The Use of a Plate Conveyor for Transporting Aluminum Cans in the Food Industry

Jacek Caban[1], Iwona Rybicka[2]

[1] University of Life Sciences in Lublin, Faculty of Production Engineering, Department of Agricultural, Forestry and Transport Machines, 28 Głęboka, 20-612 Lublin, Poland

[2] Lublin University of Technology, Faculty of Mechanical Engineering, Nadbystrzycka 36, 20-618 Lublin, Poland

* Corresponding author's e-mail: i.rybicka@pollub.pl

ABSTRACT

The food industry is characterized by specific technical and technological conditions. The sanitary and epidemiological considerations play a very important role as well, and the materials used in production must meet the appropriate requirements. In the case of transport operations, the above-mentioned criteria must also be met. The article presents the problems of transporting beverages in aluminum can packaging using a plate conveyor. Depending on the efficiency of the production machines, the type of material (product packaging), the location of the center of gravity and the angle of friction, the parameters of the conveyor operation were determined.

Keywords: internal transport, efficiency, packaging

INTRODUCTION

The food industry is characterized by specific process conditions like: technical and technological conditions, sanitary and epidemiological considerations as well as suitable materials used in the production process. A proper choice of the technological and organizational parameters of the production processes enables more efficient and effective production of goods [17]. Traditionally, the research on the manufacturing processes was mainly conducted to the improve efficiency and accuracy and to lower the cost [12]. One of the modern challenges in the field of designing the manufacturing systems is to determine the optimal level of their flexibility from the point of view of the production tasks being performed. Whether or not a production process to be executed is capable of achieving the assumed performance parameters depends, among others, on the reliability of the machines and technological devices that make up the system under design [6]. Furthermore, a sustainable production line must also be balanced as it leads to lower costs,

good production environments and green manufacturing [22].

The production operations within an automated production line would be impossible if they did not cooperate with the means of continuous transport. Transportation plays a very important role in the logistics of manufacturing systems [3, 11]. The concept of transportation control is not constrained to fully-automated systems [8]. Bulk and mass production is being replaced by small batch production [16]. Conveyors and manipulators complete the production process and ensure the required process efficiency [1]. Depending on the conveyors construction, they are used to transport unit loads and loose materials carried in bulk. Belt conveyors mounted in a transport system consisting of conveyor modules with and without drive, turntables or arches are in common use [4]. The support and drive elements are subjected to variable loads resulting from the possibility of transporting loads of various shapes and weights on one conveyor [10]. Furthermore, the additional operating conditions of the conveyors like reduction of noise and vibrations are defined by

the normative requirements [13, 15]. In the case of the transport operations on the production line, there are many problems related to both transport operations as well as additional processes, marking, identification, etc. In [9, 14], algorithms and design procedures are described as well as the ways to control the assembled transport system in terms of eliminating bottlenecks causing queues at junction points. In order to increase the efficiency of internal transport processes as well as the correct location and tracking of transported goods, the RFID technology is used [2, 20].

In addition, transport conveyors are used in many industrial applications and logistics processes, among others: heavy industry [21, 22], agriculture [17], food and processing industry [7], in sorting areas of courier companies [5, 20], warehouse [19] etc.

One of the most frequently used type of conveyor for transporting unit loads in the food industry (e.g. bottles, cans) is a plate conveyor. The load-bearing elements of the plate conveyors are train chains, usually two-legged, connected to each other by plates, on which the transported material is moved. Plate conveyors are used not only as means of transport, but also as buffering conveyors; they also operate jointly with other technological devices, for example for filling, labeling, closing, sorting etc. Due to the fact that they can operate at high temperatures and their supporting elements are characterized by the resistance to chemical products, they are widely used in the food and chemical industry.

The article presents the selected results of the laboratory tests of a plate conveyor during the transport of aluminum cans with a drink. The conveyor as a mechatronic device consists of a physical mechanical model, a motion device (motor + gearbox) and a controller that controls the movement of the motor and the conveyor itself [18].

METHODOLOGY

Figure 1 presents the PP-4/2014 plate conveyor used in the research on determining the transport efficiency of aluminum cans packaging.

The plate conveyor is driven by an electric motor, type SK1SI40-IEC80-80S/4 TF from "NordDrivesystems" with a capacity of 0.55 kW and a rated voltage of 380 V. Using a control and measurement system consisting of an iG5A inverter, the engine speed and controller with display were adjusted. The following additional equipment was used during the tests:

- ArcoMaster electronic protractor with a spirit level,
- Electronic caliper,
- AXIS BA30C platform scale.

The transport efficiency tests were conducted for load unit (aluminum cans with a drink of 0.33 liter capacity) – Table 1, with three angles of inclination of the transport module 3°, 6° and 9°. The following parameters were recorded during the test: frequency of the inverter, linear speed of the conveyor belt, rotational speed of the drive motor of the conveyor, loading time, general transport time, distance between loads.

The plate conveyor efficiency Q was calculated on the basis of equation for the unit load:

$$Q = bG\,v/a$$

where: G – unit weight of the load [kg],

v – linear speed of the conveyor belt [m/s],
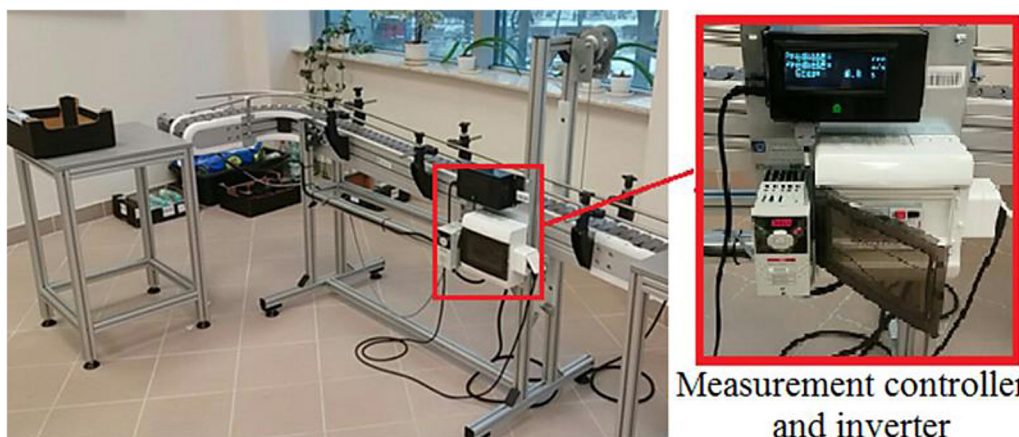
a – distance between loads [m].

Fig. 1. PP-4/2014 plate conveyor

Table 1. Characteristics of aluminum cans used during tests

Weight [kg]	Height [mm]	The diameter of the package		Contact area [mm²]
		Min. [mm]	Max. [mm]	
0.35	115	54	65.5	301.2

RESULTS AND DISCUSSION

Tables 2–4 present the results of the transport conditions tests on a plate conveyor for aluminum cans with a drink.

In the Figures 2–4 are shown the results of calculations of plate conveyor efficiency at three values of the conveyor transport module inclination angle concerning the plate conveyor speed.

Figure 5 presents the comparison of the plate conveyor efficiency results for three tested transport module angles (3º, 6º, 9º), of the transporting the aluminum cans.

While analyzing the graphs, it can be seen that their course for aluminum cans retains repeatability for the inclination angle of the 3° and 6° transport module. In both graphs, the extreme is located in the speed range from 0.4 to 0.43 m/s.

Table 2. The results of measurements of transporting aluminum cans at the angle of inclination of the transporting module equal to 3°

No.	Frequency of the inverter [Hz]	Loading time [s]	General transport time [s]	Distance between loads [m]	Conveyor speed	
					Linear [m/s]	Rotational [rpm]
1	10	1.2	17.2	0.27	0.28	39
2	11	1.2	16.5	0.28	0.31	43
3	12	1.1	15.4	0.28	0.34	47
4	13	1.1	14.7	0.30	0.37	51
5	14	1.0	14.3	0.30	0.4	55
6	15	1.0	13.3	0.35	0.43	60
7	16	1.0	13.1	0.37	0.46	64

Table 3. The results of measurements of transporting aluminum cans at the angle of inclination of the transporting module equal to 6°

No.	Frequency of the inverter [Hz]	Loading time [s]	General transport time [s]	Distance between loads [m]	Conveyor speed	
					Linear [m/s]	Rotational [rpm]
1	10	1.1	18.3	0.25	0.28	39
2	11	1.1	17.4	0.27	0.31	43
3	12	1.1	15.9	0.27	0.34	47
4	13	1.1	15.7	0.30	0.37	51
5	14	1.0	14.8	0.30	0.40	55
6	15	1.0	15.1	0.30	0.43	60
7	16	1.0	15.1	0.35	0.46	64

Table 4. The results of measurements of transporting aluminum cans at the angle of inclination of the transporting module equal to 9°

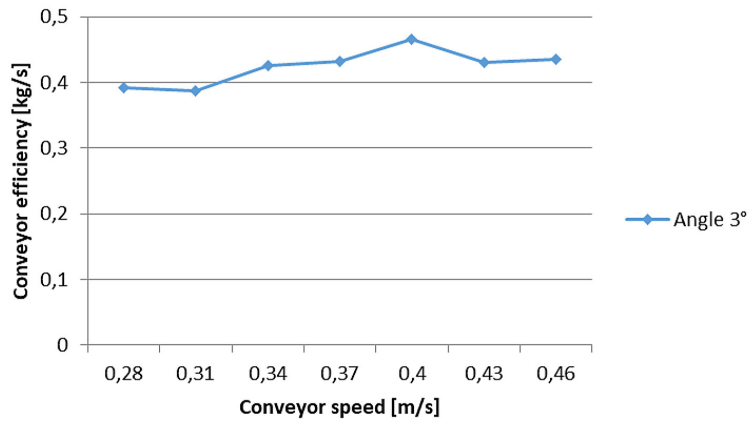| No.	Frequency of the inverter [Hz]	Loading time [s]	General transport time [s]	Distance between loads [m]	Conveyor speed	
					Linear [m/s]	Rotational [rpm]
1	10	1.1	18.4	0.30	0.28	39
2	11	1.1	17.8	0.32	0.31	43
3	12	1.1	18.0	0.34	0.34	47
4	13	1.1	17.1	0.35	0.37	51
5	14	1.1	16.5	0.37	0.40	55
6	15	1.1	17.3	0.42	0.43	60
7	16	1.1	16.5	0.47	0.46	64

Fig. 2. The dependence of the value of the plate conveyor efficiency on the conveyor speed at the inclination angle of the transport module of 3º
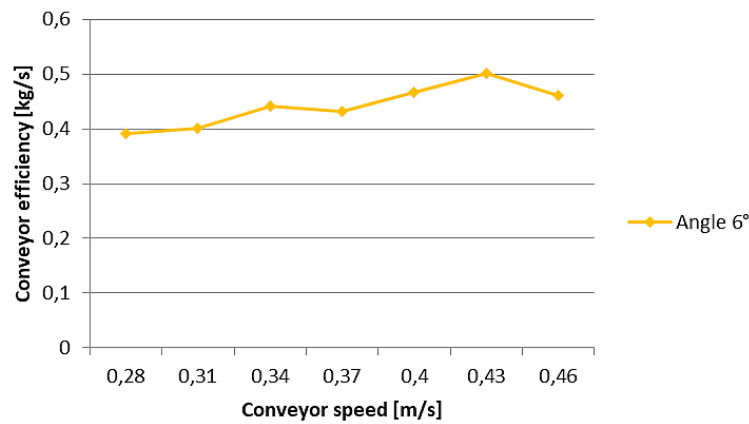

Fig. 3. The dependence of the value of the plate conveyor efficiency on the conveyor speed at the inclination angle of the transport module of 6º
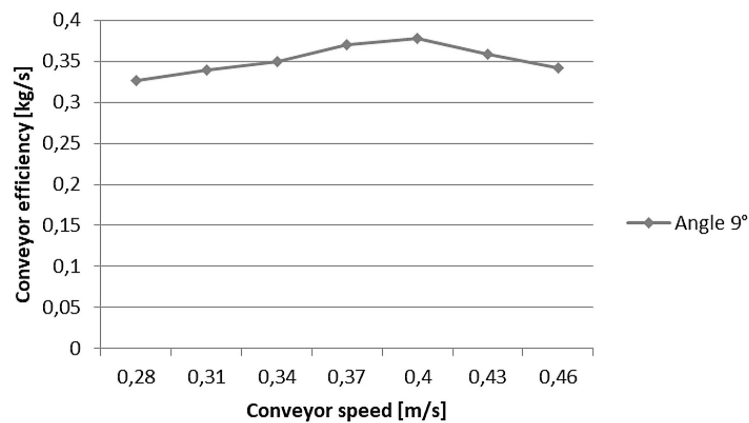

Fig. 4. The dependence of the value of the plate conveyor efficiency on the conveyor speed at the inclination angle of the transport module of 9º

The curve at an angle of 6° has a stable increase without sudden fluctuations, to the speed range to 0.43 m/s, at 0.46 m/s slight drop in the conveyor efficiency is observed. The curve at an angle of 3° has a stable increase without sudden fluctuations, to the speed range to 0.4 m/s, at next speed value a drop in the conveyor efficiency can be observed. The plate conveyor efficiency is the smallest for setting the transport module at an angle of 9°.
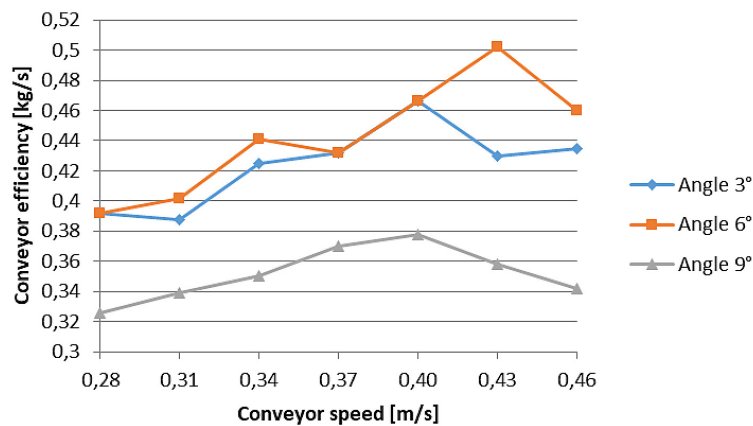
Fig. 5. A comparison of the plate conveyor efficiency results for three transport module angles

CONCLUSIONS

In this study, the results of the plate conveyor efficiency obtained during the transport of aluminum cans with the beverage at three angles of inclination of the transport module in the upward direction were presented. On the basis of the conducted study, it was noticed that the conveyor efficiency decreased with the increase of the inclination angle of the transport module. The most noticeable decrease of the conveyor efficiency occurred with the angle of inclination of the transport module amounting to 9°. The area between 6 and 9 degrees is interesting, which would have to be investigated, because in this range there was the greatest reduction in the plate conveyor efficiency, up to 20%.

During the transport of packaging in the form of aluminum cans at higher belt speeds, a slip was observed between the conveyor plate and the contact surface with the load when placing the cans on the conveyor plates. This phenomenon is caused by the difference in the velocity vectors and the direction of placing aluminum cans on the plates and the speed of conveyor movement. During the transport on the plate conveyor, the location of the center of gravity of the load and the shape of its contact surface (bottom of the package) are also important.

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