regulation of negative pressure or vacuum pump. Some types of blowers with the given operating limits are shown in the Table (Table 1) and the installed type is SNH 825 m.

Table 1: Some types of blowers with the given operating limits

Type blowers	Rpm		Δp (bar)	flow (m³/h)	vacuum (bar)	t1 (⁰C)		t2 (⁰C)	power (kW)
	max	min				max	min		
SNH804MA	4100	1200	1	960	0,5	50	-25	140	37
SNH806MA	3800	1200	1,1	1380	0,5	50	-25	140	45
SNH809MA	3800	1200	0,9	1950	0,5	50	-25	140	75
SNH811MA	3800	1200	1	2390	0,5	50	-25	140	90
SNH817MA	3300	1200	1,1	3180	0,5	50	-25	140	90
SNH822MA	3300	1200	0,8	4550	0,5	50	-25	140	132
SNH825MA	2960	720	1,1	4220	0,5	50	-25	140	132
SNH842MA	2250	720	0,93	5100	0,5	50	-25	140	132

Where: Δp (bar) - the difference between the absolute pressure on the pressure side and suction
 (1 bar = 1×10^5 Pa)
 - t_1 (⁰C) - the temperature of the intake
 - t_2 (⁰C) - the temperature of the propulsor

In the Table 2 contains the values of flow and power absorption for the pressure of a device SNH-825MA.

Table 2: Performance blowers type SNH825MA

rpm	Flow (m³ / h) and power assorbed. (W) of the set pressure										Maximum vacuum		
	0,4bar		0,5bar		0,7bar		0,8bar		0,9bar				
	m³/h	kW	m³/h	kW	m³/h	kW	m³/h	kW	m³/h	kW	bar	m³/h	kW
720	693	13.3	642	16.6	553	23.3	-	-	-	-	0,4	569	13.3
1280	1560	23.6	1508	29.5	1417	41.3	1376	47.2	1338	53.1	0,4	1434	23.6
2120	2861	39.1	2807	48.9	2713	68.4	2671	78.2	2632	88	0,5	2599	48.9
2960	4162	54.6	4106	68.2	4009	95.5	3966	109	3925	123	0,5	3891	68.2

ANALYSIS OF THE PNEUMATIC SYSTEM

Pneumatic system periodically cleans and monitors the ultrasound method to avoid congestion process during the process of exploitation. The specificity of the horizontal water pipe system is that it is built from the composite (concrete) coated with sheet in order to minimize fraying in the flow of grain. Soybean and sunflower are very harsh in its raw state, under the assumed humidity defined in the purchase (optimal 15%) and uneven shape.

Such grains during transport, usually moving on the lower part of the inner piping system and significantly damage the system. Empirical method is determined by the percentage of damage for a certain period so that the tube is rotated periodically to 180 degrees and thus extends the lifetime.

Deformation detected on his knees pneumatic systems are much more serious problem and occurs in multiple shorter service life. Reducing the number of failures achieved by installing crash cushions and extending the assumed period of reparation. Mitigation of failures is made of different materials by strengthening and extending the assumed period of reparation. Reinforcements were made materials PE 1000 (Figure 1) who has given good practical results.

The choice of material is defined according to the diagram in Figure 2. Brittle materials are avoided due to dynamic loading system while

tough and soft (elastomer) because of poor mechanical properties and formability, particularly due to external temperature variations during seasonal changes.
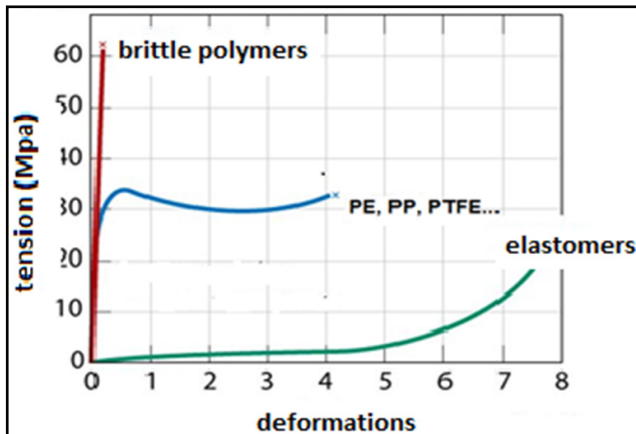

Figure 2: Diagram of the tension - deformation for polymers [04]

According to the laws of movement of grain through the pneumatic system [02, 08], the grain moves turbulent, hitting the walls bend, bouncing off each other and colliding with the consequent slowing of movement and change of continuity of movement. This chaotic movement causes discontinuity of flow and, ultimately, leads to congestion (Figure 3).

The consequences of the arrival of the grain mass at the crossings is increased friction between the grain and the walls of the pass due to the direction of movement and effects of centrifugal force. Even according to some studies detected the collision zone of grain coming out of the bend pipe (secondary collision zone) which results in a slowing of movement and potential fracture grain [03].
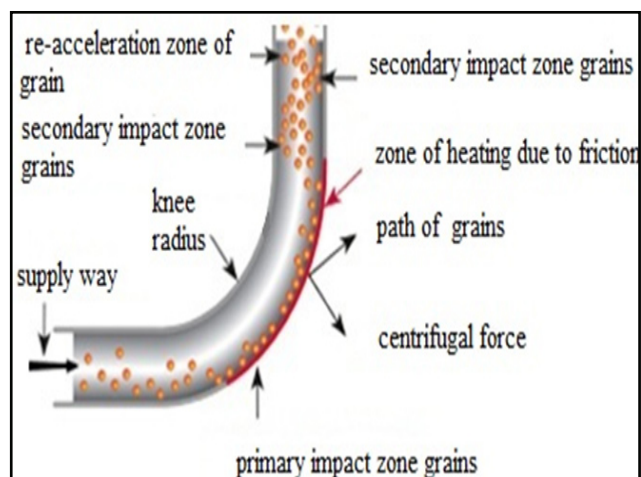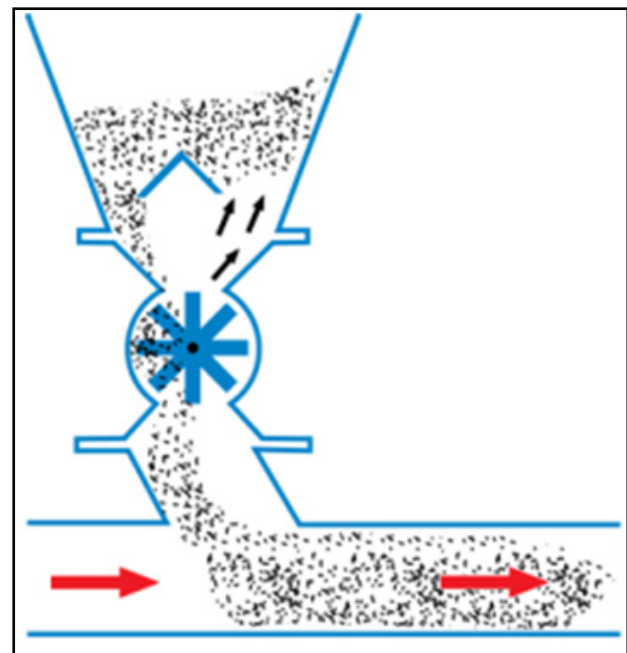

Figure 3: Principle of movement of grain through the elbow [11]

These are the main causes of deformation and there are multiple solutions: adjustment of the pneumatic system with modern shapes of elbows, installation of the Venturi pipe directly below grain dinspenser in order to obtain sufficient speed at the beginning of movement, precise regulation of air and grain velocity through pipe, etc.
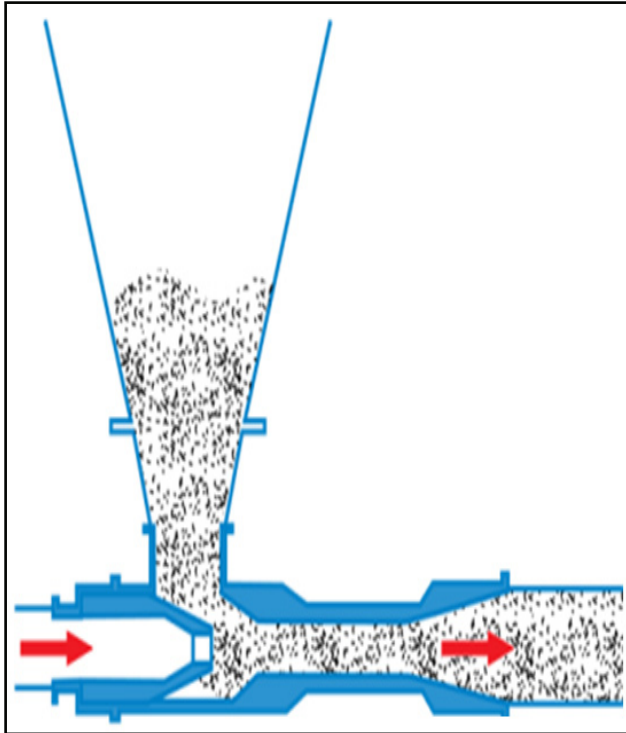
IMPROVING THE MOVEMENT OF GRAIN THROUGH THE PNEUMATIC SYSTEM

Improving the flow of grain through the pneumatic system is conditioned by maintaining the desired and projected daily capacity required for uninterrupted production. The former principle of dosing (Figure 4a) has given good results in terms of design capacity, but with the consequence of significant damage to the piping system for a certain period of exploitation. Draft decision are primarily related to the installation of the Venturi injectors [10] at the entrance to the pneumatic system (Figure 4b) a directly under the collector. This solution would be accelerated at the beginning of grain getting into a tube system and slow moving design speed evenly over the whole cross-section. Flow is hereby improves by 50% and even up to 80% with the elimination of all phenomena that negatively affect it [02].

a) Rotation injector

Figure 4a: The reduction the speed of movement of grain [10]

Tests by Foster [05, 06] indicate that the fracture of the grain is mostly influenced by the speed of air flow through the system and not the speed of moving the grain. Experimental tests for different materials show that the minimum velocity soybeans through a pneumatic system, which is 26.1 m / s, while below this speed material is very difficult to carried out through the system [06]. Another improvement s related to the transition part (knee) pipe system that the most wear the flow of air and grain mixtures. The solution is reflected in the modification of forms of knee pipe system in order to minimize or largely eliminate the causes of damage to the pipe. In the specific case of expanding the cross-section of the knee creates the effect of slowing the flow of grain and turbulent flow is reduced to laminar (Figure 6). Tests related to such modification knee show that generates much less friction on the turn, impact velocity grains on the walls is also many times smaller and perhaps most importantly, the grains do not collide uncontrollably, and become whole and compact until the end of pipe system (husking). Maintaining continent grains in basic form greatly facilitates the principle of the separation of the outer layer of the grain and thus accelerates the process economy.

b) Venturi injector

Figure 4b: The reduction the speed of movement of grain [10]

Grain flow is caused by the speed of air flow through the pipe system and the principle of movement is presented in Figure 5 [01, 02, and 03].
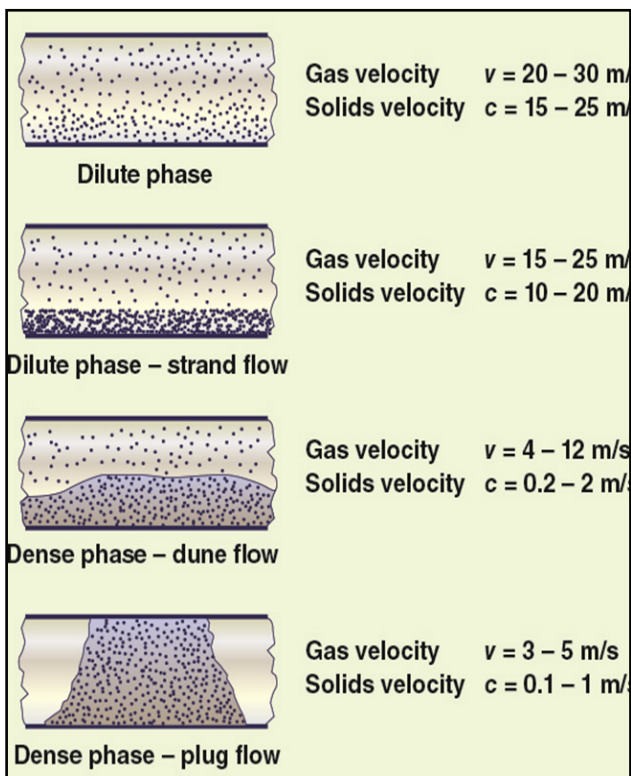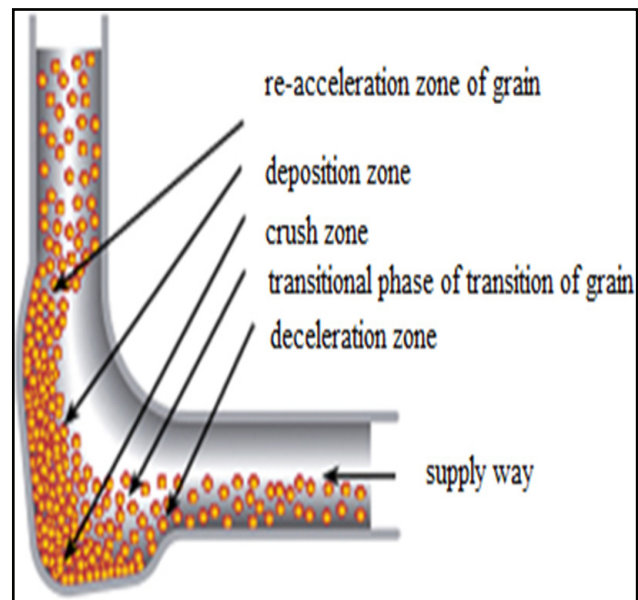
Figure 5: Dependency the speed of grain [02]

Figure 6: A modified form of the elbow [11]

Using simulation of virtual pneumatic system in Pipe Flow Expert software (version 7.4) important results were obtain in order to correctly design system. Simulation was conducted for approximate factory conditions of pneumatic system (Table 3) and results shown in the Table 3 are variations of assumed transitions (pneumatic elbows).

Table 3 : Horizontal pipeline parameters of pneumatic system

a) elbow parameters with radius	b) parameters of modified elbow
Flow = 0,1552 m3/s	Flow = 0,1490 m3/s
Mass Flow = 154,9041 kg/sec	Mass Flow = 148,6572 kg/sec
Velocity = 4,941 m/sec	Velocity = 4,741 m/sec
Length = 35,000 m	Length = 35,000 m
Inner Diam = 200,000 m	Inner Diam = 200,000 m
Start Elevation = 0,000 m	Start elevation = 0,000 m
End Elevation = 0,000 m	End Elevation = 0,000 m
Start Pressure = 0,70000 bar.g	Start Pressure = 0,70000 bar.g
End Pressure = 1,9809 bar.g	End Pressure = 2,2054 bar.g
Total dP Loss = -13,088 m.hd	Total dP Loss = -15,382 m.hd
Elevation Change = 0,000 m	Elevation Change = 0,000 m
Elevation Change Loss = 0,000 m.hd	Elevation Change Loss = 0,000 m.hd
Friction Loss = 3,268 m.hd	Friction Loss = 3,016 m.hd
Entry Fitting Loss = 0,000 m.hd	Entry Fitting Loss = 0,000 m.hd
Exit Fitting Loss = 0,284 m.hd	Exit Fitting Loss =10,146 m.hd
Pump Suction = 0,7000 bar.g	Pump Suction = 0,7000 bar.g
Pump Discharge = 2,3275 bar.g	Pump Discharge = 2,6127 bar.g
Pump Head = 16,629 m.hd	Pump Head = 19,544 m.hd
*** Pump Head Outside Curve	*** Pump Head Outside Curve
Pump NPSHa = 17,260 m.hd	Pump NPSHa = 17,260 m.hd
Pump NPSHr = 4,678 m.hd	Pump NPSHr = 4,392 m.hd
Pump Efficiency = 52%	Pump Efficiency = 60%
Pump Power = 48,8 kW	Pump Power = 47,19 kW

It is significant to notice that friction properties are in decline while mass is going through horizontal pipeline (the same properties that are bad influence on pressure and volume flow). Cause of part damage in system and increasing grain temperature is force of friction during mass movement through pneumatic system. The pressure drop on individual sections is directly proportional to the mass flow velocity and length and inversely proportional to the diameter of the pipe. In order for pressure drop to be lower, it is necessary to reduce the speed of mass movement.

CONCLUSION

Improving the implementation of grains through the pneumatic system, with the elimination of all negative influences, is the tendency of many scientists and professionals of today. The aim is to provide a mass flow with the necessary capacity by introducing dispensers with continuous flow rather than periodic, as has so far been customary. Controlling the movement of air and flow velocity grains through a pneumatic system leads to a decrease of many defects of the system and thus extend the life span. Modern production conditions assume that the system is not disturbed in any form, in order to maintain continuity of production and minimize losses. Application of modern constructive solutions, especially at crossings, leading to a decrease in the percentage of wear and heating, as mass flow, and the piping system and thus reduce grain breakage

during transport. All this requires continuity of mass flow and maintenance of production processes within the limits desirable.

In this paper with proposed solution on elbows it is shown that it is possible to reduce mass flow velocity by 10 percent without clogging the process and stops in grain material transport.

Savings in electric energy consumption by working hour can be seen in used power needed for pneumatic system. With modified shape of elbow required power of blower is P = 47,19 kW (savings of approximately 3 percent comparing to elbow with radius).

REFERENCES

1) Aptec Powder Systems, (2015) Advance in Pneumatic Conveying, Unit 1, England, 1-17.

2) Bathia, A. (2010) Pneumatic Conveying System, Course No: MO5-010, Continuing Education and Development, NY, 1-57.

3) Bell M. J. (2015) pneumatically conveying fragile materials without particle Degradation, Powder Show & Conference, Atlanta, GA, 37-44.

4) Callister, W. (2007) Materials Science and Engineering, seventh edition, Characteristics, Applications and Processing of Polymers: The University of Utah, Department of Metallurgical Engineering, John Wiley & sons, 523-571.

5) Foster, G.H, (1973) Grain breakage caused by commercial handling methods, USDA Market Research Report No. 968.

6) Haw, J. (1993) Pneumatic conveying of grains, Pac. Agri, (4), 1-13.

7) Internal documents of the company "Dijamant" from Zrenjanin.

8) Tolmač, D., Prvulović, S. (2012) Transportni sistemi, Zrenjanin: Univerzitet u Novom Sadu, Tehnički fakultet "Mihajlo Pupin", 132 str.

9) Šešlija, D. (2010), Fabrička automatizacija, deo 1, Novi Sad: Univerzitet u Novom Sadu, FTN, 130 str.

10) www.foxvalve.com, catalogue, retrieved on December 7th, 2016.

11) www.pelletroncorp.com, retrieved on December 7th, 2016