Automation of technological processes in mechanical engineering

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Abstract. This article discusses trends of production development in the engineering industry. The need to control automation processes at various stages of product manufacture has been identified. It was concluded that automation leads to increasing the efficiency of production, economic activities and quality of products, as well as making and introducing new products. On the basis of Russian and foreign experience the key stages of realization of automatic control system for technological processes were pointed out. Using the example of Business Units, the stages of implementing the latest automated equipment were considered. The project team conducted a survey of the business unit and determined that automation of the casting process in the foundry should be carried out. As a result, it was proposed to introduce an automatic cutting and grinding complex into the production process. These innovations made it possible to reduce the enterprise expenses by reducing the number of employees, as well as reduce the percentage of defects. Moreover, it became possible to solve a number of other significant problems: a decrease in the waste percentage, the need to meet the world requirements for the result of processing, elimination of the consequences of difficult working conditions (reduction in the number of accidents, noise levels and concomitant diseases). The results can be used not only for the considered objects of research, but also for organizations of other industries in order to increase the efficiency of activities through the introduction of automation of the control system of technological processes.

1. Introduction
In today's dynamic environment, industrial production has a significant impact on the economic environment. According to Rosstat, the current state of industrial development by August 2020 is at the stage of restoring industrial production, and this trend has generally remained. The index to the corresponding period of the previous year was 92.8% after 92.0% in July and 90.6% – on June. At the same time, compared to the previous month, production increased by 0.5%, while in July it amounted to 0.9% (with the elimination of the seasonal factor). According to the Center for macroeconomic analysis and short-term forecasting (CMASF), the index of the corresponding period of the previous year is set at 95.6% after 94.9% in July and 94.3% in June; with the elimination of seasonality, the growth index in August by July was + 1.4% (Figure 1).

Structurally, the tendency of the trend in August changed slightly. If in May-July the restoration of output in the affected industries was almost frontal, then in August in a noticeable part of them it stopped or even there was some backsliding. It was especially significant in two sectors, non-ferrous metallurgy,
where export supplies sat, as well as in the production of cars, where manufacturers in July clearly overestimated the speed of recovery in consumer demand. New and significant positive developments in August are the beginning of the oil production restoration and the acceleration of the increase in gas production which began a month earlier.

It should be noted that the current situation is characterized by the continued excess of production of the last year relative to consumer goods of everyday demand. At the same time, the key point is the scale of external tourism that has significantly decreased, and therefore it is not worth counting on stabilizing this situation in the face of declining incomes.

**Figure 1.** The volume of industrial production according to Rosstat, assessment of CMASF and National Research University «Higher School of Economics» (seasonality eliminated, 2017 = 100) [1]

On the basis of the proposed statistics, it could be concluded that there is a volatility of results in most areas of the industrial sector. To stabilize and dynamically develop the industrial complex as a whole, the sustainability of specific enterprises should be developed. One of the largest industries is mechanical engineering. It establishes a basic level of scientific and technological development. Due to this industry, other areas are being supplied. One of the characteristics of the machine-building complex is the profound specification of the production and significant scale.

Trends in the production development of engineering enterprises include a range of measures: providing production lines with the latest equipment, implementing control systems and automation of management. In the engineering industry, in the context of automation, it is necessary to pay attention to all kinds of factors. For example, from an engineering point of view, there is a difficulty in automating the entire production cycle. Most often this is not necessary, it could be sufficient to decide on the automation implementation at individual stages of the process.

In the foundry, for example, the charge loading process, temperature control and metal pouring into the molds are automated. Various sensors associated with the controller, feedback and remote control can minimize human involvement in this hazardous and harmful production [2].

In the machine-building complex, consisting of more than 7,5 thousand units of enterprises, one of the forms of blanks production is foundry. According to experts, at the moment in Russia there are about 1,1 thousand functioning foundry enterprises, which have significant volumes of castings and are also engaged in the production of equipment and materials for foundry production. Manufactured products (cast parts made of black alloys and non-ferrous ones) are most often used in the industry. Each industry sets its respective characteristic requirements for castings in terms of nomenclature, mechanical and operational properties, type of alloy, mass of castings, and, accordingly, type of technological processes and equipment.
2. Materials and methods

Automation of production processes in the engineering industry is a process of control, control and regulation of the production process, where part of the work is carried out not by man, but by automatic devices. One of the difficulties of mechanization and automation processes in the engineering industry is especially the use of continuous technology.

One of the basic factors of automation of technological processes and production in the engineering industry is the introduction of an automated process control complex, within which control takes place without direct human impact. This system includes various technological processes: continuous, individual and combined [3].

The implementation of the automated process control system (APCS) is carried out in stages and includes many stages. Based on the experience of domestic and foreign authors, the process of APCS implementing at the stage could be divided (Figure 2).

The key task of automation is to improve the quality characteristics of the implemented process. For the engineering industry, the basic factors for increasing production efficiency are increased productivity, reduced working time, the greatest accuracy and stabilization of operations. It is possible to solve tasks due to automation of technological processes [4].

Modern enterprises use automation everywhere, and this is not a factor depending on the size of the company. In mechanical engineering, a significant number of various operations are used in the production and manufacture of hundreds of thousands of parts, such as casting, forging, welding; multidisciplinary machining; heat treatment, multilevel assembly operations, etc.

The modification and reconstruction of foundry enterprises also consists in the gradual introduction of new environmentally friendly processes and materials, modern equipment capable of carrying out the casting process at a high quality level, while meeting the standards existing in this industry [5]. Only a small part of modern Russian enterprises direct funds for the modernization of foundry, which contributes to improving the rate of quality of cast blanks and increasing labor productivity. Other companies are only on the way to building a flexible production process system; there are problems of such automation, ensuring the continuity of the equipment process chain. These steps allow you to carry out reassignment in the production of a wide range of castings.

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**Figure 2. Key stages of implementation of automated process control system**

- **Requirements generation**
  - Site survey and rationale for implementation
  - Generation of customer’s requirements

- **Concept development**
  - Studying the automation object
  - Performance of necessary R & D
  - Development of concept options and selection of one option

- **Development of projects and tasks**
  - Development and approval of draft proposal
  - Draft design development and approval
  - Technical design development and approval
  - Development and approval of the working project

- **Commissioning**
  - Preparation of facility and personnel for entry
  - Construction and installation works and commissioning works
  - Testing: preliminary; pilot operation; acceptance tests.

- **Tracking of automated process control system**
  - Performance of works in accordance with warranty obligations
  - Post-warranty Service
3. Results

The practical use and efficiency of production automation are considered by the example of a machine-building enterprise; we designate it as a Business Unit. In this work, the implementation of systems and automation of management stages is presented in a separate fragment, since the central element of automation of production processes is the proposed automation project. In this article we focus on the first three stages of system and automation of management «development of projects and tasks».

As part of the automation project, it is necessary to take into account standard tasks to ensure production efficiency. To solve such problems, we will use the proposed stages of the system and automation of management [6].

At the first stage «Formation of requirements», the project team conducted a survey of the business unit and established the need to automate the process of processing the cast billet RF98MM-6303-CD «Crankshaft» in the foundry.

During the treatment of experimental batches, it was revealed that most of the defects after machining are at the top of the casting, so it was proposed to increase the allowance on all main and connecting rod necks from above by 1 mm, from 2 to 3 mm (Figure 3).

It becomes necessary to develop such a project and purchase an automated complex, which will be removed 1 mm on all main and connecting rod necks from above from the connector line (9 places, highlighted in red).

At the next stage, «Concept development», the automation object was studied.

The following means have been put forward to solve them:
- automation of the production process based on the introduction of new modern high-quality equipment: automatic refining complex;
- reduction of machine time due to application of implemented equipment;
- reduction of the number of employees per procurement processing activity.

At the third stage «Development of projects and tasks» it is necessary to develop a technical assignment and a preliminary design. At this stage, new progressive technological processes are being developed, the transition to which should solve the three-unit problem «quality-timing-costs». At this stage, the «sketch» expresses the best option, which allows eliminating the risks of making incorrect expensive decisions. It was decided to replace manual labor with automated equipment [7].

Manual execution of this operation entails the presence of a large number of employees, the percentage of waste is quite high, the possibility of scrap is very high (at the stage of grinding the seam), and it is necessary to meet the requirements for the treatment result that set the quality standards for the engineering industry. Another disadvantage of manual processing of a part is difficult working conditions (a large percentage of accidents, the level of noise isolation is quite low, concomitant diseases are possible). New processes require the selection of appropriate equipment.

![Figure 3. Requirements for the cast workpiece process](image_url)
The working group considered a proposal for the installation of an automatic cutting and grinding complex. P.S. Autogrinding Limited (PSAG), UK. This automatic cleaning complex is specially designed for foundry (Table 1).

| Characteristic                          | Description                  |
|----------------------------------------|------------------------------|
| Number of axes                         | 7                             |
| Operating range                        | 700 D x 350 width             |
| Nominal casting weight                 | 50 kg                         |
| Total loading power (casting + gripping)| 70 kg                         |
| Electrical switching requirements      | 17.3 KW                       |
| Pneumatic Requirements                 | 3.5 l/cycle                   |
| Cutting disk spindle                   |                               |
| Power                                  | 4.5 KW drive                  |
| Speed                                  | 3500 turns/min                |
| Typical disk sizes                     | 355 D x 12 width              |
| Grinding spindle                       |                               |
| Power                                  | 3.7 KW                        |
| Speed                                  | 15,000 turns/min              |
| Typical Disk Sizes                     | 50 D x 15 width               |
| Air offtake                            | Not determined                |
| Volume                                 | 60 m³/min                     |
| Nozzle size                            | D200                          |
| Dimensions                             | 2000 width x 3425 length x 2305 height | Weight 2450 kg |

This automatic cut-off complex has the following characteristics:
- Compact design allows 1 operator to work on 2 or more machines.
- Diamond disc technology.
- Durable grinding disc - up to 6 months; more than 25 years of successful experience, more than 2000 machines put into operation.
- Speed of reconfiguration.
- Ease of operation and programming.
- Processing of grinding dust, no contamination.

A technical design was developed to determine the quantity of equipment and, after approval by all members of the project team, it was approved. As part of the task, technological processes were established, the loading of machine tools was determined. At the next stage of this stage, a working design was developed, which reflects the scheme of optimal arrangement of equipment, taking into account workshop traffic flows [8].

One of the important stages of this stage is the design and preparation of a feasibility study for the proposed complex implementation.

In accordance with the technical assignment, the wage fund for the cleaning site was 14,035,910 rubles. Wages in the industry are on average 23,000 rubles, after taxes are paid.

To calculate the number of people per shift: 14,035,910/369,600 = 38, that is, about 19 people are needed to execute work.

Taking into account this number of personnel and the volume of castings, it turns out one person must process 30 castings per minute (or spend about 40 seconds on one casting) [9].

Based on the experience of the business unit in the foundry, about 49 people per shift are needed to organize the grinding area for processing operations in accordance with the technical one. Labor costs for the year are on average 40,000,000 rubles.

With the complete automation of the cleaning site by Koyama complexes, the cost of acquiring the machine will be 167 850 000 rubles. The introduction of the new complex makes it possible to reduce
the number of employees for the production of castings. The economic impact of the reduction in the number of workers is shown in table 2.

**Table 2.** Calculation of the rate of cost reduction for the Wage Fund

| Name | Project implementation phase | Savings (+), decreases (-), people | Average salary, rub.* | Savings (+), increase (-), rub per year |
|------|-----------------------------|-------------------------------------|------------------------|----------------------------------------|
| Before implementation | After implementation | 100 | 14 | 86 | 22 000 | 37 877 496 |

* after taxes are paid

During the implementation phase of the machine, the company understands how the expected results can be achieved. These stages of system and automation of management could be tested during the implementation of other projects at the enterprise [10].

The fifth stage is already the performance of works in accordance with warranty obligations and post-guarantee maintenance.

4. Conclusion

At the moment, only a small number of company executives are trying to maintain the usual and outdated production technologies. The head of this Business Unit believes that too conservative views unreasonably believe that automation is an economically unprofitable activity. A correct management decision in this area will be able to make significant changes to the usual situation of the enterprise. A competent leader understands that the modern situation in the industry dictates its own rules, forcing to conduct activities flexibly, not forgetting about the automation of modern production.

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