Construction of Control Systems of Flow Parameters of the Smart Conveyor using a Neural Network

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Abstract. In this paper, the results of the model for forecasting the flow parameters of a distributed transport system of the conveyor type are briefly considered. It is shown that the model of the transport system based on the neural network can be successfully applied to predict the flow parameters of the transport system which consists of a very large number of sections.
Keywords: conveyor, forecasting model, neural network.

I. Introduction

Nowadays automated systems are increasingly advancing. Thanks to modern technologies all production processes and technological operations significantly accelerate not only the work of enterprises but also bring profit. One of the most popular types of automated systems is a belt conveyor which is an endless continuously moving belt transporting bulk cargo. It is widely used in many industries - metallurgy, coal, chemical, in the production of building materials, processing and disposal of waste and others. The belt conveyor is preferably better than other modes of transport designed to transport large volumes of cargo. Also one of its advantages is simple in design, reliable in operation, has high productivity taking into account its small operating costs.

Actuality of theme. This work is devoted to the topical problem of modeling the conveyor transport system at asphalt concrete, alumina and cement plants. There are problems to increase the reliability of conveyor transport at various types of enterprises, increase production efficiency, forecast and control all work processes and equipment to avoid dangerous situations, prevention of dangerous modes of equipment, automatic alarms, regulation, control, etc.

The purpose of the study - an information system for predicting the flow parameters of a smart conveyor using a neural network.

The object of study - a smart conveyor transport system.

The subject of research - a model for predicting the flow parameters of the smart conveyor using a neural network.

II. Work of Smart Conveyor And Inspection of Conveyor Type Transport Systems

The leading trend of the "Fourth Industrial Revolution" which is happening before our eyes - Industry 4.0. Now we live in the era of the end of the third digital revolution where the characteristic features are the development of information and communication technologies, automation and robotization of production processes. Characteristic features of Industry 4.0 are fully automated productions where all processes are controlled in real time taking into account changing external conditions.

The conveyor belt is one of the areas that need to be prepared for the implementation of Industry 4.0 (smart conveyor). Because of the introduction of basic technologies of Industry 4.0 on the conveyor, there are many advantages, some of them: preventive maintenance,

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information exchange is used between not only people but also devices, sensors, data exchange and information processing without human intervention, machine tracking algorithms, etc.

The use by factories of transport systems that can make smart decisions that track, sort, combine and accumulate products is very justified and logical. Thus, they can provide all the necessary information to monitor the overall efficiency of equipment, sensors and key performance indicators.

Cyberphysical System (CPS) is the operational basis of Industry 4.0. It combines two key components of the Internet of Things (IoT) and the Internet of Services (IoS). In particular, CPS in combination with IoT and IoS creates the basis for Industry 4.0. This combination can be understood as a network in which different information is constantly processed by various powerful software tools and specializes in user interfaces.

A smart conveyor is a CPS consisting of a conveyor of any type that performs two-way data transmission. Then the data is transmitted in a compatible form and depending on the operation of the smart-conveyor, the data is processed and evaluated in a suitable system. This process aims to obtain a wide range of different indicators that provide information about the belts of the conveyor process. Based on the obtained and evaluated data, control sequences can be generated using an expert control system. Then they are sent back according to the communication interface with the conveyor control unit.

Such a CPS can be classified as a holonic CPS. Smart conveyor is, in principle, a multi-agent system as it consists of individual structural elements that are equipped with sensing and control elements. This system has many advantages. Smart conveyors and equipment help companies reduce energy consumption by saving money and minimizing the carbon footprint.

Smart conveyors use sensors to detect when a worker is too close to active tape or something is stuck in the equipment. They are then reconnected to controls that slow down the hardware until the problem is resolved.The response time of such intelligent conveyor functions is much shorter than that of workers, which minimizes the possibility of injury.

Intelligent conveyors with IoT functionality have tools that allow you to replace preventive maintenance with preventive. Maintenance personnel will not need to turn off the conveyor surfaces to inspect them. Instead, arrays of sensors monitor online equipment. With enough information, smart pipelines can begin to predict when and where equipment may fail allowing businesses to anticipate problems before they shut down systems.Smart conveyors in these automated settings minimize quality control problems to obtain the most homogeneous product as well as increase productivity through smart conveyors [1].

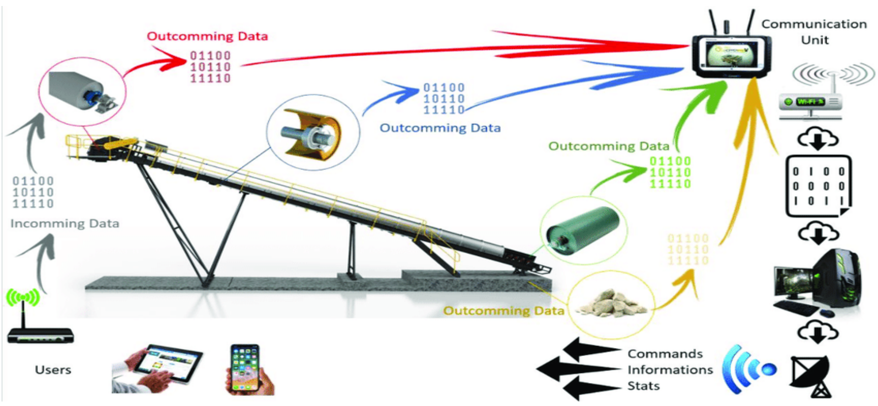


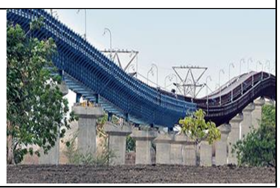
Fig. 1 – Smart conveyor [1]

A belt conveyor is a fast and convenient way to transport material from one place to another. In addition to transportation, conveyors perform unloading and loading functions and important structural units in warehousing operations [2].

An example of the use of conveyor systems is the international company BEUMER GROUP, which specializes in the development and production of systems for transportation, loading, stacking, packaging, sorting and distribution. Examples of installations using conveyor systems can be found in figure 2.

Fig. 2 – An example of a company's conveyor systems BEUMER GROUP [3]

Table 1 - Characteristics of long conveyor transport systems

Name	Length (km)	Sections	Power (kV)	Speed (m/s)	Productivity (t / h)	Image of the conveyor system
Worsley Alumina, Australia [4, 5]	50+55				3500	
From the Bu Kraa mine to the coast in El Aaiun, Western Sahara [6,7,8,9]	128.7	11			2000	
Coarse ore conveyor system Minera Los Pelambres, Chile (1998), [10]	12.7	3	25000	6.8	8700	
Dead Sea Works, Israel (1986) [11, 12]	18.11		4000	4.60	800	
Flying Belt conveyor Bra, Brazil [13, 14]	7. 2	18	3 x 615	4	1500	
Heidelberg Cement, Damoh, India [15]	21	6	350	4	1000	

Many examples using the conveyor can be given abroad, the length of transport routes can exceed 100 km [4-15] and continues to increase. To increase the reliability of transport routes are divided into sections, the technology of transportation of material which provides a length of up to 20 km. Common world practice shows that the conveyor is an efficient and environmentally friendly way to supply raw materials. Table 1 summarizes some examples of the longest conveyor systems from around the world which are used in many industries. Below the table is a brief description of each of these systems [4-15].

The Worsley Alumina Plant (Worsley Alumina, Australia) (see figure 4) is located in Worsley, Western Australia (fig. 5). Worsley Alumina includes a bauxite mine near the town of Boddington and an alumina plant near Worsley. Bauxite is mined (fig. 6) near the town of Boddington, 130 kilometers southeast of Perth. It is transported by land conveyor to an alumina plant near Collie and turned into alumina powder and then delivered by rail to the port of Banbury. Worsley Alumina is the longest in Australia. Its conveyor belt passes through 42.5 km of forests crossing 29 roads and 2 rivers. It travels at a speed of 25 km / h and the conveyor can load semi-trailers in about 30 seconds.

Fig. 4 – Location Worsley Alumina [4]

Fig. 5 – Bauxite mining, conveyor system Worsley Alumina [5]

Fig. 6 – Conveyor Worsley Alumina [5]

The world's longest conveyor belt is located in southern Morocco (from Bou Krai to the coast in El Aaiun, Western Sahara) which is shown in fig. 7 (a, b). Thanks to this tape in the depths of the desert on the South African coast there is a continuous flow of chalky white powder-belt, the presence seems to be a bright gust of wind powder scattered around it on brown earth. It travels 61 miles across the rugged terrain of Western Sahara from the mines of Bu Kraa to Port El Aaiun where massive ships transport its contents around the world (see fig. 8). White powder - a phosphate rock - a commodity, valuable and vital.

a)

b)

Fig. 7 - Conveyor belt from the Bu Kraa mine to the coast in El Aaiun near (a) and from a height (b) [6]

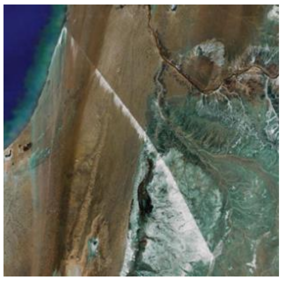


Fig. 8 – Pouring phosphate from the conveyor from the Bu-Kraa mine [6]

Also one of the longest conveyor belts delivers limestone from a mine in India to a cement plant in Bangladesh (see figure 9, figure 10). It was put into operation in 2005. In the northeast of Bangladesh is the cement plant Lafarge Surma (see fig. 11, fig. 12). Since the plant does not have its own limestone mine the raw materials must be extracted and transported from a mine located in India a few kilometers to the north. And today this conveyor is one of the longest in the world and has a length of about 35 km. The conveyor plant transports 1.2 million tons of raw materials per year and has only two drive stations: in the main part two engines of 630 kW and in the tail part one engine of 630 kW.

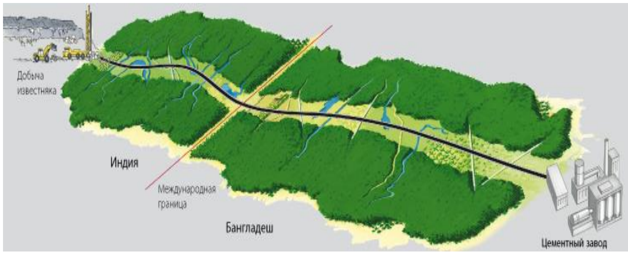


Fig. 9 – Location of a conveyor belt from a mine in India to a cement plant in Bangladesh [16]

Fig. 10 – Conveyor system in Bangladesh [6]

Fig. 11 – Conveyor system in India [17]

Fig. 12 – India-Bangladesh conveyor system [18]

The Minera Los Pelambres conveyor system is one of the world's largest copper mines in Chile located in the high Andes at an altitude of 3 200 meters (see figure 13). Environmental conditions - the lack of sufficient space and the appearance of avalanches - required the location of the concentrator at a distance of about 10 km from the mine at an altitude of 1800 m (see fig. 14 and 15). Initially, daily ore production was planned at 85 000 tons. At a later stage it was to increase to 197 500 tons.

Fig. 13 – Location Minera Los Pelambres [19]

Fig. 14 – Conveyor system Minera Los Pelambres [20]

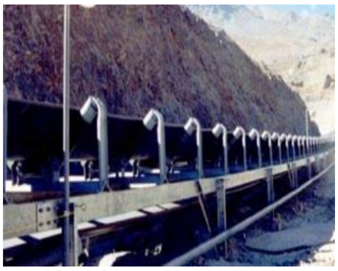


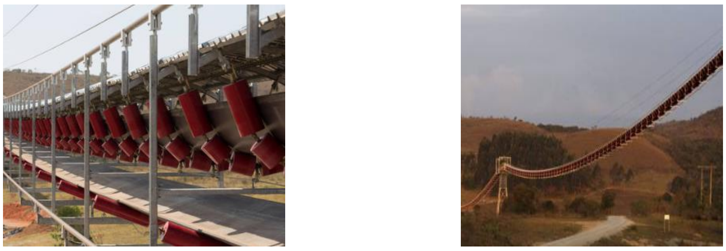
Fig. 15 – Primary crusher of the conveyor system Minera Los Pelambres [19]

The Dead Sea Works conveyor belt (see figure 16 (a, b, c)), located at 18 km, was planned at the Dead Sea plant to transport more than a million tons of potash fertilizers annually from the production site (400 meters above sea level sea) to the main plant of the Dead Sea on the shores of the Dead Sea (400 meters below sea level). The belt replaced a winding 39-kilometer route of the truck, on which 200 semi-trailers a day loaded with potash fertilizers due to traffic jams, posed a safety hazard, damaged the road and spewed diesel fuel vapors.

a) b) c)

Fig. 16 – DSW conveyor belt from different angles (a, b, c) [13]

The world's longest overhead conveyor belt (FlyingBelt) began operating in Barroso, Brazil (see figure 17 (a, b)). The 7.2-kilometer-long conveyor belt transports material over obstacles such as difficult terrain, while harming the environment. The system transports about 1 500 tons of limestone per hour from the quarry to the plant - a productivity that will require more than 40 trucks in the same time (fig. 18). The use of this technology significantly reduces traffic while preserving the environment. The world's longest aerial conveyor belt uses one 14.4 km long rubber belt as well as 60 000 meters of rope and 25 000 rollers.



a) b)

Fig. 17 – Conveyor belt system Flying Belt [15]

Fig. 18 – Conveyor system Flying Belt [15]

The conveyor system commissioned for Heidelberg Cement consists of six conveyor spans with a total length of 20 790 meters. Four flights connect the mine with the bunker. From the bunker, one flight is sent to the factory and the other - to the warehouse. The six flights are 640 meters, 9800 meters, 8150 meters, 1600 meters, 475 meters and 125 meters long (20 790 meters in total). The 1000 mm wide belt conveyor is designed to transport limestone at an average speed of 4.0 meters per second from the quarry to the plant (see fig. 19, fig. 20, fig. 21). The capacity of this conveyor system is 1000 t / h.

Fig. 19 – Conveyor belt Heidelberg Cement, Damoh [21]

Fig. 20 – Conveyor system Heidelberg Cement, Damoh [21]

Fig. 21 - Conveyor movement Heidelberg Cement, Damoh [21]

III. Simulation of Smart Conveyor Systems

Modeling is a method of knowing the world around us that to study objects, systems, processes and phenomena based on their models. Modeling is an important tool for understanding the dynamics of corporate systems, especially in recent years. Successful companies have long used modeling as a tool for operational and strategic management [22]. Many large systems including conveyor systems, require modeling and further analysis.

Modeling of smart conveyor systems is necessary for engineering analysis and further approval of a more efficient engineering solution. Since the creation of ready-made systems is quite time-consuming, time-consuming process, this method greatly simplifies the work and helps to accurately represent the system, analyze it in detail and changes, prevent major errors and optimize work. The process of building models is a complex, complex task that requires a clear plan, great care and accuracy. According to the modeling technology and areas of application, there are many types of modeling, some of them: information, computer, mathematical, biological, digital, physical, graphic, etc. In this section the branched conveyor systems are considered. Information graphic models were used to describe these models.

One of the most complex and large transport systems is the Lubin mine in Lubin, in western Poland. Figure 22 shows one of the lines of this mine. The information graphic model of this mine, developed by me is shown in figure 23. Lubin is one of the largest reserves of copper and silver in Poland, whose reserves are estimated at 347 million tons of ore with a content of 1.26% copper and 58 g / t of silver. Work on the Lubin mine is carried out on an area of 158 km2 [23].

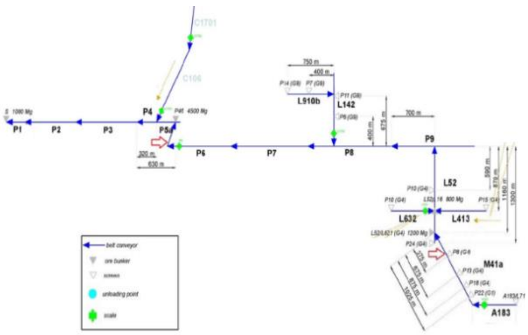


Fig. 22 – Information schematic model of one of the lines of the Lubin conveyor system [24]

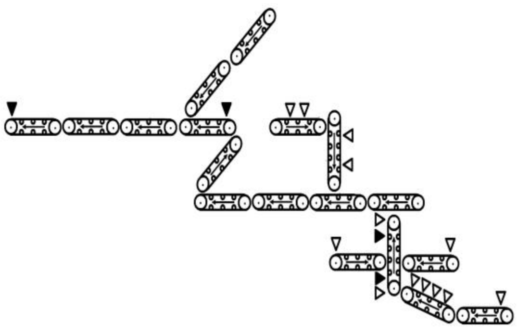


Fig. 23 – Information graphic model of one of the lines of the Lubin conveyor system

Figure 24 also shows the Lubin mine but a different line with the railway crossing. For a clearer and clearer understanding of the process of conveyor systems, a graphical model of this transport system was developed based on the line of the Lubin mine (see fig. 25).

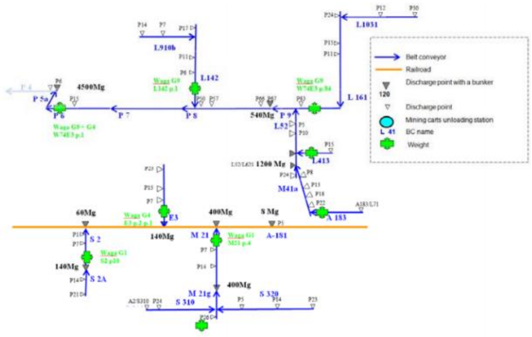


Fig. 24 – Information schematic model of one of the lines of the conveyor system Lubin [25]

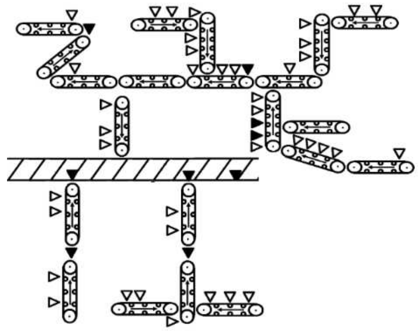


Fig. 25 – Information graphic model of one of the lines of the Lubin conveyor system

The question of describing such branched conveyor systems is relevant, as over time more and more conveyor systems are being developed. It is necessary to clearly design the model for further analysis of the system and eliminate errors on the model, not on the finished system. Hence the increased need for system modeling. The study of this work is to build a model for a multi-section conveyor line.

A. Model using a neural network in modeling a smart conveyor

Models using neural networks are a very promising class of models for designing highly efficient control systems for a distributed dynamic conveyor-type transport system. The main models used to design optimal control systems for the parameters of the flow of the transport conveyor are numerical methods. Based on the review of conveyor-type transport systems it can be seen that most systems are very large, multi-section, causing significant difficulties and requiring significant computing resources. In such cases, it is appropriate to use a neural network model as it significantly speeds up the entire calculation process. Neural network learning is a major factor in determining the quality of a model. Qualitative training of a neural network capable of modeling a specific transport system requires the collection of relevant data in large quantities.

Artificial neural networks are the simplest definition of the human brain and the building blocks are neurons. In multilayer artificial neural networks there are also neurons located similarly to the human brain. Each neuron is associated with other neurons with certain coefficients. During training information is distributed to these connection points, so that the network learns [26].

The most important advantage of control systems based on neural network models is that the response time of the control system is much less than for numerical models. A model using a neural network can be successfully used to describe multi-section pipeline systems provided that data are available for neural network training [27].

Similarly, the advantage of using an artificial neural network is that the information is stored throughout the network, rather than in a database. The disappearance of several pieces of information in one place does not interfere with the network. The neural network is able to work with incomplete knowledge: after learning an artificial neural network, the data can give results even with incomplete information. If one or more cells are damaged, the neural network does not interfere with the generation of the output signal. This feature makes networks fault-tolerant. If we talk about the memory of the neural network, it is distributed: in order for the network to learn, it is necessary to identify examples and train the network in accordance with the desired result, showing these examples in the network. Another advantage is the possibility of parallel processing: artificial neural networks have a numerical force that can perform more than one job at a time [26].

But there is a downside to using neural networks. One of the main disadvantages is the hardware dependency. Artificial neural networks require processors with parallel computing power according to their structure. An important problem of an artificial neural network is the incomprehensible behavior of the network. When a network develops a solution for research, it does not give clues as to why and how, and this reduces trust in the network. There is no specific rule for determining the structure of artificial neural networks. The appropriate structure is achieved through trial and error. Another disadvantage is that the duration of the network is unknown: the network is reduced to a certain value, an error in the sample means that the training is completed. This value will not give us optimal results [27].

All the above advantages and disadvantages of neural networks and the problems that arise during their use are very relevant today. All the disadvantages of artificial neural networks are developing in the field of science that will be eliminated in the future, and their advantages are growing every day that means that artificial neural networks will become an integral part of our lives, which is becoming increasingly important. Despite the shortcomings of the artificial neural network this paper develops a neural network model for a multi-section pipeline to predict flow parameters.

IV. Results

To analyze the learning process of the neural network, the order of data for learning is recorded. This allowed for multiple repetitions of training with different network parameters and to compare the effect of changing parameters. The weights were initialized by random values in the range $[0.0;1.0]$ c uniform distribution density. The learning process for some variants of the parameters reached 279,000 epochs (so-called one iteration in the learning process). Characteristics are used as input nodes of the neural network for modeling the transport system $\gamma_m(\tau)$, $g_m(\tau)$ input sections 1, 2, 4, 5 at intervals $0 \le \tau \le T_k = 100$.

In the course of the experiments, calculations were performed for 1, 2, 4 and 5 sections. A study was also conducted when the input sections were: a) 1 and 2, the output - 3; b) 1, 2, 4, 5, initial - 6; c) 1, 2, 4, 5, output - 7 and 8. Number of hidden layers - 20. Type of functions of flow parameters $\gamma_m(\tau)$ i $g_m(\tau)$ for the input section m = 1 for the time interval $0 \le \tau \le 2$ shown in fig. 26 and fig. 27.

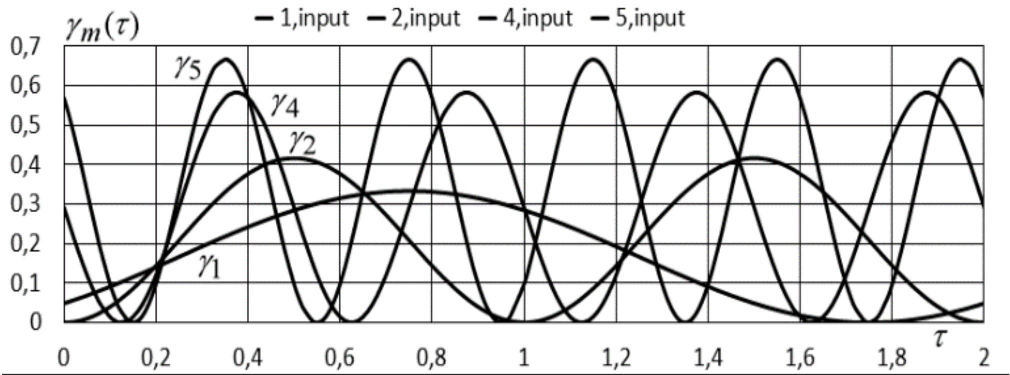


Fig. 26 – Type of material flow function $\gamma_m(\tau)$ at the entrance of the 1st section

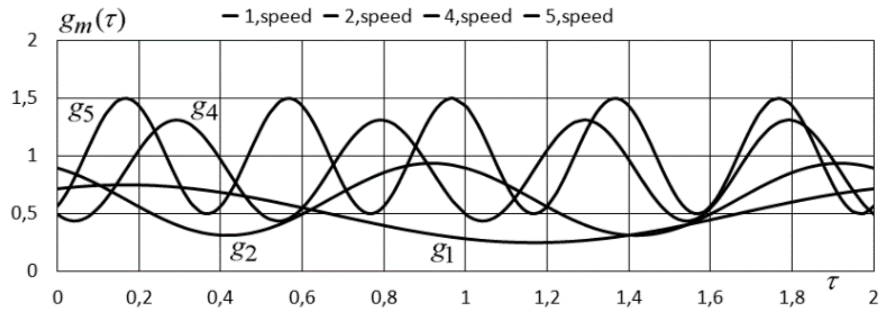


Рис. 27 – View of the belt speed function $g_m(\tau)$ 1st section

Forecasting flow parameters $\gamma_m(\tau)$ i $g_m(\tau)$ for the input section m = 2 for the time interval $0 \le \tau \le 2$ shown in fig. 28 and Fig. 29.

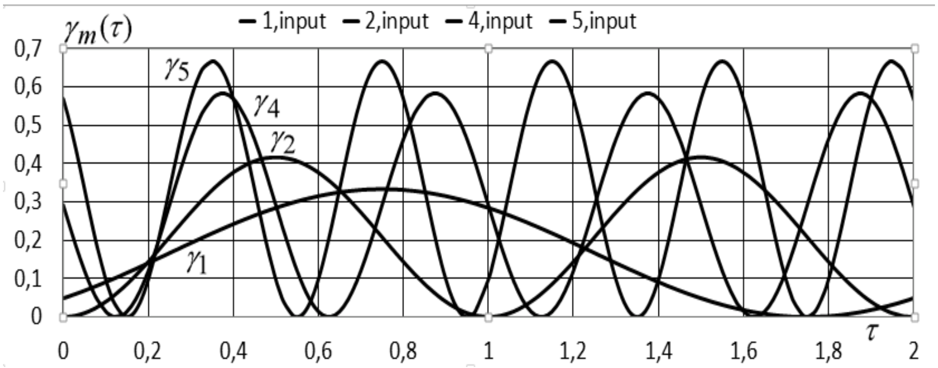


Fig. 28 – Type of material flow function $\gamma_m(\tau)$ at the entrance of the 2nd section

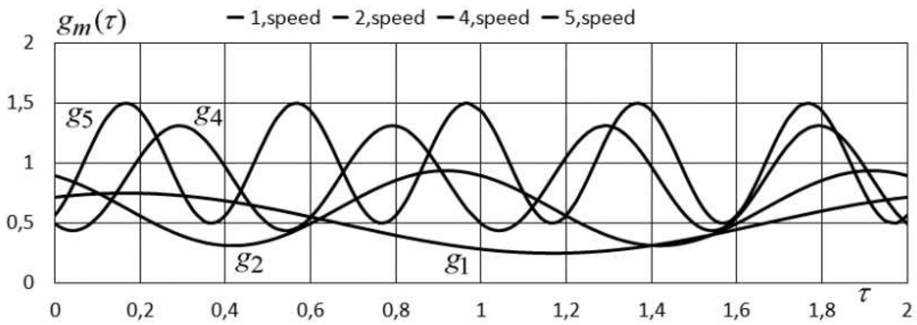


Fig. 29 – View of the belt speed function $g_m(\tau)$ 2nd section

The form of the functions of the flow parameters and for the input section m = 4 for the time interval is shown in fig. 30 and fig. 31. Forecasting flow parameters $\gamma_m(\tau)$ i $g_m(\tau)$ for the input section m=5 for the time interval $0 \le \tau \le 2$ shown in fig. 32 and fig. 33.

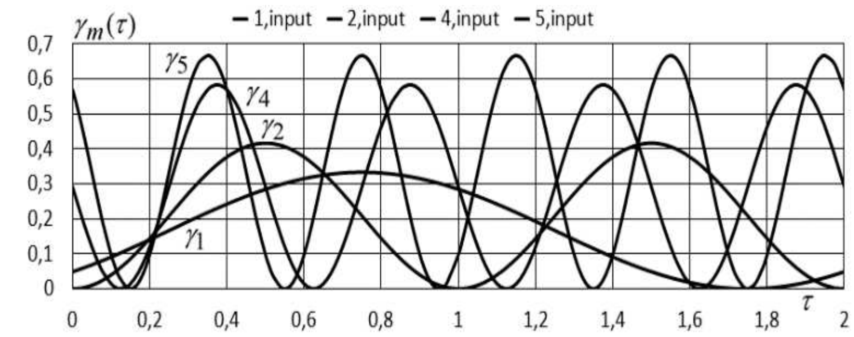


Fig. 30 – Type of material flow function $\gamma_m(\tau)$ at the entrance of the 4th section

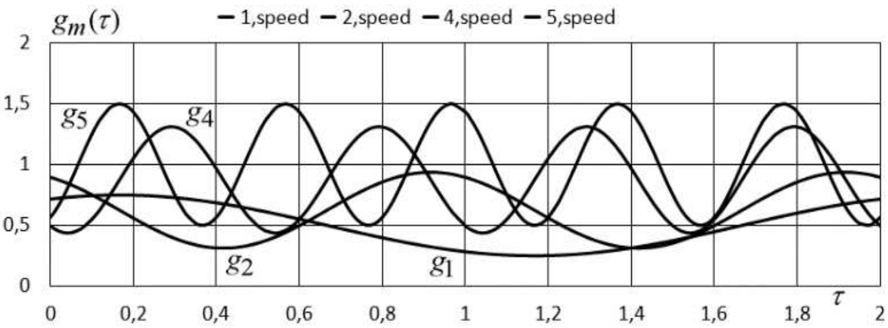


Fig. 31 – View of the belt speed function $g_m(\tau)$ 4th section

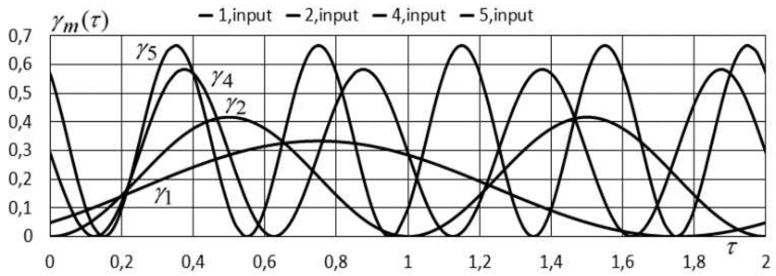


Fig. 32 – Type of material flow function $\gamma_m(\tau)$ at the entrance of the 5th section

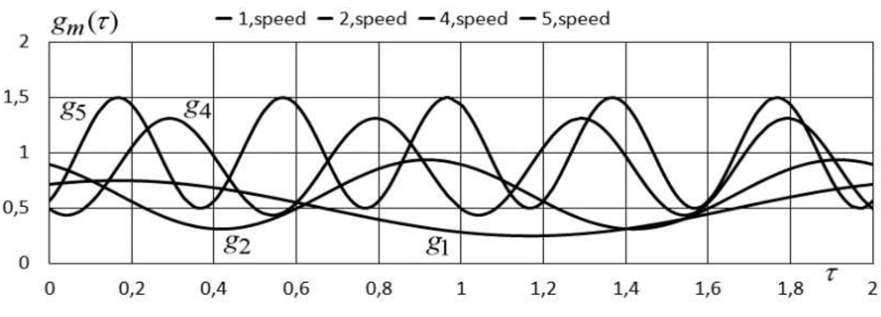


Fig. 33 – View of the belt speed function $g_m(\tau)$ 5th section

B. The results of predicting the flow parameters of the smart pipeline using a neural network

According to formula 3.3, the minimum errors were found for each study:

$MSE_1 = 0{,}0026;$ $MSE_2 = 0{,}0026;$ $MSE_3 = 0{,}0068;$

$MSE_4 = 0{,}0096;$ $MSE_{1,2\_3} = 0{,}0023;$ $MSE_{1,2,4,5\_6} = 0{,}2338;$

$MSE_{1,2,4,5\_7,8} = 0{,}2240.$

You can see the difference, for example, between MSE1 and MSE4. MSE4 is larger, indicating the presence of peak values of the output stream. Characteristics are used as input nodes of the neural network for modeling the transport system $g_m(\tau)$ input sections 1, 2, 4, 5 on the interval $0 \le \tau \le T_k = 100$. Predicting the values of the output flow parameters for sections 1, 2, 4, 5 is presented in fig. 34.

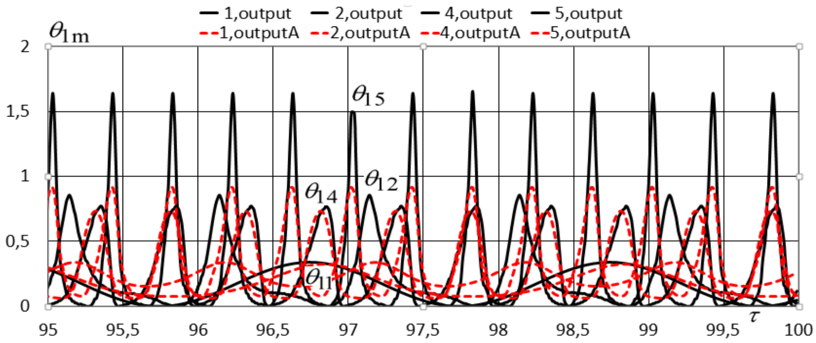


Fig. 34 – Calculation of the initial material flow $\theta_{1m}(\tau, \xi_m)$ m - th using a neural network

In fig. 35 shows the calculation of the material flow of the 1st and 2nd sections, the source - the 3rd. In fig. 36 and 37 calculate the material flow of sections 1,2,4,5, at the output 6 and 7 and 8, respectively.

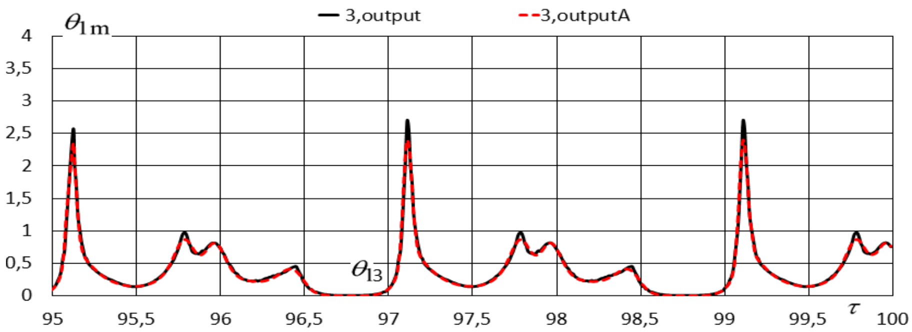


Fig. 35 – Calculation of the initial material flow $\theta_{1m}(\tau, \xi_m)$ 3rd using a neural network

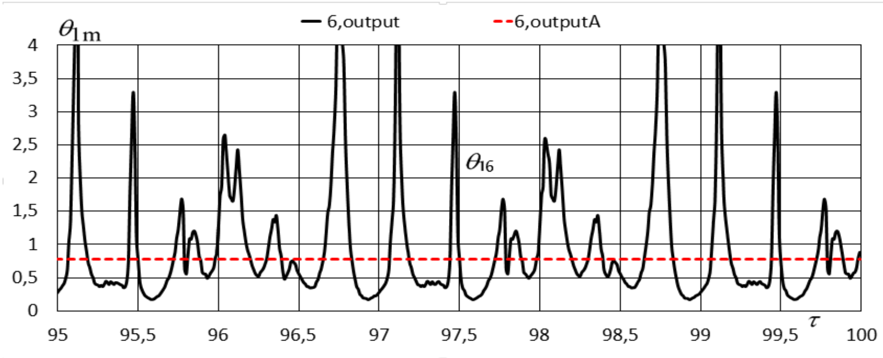


Fig. 36 – Calculation of the initial material flow $\theta_{1m}(\tau,\xi_m)$ 6th using a neural network

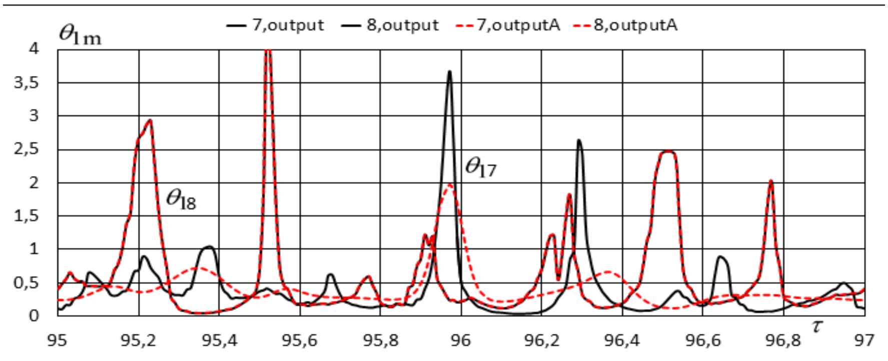


Fig. 37 – Calculation of the initial material flow $\theta_{1m}(\tau,\xi_m)$ 7th and 8th using a neural network

The value of MSE for each subsequent section increases. The exception is the last 2 experiments. For these sections, the prediction error remains approximately on the same level as the prediction error of the previous section. Probably, this is because the flows after the sixth section diverge, and the total forecasting error decreases accordingly.

V. Conclusions

Industry 4.0 has ceased to be just a concept addressed to a narrow range of industrial areas. Such areas include the transportation of materials by different types of conveyors. The priority is to find ways to implement and use Industry 4.0 for smart pipeline issues, and the main goal is to make work easier and more efficient. Large conveyor transport systems were inspected. The need for modeling of these systems is considered. The use of neural networks and their architecture, the main advantages and disadvantages for predicting a smart conveyor to ensure the functioning of cement, asphalt plants, etc. are considered. Neural network models were considered to create the smart pipeline of the future.

An information model for predicting the flow parameters of a smart conveyor is proposed. The analysis of the model using the neural network and the corresponding calculations are carried out. The results of the analysis of the neural network model show that the neural network is a good tool for predicting control systems for the output flow parameters of the smart pipeline. Especially effective when the conveyor consists of a large number of individual sections. The forecast model allows to determine the peak values of the transport system parameters.

In addition to the main purpose of the work, the method of estimating the value of the duration of the transition period, forecasting parameters for multi-section transport systems is additionally given. Analysis of the experiments shows that the reduction of prediction error can be achieved by including additional sensors which are the speed of the conveyor belt.

An important result of the research is the conclusion that this information model using a neural network is appropriate and successful in the use of conveyor-type transport systems because it successfully copes with the task - forecasting flow parameters. The assumptions obtained during the experiments can be considered a prospect for further research to improve the forecast of the smart pipeline.

VI. REFERENCES

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