Mining Science, vol. 32, 2025, 223–239

www.miningscience.pwr.edu.pl

Mining Science

(Previously Prace Naukowe Instytutu Gornictwa Politechniki Wroclawskiej, ISSN 0370-0798)

ISSN 2300-9586 (print)
ISSN 2353-5423 (online)

Received March 7, 2025; Reviewed; Accepted September 29, 2025

COMPARISON OF A CONVENTIONAL AND PIPE CONVEYOR IN TERMS OF THEIR ENERGY EFFICIENCY USING SIMULATION MODELING

Bohdana BOBINICS, Daniela MARASOVÁ*, Peter BINDZÁR

Tecnical University of Košice, Faculty of Mining, Ecology, Process Control and Geotechnologies, Park Komenského 14, 042 00 Košice, Slovakia

Abstract: The article presents a simulation model of a conventional and pipe conveyors created in the Tecnomatix Plant Simulation environment. The main objective was to analyse the normal forces, throughput, and energy consumption of both types of conveyors. The model allows for variable input parameters and experimental comparisons. Four experiments were conducted as part of the research, changing the belt filling coefficient and the design characteristics of the idlers. The results showed that a conventional conveyor transports more material than a pipe conveyor with the same belt width. However, the higher productivity of the conventional conveyor is also associated with higher electricity consumption. Conversely, for the same amount of transported material, the conventional conveyor has slightly lower energy consumption compared to the pipe conveyor. The analysis also confirmed the stability of both systems during long-term simulation. The most significant impact on performance was the filling coefficient, which directly affected the amount of transported material. The results provide practical insights for optimising the design and operation of belt conveyors.

Keywords*: *conventional conveyor, pipe conveyor, energy efficiency, simulation, material throughput, energy consumption

1. INTRODUCTION

Nowadays, belt conveyors play an important role in material transportation methods. The development of conveyors and conveyor belts has a long history: as far back as 1890,

* Corresponding author: bohdana.bobinics@tuke.sk (B. Bobinics)

doi: 10.37190/msc/215173

conveyor belts were already being used to transport ore in mines. One of the main problems with conveyor belts at that time was their design. They could not withstand long-term loads and wore out quickly. Since then, production technologies have evolved and improved significantly, and modern research is shifting its focus to the energy efficiency and reliability of systems (Baldwin 2024).

Konieczna-Fuławka (2025) summarises the current state and modern trends in reducing energy consumption: the right choice of conveyor design and preventive maintenance have a striking and decisive impact on reducing energy consumption. The publication (Bajda et al. 2022) presents solutions that have an impact on the optimization and thus the reduction of energy consumption costs by belt conveyors. This is due, among other things, to the use of better materials for conveyor belts, which reduce their rolling resistance and noise, and also improve the ability to absorb impact energy from material hitting the belt. Energy consumption is mainly influenced by the use of appropriate drive systems and simulation of their operation. Experimental verification of the drive simulation model due to dangerous vibrations is presented by the authors of the article Moravič et al. (2024).

The main source of energy consumption is resistance movements, and the most energy-intensive type of resistance is rolling resistance. Zhao et al. (2019) created a mathematical model of the indentation rolling resistance of a belt conveyor and showed that prediction is the key to reducing power consumption.

At the level of design parameters for horizontal transport by belt conveyor, the difference in conveyor combinations has a significant and striking effect on energy consumption. Several short conveyors will consume more energy than one longer one. That is why authors Jena et al. (2023) recommend using one long conveyor instead of several shorter ones. The same conclusion was reached by the authors Grujić et al. (2019), who addressed the reliability of belt systems and proposed reducing the number of conveyors while maximizing the conveyor length and the possibility of using pipe conveyors.

He et al. (2010) point out the importance of choosing the correct distance between roller supports and its impact on conveyor energy consumption, as well as pointing out the relationship between total life cycle cost and belt. The authors propose a mathematical model to find the optimal compromise.

Authors Schützhold et al. (2014) write about the traditional design of conveyor systems and note that to improve energy efficiency, it is necessary to evaluate the entire electromechanical system – starting with the conveyor belt and idler panel.

Improving energy efficiency is also about choosing the right conveyor capacity and rigidity (Ambrisko et al. 2015).

Research into energy balance during impact processes also has a place. Authors Ambriško et al. (2023) describe this research in the article "Energy Balance of the Dynamic Impact Stressing of Conveyor Belts".

Along with conventional conveyors, pipe conveyors are also beginning to develop. Japan Pipe Conveyor Co., Ltd. has been developing them since 1970. In 1979, the first conveyor of this type was put into operation. The author of the article specifically noted the advantages of this type of conveyor (Ford, 1996).

The simulation approach is becoming increasingly popular and provides an opportunity to analyse electricity consumption. Prokuda and Burtnyi (2022) demonstrate the possibility of using simulations to analyse electricity consumption for conveyor transport in mines. The model created enabled the authors to provide practical recommendations for reducing energy consumption in mines.

At the same time, Mhlongo et al. (2020) point out that poor dynamics and poor control of conveyor speed are likely to lead to unnecessary electricity consumption.

There are many types of combinations of different software for modelling and simulation for the operation of conveyors and conveyor systems. The article by Dadhich et al. (2024) contains information about an automatic material feeding system consisting of various parts. The authors created a simulation model of the ASMFS system using CAD and also mathematically modelled it using a connection graph. The mass flow of material is regulated using the MATLAB programme.

Since conveyors operate continuously, authors Junglas and Schmedes (2022) focus on the difficulties of modelling through discrete-event modelling of the process of continuous pouring of bulk materials onto a conveyor belt. In their article, the authors propose a solution to this problem using the SimEvents programme.

Additionally, author Xie (2001) show that taking into account dynamics and design features makes it possible to simulate unstable modes, such as the conveyor start-up phase.

When writing about simulations, it is impossible not to mention two interesting concepts, such as digital shadow and digital twin. The digital shadow concept is a digital representation of a specific conveyor line, which is continuously updated with actual data from the equipment (Husár et al. 2024).

The digital twin concept is used to deepen digital automation and improve management decisions in the era of Industry 4.0. The model simulates the operation of the conveyor and transparently connects to the PLC for instant control of the conveyor (Aniba et al. 2024).

The use of digital twins for conveyors also improves maintenance efficiency. In this case, the digital twin concept enables in-depth analysis and faster detection of technical problems before they arise using a prediction method (Pulcini and Modoni, 2024).

An important factor in using the Digital Twin concept is establishing a connection between the real conveyor and its virtual copy. The authors Liyanawaduge et al. (2023) managed to establish this connection in their article by adding the use of Internet of Things (IoT) and Virtual Reality (VR). The right combination of these technologies ensured smooth operation between the physical conveyor and its digital copy. The use of VR equipment made it possible to control the physical system. The accuracy of this model is at a high level.

2. METHODS AND METHODOLOGY

The main objective of this article was to create a simulation model of the conveyor's operation (Fig. 1), taking into account the normal forces of this conveyor. The work compares the results between a conventional belt conveyor and a closed-type pipe conveyor. This model was created using the Tecnomatix Plant Simulation programme.

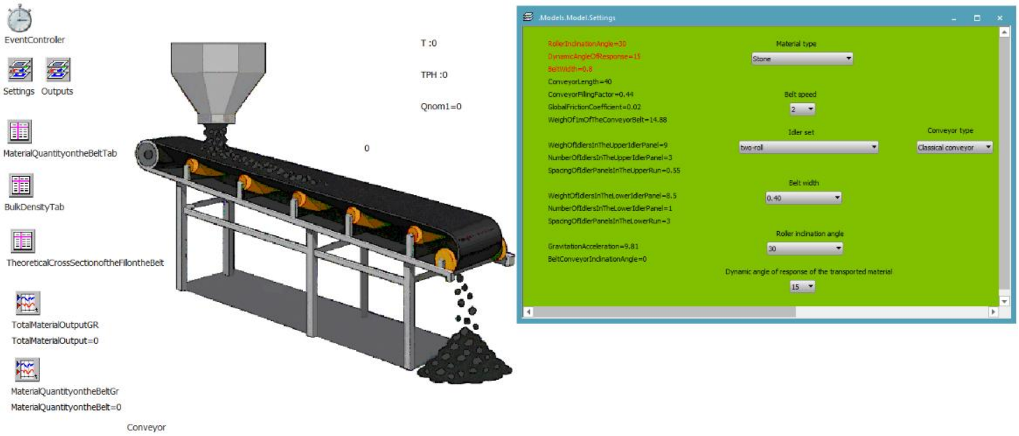

Fig. 1. Conveyor model printscreen

Figure 1 shows the main window of the belt conveyor model, and the second window called "Settings" shows the model settings, where the basic parameters for its operation are set, including: conveyor belt speed, width, etc. In the middle of the main window, there is a conveyor: on the left side, there is a bulk hopper, from where the material is fed onto the belt, followed by the conveyor itself with idler supports, and on the right side, it ends with a discharge chute, where unloading takes place. Above the unloading area there are calculated values indicating the amount of material that has passed through the conveyor, the hourly productivity, and the calculated productivity according to the formula. This window also contains numerous tables and other blocks used to calculate the conveyor's throughput capacity and normal forces during operation in the simulation.

The main additional data required for simulation can also be found in the "Settings" window, including geometric characteristics, physical and mechanical properties of the material, and structural elements. This data makes it possible to calculate the normal forces based on the amount of material. This data also includes the following: the mass of individual elements – for example, the mass of a single idler, the mass of the belt per metre of length. The number of idlers in the upper and lower panel and the distance between them are also taken into account.

Model calculations are based on adjusted formulas taken from ISO 5048, which replaced the now-invalid STN EN 26 3102 standard.

This model was created for conveyors up to 250 metres long. The main formula used to calculate the normal forces is (STN 26 3102, 1995):

$$F_H = f \cdot L \cdot g \cdot [m_{rh} + m_{rd} + (2 \cdot m_2 + m_1) \cdot \cos\delta][\mathrm{N}], \tag{1}$$

where:

FH – normal forces [N],

f – global friction coefficient [–],

L – belt conveyor length [m];

g – gravitational acceleration [m·s^{-2}],

m_{rh} – weight of rotating parts of idlers in the upper run per 1 m of the conveyor belt length [kg·m^{-1}],

m_{rd} – weight of rotating parts of idlers in the lower run per 1 m of the conveyor belt length [kg·m^{-1}],

m_1 – weight of the load per 1 m of the conveyor belt length [kg·m^{-1}],

m_2 – weight of 1 m of the conveyor belt [kg·m^{-1}],

δ – belt conveyor inclination angle [°].

Based on formula (1), a program code that implements the calculation logic in the model and calculates the necessary data and results was created. The code was created so that it calculates the individual values required for analysis step by step. First, the weight of the rotating parts of the idlers in the upper run per 1 m of the conveyor belt length is calculated, then the weight of the rotating parts of the idlers in the lower run per 1 m of the conveyor belt length is calculated, as well as the weight of the load per 1 m of the conveyor belt length.

After the above calculations, the data is substituted into the final formula for calculating the normal forces. Please note that this type of force varies depending on the amount of material per 1 metre of the belt, which is not a constant value.

The logic of this model is written in the form of conditional if-else statements (see Fig. 2).

More attention should be paid to the "MaterialQuantityontheBeltTab" table, which contains the main data with simulation results. It stores the calculated data related to the process of transporting material by a belt conveyor. The table has three main columns. The first column shows the moment when the data was recorded, i.e., the simulation time. The second column shows the amount of material on the conveyor belt at the recorded moment, with units given in kilograms. The third column contains the values of the normal forces that arise during the operation of the conveyor.

```
var f, L, mrh, mrd, mr1, mr2, nh, th, nd, td, m1, m2, m20, m16, g, Fh: real

f := Settings.GlobalFrictionCoefficient
L := Settings.ConveyorLength
mr1 := Settings.WeightOfIdlersInTheUpperIdlerPanel
nh := Settings.NumberOfIdlersInTheUpperIdlerPanel
th := Settings.SpacingOfIdlerPanelsInTheUpperRun

If Outputs.TheWeightOfRotatingPartsOfIdlersInTheUpperRunPer1mOfTheCBLength = 0
    mrh := mr1 * nh / th
    Outputs.TheWeightOfRotatingPartsOfIdlersInTheUpperRunPer1mOfTheCBLength := mrh
else
    mrh := Outputs.TheWeightOfRotatingPartsOfIdlersInTheUpperRunPer1mOfTheCBLength
end

nd := Settings.NumberOfIdlersInTheLowerIdlerPanel
td := Settings.SpacingOfIdlerPanelsInTheLowerRun
mr2 := Settings.WeightOfIdlersInTheLowerIdlerPanel

If Outputs.TheWeightOfRotatingPartsOfIdlersInTheLowerRunPer1mOfTheCBLength = 0
    mrd := mr2 * nd / td
    Outputs.TheWeightOfRotatingPartsOfIdlersInTheLowerRunPer1mOfTheCBLength := mrd
else
    mrd := Outputs.TheWeightOfRotatingPartsOfIdlersInTheLowerRunPer1mOfTheCBLength
end

m20 := Settings.WeighOf1mOfTheConveyorBelt

If Settings.WeighOf1mOfTheConveyorBelt = 0
    m2 := B * m20
    Settings.WeighOf1mOfTheConveyorBelt := m2
else
    m2:= Settings.WeighOf1mOfTheConveyorBelt
end


var MassOfLoadPerMeterOfBelt : real
MassOfLoadPerMeterOfBelt := Conveyor.CurrentAmount / ConveyorLength
m1 := MassOfLoadPerMeterOfBelt

var AR : real
AR := asin(0.7/ConveyorLength)
g := Settings.GravitationAcceleration
Fh := f * L * g * (mrh + mrd + (2 * m2 + m1) * cos(AR))
Outputs.NormalForces := Fh

var EC : real
EC := (Fh * v) / (1000 * 0.8)
```

Fig. 2. Screenshot of the code on which the simulation model is built

2.1. INPUT DATAS FOR SIMULATION

To implement the experiments, the main goal was to select the correct input data for simulation. This input data is shown in the table. The following tactic was chosen: to conduct four experiments comparing a conventional conveyor and a pipe conveyor in each experiment.

Table 1 represents the input data for simulations. In these simulations, comparisons were made between a conventional belt conveyor (CC) and a pipe conveyor (PC). A total of four experiments were performed.

Table 1. Input data table for simulations

	EXP1		EXP2		EXP3		EXP4	
Conveyor type	CC	PC	CC	PC	CC	PC	CC	PC
Conveyor length [m]	63	63	63	63	63	63	63	63
Conveyor speed [m·s^{-1}]	2	2	2	2	2	2	2	2
Material type	Stone	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Belt width [m]	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Roller inclination angle [°]	30	–	30	–	30	–	30	–
Dynamic angle of repose [°]	15	–	15	–	15	–	15	–
Feeding deviation up to [%]	–25	–25	–25	–25	–25	–25	–25	–25
Conveyor filling factor [–]	0.44	0.44	0.8	0.8	0.44	0.44	0.8	0.8
Efficiency of the drive station [–]	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Global friction coefficient [–]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Weight of idlers in the upper idler panel [kg·m^{-1}]	9	4.7	9	4.7	9	4.7	9	4.7
Number of idlers in the upper idler panel [–]	3	6	3	6	3	6	3	6
Spacing of idler panels in the upper run [m]	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Weight of idlers in the lower idler panel [kg·m^{-1}]	8.5	8.5	8.5	8.5	9	4.7	9	4.7
Number of idlers in the lower idler panel [–]	1	1	1	1	3	6	3	6
Spacing of idler panels in the lower run [m]	3	3	3	3	0.55	0.55	0.55	0.55
Weigh of 1m of the conveyor belt [kg·m^{-1}]	14.88	14.88	14.88	14.88	14.88	14.88	14.88	14.88
Gravitation acceleration [m·s^{-2}]	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81

In all four cases, the conveyor length is 63 metres, the conveyor belt width is 0.8 metres, the roller inclination angle with a unit of 30 and the dynamic angle of response with a unit of 15 are used only in the case of a conventional conveyor. Feeding deviation for all conveyor types could reach a maximum of –25%. The conveyor filling factor varies depending on the experiment; in Experiments 1 and 3, this unit is 0.44, and in Experiments 2 and 4, this unit is 0.8. The global friction coefficient has a value of 0.02 for all experiments.

Weight of idlers in the upper idler panel of conventional conveyor has three idlers weighing 9 kg each, while a pipe conveyor has six idlers weighing 4.7 kg each. The spacing of idler panels in the upper run is constant for all experiments and equals 0.55 m. The values for the lower idler supports differ slightly. In the first two experiments, the values for the conventional conveyor and the pipe conveyor are the same, which is 1 idler weighing 8.5 kg and a spacing of idler panels in the lower run equal to 3 metres. For Experiments 3 and 4, the data changed slightly. In the case of a conventional conveyor, there are 3 idlers weighing 9 kg and the spacing of idler panels in the lower run is 0.55 m. In the case of a pipe conveyor, there are 6 idlers weighing 4.7 kg and the spacing of idler panels in the lower run is also 0.55 m.

The weight of 1m of the conveyor belt for all experiments is the same and is 14.88 kg.

In addition to the data in the table, the program code from the figure 2 also contains conveyance height with a value of 0.7 m.

In summary, table shows the main differences between the two types of conveyors and between the changes in input data in the experiments. The main difference between a conventional conveyor and a pipe conveyor is the number of idlers and their weight.

3. RESULTS

3.1. EXPERIMENT 1

Graph (Fig. 3) shows the amount of material on the conveyor belt over a 5-hour period of Experiment 1 for the conventional and pipe conveyors. Based on this graph, it is clear that both conveyors operate steadily, without sharp jumps or drops, not taking into account the run-up at the beginning of the simulation, when the values rise from 0. Calculating the average value for this case, there is a value of 3002.16 kg for the conventional conveyor (green line), while the value for the pipe conveyor (red line) is 2593.89 kg. The graph also shows that the conventional conveyor transports more material per unit of time.

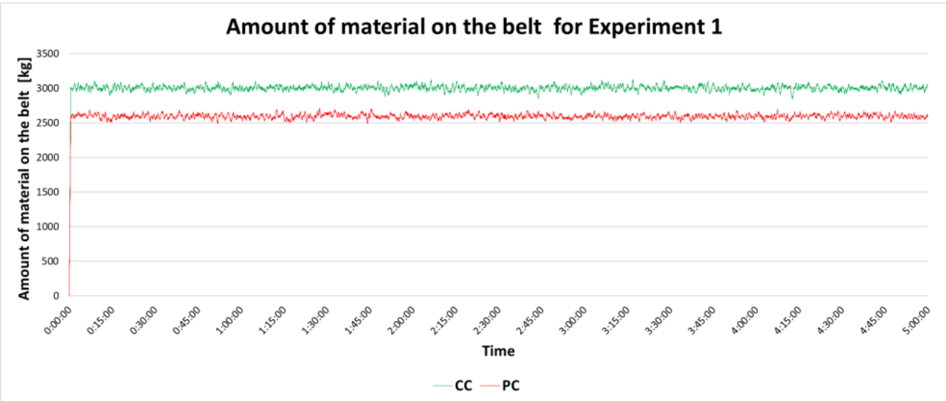

Fig. 3. Amount of material on the belt for Experiment 1

The graph (Fig. 4) illustrates energy consumption over five hours during Experiment 1 for two types of conveyors. The graph shows that the conventional conveyor (green line) requires slightly more energy, with an average value of 3.81 kW. This is due to the larger amount of material on the conveyor belt. The pipe conveyor, on the other hand, shows slightly lower figures, with an average value of 3.68 kW.

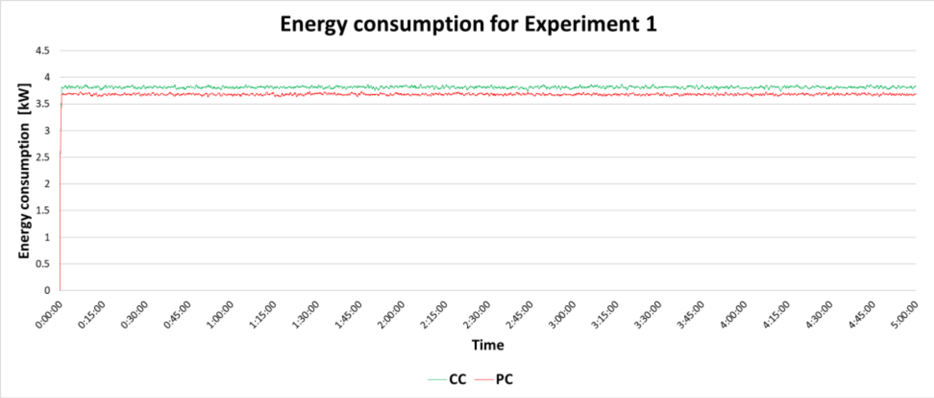

Fig. 4. Energy consumption for Experiment 1

3.2. EXPERIMENT 2

The graph (Fig. 5) shows the results from Experiment 2, where, as in the case of the graph, the amount of material on the conveyor belt was measured over a 5-hour simulation period. Both the green and red curves appear to be fairly stable, without excessive jumps or drops, indicating the relative stability of both the conveyor and the process of feeding material onto the conveyor belt. The average value for the conventional conveyor is higher (5461.47 kg) than for the pipe conveyor (4716.47 kg) with the same conveyor filling factor. This is clearly visible in the graph, where the distance between the curves remains almost the same throughout the entire time.

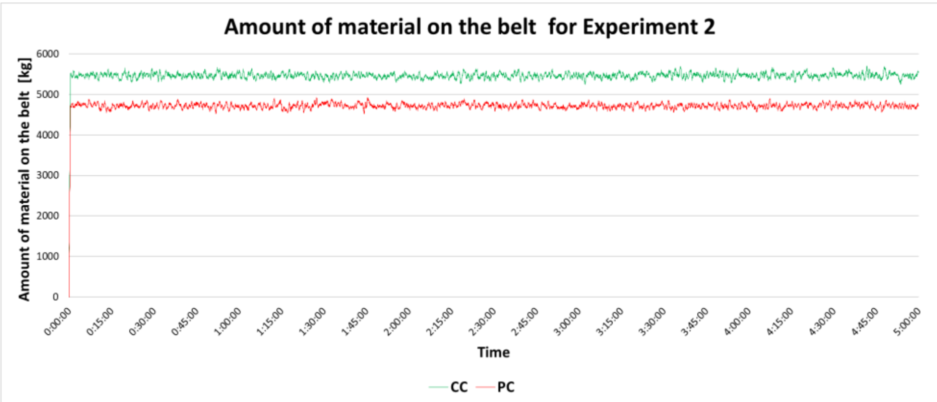

Fig. 5. Amount of material on the belt for Experiment 2

The graph (Fig. 6) shows the energy consumption dynamics of two types of conveyors during Experiment 2. Based on the previous graph, the energy consumption graph also indicates the stability of the system, where the conventional conveyor demonstrates a higher level of energy consumption (average value of 5.02 kW), while the pipe conveyor consumes less electricity (average value of 4.72 kW). This difference is due to the larger amount of material on the conveyor belt in the case of the conventional conveyor and the similarity of the input data for both conveyors.

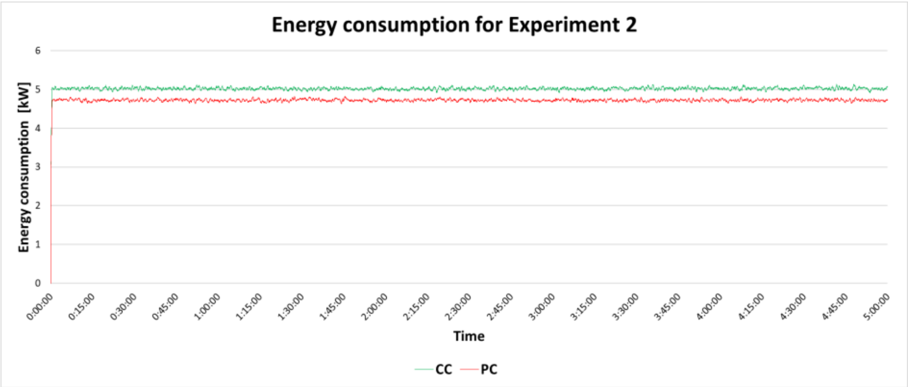

Fig. 6. Energy consumption for Experiment 2

3.3. EXPERIMENT 3

The graph (Fig. 7) shows the results of Experiment 3, which analysed the amount of material on the conveyor belt over 5 hours of simulation time. The green and red curves remain flat and do not show significant fluctuations throughout the entire time, which indicates the stability of the process. The green line (conventional conveyor) runs higher and its average value is 3003.35 kg. The red line (pipe conveyor) is located lower and its average value is 2591.69 kg.

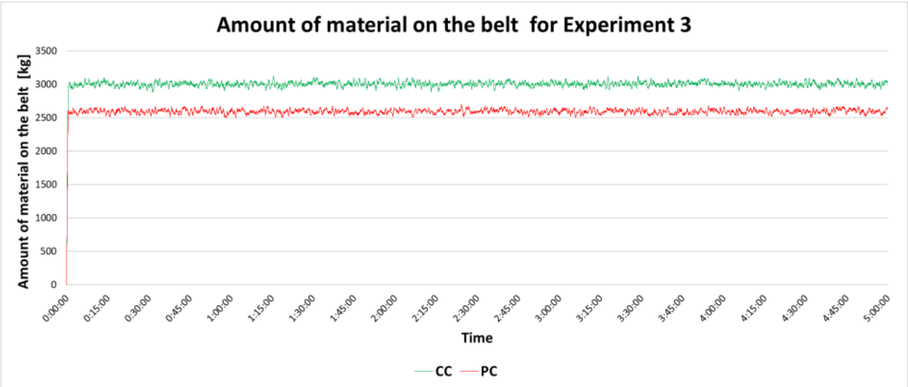

Fig. 7. Amount of material on the belt for Experiment 3

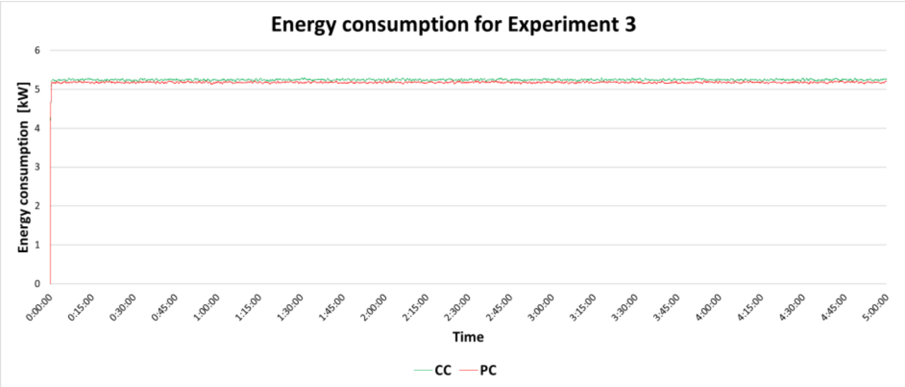

Fig. 8. Energy consumption for Experiment 3

The values for the conventional conveyor (green line) and pipe conveyor (red line) are very close to each other. The average value for the conventional conveyor is 5.24 kW, and for the pipe conveyor – 5.18 kW. Comparing all previous experimental results, in Experiment 3, the two curves are very close to each other, indicating very similar energy consumption for the conventional conveyor and pipe conveyor.

3.4. EXPERIMENT 4

The results of analysing the amount of material on the conveyor belt over 5 hours for Experiment 4 are shown in the graph (Fig. 9). As in previous experiments, the stability of the system is evident, which is due to the adjustment of deviations when pouring material. This deviation can reach a maximum of -25%, which prevents the system from experiencing significant fluctuations.

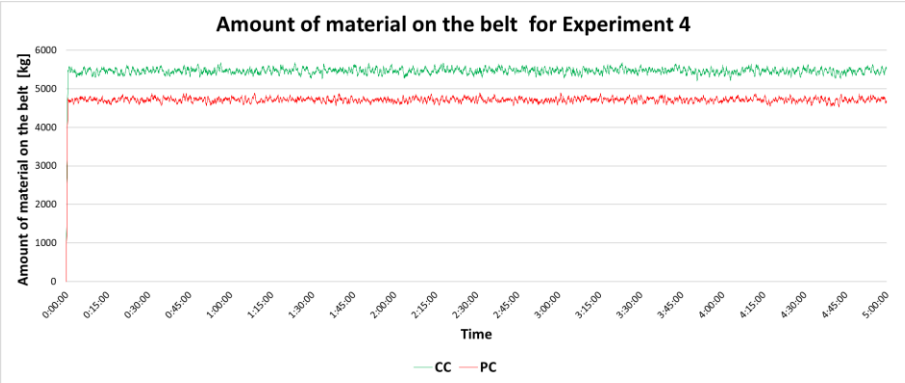

Fig. 9. Amount of material on the belt for Experiment 4

For a conventional conveyor, the average amount of material on the conveyor belt is 5457.95 kg, while for a pipe conveyor this value is lower and amounts to 4709.04 kg.

The fourth experiment confirms the trend of the previous experiments.

The results of the energy consumption analysis for two types of conveyors over 5 hours for Experiment 4 are shown in the graph (Fig. 10). The conventional conveyor, represented by the green line, has an average energy consumption of 6.45 kW, while the red line, representing the pipe conveyor, has a value of 6.21 kW.

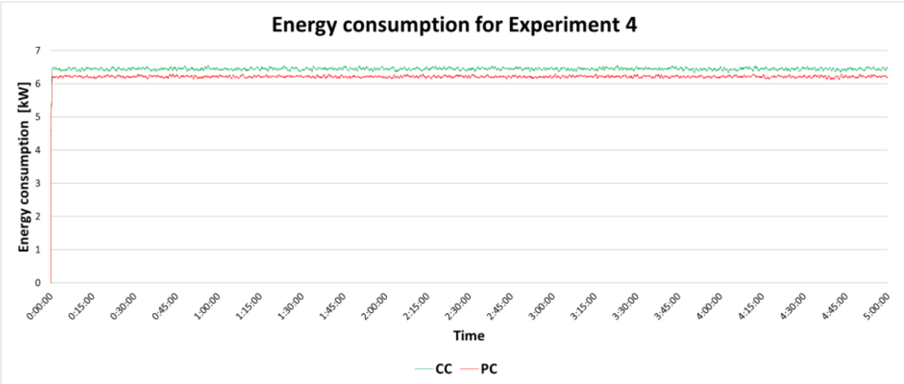

Fig. 10. Energy consumption for Experiment 4

The difference between the energy consumption of the two systems in the graph appears more significant than in Experiment 3.

Table 2. Material outputs during simulation [kg]

Material outputs during simulation [kg] – simulation results						
Time [h]		1:00:00	2:00:00	3:00:00	4:00:00	5:00:00
EXP 1	CC	340 195.34	683 804.30	1 026 910.63	1 370 724.53	1 713 942.31
	PC	294 122.33	591 011.27	887 720.74	1 184 008.01	1 480 882.47
EXP 2	CC	619 781.30	1 243 833.19	1 867 400.44	2 492 450.76	3 117 953.32
	PC	534 767.88	1 074 565.94	1 614 037.71	2 152 741.84	2 692 513.59
EXP 3	CC	340 009.91	683 625.99	1 027 334.17	1 371 281.20	1 714 647.42
	PC	293 968.61	590 050.06	886 844.58	1 182 928.05	1 479 594.20
EXP 4	CC	618 201.74	1 242 709.15	1 868 019.99	2 492 456.56	3 115 966.51
	PC	534 009.24	1 072 569.95	1 610 812.68	2 149 960.26	2 688 468.94

Table 2 contains the results of simulations based on the Material outputs indicator for four experiments. The table shows how much material passed through the system in a given period of time. The column headings with numbers indicate the simulation time. The CC mark is used for a conventional conveyor, and the PC mark is used to denote a pipe conveyor.

It is clear that the amount of material transported varies depending on the input data in the experiments.

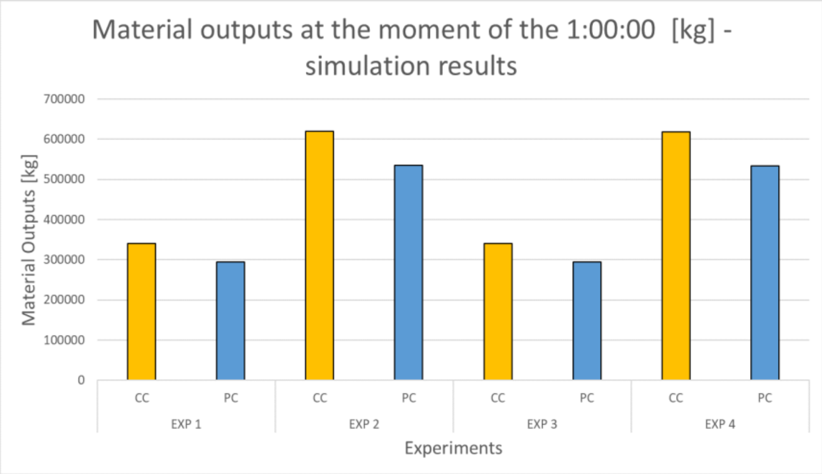

Fig. 11. Material outputs at the moment of the 1:00:00 [kg]

The bar chart (Fig. 11) shows Material outputs at the moment of 1:00:00 for four experiments and two types of conveyors. The conventional conveyor is marked in yellow, and the pipe conveyor is marked in blue. The graph shows that the conveyor filling factor has the greatest impact on material outputs, with its values increasing from 0.44 in Experiment 1 to 0.8 in Experiment 2, and the same pattern is repeated in Experiments 3 and 4. Experiments with a higher filling factor show significantly higher volumes of transported material. It is also worth noting that the conventional conveyor shows better results than the pipe conveyor in all experiments. This indicates that the filling factor plays an important role in studying system performance.

Table 3 shows the results of energy consumption simulations for four experiments. Each experiment compares a conventional conveyor (CC) and a pipe conveyor (PC), with data provided for each hour of operation, from the first to the fifth.

The graph (Fig. 12) shows the results of energy consumption at 1:00:00 for four experiments. This image shows that in experiments 2 and 4, energy consumption units are higher than in experiments 1 and 3. It is also worth noting that in all experiments, the energy consumption of the conventional conveyor is higher than that of the pipe conveyor, as in the previous graph. This is due to the larger amount of material on the conveyor belt, which increases the number of normal forces, thereby increasing energy consumption.

Table 3. Energy consumption at the moment of the following time [kW]

Energy consumption at the moment of the following time [kW] – simulation results						
Time [h]		1:00:00	2:00:00	3:00:00	4:00:00	5:00:00
EXP 1	CC	3.80	3.82	3.81	3.80	3.84
	PC	3.69	3.68	3.66	3.68	3.69
EXP 2	CC	5.05	5.01	5.04	5.02	5.07
	PC	4.73	4.71	4.68	4.72	4.73
EXP 3	CC	5.22	5.27	5.25	5.23	5.26
	PC	5.18	5.19	5.15	5.20	5.19
EXP 4	CC	6.46	6.45	6.41	6.48	6.46
	PC	6.17	6.21	6.21	6.20	6.20

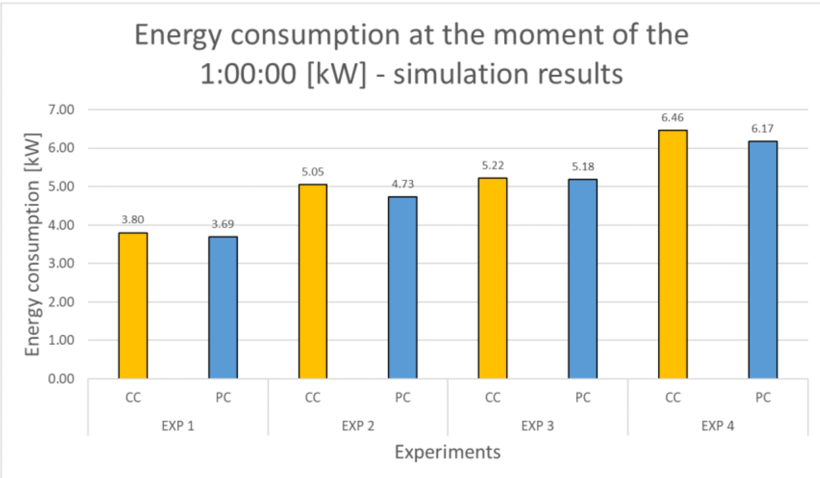

Fig. 12. Energy consumption at the moment of the 1:00:00 [kW]

Figure 13 shows a comparison of the average energy consumption values for two types of conveyors during four experiments. This graph is quite similar to the previous one, indicating the stability of this system, in which there are no significant jumps or deviations. As can be seen, the trend of the previous graph continues, with the conventional conveyor having higher energy consumption than the conventional one.

Figure 14 shows a comparison of energy consumption at the same hourly throughput for a conventional conveyor and a pipe conveyor. The yellow bar corresponds to a conventional conveyor (CC) with an energy consumption of 3.59 kW, while the blue bar (PC) corresponds to a pipe conveyor with an energy consumption of 3.66 kW. The difference between the systems is insignificant due to the high similarity of the input data, but it can still be stated that the pipe conveyor has slightly higher energy consumption under the same throughput conditions. This is due to greater forces in the structure's resistance due to the larger number of idlers and the bending of the conveyor belt into a tubular shape.

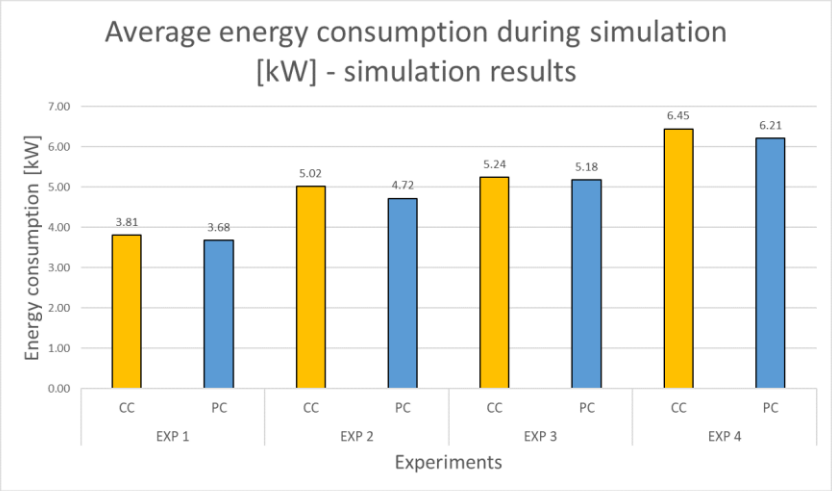

Fig. 13. Average energy consumption during simulation [kW]

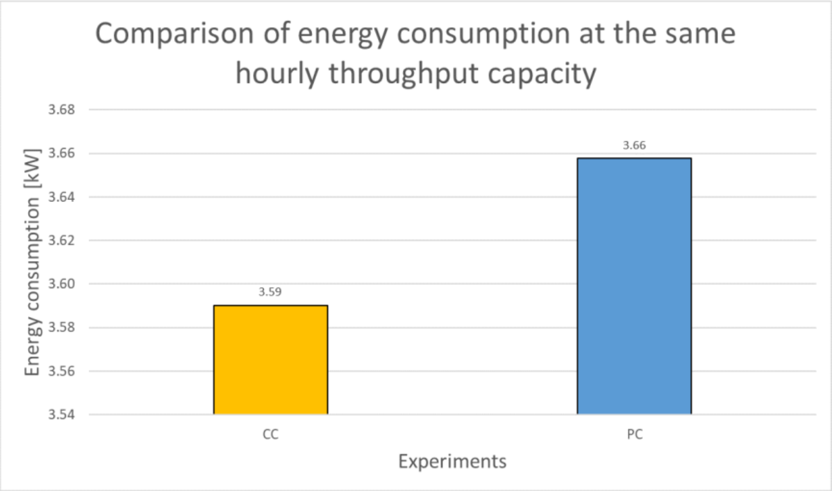

Fig. 14. Comparison of energy consumption at the same hourly throughput capacity

5. CONCLUSION

During the study, the operation of a conventional and pipe conveyor was simulated in order to compare the productivity and energy consumption of these conveyors.

The model is designed in such a way that it allows changing the input parameters of the system.

All four experiments indicate that a conventional conveyor transports more material than a pipe conveyor with the same conveyor belt width. This also increases electricity consumption (because more material is on the conveyor belt).

As for the pipe conveyor, its efficiency is lower compared to the conventional conveyor. It can also be said that with the same amount of material transported, the conventional conveyor has slightly lower electricity consumption than the pipe conveyor.

All experimental results show the stability of the system, which is due to the relative stability of material filling on the conveyor belt.

The conveyor filling factor significantly affects the experimental results. The higher the factor, the more material is transported by the conveyor.

ACKNOWLEDGEMENTS

This work was financially supported by the Slovak Grant Agency under the grants SK-PL-23-0052, APVV-23-0342, VEGA 1/0728/24, KEGA 013TUKE-4/2023.

REFERENCES

AMBRIŠKO Ľ., MARASOVÁ D., Jr., KLAPKO P., 2023, *Energy Balance of the Dynamic Impact Stressing of Conveyor Belts*, Applied Sciences, Vol. 13, No. 7, 4104, DOI: 10.3390/app13074104.

AMBRISKO L., MARASOVÁ D., Jr., GRENDEL P., LUKÁC S., 2015, *Application of logistics principles when designing the process of transportation of raw materials*, Acta Montanistica Slovaca, Vol. 20, No. 2, 141–147.

ANIBA Y., BOUHEDDA M., BACHENE M., SEDDIKI M., TOBBAL A., HAMRANI A., BENYEZZA H., 2024, *Enhanced digital twin development for a conveyor belt system: integrating PLC control, CNN decision-making, Gradio-based HMI, and fuzzy logic*, Brazilian Journal of Technology, Vol. 7, No. 4, [pages not specified], DOI: 10.38152/bjtv7n4-035.

BAJDA M., HARDYGÓRA M., MARASOVÁ D., 2022, *Energy Efficiency of Conveyor Belts in Raw Materials Industry*, Energies, Vol. 15, No. 9, 3080, DOI: 10.3390/en15093080.

BALDWIN C.K., 2024, *The Belt Conveyor*, Transactions of the ASME, Vol. 30 (January), 187–211. DOI: 10.1115/1.4060261.

DADHICH S.P., MAKKAR M., KHATRI K.K., 2024, *Modeling Simulation and Control of an Automatic Solid Material Feeding System*, 2024 10th International Conference on Control, Decision and Information Technologies (CoDIT), Valletta, Malta, 779–784. DOI: 10.1109/CoDIT62066.2024.10708266.

FORD N., 1996, The pipe conveyor, Quarry Management, May 1996.

HE Q., DONG D., HE Z., DU D., 2010, *Analytical Model between Power and Idler Spacing of Belt Conveyor*, 2010 Second International Conference on Computer Modeling and Simulation, Sanya, China, 8–10, DOI: 10.1109/ICCMS.2010.315.

HUSÁR J., HREHOVA S., TROJANOWSKI P., BRILLINGER M., 2024, *Optimizing the Simulation of Conveyor Systems through Digital Shadow Integration to Increase Assembly Efficiency*, Technologia i Automatyzacja Montażu (Assembly Techniques and Technologies), Vol. 123, No. 1, 16–22, DOI: 10.7862/tiam.2024.1.3.

JENA M.C., MISHRA S.K., MOHARANA H.S., 2023, *Experimental investigation on maximizing conveying efficiency of belt conveyors used in series application and estimation of power consumption through statistical analysis*, Environmental Progress and Sustainable Energy, Vol. 42, Issue 3, e14031, DOI: 10.1002/ep.14031.

GRUJIC M., MALINDZAK D., MARASOVÁ D., 2011, *Possibilities for reducing the negative impact of the number of conveyors in a coal transportation system*, Tehnički vjesnik – Technical Gazette, Vol. 18, No. 3, 453–458.

JUNGLAS P., SCHMEDES L., 2022, *Discrete event-based modeling of conveyors for dry bulk material*, ARGESIM Report 20, 57–64, DOI: 10.11128/arep.20.a2003, ISBN 978-3-901608-97-1.

KONIECZNA-FUŁAWKA M., 2025, *Energy-Saving Solutions Applied in Belt Conveyors: A Literature Review*, Energies, Vol. 18, No. 12, 3019, DOI: 10.3390/en18123019.

LIYANAWADUGE N.N., KUMARASINGHE E.M.H.K., IYER S.S., KULATUNGA A.K., LAKMAL G., 2023, *Digital Twin and Virtual Reality Enabled Conveyor System to Promote Learning Factory Concept*, 2023 IEEE 17th International Conference on Industrial and Information Systems (ICIIS), Peradeniya, Sri Lanka, 85–90, DOI: 10.1109/ICIIS58898.2023.10253555.

MHLONGO I.N., NNACHI G.U., NNACHI A.F., ADESOLA A.T., 2020, *Modelling and Simulation of Conveyor Belt for Energy Efficiency Studies*, 2020 IEEE PES/IAS PowerAfrica, Nairobi, Kenya, 1–5, DOI: 10.1109/PowerAfrica49420.2020.9219974.

MORAVIC M., MARASOVÁ D., KRÓL R., OZDOBA M., SLÍVA A., KUBALA D., 2024, *Application of the method of reducing rotating masses in mining transport systems*, Acta Montanistica Slovaca, Vol. 29, No. 4, 1058–1068, DOI: 10.46544/AMS.v29i4.22.

PROKUDA V.N., BURTYNI D.I., 2022, *Ways of analysis of electric consumption of main conveyor transport*, *Electrical Engineering and Power Engineering*, No. 1, 42–48, DOI: 10.15588/1607-6761-2022-1-4.

PULCINI V., MODONI G., 2024, *Machine learning–based digital twin of a conveyor belt for predictive maintenance*, The International Journal of Advanced Manufacturing Technology, Vol. 133, 6095–6110, DOI: 10.1007/s00170-024-14097-3.

SCHÜTZHOLD J., BENATH K., MÜLLER V., HOFMANN W., 2014, *Design criteria for energy efficient belt conveyor drives*, 2014 International Symposium on Power Electronics, Electrical Drives, Automation and Motion, Ischia, Italy, 1256–1263, DOI: 10.1109/SPEEDAM.2014.6871921.

STN 26 3102, 1995, *Conveyer plants. Belt conveyers. Calculation principles*, Bratislava: Úrad pre normalizáciu, metrológiu a skúšobníctvo SR.

XIE H., 2001, *Computer Applications in the Mineral Industries*, CRC Press, London, 888 pp., DOI: 10.1201/9781003078661.

ZHAO X., MENG W., ZHOU L., 2019, *Research on Indentation Rolling Resistance Based on Viscoelasticity of Cover Rubber under a Conveyor Belt*, *Mathematical Problems in Engineering*, Vol. 2019, Article ID 1781427. DOI: 10.1155/2019/1781427.