Malyi, Oleksandr; Furmanova, Nataliia; Onyshchenko, Vadym et al.

Article

Analysis of experience in optimizing the operation of an automated production line for folding cardboard boxes

Reference: Malyi, Oleksandr/Furmanova, Nataliia et. al. (2024). Analysis of experience in optimizing the operation of an automated production line for folding cardboard boxes. In: Technology audit and production reserves 1 (2/75), S. 37 - 45.
https://journals.uran.ua/tarp/article/download/297399/290651/687251.
doi:10.15587/2706-5448.2024.297399.

16. Taştan, M., Gökozan, H. (2019). Real-Time Monitoring of Indoor Air Quality with Internet of Things-Based E-Nose. *Applied Sciences, 9 (16)*, 3435. doi: https://doi.org/10.3390/app9163435
17. *FreeRTOS*. Available at: https://docs.espressif.com/projects/esp-idf/en/latest/esp32/api-reference/system/freertos.html Last accessed: 15.11.2022

Andrii Zuiev, *PhD, Associate Professor, Department of Automation and Control in Technical Systems, National Technical University «Kharkiv Polytechnic Institute», Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0001-8206-4304*

✉ ***Viktoriia Krylova,*** *PhD, Associate Professor, Department of Automation and Control in Technical Systems, National Technical University «Kharkiv Polytechnic Institute», Kharkiv, Ukraine, e-mail: viktoriia.krylova@khpi.edu.ua, ORCID: https://orcid.org/0000-0002-4540-8670*

Anatolii Hapon, *PhD, Associate Professor, Department of Automation and Control in Technical Systems, National Technical University «Kharkiv Polytechnic Institute», Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0002-2582-6154*

Stanislav Honcharov, *Postgraduate Student, Department of Automation and Control in Technical Systems, National Technical University «Kharkiv Polytechnic Institute», Kharkiv, Ukraine, ORCID: https://orcid.org/0009-0002-9874-3189*

✉ *Corresponding author*

UDC 658.51
DOI: 10.15587/2706-5448.2024.297399

Oleksandr Malyi, Nataliia Furmanova, Vadym Onyshchenko, Iryna Pospeieva, Pavlo Kostianoi

ANALYSIS OF EXPERIENCE IN OPTIMIZING THE OPERATION OF AN AUTOMATED PRODUCTION LINE FOR FOLDING CARDBOARD BOXES

The object of research is an automated system for controlling the bending mechanisms of the folding-gluing line for cardboard packaging products. In the work, the ways of optimization and the development of an automated control system for the bending mechanisms of the folding and gluing line, which makes it possible to fold various structures and standard sizes of cardboard boxes using modern automation tools based on programmable logic controllers, were carried out in the work.

A mathematical model has been proposed to describe operations on the folding-gluing line. Based on the model, a methodology has been developed for calculating the parameters of the automated control system for the box folding production line, depending on the technical parameters of the line and the parameters of the boxes to be bent. This will make it possible to choose optimal technological modes of the production process and obtain high quality parameters of cardboard packaging products. To verify the mathematical model of the production line, software has been developed in the Delphi development environment, which was applied with the developed automated production process control system based on a programmable logic controller (PLC) and an operator panel. This produced a number of results, in particular, controlling the speed of the hook bend in proportion to the speed of the line. And also provided an opportunity to increase line speed and, accordingly, production productivity. It has been possible to change the mutual location of system elements, which made it possible to reduce the distance between workpieces and increase the capacity of the line tape by 30 %.

The obtained research results were implemented at the production enterprise of typographic products «Dinas» (Zaporizhzhia, Ukraine), which contributed to the improvement and optimization of production processes. Conducting further research will provide an opportunity to expand the proposed methodology for use on all types of folding and gluing lines.

Keywords: *automated system, technological process, structural diagram, programmable logic controller, panel-controller.*

Received date: 11.12.2023
Accepted date: 23.01.2024
Published date: 29.01.2024

How to cite
Malyi, O., Furmanova, N., Onyshchenko, V., Pospeieva, I., Kostianoi, P. (2024). Analysis of experience in optimizing the operation of an automated production line for folding cardboard boxes. Technology Audit and Production Reserves, 1 (2 (75)), 37–45. doi: https://doi.org/10.15587/2706-5448.2024.297399

1. Introduction

Cardboard is often used as packaging material for various products. It has a low cost, a wide range of standard sizes, design and assembly variability. Dense paper packaging simply folds, saves space during storage, and is easily disposed of. At the same time, the boxes are quite strong, which led to their use in various industries, from the food

ISSN 2664-9969

industry to the manufacture of cosmetics and souvenirs [1]. In order to provide the enterprise with appropriate packaging, it is necessary to automate the production of cardboard boxes at the factory.

The production of a cardboard box consists of such technological operations as printing, decorative decoration, stamping and assembly. Separate equipment is used for each technological operation [2]. For a full cycle of automation of the production of cardboard boxes, it is necessary to automate a complete list of technological operations. The most difficult stage of production is the folding and gluing of the box, since the boxes have different dimensions and designs [3]. When assembling boxes, their structures are fastened with staples or glue. An exception is constructions that are fastened without additional fastening materials. Some are assembled directly from the pattern, others to create a closed contour it is enough to glue one side seam at a time. The latter then make up the provision of a flat shape. Such boxes are very convenient to store and transport. Stacked flat boxes save a lot of space.

Boxes have different shapes and designs. In the process of manufacturing products from cardboard and corrugated cardboard (boxes), it is necessary to glue the blanks, which can be done with the help of special equipment – folding and gluing units. They are designed for these purposes and today are presented in various models, differing among themselves in terms of technical characteristics, properties and capabilities.

Folding and gluing lines (FGL) provide automation of the final technological operations of cardboard packaging production [4]. The market traditionally offers a large range of FGL from different manufacturers, so printers have a lot to choose from. If the selection criteria – technological capabilities, performance, price, reliability are quite universal, then specific priorities are determined by the tasks facing each enterprise and subjective factors.

Modern automatic FGLs [5] include the following technological modules and nodes:
- self-loading machine for automatic feeding of blanks of cardboard boxes;
- pre-folding section, in which the primary folding of the valves is performed;
- folding section for glue application;
- final folding section, in which the box is formed;
- section of reinforced pressing to ensure high-quality formation of the box and fixation (adhesion) of glue;
- receiving device.

Depending on the production tasks, the FGL can be equipped with additional modules, for example, a device for rotating products by 90°.

The number of gluing points determines the nomenclature of finished products. One gluing point is sufficient for the production of simple boxes, three gluing points are required for boxes with a self-assembling bottom, and more gluing points are required for the production of complex boxes. Optimizing the technological process of assembling boxes makes it possible to increase production productivity [6], especially when using automated control systems [7].

The aim of research is to develop ways to optimize and design an automated system for controlling the bending mechanisms of the folding-gluing line for cardboard packaging products.

2. Materials and Methods

The development of optimization methods has been carried out on the basis of the «Dinas» printing house to optimize production by accelerating the number of products produced per unit of time and to universalize the process of reconfiguring the line when the size of the workpiece changes, as well as in cases where it is necessary to change individual elements of the line due to their failure.

Available production line has some disadvantages:
- it does not have the possibility of electronic setting of parameters of cardboard box blanks;
- it does not have the possibility of changing the speed of production;
- it is not possible to replace individual components of the line when they fail.

Therefore, the paper proposes the development of methods for optimizing the existing line and the implementation of these methods in the line control automation system.

It is suggested to make the following optimization:
- provide an opportunity to control the hook bending speed in proportion to the speed of the line, which will increase the speed of the line and, accordingly, production productivity;
- implement the possibility of entering the dimensions of the cardboard blanks to be processed, which will allow to shorten the process of reconfiguration during the change of the blank;
- realize the possibility of changing the mutual location of system elements without affecting the performance;
- implement the possibility of changing individual components of the production line in the event of their failure without the need to change the switching and electrical circuit;
- ensure the accounting of the amount of products produced on the line.

To implement the described changes, it is necessary:
- to develop a structural diagram of the automated line;
- to develop a mathematical model of the line's operation with an indication of the interrelationships between all parameters;
- on the basis of the model, to implement software for modeling the production process and identify the optimal coefficients of the interconnection of elements, as well as their influence on the optimal modes of operation of the line;
- to select components for the implementation of an automated production line management system;
- to develop the switching scheme of the automated control system of technological processes (ACSTP) of the line;
- to develop the software of the automatic control system of the line for the programmable logic controller (PLC) and the operator's panel.

3. Results and Discussion

3.1. Development of a structural diagram and mathematical model of the production line to optimize its operation. The system consists of a PLC that interrogates the sensors and a line encoder that sends control signals to the servo amplifier and reads information in the event of a servo amplifier error. An error detector, hook start and stop buttons can also be connected to the PLC. The operator's touch panel is used to display the current state of operation and to set parameters in the system. The use of PLC is a frequent solution for production lines of this type [8, 9].

The structural diagram of the system is shown in Fig. 1.

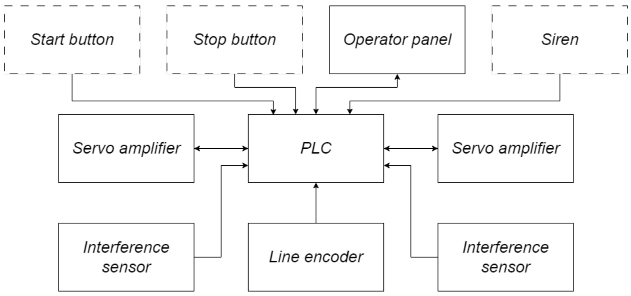
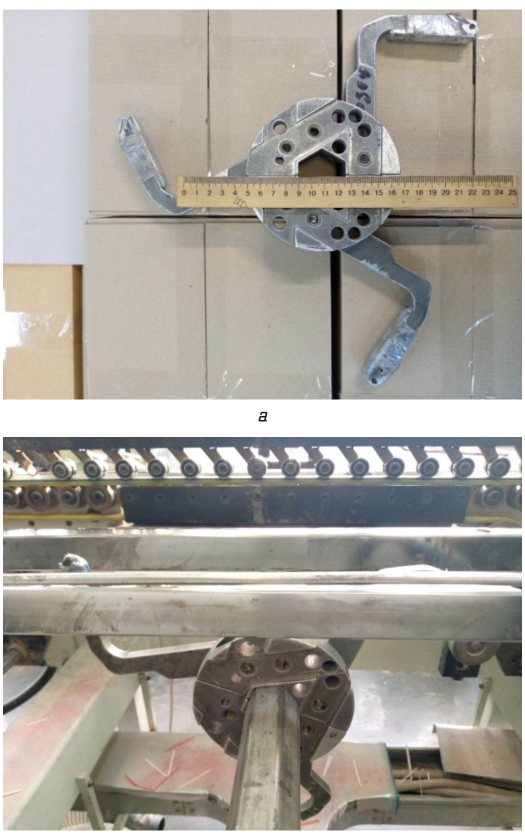


Fig. 1. Structural diagram of the hook control system for bending the line

The production line bends the box from the cardboard blank according to the previous cutting. The process of feeding the workpiece to the production line can be implemented in various ways [10]. Mechanisms based on hooks are often used in such systems [11].

The developed system controls the bending hooks in two sections. To determine the moment of activation of the bending hook, infrared interference sensors are used. When there is an obstacle in the field of view of the sensor (the distance from the sensor to the line tape is adjusted by a resistor on the sensor itself), the contacts are closed (+24 V appears on one of the sensor contacts). The signal informs the system that a box blank has come under the sensor. Depending on the settings, after passing the set distance along the line, a signal to start the hook rotation with a calculated delay is sent to the servo motor via the servo amplifier (Fig. 2).

To optimize the production process, the maximum possible number of parameters is set in the mathematical model.



a

b

Fig. 2. Photo of one of the hooks of the line:
a – outside the production line; *b* – during work as part of the production line

Adjustable system parameters (set based on the parameters of the production line and the box to be bent) include the following indicators:

- the number of pulses that must be applied to the servo amplifier to turn the motor to full speed *SP*, pcs.;
- the number of pulses from the encoder corresponding to the shift of the production line by 1 mm *PMM*, pcs.;
- the number of pulses from the encoder corresponding to its complete cycle *ER*, pcs.;
- the number of hooks on the section *H*, pcs.;
- the size in mm of the outer side of the bending hook *L*1, mm;
- the size in mm of the inner side of the bending hook *L*2, mm;
- the distance in mm from the edge of the hook to the *L*3 axis, mm;
- the distance in mm from the inner side of the hook to the *L*4 axis, mm;
- the distance from the inner side of the hook to the fastening circle *L*5, mm;
- the diameter of the fastening circle *D*, mm;
- the distance between the beam of the sensor and the hook axis *L*6, mm;
- the size of the box to be bent *L*7, mm;
- the size of the area of the box that does not bend, *L*8, mm;
- the angle of rotation of the hook for bending α, deg.

Calculated system parameters include the following indicators:

- the angle of hook rotation in order to hide it, β, degree;
- the distance in mm that the line must pass to the beginning of the bend *L*0, mm;
- the distance in mm that the line must travel while the *LT* bend is made, mm;
- the distance in mm that the line must travel after the bend before the beginning of hiding *LW*, mm;
- the distance in mm that the line must pass while the *LH* is being hidden, mm;
- the number of pulses that must come from the encoder to start bending the hook *P*0, pcs.;
- the number of pulses that must come from the encoder while the hook bends *PT*, pcs.;
- the number of pulses that must come from the encoder after the end of the bend before the start of *PW* hiding, pcs.;
- the number of pulses that must come from the encoder while the hook is hiding *PH*, pcs.;
- the number of pulses that are supplied to the servo amplifier for bending at the angle α – *PA*, pcs.;
- the number of pulses that are supplied to the servo amplifier for bending at the angle β – *PB*, pcs.;
- the number of adjustment pulses after *H* revolutions to obtain a full revolution of the *PC* engine, pcs.;
- the coefficient that determines the linear relationship between the number of pulses coming from the encoder and the number of pulses fed to the servo amplifier (how many pulses are fed to the servo amplifier when one pulse is received from the encoder during bending and hiding) *KL*, pcs.;
- line movement speed: V_p, pulses/s; V_{mm}, mm/s; V_m, m/min;
- the time after which it is necessary to start bending the hook at a constant speed V_{mm} – t_1, s;
- time from bending of the hook at a constant speed V_{mm} – t_2, s;

 ISSN 2664-9969

– the time after which it is necessary to start hiding the hook at a constant speed V_{mm} – t_3, s;
– hook hiding time at constant speed V_{mm} – t_4, s;
– the frequency of pulses to the servo amplifier for bending and hiding the hook at the speed of the line V_p – F, Hz.

The linear parameters of the shafts connecting the encoder to the production line are as follows (Fig. 3):
– $R1=115$ mm;
– $R2=90$ mm;
– $R3=30$ mm.

The measured current values are indicated, but the optimized system allows them to be changed.

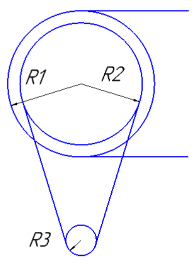


Fig. 3. Parameters of connecting the encoder to the line

At a line speed of 20 m/min, the number of pulses is 1600 pulses/s.

At a line speed of 30 m/min, the number of pulses is 2300 pulses/s.

The relationship between the angle to hide the hook, the angle of rotation and the number of hooks installed on the shaft:

$$\beta=\frac{360}{H}-\alpha. \quad (1)$$

Distances characterizing the box and hook parameters:

$$L0=L6-L4+L8-L7/2, \quad (2)$$

where $LT=L7$, $LW=L2$.

Dependence of the distance that the line must travel while hiding from linear and angular parameters:

$$LH=\frac{\beta\cdot LT}{\alpha}=\left(\frac{360}{\alpha\cdot H}-1\right);\ LT=\left(\frac{360}{\alpha\cdot H}-1\right)L7. \quad (3)$$

Dependence of the number of pulses that must come from the encoder to start bending the hook on the linear dimensions of the hook and the box:

$$P0=PMM\cdot L0=PMM\cdot(L6-L4+L8-L7/2). \quad (4)$$

Dependence of the number of pulses that must come from the encoder during bending of the hook on the bending area and the number of pulses per full revolution of the encoder:

$$PT=PMM\cdot LT=PMM\cdot L7. \quad (5)$$

Dependence of the number of pulses that should come from the encoder while the hook bends, on the number of pulses per full revolution of the encoder and the linear size of the hook:

$$PW=PMM\cdot LW=PMM\cdot L2. \quad (6)$$

Dependence of the number of pulses that should come from the encoder while the hook is hiding, on the set linear and angular dimensions:

$$PH=PMM\cdot LH=PMM\cdot L7\left(\frac{360}{\alpha\cdot H}-1\right). \quad (7)$$

The number of pulses supplied to the servo amplifier for bending by an angle α is determined by the ratio:

$$PA=\frac{SP\cdot\alpha}{360}. \quad (8)$$

The number of pulses supplied to the servo amplifier for bending by the angle β is determined by the ratio:

$$PB=\frac{SP\cdot\beta}{360}=\frac{SP}{H}-\frac{\alpha SP}{360}. \quad (9)$$

The number of adjustment pulses after H revolutions to obtain a full revolution of the engine:

$$PC=SP-H\cdot(PA+PB). \quad (10)$$

The coefficient, which is determined by the linear relationship between the number of pulses coming from the encoder and the number of pulses fed to the servo amplifier:

$$KL=\frac{PA}{PT}=\frac{\alpha SP}{360\cdot PMM\cdot L7}. \quad (11)$$

The ratio for determining the speed of line movement, depending on the units of measurement (in pulses/s – V_p, mm/s – V_{mm} and m/min – V_m):

$$V_{mm}=PMM\cdot V_p=\frac{PMM\cdot P}{t}, \quad (12)$$

$$V_m=\frac{60V_{mm}}{1000}=\frac{60\cdot PMM\cdot P}{1000t}. \quad (13)$$

Determination of the time after which it is necessary to start bending the hook at a constant speed V_{mm}:

$$t_1=L0/V_{mm}=P0/V_p. \quad (14)$$

Determination of hook bending time at constant speed V_{mm} – t_2:

$$t_2=LT/V_{mm}=PT/V_p. \quad (15)$$

Determination of the time after which it is necessary to start hiding the hook at a constant speed V_{mm}:

$$t_3=LW/V_{mm}=PW/V_p. \quad (16)$$

Determination of hook hiding time at constant speed V_{mm}:

$$t_4=LH/V_{mm}=PH/V_p. \quad (17)$$

The ratio for determining the frequency of pulses to the servo amplifier for bending and hiding the hook at the line speed V_p:

$$F = KL \cdot V_p = \frac{\alpha \cdot SP \cdot V_p}{360 \cdot PMM \cdot L7}. \qquad (18)$$

3.2. Production process modeling software. To verify the mathematical model of the production line, software was developed in the Delphi development environment.

The developed software allows to enter all the measurement parameters of the elements of the production line and, based on them, calculate all the parameters that must be determined according to the mathematical model.

The interface of the main program window is shown in Fig. 4.

In addition, the developed software has the possibility to animate the process of the cardboard blank of the box along the production line and the bending of the hook according to the entered parameters.

Animation is possible both step-by-step and in real time.

3.3. Development of the hardware part of the automated production line control system. The following system elements were selected: Wenglor HM24PA2 obstacle sensors; line encoder LPD3806-600BM-G5-24C; Mitsubishi MR-J2S servo amplifiers; line encoder LPD3806-600BM-G5-24C; PLC Delta AS228; operator panel Delta DOP-107BV; the sensor providing a signal about an obstacle is HM24PA2.

The LPD3806-600BM-G5-24C encoder is used to obtain the speed of the production line.

Incremental angle photoelectric converters (angle sensors, angle encoders) are designed to determine the amount of angular movement (tilt, turn, rotation) of executive bodies of controlled mechanisms.

HC-MFS23 servo amplifier is selected to coordinate the PLC and the motor that rotates the hooks.

The next stage of the system development was the assembly of the switching circuit and setting the parameters of the components included in the system.

3.4. PLC program development. The PLC program is created in the ISPSoft development environment in the LD language (Fig. 5). This environment is used for programming ACS of various production lines, including for creating cardboard products [12].

In addition to the state of the inputs, the program uses additional system variables that store the state in order to display them on the operator panel. Addresses, names and assignments of variables associated with PLC input and output contacts are given in Table 1 and Table 2, respectively.

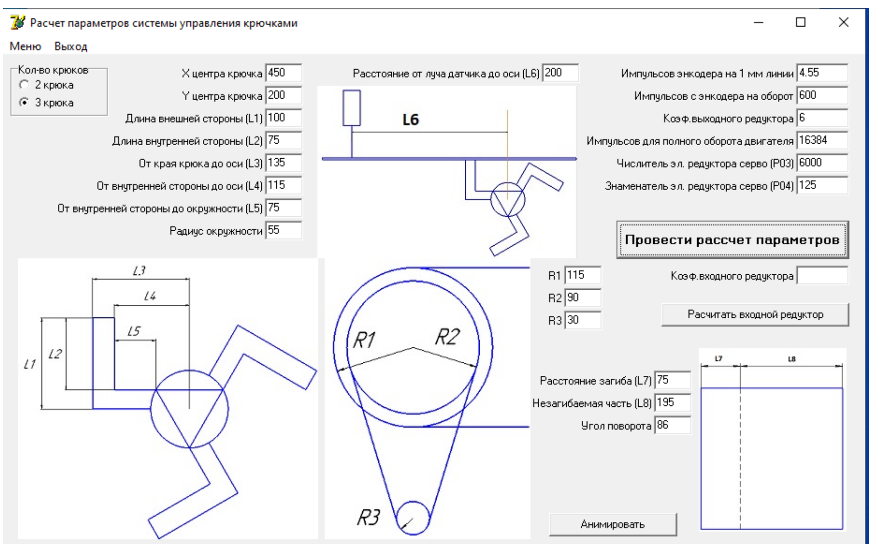


Fig. 4. The main window of the program for calculating parameters according to the mathematical model

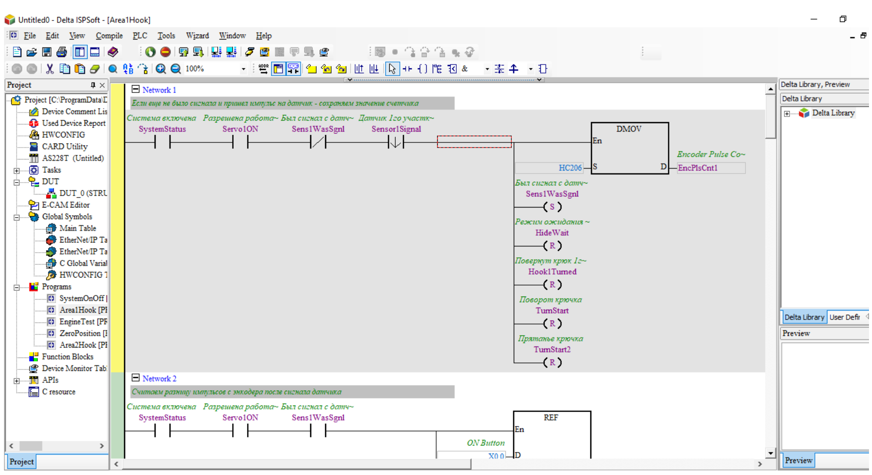


Fig. 5. Writing a PLC program in the ISPSoft development environment

ISSN 2664-9969

Table 1

User variables associated with PLC input pins

No.	Address	Name	Description
1	X0.0	ButtonON	Power button state
2	X0.1	ButtonOFF	Power button status
3	X0.2	EncoderAPin	Contact A of the production line encoder
4	X0.3	EncoderBPin	Contact B of the production line encoder
5	X0.4	Sensor1Signal	Signal of the 1st section fault sensor
6	X0.5	Sensor2Signal	Signal of the 2nd section fault sensor
7	X0.6	RD2	Signal RD pin CN1A-19 of the 2nd servo amplifier
8	X0.7	DO1_2	Signal DO1 pin CN1B-4 of the 2nd servo amplifier
9	X0.8	ZSP2	Signal ZSP pin CN1B-19 of the 2nd servo amplifier
10	X0.9	TLC2	TLC signal pin CN1B-6 of the 2nd servo amplifier
11	X0.10	INP1	Signal INP pin CN1A-18 of the 1st servo amplifier
12	X0.11	INP2	Signal INP pin CN1A-18 of the 2nd servo amplifier
13	X0.12	RD1	Signal RD pin CN1A-19 of the 1st servo amplifier
14	X0.13	DO1_1	Signal DO1 pin CN1B-4 of the 1st servo amplifier
15	X0.14	ZSP1	Signal ZSP pin CN1B-19 of the 1st servo amplifier
16	X0.15	TLC1	TLC signal pin CN1B-6 of the 1st servo amplifier

Table 2

User variables associated with PLC output pins

No.	Address	Name	Description
1	Y0.0	PPServo1	Signal PP pin CN1A-3 of the 1st servo amplifier (forward pulses)
2	Y0.1	NPServo1	Signal NP CN1A-2 of the 1st servo amplifier (reverse pulses)
3	Y0.2	SON2	SON signal pin CN1B-5 of the 2nd servo amplifier
4	Y0.3	ABSR2	ABSR signal pin CN1B-9 of the 2nd servo amplifier
5	Y0.4	PPServo2	Signal PP pin CN1A-3 of the 2nd servo (forward pulses)
6	Y0.5	NPServo2	Signal NP pin CN1A-2 of the 2nd servo amplifier
7	Y0.6	ABSM2	ABSM signal pin CN1B-8 of the 2nd servo amplifier
8	Y0.7	CR2s	Signal CR pin CN1A-8 of the 2nd servo amplifier
9	Y0.8	SON1	SON signal pin CN1B-5 of the 1st servo amplifier
10	Y0.9	ABSM1	ABSM signal pin CN1B-8 of the 1st servo amplifier
11	Y0.10	ABSR1	ABSR signal pin CN1B-9 of the 1st servo amplifier
12	Y0.11	CR1s	Signal CR pin CN1A-8 of the 1st servo amplifier

In general, a complete list of variables used by the user can be seen in the Main Table item in the development environment. The PLC program consists of 5 subprograms:

– SystemOnOff;
– Area1Hook;
– Area2Hook;
– EngineTest;
– ZeroPosition.

3.5. Development of an operator panel program. The operator panel program was developed in the DOPSoft environment (Fig. 6–9).

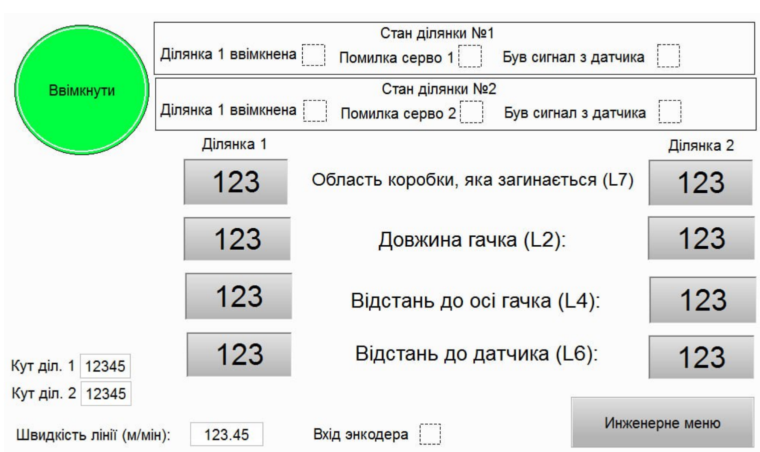


Fig. 6. The main menu of the panel program

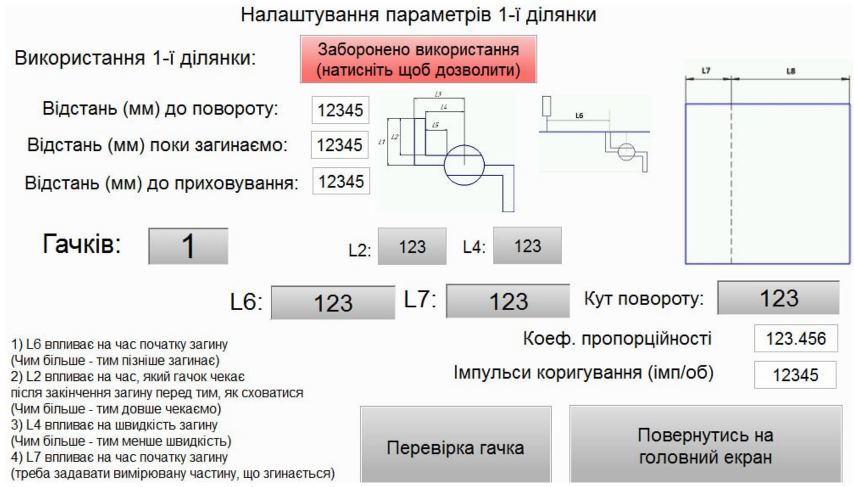


Fig. 7. Window for setting the parameters of the 1st section

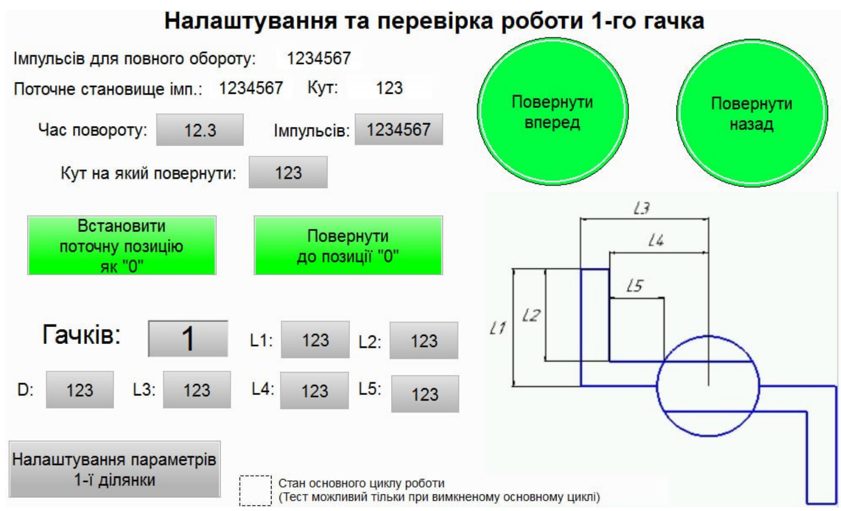


Fig. 8. Hook setting window of the 1st section

Fig. 9. Engineering menu window

3.6. Practical meaning. The developed system allows the operator to simplify the process of operation and maintenance of the production line, which reduces the probability of errors and increases work productivity.

The developed technique and automated system can be used in real production of packaging boxes with the possibility of adjustment to the equipment parameters.

3.7. Limitations of the study. Intended for implementation at the «Dinas» typographic production enterprise in the city of Zaporizhzhia (Ukraine), the obtained research results contributed to the improvement and optimization of production processes in the field of printing. The limitation for the use of the developed methodology is the specific characteristics of the production line served by the enterprise.

The studied technique shows its effectiveness when applied to lines that produce products with the property of exclusively longitudinal bending with the help of hooks.

3.8. The influence of martial law conditions. In connection with the introduction of martial law in Ukraine and the significant complication of production activities, in particular in the eastern and southern regions, the possibilities for the development and functioning of industrial production are currently limited. Therefore, the results of the study were implemented for only one production line, which is a consequence of the closure or relocation of a significant number of enterprises. On the other hand, during the martial law, the need to adapt and optimize production processes increases, which confirms the relevance of the work.

3.9. Prospects for further research. Further scientific research, based on the features of individual operations of the technological process, can contribute to the expansion of the proposed methodology with the aim of applying it to all categories of folding and gluing lines in industrial production.

4. Conclusions

In the work, the optimization of the production line for folding cardboard boxes for the «Dinas» printing house has been carried out by creating a mathematical model of the line, followed by the development of an automated production process control system based on a PLC and an operator panel:

– the ability to control the bending speed of the hooks in proportion to the speed of the line has been implemented, which makes it possible to increase the speed of the line and, accordingly, production productivity (the average speed of the lines has increased from 30 to 80 m/min);

– the possibility of entering the dimensions of the cardboard blanks to be processed has been implemented, which made it possible to reduce the process of reconfiguration during a blank change from several hours to a few minutes;

– the possibility of changing the mutual location of the system elements was implemented, which made it possible to reduce the distance between the workpieces, which increased the capacity of the line tape by 30 %;

– the possibility of changing individual components of the production line in the event of their failure without the need to change the switching and electrical circuit has been implemented;

– accounting for the number of products produced on the line is ensured by entering the counter of produced boxes on the screen of the operator's panel (the data is stored in the magnetic memory).

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

The research was performed without financial support.

Data availability

The data will be made available on reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

References

1. Twede, D., Selke, S. E., Kamdem, D. P., Shires, D. (2014). *Cartons, crates and corrugated board: handbook of paper and wood packaging technology*. DEStech Publications, Inc. Available at: https://destechpub.com/wp-content/uploads/2015/01/Cartons-Crates-and-Corrugated-Board-2nd-Ed-preview.pdf
2. Freddi, A., Salmon, M. (2019). Design of a Packaging Machine: General Description and Conceptualization. *Design Principles and Methodologies*. Springer Tracts in Mechanical Engineering. Cham: Springer, 205–237. doi: https://doi.org/10.1007/978-3-319-95342-7_9
3. Zhang, X. (2022). The Application of Folding Structure in Paper Packaging Design. *Proceedings of the 2021 Conference on Art and Design: Inheritance and Innovation (ADII 2021)*. Atlantis Press, 281–285. doi: https://doi.org/10.2991/assehr.k.220205.046
4. Shan, S., Ma, Y., Tang, C., Chen, X. (2018). Folding cartons: Interactive manipulation of cartons from 2D layouts. *Computer Aided Geometric Design, 62,* 228–238. doi: https://doi.org/10.1016/j.cagd.2018.03.018
5. Zhu, L., Xie, B., Zhang, Y. J., Yu, L.-F. (2019). Cartonist: Automatic Synthesis and Interactive Exploration of Nonstandard Carton Design. *Computer-Aided Design, 114,* 215–223. doi: https://doi.org/10.1016/j.cad.2019.04.007
6. Garbowski, T., Gajewski, T., Knitter-Piątkowska, A. (2022). Influence of Analog and Digital Crease Lines on Mechanical Parameters of Corrugated Board and Packaging. *Sensors, 22 (13),* 4800. doi: https://doi.org/10.3390/s22134800
7. Srivastava, A., Kumar, V., Singh, A. K. (2018). Computerized and electronic controls in food packaging. *Journal of Applied Packaging Research, 10 (1),* 3.
8. Xiao, L., Qu, B., Shi, E. (2021). Design of Automatic Packing System in Workshop Based on Programmable Logic Controller (PLC). *2021 4th International Conference on Information Systems and Computer Aided Education*, 2268–2272. doi: https://doi.org/10.1145/3482632.3484142
9. Hambir, P., Joshi, N., Karande, P., Kolhe, A., Karande, P., Kolhe, A. (2019). Automatic weighing and packaging machine. *International Research Journal of Engineering and Technology, 7 (5),* 2129–2138.
10. Rehei, I. I., Behen, P. I. (2023). Blanks extraction and feeding devices of semi-finished cardboard in the technological section of packaging equipment: analysis, perspectives and ways of improvement. *Printing and Publishing, 1 (85),* 164–173. doi: https://doi.org/10.32403/0554-4866-2023-1-85-164-173
11. Wang, D., Ge, C. (2016). Opening of Perforated Folding Cartons: From the Field to Testing. *Packaging Technology and Science, 30 (8),* 411–425. doi: https://doi.org/10.1002/pts.2266
12. Monir, M., Nasser, M., AbdelGhaffar, E., Omar, M., Sabry, Y., Mandour, M. (2022). PLC Based Automatic Packaging System. *The International Undergraduate Research Conference, 6 (6),* 1–5.

Oleksandr Malyi, *PhD, Associate Professor, Acting Head of Department of Information Technologies of Electronic Devices, Zaporizhzhia Polytechnic National University, Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0000-0002-8457-8154*

✉***Nataliia Furmanova,*** *PhD, Associate Professor, Department of Information Technologies of Electronic Devices, Zaporizhzhia Polytechnic National University, Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0000-0002-8670-2948, e-mail: nfurmanova@gmail.com*

Vadym Onyshchenko, *PhD, Associate Professor, Department of Information Technologies of Electronic Devices, Zaporizhzhia Poly-*

technic National University, Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0000-0002-4213-7131

Iryna Pospeieva, Senior Lecturer, Department of Information Technologies of Electronic Devices, Zaporizhzhia Polytechnic National University, Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0009-0004-7100-9245

Pavlo Kostianoi, Postgraduate Student, Department of Information Technologies of Electronic Devices, Zaporizhzhia Polytechnic National University, Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0000-0003-0833-8084

✉Corresponding author

UDC 004.9:379.85
DOI: 10.15587/2706-5448.2024.298422

Artur Kondra,
Valeriia Savchuk,
Sergiy Pasichnyk,
Nataliia Kunanets,
Hanna Mashika

DEVELOPMENT OF INFORMATION SYSTEM FOR PLANNING PERSONALIZED TOURIST ROUTES

The object of research is processes of information and technological planning of tourist trips. The article analyzes the processes of information technology planning of tourist trips and develops an information system for personalized planning of tourist routes using graph theory. The paper describes in detail a new approach to the formation of optimal routes based on graph models and the analysis of personal preferences of users.

The developed information system uses graph theory to represent and optimize tourist routes, taking into account various criteria such as distance, travel time, and individual user preferences. Algorithms for calculating optimal routes are designed to improve the quality of recommendations and provide a high level of personalization.

The functionality of the information system for planning tourist routes is based on the use of a number of innovative approaches and technologies that make the system more efficient, accurate and attractive to users. This takes into account the need to use modern route optimization algorithms. Algorithms have been developed to optimize tourist routes based on various criteria, such as cost, time, personal preferences, and environmental aspects. The introduction of intelligent analytical tools for predicting tourist trends helps to determine the popularity of places and other factors that influence the choice of routes. For the audio support of the excursion route, an algorithm for generating multimedia information content that is relevant to an individual personalized excursion route and its duration is used. The authors formulate the requirements and analyze the functionality of the information system for personalized planning of tourist routes, since a personalized approach and the use of graph models facilitate route planning that takes into account various aspects, including user-friendliness, accuracy of recommendations, system flexibility and security.

The developed information system can open up new opportunities for individual and intelligent planning of tourist routes, providing users with a unique tourist experience.

Keywords: *information system, tourism industry, graph theory, personalized planning, optimal routes, unique tourist experience.*

Received date: 02.01.2024
Accepted date: 09.02.2024
Published date: 13.02.2024

How to cite
Kondra, A., Savchuk, V., Pasichnyk, S., Kunanets, N., Mashika, H. (2024). Development of information system for planning personalized tourist routes. Technology Audit and Production Reserves, 1 (2 (75)), 45–52. doi: https://doi.org/10.15587/2706-5448.2024.298422

1. Introduction

The use of information technology in tourism in today's information society has a very positive impact on the quality and convenience of travel. Information systems provide convenient tools for navigation, mapping, and route planning. Users can quickly find not only tourist attractions, but also restaurants, hotels, transportation, etc. Information systems provide users with instant access to a large amount of information about tourist attractions, events, cultural activities, restaurants, hotels, and other important travel details. Thanks to information systems, users can easily book hotels, transportation tickets, excursions, and use travel management functions to make changes to their plans. Information systems equipped with language translation functions facilitate communication between users in places where language barriers may arise, and provide the ability to get recommendations for restaurants, shops, and other places from other users, making it easier for tourists to make choices. Information systems can serve as a means to obtain safety information and provide alerts in case of emergencies, as well as provide contacts for local emergency services. In general, mobile information technologies facilitate and enrich the tourist experience, making it more convenient, interactive and rich.