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Digital Model and Assembling of a Lathe

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Abstract. The article aims at developing a digital model of a lathe and the related technology for its assembling. The study is based on analyzing the service purpose and technological capabilities of modern modular machine tools, justification and development of the machine tool design according to the specified production conditions, and development of a technological process for assembling the proposed modular machine tool. The geometric modeling techniques and the design documentation were implemented to justify the rational choice of design parameters of the machine tool design and its spatial model. The proposed approach also considers structural elements and the relationships between them. As a result, a conceptual approach was proposed to design technological processes of lathe assembly with a wide range of technological capabilities. It allows implementation of the up-to-date strategy from idea to finished product at industrial enterprises. The practical significance of the obtained results for the machine-building industry is in the proposed practical recommendations for developing the technological process for assembling lathes.

Keywords: industrial growth, manufacturing engineering, modular machine tool, rational design.

1 Introduction

The modern world machine tool industry is determined by various structural layouts [1]. After analyzing the layout of metal-cutting machines [2–4], it can be summarized that machines with the same type of structures can be composed differently, and vice versa. It is also possible to make certain conclusions about the need to identify and analyze layout quality factors at constructing layouts. To achieve this goal, it is necessary to separate the layout factors of machine tools from the factors that affect the structural development of nodes.

Layout refers to a system of arrangement of modules and guides of a machine tool, distinguished by structure, proportions, and properties [5].

A module is a structurally and functionally complete unit, which is an integral part of the overall design of the designed machine tool. The following modules are distinguished in manufacturing engineering: a technological module is a technological structural unit of the layout. In other words, the smallest component of the machine's layout elements is necessary to perform the shaping operation; a design module is a unit of machine unification, which is both functionally and structurally independent unit that can be used individually and in various combinations with other modules.

The work aims to develop a digital model of a lathe and design the assembly technology. To achieve the set goals, the following tasks need to be solved:

– to analyze the service purpose and technological capabilities of modern modular machine tools;

– to justify and develop the design of a modular machine according to the specified production conditions;

– to develop a technological process for assembling a modular machine tool.

The object of the research is the process of design and technological support of machine-building production. The subject of the research is the assembly process of a multiaxis lathe.

2 Literature Review

The market situation in manufacturing engineering is constantly changing, affecting production needs. To compete with other manufacturers, companies must quickly adapt to the demand for custom orders [6].

Modular and reconfigurable machine tools can be a key solution to meet the demands of today's markets for rapidly changing products and product specifications.

That is why this issue is an important problem in machine-building production today. The ability to reconfigure machine tools according to production requirements offers economic benefits. In the case of a modular layout, the equipment is also justified from an environmental point of view. Thus, modular equipment impacts the sustainable development of manufacturing engineering [7, 8].

The constant change in consumer demands is the subject of today's manufacturing environment [9, 10]. The goal of machine-building companies is to make maximum profit by providing customers with products, which means that product quality, production cost, and final price are key factors. Modular systems are possible options for implementing changes in production systems and production in general [11, 12].

Due to the significant technological development of mechanical engineering, designers and technologists face many production issues [13], particularly regarding the dynamic components of structures, power loads, and temperature modes. Conventionally designed processing equipment usually shows a reasonable efficiency level. However, in cases with a wide range of products or a large number of operations to be performed [14], it is much more reasonable to use modular equipment, especially from an economic point of view [15].

Based on the above factors, in this work, a modular approach was chosen as one of the appropriate and effective ways to implement the processes of manufacturing machine parts.

In modern realities, two main principles for building modular metalworking equipment can be noted. Firstly, the entire machine set is based on the "basic" assembly component. The machine tool company is guided by the principle of creating one basis and a wide range of different modules, the choice of which already depends on the individuality of the order. The production of modular equipment according to this principle is engaged in companies LNL Machine Tools, Inc., Unitech Company Group, Josef Fill Company, Mikron, Huron Graffenstaden, and others.

Secondly, the machine consists of various components, among which it is difficult to identify one main. The key point of this approach is the ability to assemble a wide range of finished units into a machine without much difficulty. The layout of the machine tool depends on the specifics of the order. The production according to this approach is carried out, for example, by the company Shenzhen Zhouyu Intelligent Technology Co., Ltd.

The use of the modular principle of machine tools construction, based on the 2nd principle, allows:

– to reduce the time of development, design, and manufacture of machine tools for processing the specified range of workpieces according to the specified technical and technological characteristics;

– to reduce the cost of metal-cutting machines through standardization and unification of elements;

– to increase the reliability of the machine tool due to the development of the modules and a possible correspondence of this module design to the task;

– to increase machine accuracy;

– to increase the flexibility of machines by allowing them to be reconfigured more quickly to meet specific production conditions;

– to improve operating conditions and maintainability by reducing the variety of kit elements.

3 Research Methodology

Since the kit can perform various production tasks, the task at hand directly impacts the purpose of the kit. This kit can be implemented both in the educational process and in experimental and single-part production.

The kit includes 112 parts and standard products, allowing for the assembly of 17 different layouts, namely: a gear milling machine; an indexing machine; a vertical drilling machine; a horizontal milling machine; a jig saw and arc console machine; a beading machine; and 3 metal lathe layouts; 3 wood lathe layouts; 3 grinding machine layouts and 2 vertical milling machine layouts. Three different layouts can be assembled at the same time. Table 1 shows the main technical parameters of the kit.

Table 1 – Main technical parameters of the kit

Operating voltage, V	Drive power, W	Turning/milling spindle speed, rpm
12	35	20000/12000

Other features and elements depend on the specific layout.

Regardless of the layout, the kit is focused on single-part production. The kit allows you to implement the following machining methods: turning, grinding, milling, drilling, and hole finishing.

Turning is one of the main types of machining that the set can realize. A large number of technological possibilities can be realized with the help of the turning layout. The main advantages of the lathe layout include the following. With the help of turning equipment, it is possible to process many different surfaces, for example, external and internal cylindrical smooth and stepped surfaces, external and internal conical surfaces, grooves, holes, cuts, and others.

The turning layout provides machining of body-of-rotation type workpieces with a maximum diameter of the workpiece to be machined of 50 mm. Workpieces can be based on the outer cylindrical surface with installation in a three-jaw chuck for short parts such as shaft-collars, flanges, and others, or along the outer cylindrical surface and the center hole with installation in a three-jaw chuck and the right center for long parts such as shafts.

The turning layout considered in the paper can be used for machining such materials as non-ferrous metals (e.g., aluminum and copper.), wood, plywood, foam plastic, plastics, and composite materials (carbon fiber and fiberglass). The technical characteristics of the machine are shown in Table 2.

The technological capabilities of the machine tool are illustrated by an example of machining a complex-profile part (Figure 1), which can be machined in one setup.

Table 2 – Technical characteristics of the machine tool

Characteristics	Value
Distance between centers, mm	135
The largest diameter of the workpiece to be machined, mm	50
Drive power, W	35
Supply voltage, V	12
Rotary module rotation range, deg	360
Spindle speed, rpm	20,000
Dimensions, mm	220×160×200
Weight, kg	6.5

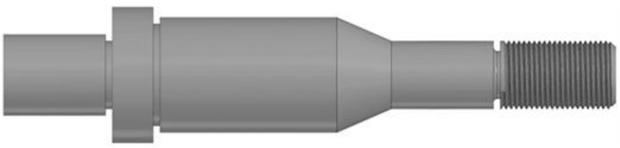

Figure 1 – Body-of-rotation type part for machining on a lathe

The production of this part type in one setup is possible thanks to an additional axis for turning the cutting tool.

The machine layout consists of functional modules, a set of assembly units, and parts that perform a single functional purpose (Figure 2).

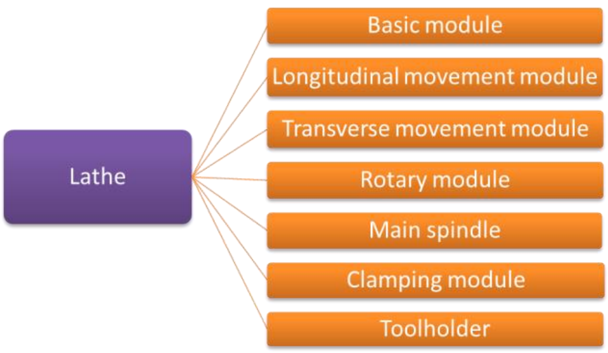

Figure 2 – Structural diagram of the turning layout

The proposed layout (Figures 3–9) consists of a basic module, a longitudinal movement module, a transverse movement module, a rotary module, the main spindle, a clamping module, and a toolholder.

The basic module (Figure 3) consists of the main components of the kit, which are rigid elements of this layout. The base module is used to combine other units and modules. The base module consists of a column and two riser blocks connected with connectors and screws.

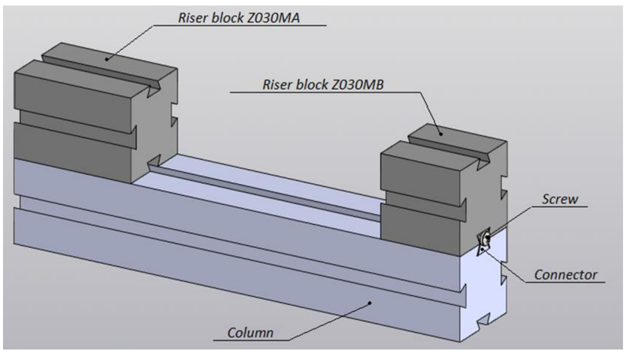

Figure 3 – Basic module

The main task of the longitudinal movement module (Figure 4) is the movement along the *Z* axis of the cutting tool installed in the toolholder, located in the transverse movement module. The longitudinal movement module consists of a longitudinal slideway, a saddle, a lead screw, a strap screwed with two screws, a flywheel fastened with a nut, and a handle.

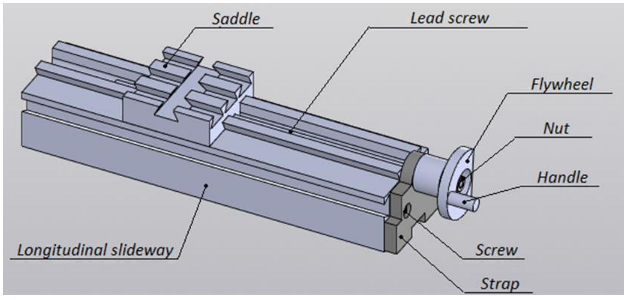

Figure 4 – Longitudinal movement module

The main task of the transverse movement module (Figure 5) is the movement along the *X* axis of the cutting tool installed in the toolholder, located in the rotary module. The transverse movement module consists of a transverse slideway, a lead screw, a strap that is screwed with two screws, a flywheel that is fastened with a nut, and a handle.

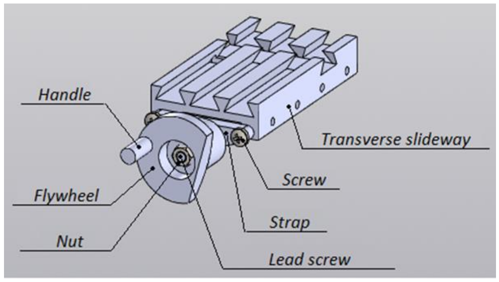

Figure 5 – Transverse movement module out

The main task of the rotary module (Figure 6) is the basing of the toolholder and its rotation. The rotary module consists of a rotary table, a fixing part screwed with two screws, and a transverse movement module.

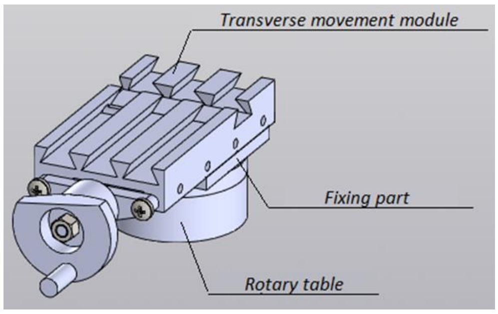

Figure 6 – Rotary module

The main spindle (Figure 7) is an electric motor that transmits rotation to the shaft with a V-belt transmission. A three-jaw chuck is attached to the main spindle, which ensures the workpiece base during machining. The clamping module (Figure 8) clamps workpieces. The clamping module consists of a tailstock, a flywheel, and a handle. The toolholder (Figure 9) is designed to install and fix the cutting tool by pressing with screws. The toolholder is mounted on the rotary module. Figure 10 shows a spatial model of a multiaxis lathe assembly.

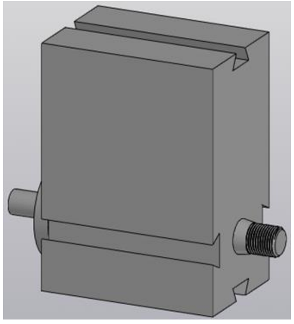

Figure 7 – Main spindle

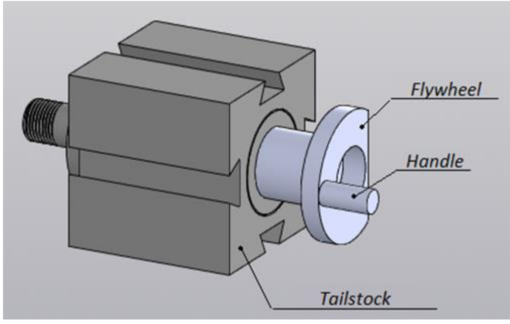

Figure 8 – Clamping module

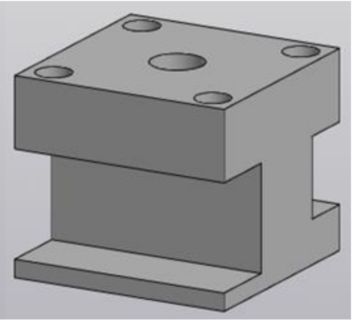

Figure 9 –Toolholder

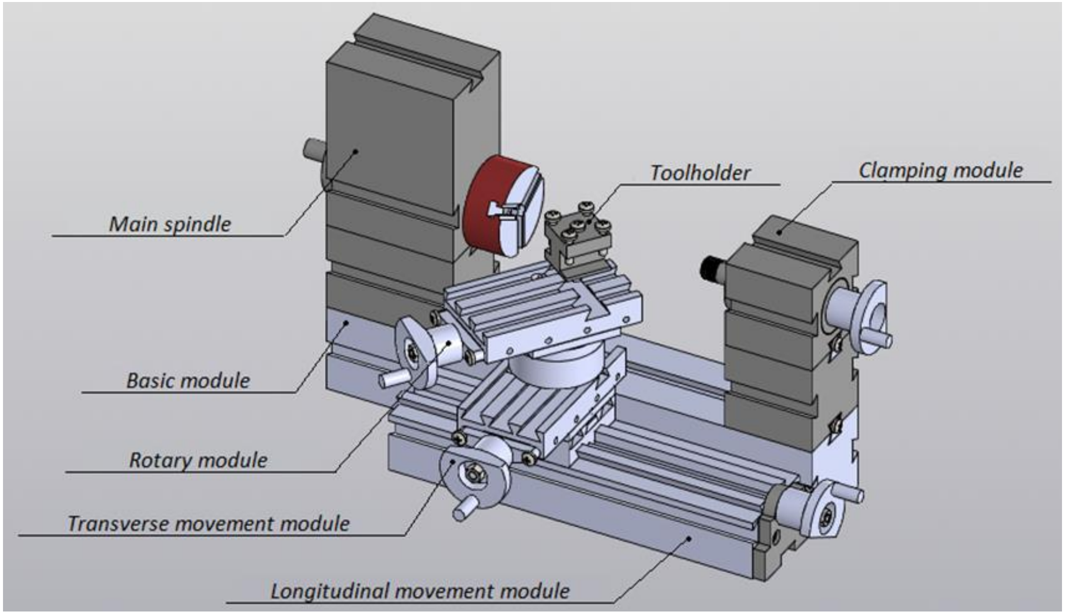

Figure 10 – Assembled lathe

4 Results

A technology for assembling a lathe based on an algorithm, which provides for the preliminary assembly of individual components, has been developed. The developed technological scheme for the base module assembly is shown in Figure 11.

The basic module assembly process starts by connecting two riser blocks (Z030MA and Z030MB) to the column using connectors and screws. Uniform parts can be connected on either side due to their special design. It is also possible to install straps to increase the rigidity of the machine.

The developed technological scheme for the longitudinal movement module assembly is shown in Figure 12.

The assembly process begins by placing the saddle on the longitudinal slideway. After that, the lead screw is screwed on. The strap is screwed on with two screws. The next step is to attach the flywheel with a nut. Handle screwed to the flywheel.

The developed technological scheme for the transverse movement module assembly is shown in Figure 13.

Transverse guides are taken as a basis. The 1st step is positioning the lead screw, after which the strap is screwed with two screws. The next step is to attach the flywheel with a nut. The handle is screwed to the flywheel.

The developed technological scheme for the rotary module assembly is shown in Figure 14.

The assembly process begins by screwing the fixing part to the rotary table with two screws. The next step is to attach the transverse movement module in the assembly to the fixing part.

The developed technological scheme for the clamping module assembly is shown in Figure 15.

The tailstock is taken as the basis of the clamping module, to which the flywheel and handle are attached.

Overall, the developed technological scheme for the lathe assembly as a whole is shown in Figure 16.

Assembling the lathe begins with connecting the main spindle and the clamping module to the basic module using connectors and screws. The next step is to install the transverse movement module on the longitudinal movement module using the fixing part, single-slot nuts, and screws. The rotary module is then mounted on the transverse movement module using single-slot nuts and screws.

The next step is to install these three modules as an assembly unit to the basic module using connectors and screws. The toolholder is then attached to the rotary module with a single-slot nut and screw.

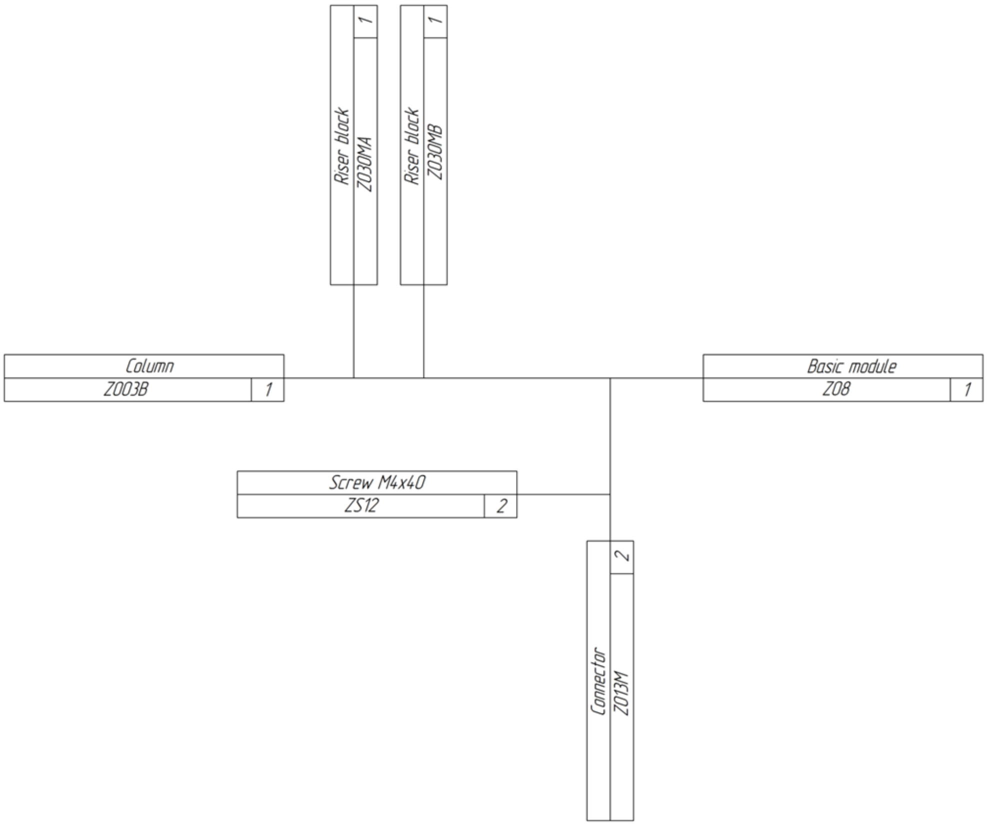

Figure 11 – Basic module assembly scheme

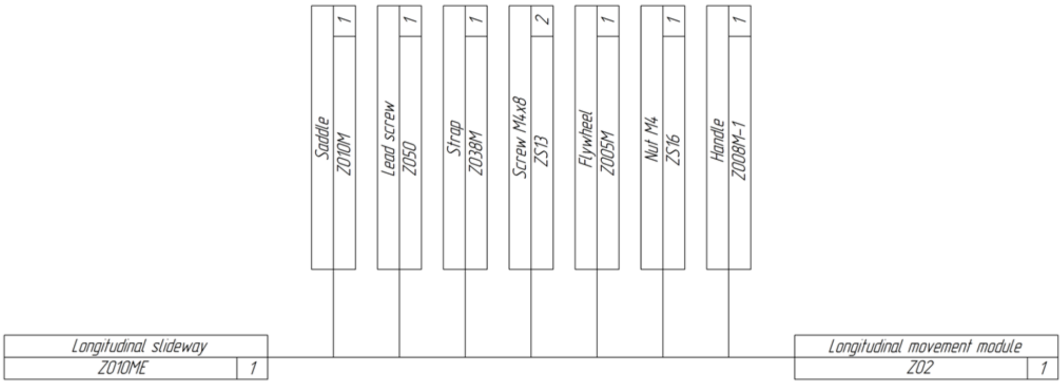

Figure 12 – Longitudinal movement module assembly scheme

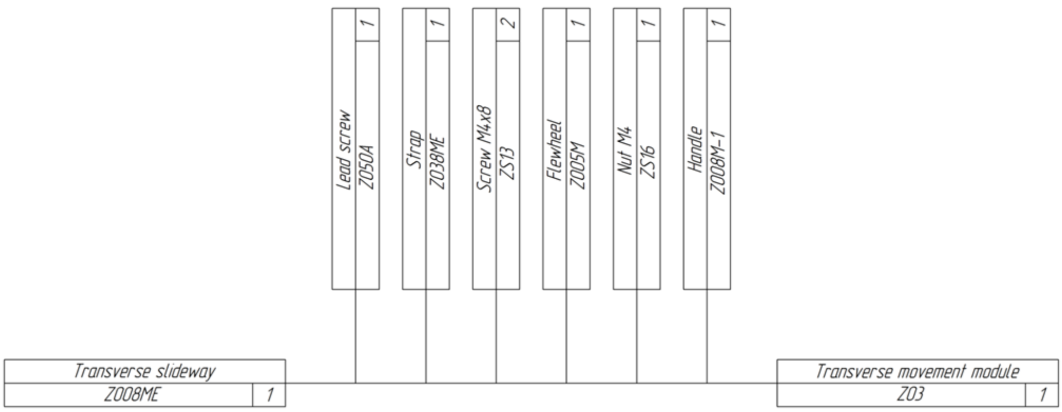

Figure 13 – Transverse movement module assembly scheme

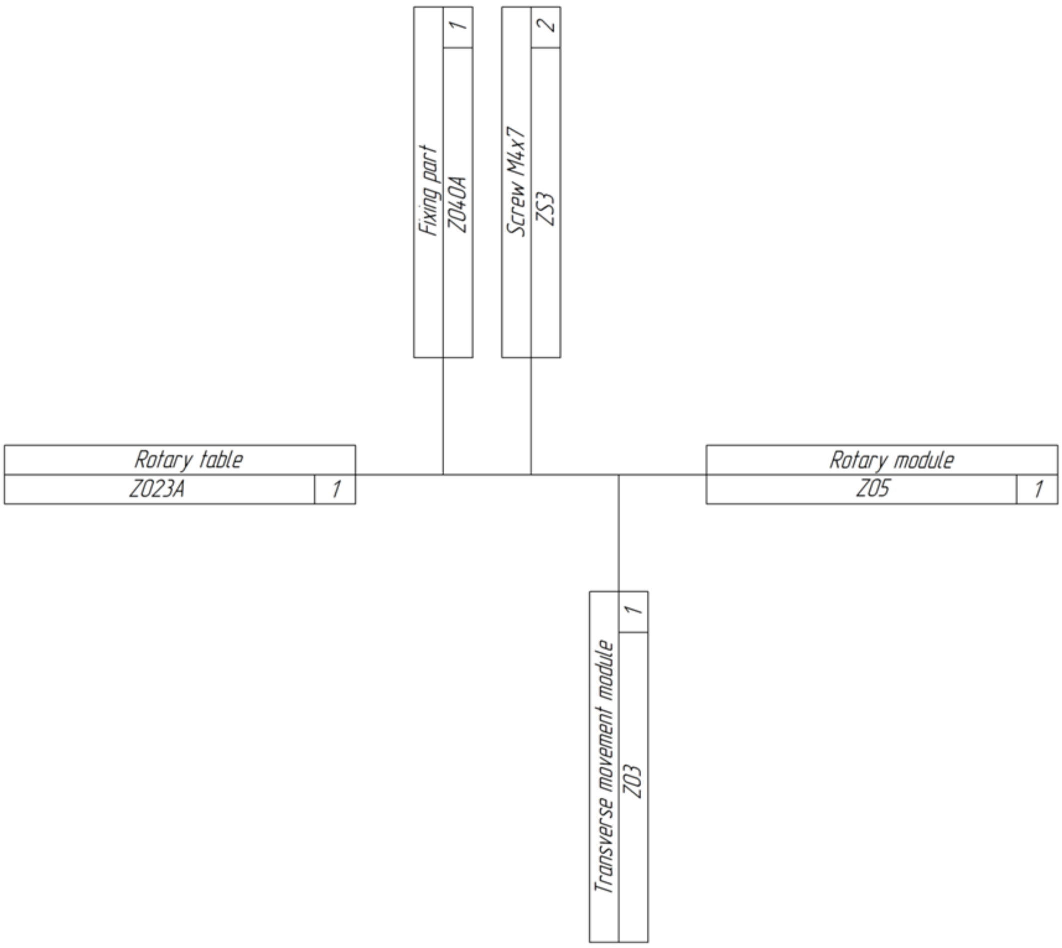

Figure 14 – Rotary module assembly scheme

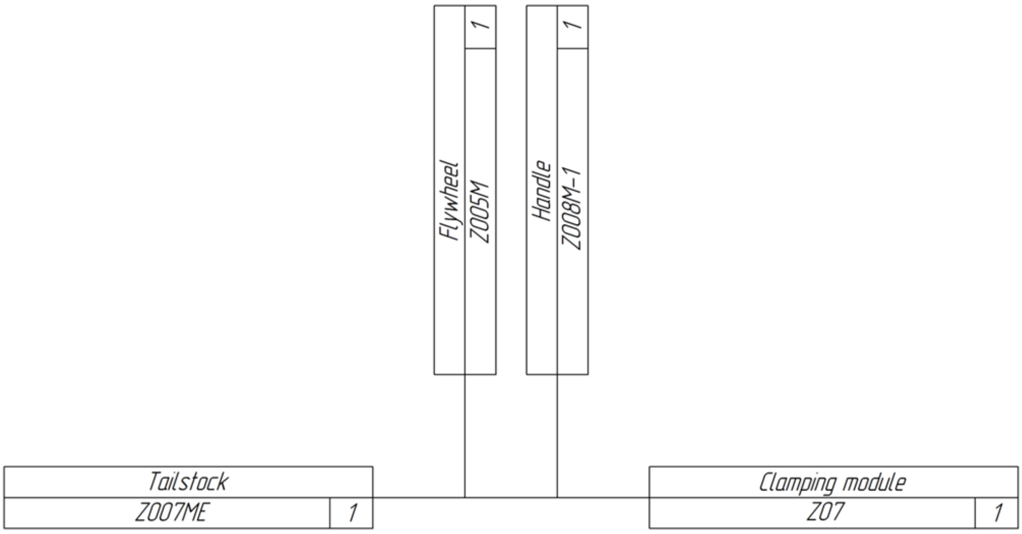

Figure 15 – Clamping module assembly scheme

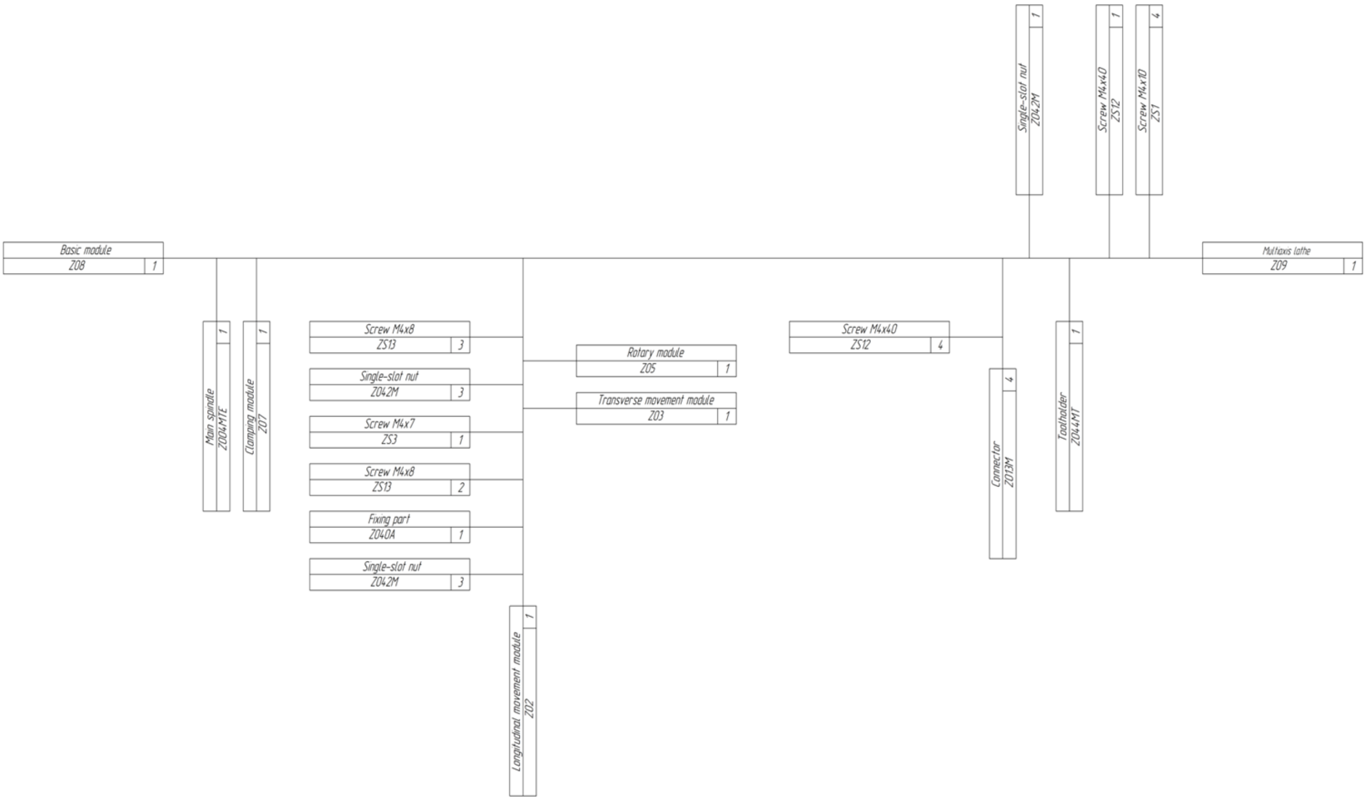

Figure 16 – Lathe assembly scheme

5 Discussion

The work results are based on engineering graphics and geometric modeling, basing theory, modular approach, technological foundations of mechanical engineering, and theoretical methods of standard machine parts manufacturing.

The scientific novelty of the obtained results is as follows. Firstly, the structural diagram and layout design solution for manufacturing a lathe, consisting of seven basic modules, is proposed. Based on this, using geometric modeling methods, a digital model of the machine tool was developed, which considers all the structural elements and the relationship between them, which made it possible to increase production efficiency due to the expansion of the technological capabilities of the machine.

Secondly, a conceptual approach to the design of technological processes of lathe assembly with a wide range of technological capabilities is proposed, which allows the implementation of the strategy “from idea to finished product” and can be implemented in industrial enterprises.

The practical significance of the obtained results for the machine-building industry is to develop practical recommendations for developing the technological process for assembling lathes.

6 Conclusions

The paper analyzes the development trends of the world machine tool industry. Particular attention has been paid to modular machines and their basic technological capabilities. The key trends determining the direction of machine tools development are high-speed machining, multiaxis complex machining by combining different methods, modular design principles, and using combined tools for machining.

Based on the analysis of metalworking equipment designs used for manufacturing parts in multiproduct manufacturing, the expediency of designing a modular lathe has been substantiated. It provides a more comprehensive range of workpieces and production flexibility.

Based on the service purpose of the lathe, the choice of design parameters of the machine tool design has been justified theoretically. The spatial model of the machine tool, which considers all structural elements and relationships between them, has been developed. The related design documentation has been prepared using geometric modeling.

A technological scheme for assembling a lathe and individual functional modules has been developed, which made it possible to develop a technological process for assembling a prototype machine tool and formulate practical recommendations.

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