

Automation of repair company processes through the use of digital models

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Abstract. The article discusses the improvement of the process of picking and assembling an internal combustion engine, during repair, using the method of complete interchangeability, by digitizing it. The purpose of the study is to create a digital model of the process of picking and assembling an internal combustion engine during repair for an enterprise. In the study of the theoretical basis, which serves as the basis for the implementation of the picking and assembling process by the method of complete interchangeability, methods of analysis and synthesis were used. The Business Studio software product was used to design the digital model, the IDEF0 notation was used to determine the location of the picking and assembling process, and the BPMN notation was used to model the diagram of the process in question. As a result of the work, a diagram of the decomposition of the work processes of the repair enterprise was obtained, as well as a simulation model of the process of picking and assembling of the internal combustion engine, which presents the operations, the process, its resources, main events, and also details the features of the method of complete interchangeability. The resulting model makes it possible to optimize the order of assembly cycles, based on current information about the state of the enterprise, its resources and consumer requirements.

1 Introduction

Digitalization is an actual trend in various spheres of life and production. Without the introduction of modern digital technologies, no industry, no production will be able to develop and compete both domestically and on the global market. Digitalization of production implies the transition to new process models and production tools based on information technologies [1].

Currently, digital modeling of business processes is becoming an integral stage of the harmonious development and growth of a modern enterprise. Modeling business processes using modern IT approaches is an essential reserve for improving the efficiency and reliability of production enterprises and organizations [2, 3].

The IDEF0 notation is simple and understandable, but has limited use, both in terms of describing complex processes and further digitalizing the process. Therefore, it is advisable

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to use this notation to describe top-level processes, where there is no need for detailed regulation of individual activities within this process. The IDEF0 notation is simple and understandable, but has limited use, both in terms of describing complex processes and further digitalizing the process. Therefore, it is advisable to use this notation to describe top-level processes, where there is no need for detailed regulation of individual activities within this process.

Using BPMN as a notation for business process modeling is a powerful and modern tool. BPMN notation is widely used for the design of complex technological processes [4], as it has a number of advantages that allow using a visual model not only as an explanation of instructions and regulations, but also to carry out simulation modeling based on them.

Thus, research aimed at creating digital models of real production processes, including those of a repair company, is relevant and allows us to solve the problem of introducing digital technologies and increasing the level of digitalization of production.

2 Research materials and methods

To design the picking and assembling process during the repair of the internal combustion engine, IDEF0 notation (Function Modeling – a method of functional modeling), BPMN notation (Business Process Model and Notation – a system of symbols (notation) and their descriptions in XML for modeling business processes) were used with which a contextual diagram and its decompositions were constructed.

3 Results

Engine overhaul is a complex technological process that includes several stages: disassembly of the engine, cleaning of parts, defective parts, repair and restoration work, picking and assembling, running-in and testing of the repaired engine. It is also advisable to set out such steps as entrance control and storage of spare parts, and disposal of parts and materials. To visually represent the overhaul of the internal combustion engine from the standpoint of the process approach, we will make up its model in IDEF0 notation, presented in Figure 1, define the main attributes of the process: inputs, outputs, regulators and resources. The inputs of the process are: an engine requiring major repairs (faulty), supplies and components coming from the supplier. The output of the process is a repaired (restored) engine, accompanying documentation (test reports, warranty documents, etc.), as well as parts and materials for disposal. Process regulators – technical requirements for capital repairs, internal and external regulatory documentation of the enterprise (GOST standards, methodological guidelines, instructions, orders and orders).

As can be seen from the diagram (Figure 1), the picking and assembling is almost at the final stage of engine overhaul, therefore, errors made during picking and assembling can not only negatively affect the performance of the engine, but also devalue the work carried out at previous stages.

The input for the picking and assembling process is new parts, parts with acceptable wear and refurbished parts. The output of the picking and assembling process is the assembled engine and the parts rejected in this process. Those of the rejected parts that are subject to restoration are sent for repair, and the incorrigible defect is sent to a scrap yard for disposal. A request for new parts is formed when, when determining the nomenclature of necessary parts, restored parts and parts with acceptable wear are not enough.

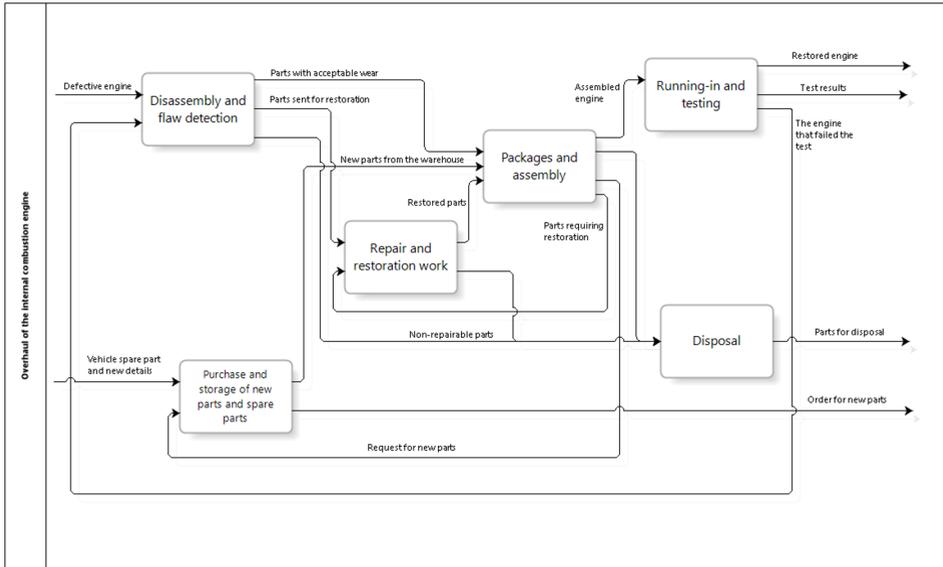


Fig. 1. ICE overhaul process model in notation IDEF0.

Next, the decomposition of the picking and assembling process is carried out (Figure 1), and a digital model of the process is compiled in BPMN notation. When organizing the picking and assembling processes, the main factor is the assembly method, since it determines the order of assembly operations. To ensure the accuracy of assembly, repair companies use many different methods, one of them is the methods of interchangeability, divided into methods of complete interchangeability, incomplete and group. All of them provide clarity and ease of assembly organization. A distinctive feature of complete interchangeability is the narrowed tolerance fields and the need for high-precision machining of parts, which allows you to connect any parts without additional work. In case of incomplete or partial interchangeability, fitting and selection work is allowed for a certain percentage of completed parts, which is assigned in advance. Group interchangeability is characterized by the expansion of the tolerance fields of the assembled parts by sorting them into specified size groups during assembly. As part of the ongoing research, a model will be developed for picking and assembling using the method of complete interchangeability.

To create a model of the assembly process using the method of complete interchangeability, have been defined the following: inputs, outputs, resources, and mechanisms of the process, as well as the interaction between inputs and outputs with the production system. The process has been divided into separate actions, and process events such as start, intermediate, and end have been defined.

The starting event for the projected process is the receipt of parts in the assembly shop (assembly area). New parts are ordered by the company from suppliers in cases where some of the parts of the engine being restored are not repairable and need to be replaced. Repair companies regularly face situations when spare parts and components are supplied for picking and assembling from different and independent sources. This situation has a significant impact on the quality of picking and assembling and, as a result, on the overall quality of the repair process. Therefore, it is important to create an effective verification system for spare parts and components at a repair facility [5]. In addition, a distinctive feature of the repair process is the presence of worn and restored parts at the assembly operation, which come from the "exit" of the defect processes and repair and restoration

work. It follows from this that special attention should be paid to the quality of the process of defective worn parts [6] and its metrological support [7, 8]. A set of measures to improve the quality of defects, verification of spare parts, picking and assembling has a positive effect on the quality level of repairs in general, which ultimately reduces losses from internal and external defects at the repair enterprise [9].

The picking and assembling model in BPMN notation is shown in Figure 2. The model reflects: the starting, final and intermediate events of the process; gateways that determine the merging and separation of flows of operations within the process; the movement of material objects used and created in the process.

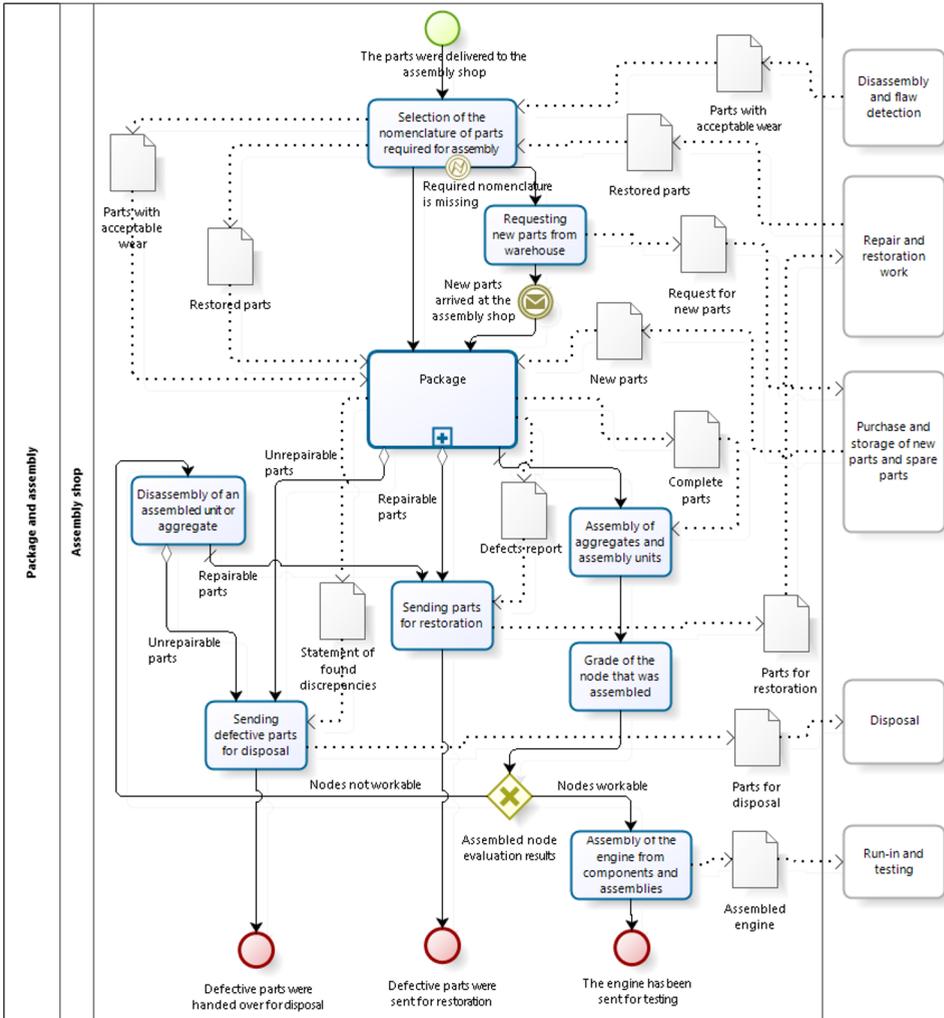


Fig. 2. Model of the picking and assembling process in notation BPMN.

During the picking process, the parts are sorted by type: "Shaft" and "Hole", for subsequent evaluation of their characteristics. Parts with characteristics corresponding to technical requirements are called suitable, and from them, subsequently, assembly kits are formed. Since the method of complete interchangeability is used in this case, the selected components are immediately sent for assembly, which is ensured by tests carried out at

previous stages screening out parts with tolerances of insufficient accuracy, which eliminates the need for additional processing of parts.

For parts with inconsistencies, the degree of defect is assessed, and in the case when a correctable defect is detected, such parts are sent for repair for correction and restoration with a report on defects found in them, after which they can be allowed to be assembled in the next cycle. Those parts whose defects are assessed as incorrigible are sent to the scrap metal warehouse for recycling, with the preparation of an act of inconsistency in which the defects and possible causes are described in detail.

After completion of the picking, the completed parts and pairs are transferred for assembly. The assembled components are evaluated from the point of view of the profitability of their use for subsequent engine assembly, where they are directly transferred if the evaluation results are successful. When defects are detected, the components are disassembled, and their components, depending on the degree of defect, are sent for repair or to a scrap yard for recycling. An engine is assembled from suitable components and assemblies, which is then sent for running-in and testing [10, 11]

The complete interchangeability acquisition process model is also constructed in BPMN notation and is shown in Figure 3.

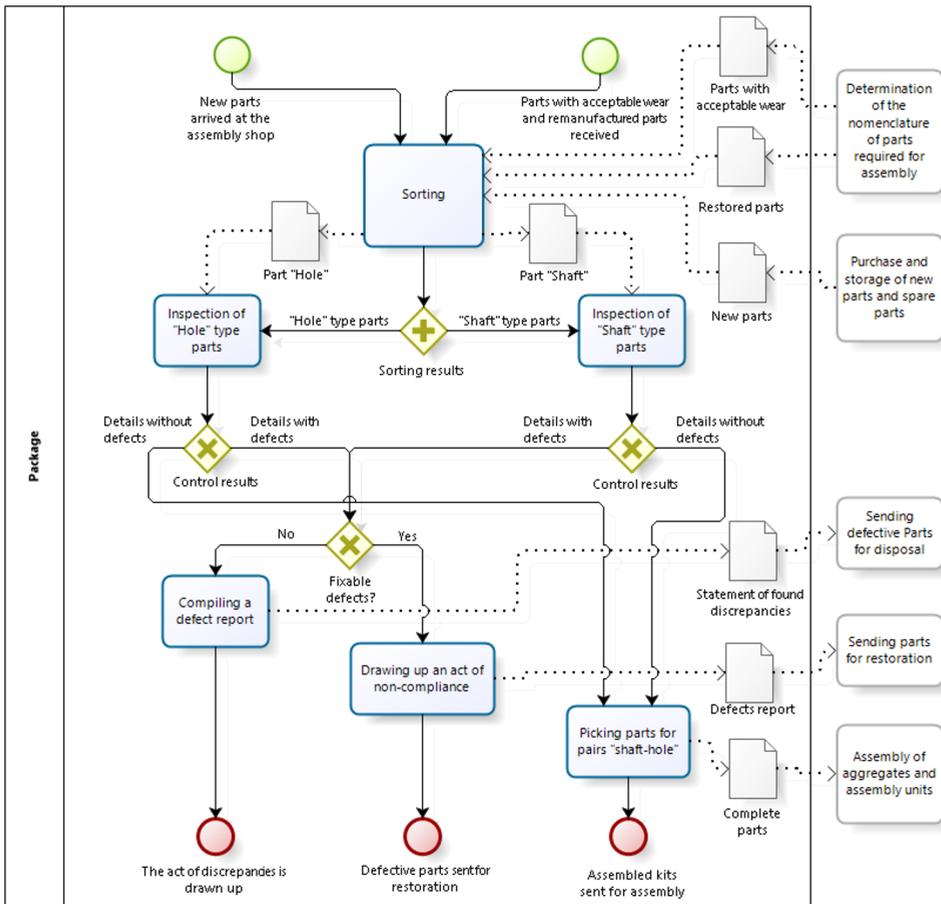


Fig. 3. Model of the picking process (by the method of complete interchangeability) in the notation BPMN.

At the next stage, the verification of the developed model was carried out. Verification allows you to identify errors or inconsistencies in the behavior of the model that occurred at the construction stage when compared with the real process. Verification includes checking the requirements for compliance with the standards of the enterprise in terms of the technological process, checking the completeness of the model, using a single terminology when describing the process. It is thanks to the successful verification of the process model that it is possible to proceed to the stage of simulation and analysis.

The very structure of operations and processes can be built using various software, which allows not only to build digital models of processes in various notations and formats, but also to conduct simulation modeling to visually display the process with all the details, as well as to evaluate the selected methods and means of organizing the process, taking into account the various factors accompanying them. In this case, the models were built in the Business Studio program, using the IDEF0 notation (Figure 1) and BPMN (Figures 2, 3). The functionality of this program allows to use it for simulation modeling. To do this, data related to production resources are entered into the program, for example, the cost of parts and components used in assembly, the time spent on carrying out the process operation, the amount of auxiliary materials used, workers' wages and other quantitative characteristics related to the resource base.

The construction of a simulation model requires known statistical characteristics of the process related to the probability distribution of process variables. This is an assessment of the distribution of random events, confidence probabilities, testing hypotheses about the laws of distribution of random variables, etc.

The implementation of a simulation model at a repair facility opens up opportunities for managing the order of assembly cycles based on the state of the enterprise and the needs of the customer. It also becomes possible to adapt the use of enterprise resources to specific needs by manipulating their numerical characteristics, such as cost, quantity, time, as well as accuracy parameters.

4 Conclusion

Thus, the main characteristics of the picking and assembling process during engine repair have been determined, and a digital model of the process in IDEF0 and BPMN notations has been developed. Further ways of applying simulation modeling using the constructed models in repair production are determined.

References

1. M. L. Kheifetz, *Journal of Advanced Materials and Technologies* **6(1)**, 18-29 (2021)
2. O. O. Shendrikova, I. F. Elfimova, *The Organizer of the Production* **27(1)**, 16-24 (2019) DOI: 10.25987/VSTU.2019.88.65.002.
3. G. G. Kulikov, T. K. Gindullina, V. N. Kapustin, et al., *Bulletin of the South Ural State University. Series: Computer Technologies, Automatic Control, Radio Electronics* **22(4)**, 109-118 (2022) DOI: 10.14529/ctcr220411.
4. T. Lopes, S. Guerreiro, *Business Process Management Journal* **29**, 133-162 (2023)
5. A. A. Gureev, *Quality. Innovation. Education* **2(166)**, 96-100 (2020) DOI: 10.31145/1999-513x-2020-2-96-100.
6. O. A. Leonov, N. J. Shkaruba, Yu. G. Vergazova, *Agroengineering* **24(4)**, 48-52 (2022) DOI: 10.26897/2687-1149-2022-4-48-52.

7. G. I. Bondareva, O. A. Leonov, N. J. Shkaruba, Yu. G. Vergazova, *Rural Mechanizer* **10**, 27-29 (2022) DOI: 10.47336/0131-7393-2022-10-27-28-29.
8. O. A. Leonov, N. Zh. Shkaruba, *Measurement Techniques* **65(8)**, 564-568 (2022) DOI: 10.1007/s11018-023-02121-z.
9. N. Z. Shkaruba, O. A. Leonov, *Russian Engineering Research* **41(3)**, 211-214 (2021) DOI: 10.3103/S1068798X21030175.
10. M. N. Erokhin, O. A. Leonov, N. Zh. Shkaruba, et al., *Russian Engineering Research* **41(12)**, 1156-1160 (2021) DOI: 10.3103/S1068798X2112011X.
11. G. I. Bondareva, G. N. Temasova, O. A. Leonov, et al., *Russian Engineering Research* **42(2)**, 151-154 (2022) DOI: 10.3103/S1068798X22020046.