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# Research of logistic processes in production of technical difficult products

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Automation of production processes, which is widely used at foreign enterprises and largely reduces the labor intensity of products, is of particular relevance. In addition, in some cases, the installation of more productive equipment leads to a reduction in its quantity and allows you to partially free up production space. Technical re-equipment should concern, first of all, those workshops and production areas where cost reduction will be of greatest importance.

The reasons for the need for technical re-equipment of small machining enterprises can be grouped in the following areas:

- increasing the technological stability of production;
- reduction of production cycles of parts and assembly units, acceleration of the turnover of investments;
- reduction of terms and cost of preparation of production;
- reduction of labor intensity, reduction of production costs;
- reduction of rejects and costs for the restoration of defective products;
- reducing the cost of upgrading and repairing equipment.

The success of the enterprise, its competitiveness in market conditions, largely depends on how the issue of managing costs in the process of production and sale of products is resolved. It is especially important to re-solve this issue in the case of a diversified nature of production. The research methodology in this work will be the use of the SMED equipment changeover system to save time in the production of multi-product parts. If the changeover process takes very little time, it can be carried out as often as required. This, in turn, means that if we manufacture products in small batches, we can get many advantages: flexibility, fast delivery, productivity, high quality.

The enterprise can meet the changing needs of customers without the overhead of stockpiling. Manufacturing in small batches will reduce the time spent preparing the order for shipment, as well as the time the customer waits for the required product. Accordingly, the likelihood of damage to products is reduced, since their stor-age time is reduced. The volume of production rejects is also reduced due to fewer errors during setup and trial runs of equipment.

***Keywords:*** production process, simulation, conveyor system, equipment changeover problem.

## Introduction

Enterprise management is a type of activity that is aimed at regulating the course of production processes in accordance with a set goal. The goal of the activities of most enterprises that produce and sell their products to consumers, maximizing profits and managing costs is one of the ways to achieve it.

The production process is a certain sequence of actions for converting raw materials into finished products. Manufacturing processes are divided into five main stages: preparation; treatment; control; transportation; storage.

Preparation includes cleaning, disassembly and assembly. Processing changes the shape or properties of materials. Control implies comparison with a standard. Transportation is the movement of products. Accordingly, storage is a period during which there is no processing, transportation or product control. Each stage of the production process consists of changeover operations, i. e. operations for the preparation or adjustment of equipment, which are performed before and after the processing of each batch of the product.

Many companies manufacture their products in large batches only because the length of the changeover process makes it very costly to replace products on the line. Losses associated with equipment downtime some-times amount to millions of hryvnias. At the same time, the manufacture of products in large batches also has several disadvantages: delays; losses associated with product inventories; deterioration in quality.

Customers have to wait until the enterprise has manufactured the entire batch of the product (product), although it would be enough to produce a smaller quantity. Subsequent storage of unsold products generates additional costs, requires the involvement of other re-sources of the enterprise and increases the likelihood that these products will have to be sent for processing or even for destruction due to deterioration. Naturally, all this does not add value to the product (product).

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## 1. Analysis of recent research and publications

Regardless of the type of equipment used, all traditional changeover procedures consist of four stages [1]:

1– Preparation, adjustment, inspection of materials and tools;

2 – Assembly and disassembly of removable elements;

3 – Measurements, setup and calibration;

4 – Trial runs and calibration.

The main reason traditional changeovers are time-consuming is that internal and external setups are inter-mixed. Many tasks that can be performed while the equipment is running are performed only after it has been stopped [2].

At the same time, the SMED system is designed to simplify and reduce changeover steps. For example, it allows you to reduce the operation time at the third stage of a traditional changeover, offering to perform all or most of the preparatory operations with the equipment running, as well as to ensure the manufacture of quality products immediately after start-up without trial runs and adjustments, in other words, to completely abandon the fourth stage of the traditional changeover [3].

In the production system, there is a "classical" problem of equipment readjustment, which was inappropriate to solve by mathematical programming methods [1] due to the need to take into account the dynamic properties of the real production process and the "secondary" factors affecting it.

The search for "successful" algorithms for change-over of automatic stations for different sequences of product batches is easiest to carry out by drawing up appropriate rules of thumb, the effectiveness of which can be verified by direct simulation [4, 5].

## 2. Purpose of the study

The work carried out a study of logistics processes in the production of technically complex products, which is based on the introduction of logistics concepts in the automation of multi-product production.

## 3. Experimental part

The object of modeling is a production line where control and testing of gearboxes (hereinafter referred to as products) for high-power diesel engines is carried out. The basis of the line configuration is a closed conveyor system, with the help of which the transportation of products installed on special carriers is carried out. In the form of an equivalent closed-loop queuing system, the line is shown in fig. one.

The processing of the product begins with its installation on the carrier at workstation 1, then it moves through another 10 workstations, at the last of which the product is removed from the carrier, which is the end of its processing cycle. The carrier does not leave the conveyor system, and after unloading at station 11, it again enters station 1, where a new product is installed on it. At stations 1-4 and 7-11, operations are performed by workers, and at stations 5.1-5.8 and 6.1-6.7 operating in parallel, where the main operations for testing products are carried out, the operating mode is fully automatic.

The main difficulty in organizing the work of this production line is due to the fact that batches of products of various types are supplied to its input. This fact directly affects the real productivity of automatic stations 5.1-5.8 and 6.1-6.7, since it becomes necessary to change them, associated with a change in the type of processed products. With an increase in the frequency of changeover operations, the possible useful time of the stations is reduced and, as a result, their real productivity (throughput).

The problem posed on the readjustment of automatic stations 5.1-5.8 and 6.1-6.7 has the following formulation: if a new batch of products arrives at the input of the system, then at what points in time and for which stations should their changeover be started?

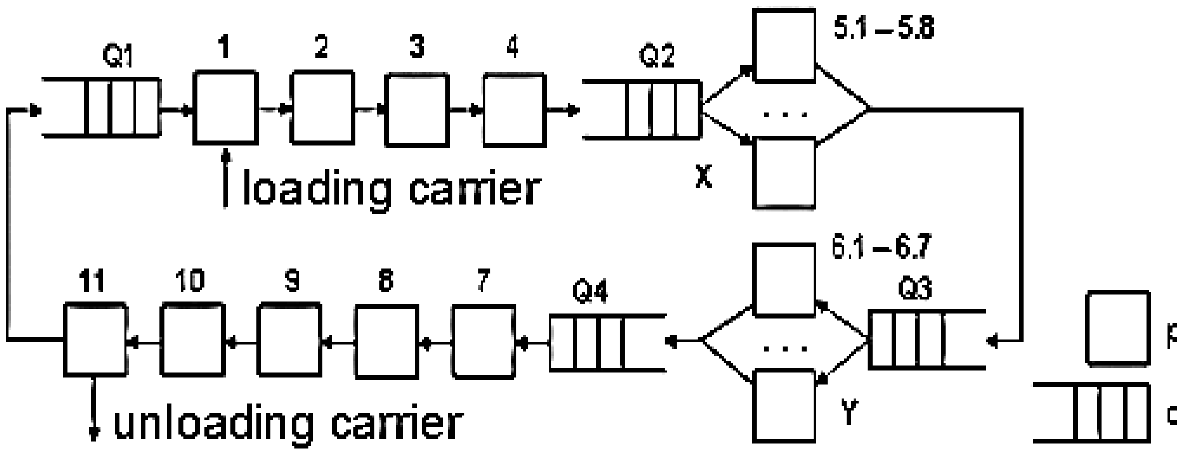


Fig. 1. Representation of the production line in the form of a closed queuing system

The solution to this problem should be subordinated to the desire to achieve the maximum throughput of the system as a whole. The search for "successful" algorithms for changeover of automatic stations for different sequences of batches of products is easiest to carry out by drawing up appropriate rules of thumb, the effectiveness of which can be verified by direct simulation.

It is assumed that products of four types A, B, C and D can enter the production line in batches of 1 – 200 units. Specific sequences corresponding to the structure of the production program are coded as arbitrarily long strings of the form "10A20B10A30C10A20D ... etc." If a sequence containing, for example, only 50 articles of type A and B is repeated, then it can be written in the form "50A50B". Some products, after the completion of the relevant inspection or testing operation, are declared defective. After receiving this status, the product is not sent to the automatic stations, but using the available transport routes is directed directly to the unloading station 11. The probability of detecting a reject at each workstation is set as part of the initial model data.

The production line simulation model was developed using the Anylogic simulation package. The model displays all the properties and parameters of the real line, which were described above. The presetting of changeover algorithms consists in creating so-called "masks", with the help of which it is indicated which automatic stations are intended to process products of types A, B, C and D. As a result, each station can be configured to process one, two, three or all four types of products. The set of data entered in the "masks" determines the so-called station availability rules. The second group of rules are the rules for choosing stations, which are implemented at the moments when at the point X or Y (Fig. 1) for the next product a station must be determined to which it will be directed. The set of rules for the availability and selection of stations is called a changeover strategy. The term "option 1" will refer hereinafter to the use of rules in which the station with the maximum number of occupied seats is selected, and the term "option 2" - with the minimum number of occupied seats.

## Results and discussion

The main indicator of the efficiency of a production line is its productivity (throughput), measured as the average number of products per hour removed from media at station 11. This indicator is displayed in all the diagrams below illustrating the results of simulation experiments. Although option 2 performs better in almost all experiments than the results obtained using option 1, the latter are also shown in the diagrams in order to further confirm the robustness of the model and the reliability of the results.

Experiment 1: Varying the number of carriers in the system. For this experiment, a repetitive sequence of batches of 2A2B products was chosen, in which there was no need to change the machine tools at all. The model was run with the number of carriers constantly circulating in the system, which varied in the range of 50 ... 140. The results (Fig. 2) point to the disadvantage of option 1, in which an acceptable level of performance is achieved only with 85 media, since this option tends to form the longest possible queues, as a result of which a large number of media “freeze” in the input buffers of automatic stations. With the number of carriers in the range of 85 ... 115, the system demonstrates a stable mode of operation with the maximum possible productivity (in the case of option 2) equal to 77.6 items per hour.

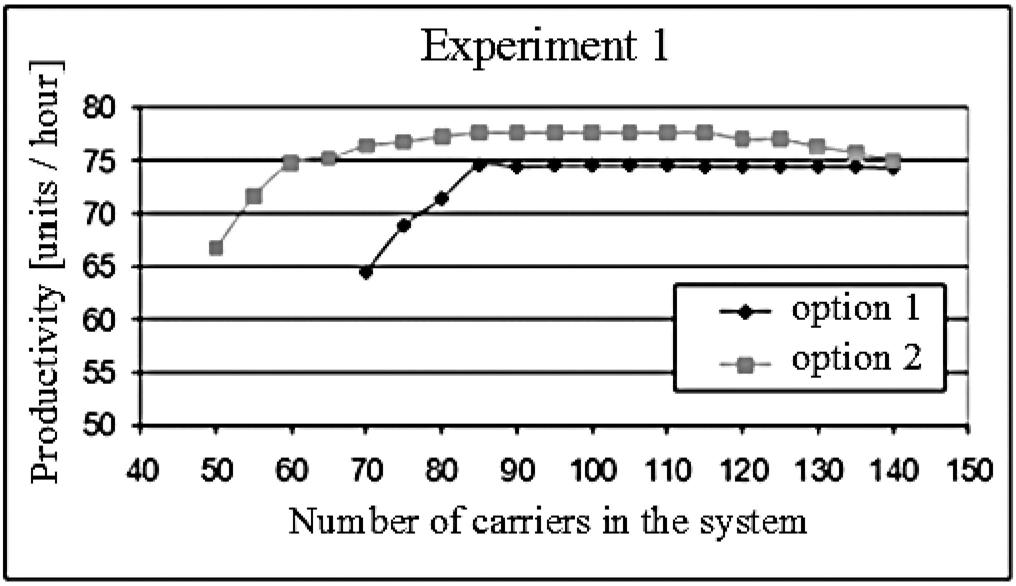


Fig. 2. Results of experiment 1

Experiment 2: Varying the size of batches of products. Only two types of products (A and B) enter the system in the form of batches of the same size, and this size varies in the range from 200 to 1. In fig. 3 shows the simulation results obtained using standard options 1 and 2, when all automatic stations were available for processing both types of products and changeovers began each time a new type of product appeared at the test position. It can be seen that at batch sizes < 30, the effectiveness of these strategies drops sharply, since more than 25 % of the station operation time is spent on changeovers. With large batch sizes, experimental attempts to "free" some stations from readjustment have always led to a decrease in line productivity. For batch sizes ≥ 30 in Fig. 3 shows the performance values that cannot be improved by changing the changeover strategy.

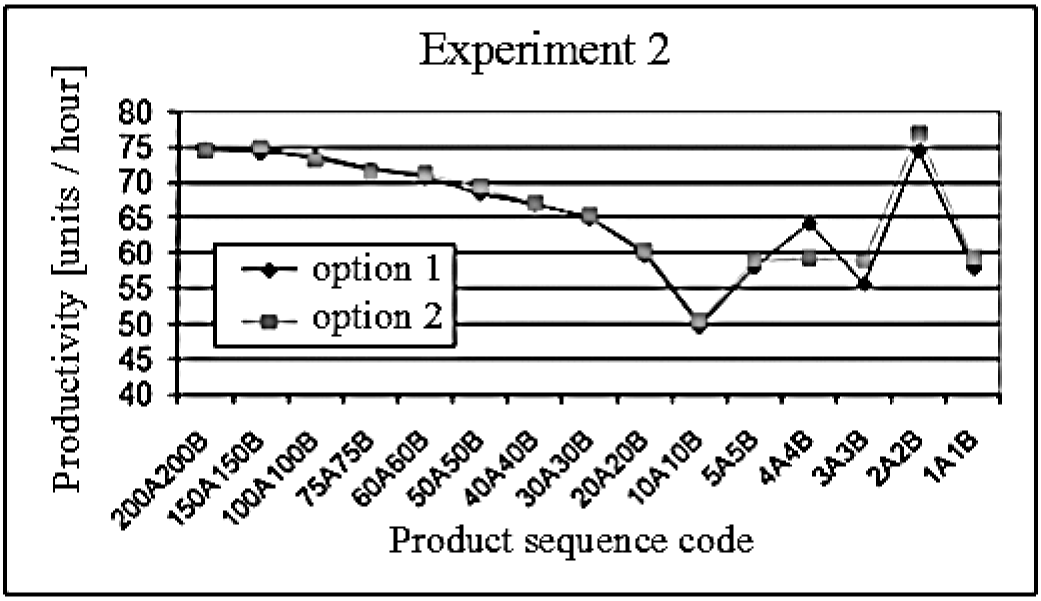


Fig. 3. Results of experiment 2

Experiment 3: Finding Optimal Changeover Strategies. For sequences of equal-sized batches such as "20A20B", "10A10B", etc. In this way, it was possible to find a simple scheme for assigning the type of products to specific stations, which, together with option 2, which means the choice of input buffers with a minimum number of occupied places, was called the "optimal strategy" and which ensured the maximum possible line performance with almost complete rejection of changeover (fig. 4):

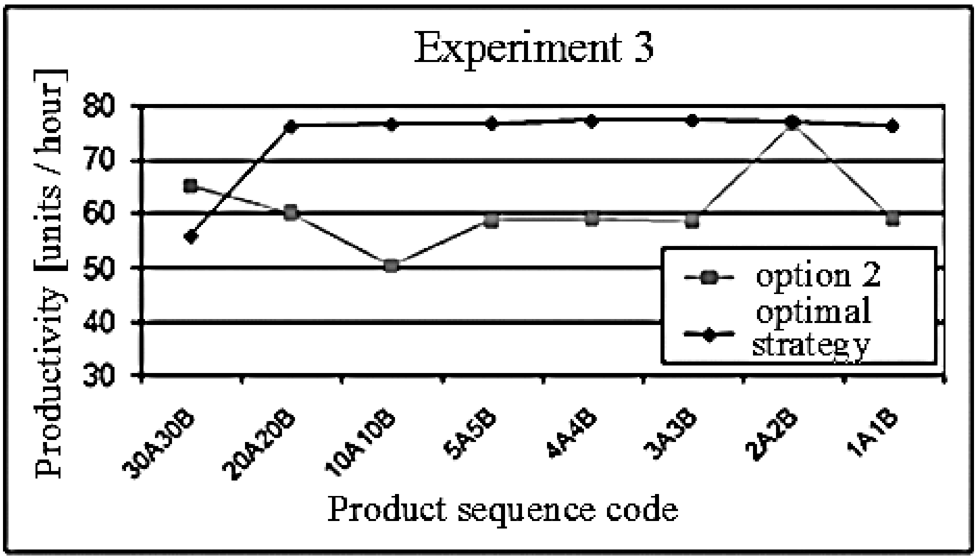


Fig. 4. Results of experiment 3

Experiment 4: limiting the number of service workers. All previous experiments were carried out on the condition that the number of setup workers was unlimited. In fig. 5 shows the effect of reduced system productivity for both standard cases when the number of available field technicians is reduced to two. For small lot sizes, where the number of changeovers can be relatively large, this reduction can be > 50%.

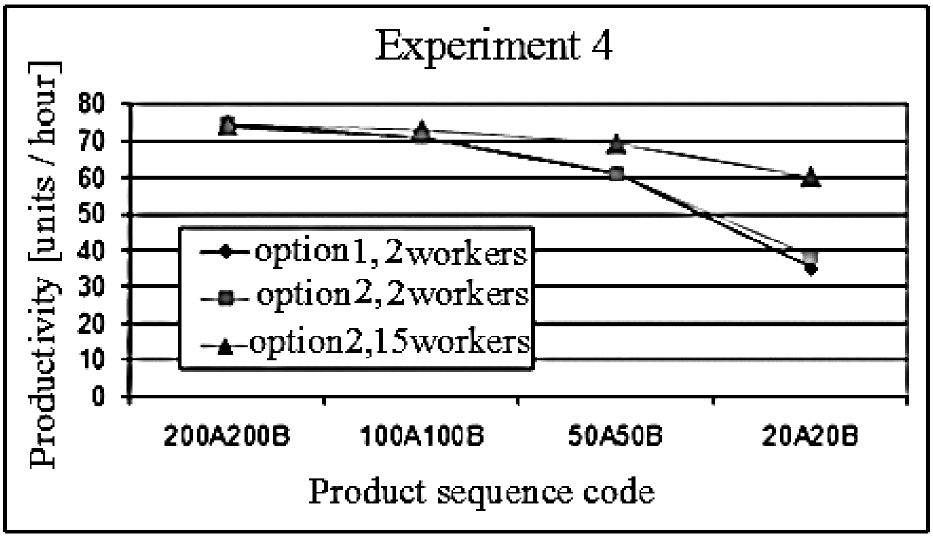


Fig. 5. Results of experiment 4

## Conclusions

The success of the enterprise, its competitiveness in market conditions, largely depends on how the issue of managing costs in the process of production and sale of products is resolved. It is especially important to resolve this issue in the case of a diversified nature of production. The proposed reduction of losses due to a quick changeover of equipment allows to reduce the size of the optimal batch, as a result, to quickly manage stocks and, as a result, reduce the lead time. In addition, the smaller the batch, the easier it is to identify quality and quantity deviations. Thus, logistics is becoming a factor in the formation of key competencies and a source of the main competitive advantages of enterprises.

## References

1. Pyzdek T. Fast Work Changeover //The Lean Healthcare Handbook. – Springer, Cham, 2021. – С. 101-112.
2. Serdiuk O., Baranov O, Rudenko N. Tool storage and delivery in flexible manufacturing //14th International Doctoral Students Workshop on Logistics. – 2021. – С. 91.
3. Serdiuk O., Baranov O., Rudenko N. Calculation of transport system in flexible manufacturing // 10.25673/85925. – 2022.
4. Toluev, Yu. I., & Plankovsky, S. I. (2009). Modeling and simulation of logistics systems. Kyiv, Ukraine: Millennium.
5. Koch M., Tolujew J. Grouping Logistics Objects For Mesoscopic Modeling And Simulation Of Logistics Systems //ECMS. – 2013. – С. 636-643.

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# Дослідження логістичних процесів при виробництві технічно-складної продукції

Особливу актуальність в даний час має автоматизація виробничих процесів, яка широко застосовується на сучасних підприємствах і значною мірою дозволяє знижувати трудомісткість продукції. Крім того, у ряді випадків встановлення більш продуктивного обладнання веде до скорочення його кількості та дозволяє частково вивільнити виробничі площі. Технічне переозброєння має стосуватися насамперед тих цехів та ділянок виробництва, де зниження витрат матиме найбільше значення. Причини необхідності технічного переозброєння малих підприємств механообробного профілю можна згрупувати наступним напрямкам:

- підвищення технологічної стійкості виробництва;
- скорочення циклів виготовлення деталей та складальних одиниць, прискорення оборотності вкладених коштів;
- скорочення термінів та вартості підготовки виробництва;
- скорочення трудомісткості, зниження собівартості продукції;
- скорочення шлюбу та витрат на відновлення дефектної продукції;
- скорочення витрат на модернізацію та ремонт обладнання.

Успіх діяльності підприємства, його конкурентоспроможність у ринкових умовах, значною мірою залежить від того, як вирішується питання управління

витратами, що мають місце у процесі виробництва та реалізації продукції. Особливо важливим є вирішення цього питання у разі багатономенклатурного характеру виробництва.

Методикою дослідження у цій роботі буде застосування системи переналагодження устаткування SMED задля економії часу під час виробництва багатономенклатурних деталей.

Якщо процес переналагодження займає дуже мало часу, його можна проводити так часто, як це потрібно. Це в свою чергу означає, що якщо ми вироблятимемо продукцію малими партіями, то зможемо отримати багато переваг: гнучкість, швидке постачання, продуктивність, високу якість.

Підприємство може задовольнити мінливі потреби замовників без витрат за зберігання запасів продукції. Виробництво малими партіями дозволить скоротити час, що витрачається на підготовку замовлення до відправлення, а також очікування замовником необхідної продукції. Відповідно, знижується ймовірність псування виробів, оскільки скорочується час їх зберігання. Зменшується і обсяг виробничого браку через меншу кількість помилок під час налагодження та пробних пусків обладнання.

**Ключові слова:** виробничий процес, імітаційне моделювання, конвеєрна система, завдання про переналагодження обладнання.

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