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Current Trends in the Development of Automation Systems in Mechanical Engineering

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Abstract. In this scientific study, the problem of automation of machine-building production is justified. A 3D model of the lathe is presented and its design is improved. Standard layout schemes based on the upgraded spindle assembly have been developed, which make it possible to increase the speed of this type of machine. The results obtained make it possible to achieve the desired cutting speed, which has significantly increased by 2-2,5 times. The constructed dependence of the deviation on the roundness of samples by the finite element method allows predicting the main indicators: feed rate, spindle speed, cutting depth, static imbalance, initial and final pressure. Also, the obtained analytical results allow us to establish the main regularities of forming the accuracy of this lathe.

1 Introduction

The development of new technologies and manufacturing processes is conditioned by the raise of requirements applied to materials and products made out of them [1]. Considerable attention has been recently paid to the problem of creation of learning systems, which are capable of improving their functioning in the course of time [2]. Analysis of the current level of development of automation of machine-building production shows that the most effective way to increase the competitiveness of machine tools, which leads to a reduction in the cost of design, production and operation of equipment, is the use of new intelligent technologies [3, 4]. The most important component of which is automated research systems [5, 6]. It should be noted that the practice of modern production and enterprises shows how quickly the requirements for the volume of batches of parts, the speed of their manufacture, cutting modes change with the advent of new materials, etc [7, 8, 9]. Thus, there is a need to develop machine systems based on computer modelling that could meet new requirements [10, 11]. It should also be noted that new machines should have quality indicators of rigidity and accuracy [12], while improved developments should be equipped with modern devices and systems [13] that could simplify the implementation of certain procedures, such as [14]: clamping the workpiece, positioning, tool replacement, as well as setting up equipment for batch production [15]. Based on previous research, the authors observed this that published rare research work on the use of machine learning in production [16]. Thus, current trends in the development of automation systems in mechanical engineering technology are an urgent task of our time, which require constant improvement and significantly new research results.

2 Main part

The study of current trends in the development of automation is covered in the works [17, 18]. The team of authors [19, 20] was engaged in research in the field of Industry 4.0. These studies are partly related to the desolate production technology [21, 22], that is, scientists are faced with the task of replacing manual labour of human labour with technical and automated research systems at all stages of development [23, 24]. Scientific results [25] reveal the basic principles of constructing ABC technological processes, the principles of creating automated production systems, and other subtleties of production automation [26, 27].

The peculiarity of these works is that the development trends of automated control systems are limited by thermal deformations of machine tools, which affect the accuracy of processing, which leads to a 30-50% increase in their cost [28, 29]. Thus, there is a need to create and improve such competitive metal-cutting machines that would fully satisfy the design and production conditions of any production or enterprise [30, 31]. It should be noted that the priority direction of improving the competitiveness of machines is to improve their quality due to the developed standard layout schemes of the spindle assembly, as well as accuracy and strength indicators, at least ± 1,5 %, which fully meets the requirements of GOST and technical conditions of production operation. Research teams [32, 33] describe a number of problems that focus mainly on the stiffness indicators of machine tools of any type [34]. At the same time, the permissible limits of the main parameters put forward by the standards for the operation of lathes are not taken into account, as well as external conditions that may affect the operation of the lathe are not taken into account. Taking into account a number of problems that still need to be improved and investigated, as well as an analysis of the current level of development of automation of machine-building production show that the most effective way to increase the competitiveness of metal-cutting machines is to reduce their design cost based on modernization, taking into account all the necessary conditions for the production and operation of equipment [35]. Thus, solving these problems requires a more comprehensive approach, including a set of new intelligent technologies, the most important component of which is automated control systems, which is an urgent task of our time.

The purpose of this paper is to investigate the process of modelling a lathe, as well as to develop standard layout schemes based on the upgraded spindle assembly. Construct the dependence of the deviation on the roundness of the samples using the finite element method.

Materials. Due to the increase in productivity and efficiency of mechanical processing processes, the issue of modelling forming units of metal-cutting machines in modern mathematical and computer modelling systems is becoming increasingly important. It is important to note that the analysis of the balance of pliability and vibration patterns of the main components of lathes shows that the main components of turning automation include: the spindle, the workpiece and the caliper group, which determines the functioning of the machine as a whole. The stiffness and vibration resistance characteristics of the spindle on elastic supports depend on the size of the cantilever part of both the spindle itself and the length of the workpiece.

Obviously, a lathe is a type of machine that is designed to perform a variety of turning operations, as well as for cutting metric, inch, modular, pitch and end threads. The main components of the lathe include: bed, headstock, tailstock, caliper, guitar, feed box, gearbox and apron.

The basis for automation of lathes is the bed, which serves for the installation of all major assembly units. The caliper carriage and tailstock move along the bed guides.

The headstock is usually rigidly installed on the left side of the frame. It should be noted that it also contains a gearbox. A chuck is attached to the spindle in which the workpieces are clamped.

The tailstock supports the free end of long workpieces, or is used for drilling holes. It consists of three parts: the body, the panel and the plate. A centre or axial tool can be installed in the conical pinole hole. If necessary, the tailstock body is shifted in the transverse direction to process conical surfaces.

The caliper is designed for fixing the cutters in the tool holder, and is also responsible for moving them in the longitudinal and transverse directions.

The guitar is used to transmit rotation from the gearbox to the feed box.

The feed box transmits rotation to the lead screw or lead shaft. Its design allows you to adjust the machine to the required feed or thread cutting step.

The apron contains gears that serve to transmit torque to move the caliper in a parallel direction or perpendicular to the spindle axis. In this case, the feed is carried out by means of a flywheel, which is connected through gears to a gear rack attached to the machine bed.

In Fig. 1 a general view of the lathe is represented.

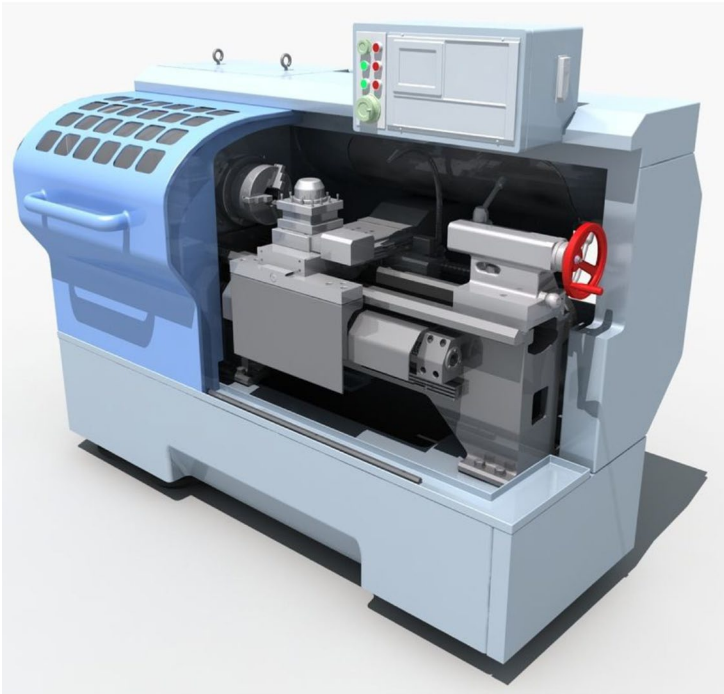

Figure 1. 3D lathe model

The principle of operation of the lathe proposed by us is as follows: mechanical feed from the running shaft is carried out through a worm located on a sliding key. The worm rotates the wheel and through the cam clutch and gears, the movement is transmitted to the pair to the rack with the gear. When processing threads, the torque is transmitted through the lead screw to the master nut, in all other cases it is open. It should be noted that when processing complex curved surfaces on the machine, a hydraulic copying caliper can be used, which automates the processing process. In turn, when processing holes with a special lock, the tailstock can be connected to the caliper and receive mechanical feed. The apron is presented in the form of a spring coupling, which allows you to process parts with a stop, and also automates the processing process.

Tests. The optimization parameter is the development of the main standard layout schemes for spindle units, as well as some deviation from the roundness of the surfaces of samples that were made of grade 45 steel on a lathe (Figure 1) with an upgraded spindle assembly (Figure 4 and Figure 5). It should be noted that an important factor that affects the optimization process in this case is the cutting modes, which mainly include the feed functions – S, spindle speed – n and cutting depth – t. A static imbalance – D_{CT} was also recorded, which fluctuated within acceptable limits, and the initial pressure – P was set, which actually did not change after the experiment.

Fig. Figure 2 shows the developed standard layout scheme of the spindle assembly.

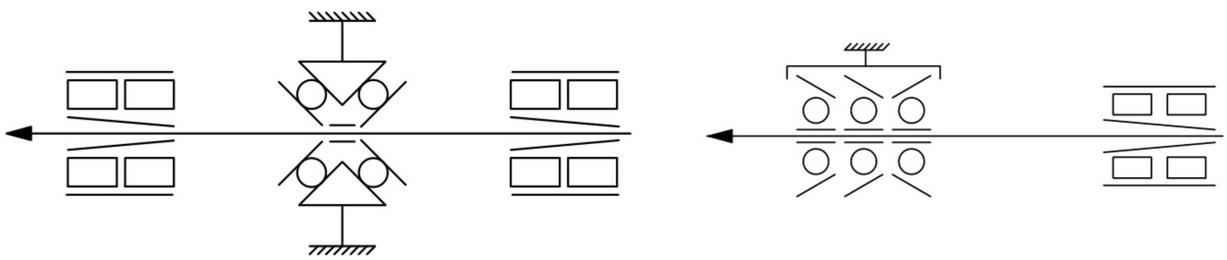

Figure 2. Typical layout of a spindle assembly

It should be noted that the results obtained allow us to obtain high rigidity and speed. At the same time, the maximum frequency is 4500 rpm, and the stiffness is reached by 10/10 Kr. It should also be noted that a typical layout scheme for the spindle assembly has been developed in Fig. 2 allows you to predict the speed of the machine, which is shown in Fig. 3.

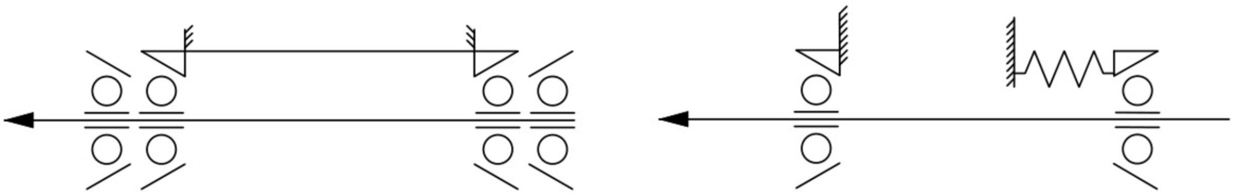

Figure. 3. Typical lathe speed scheme

An important point is that by increasing the speed, we were able to achieve the desired cutting speed, which increased by 2-2,5 times. These advantages are mainly achieved with the help of an upgraded spindle assembly. And also, a small deviation that occurs on the treated surface of the sample, which was made of steel grade 45. Figure 4 shows an upgraded spindle assembly using the SolidWorks software product. And Figure 5 presents a spindle assembly that was manufactured under production conditions in compliance with all basic GOST requirements.

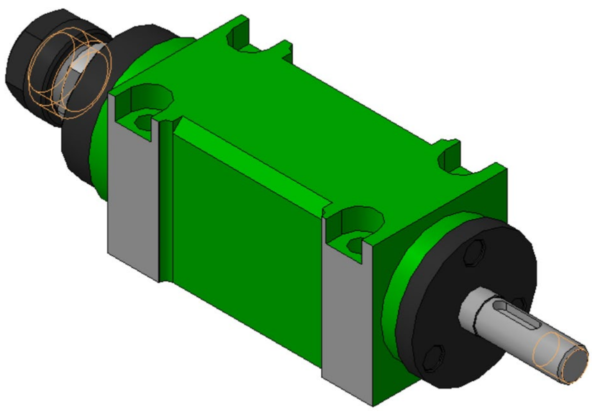

Figure 4. Upgraded spindle assembly using the SolidWorks software product

Figure 5. A spindle assembly that is manufactured under production conditions

It should be noted that the diameter of the upgraded spindle assembly according to the strength criterion is d = 30 mm. During the design process, the main fastening was carried out in the front and rear supports, on which certain permissible loads were set. As part of the study, the obtained safety margin coefficient makes it possible to increase the efficiency of procedures for studying the main technical and economic properties of forming samples (products). And also, to justify the dependence of a small deviation from the roundness of products, which occurs on the treated surface.

In Figure 6 the dependence of the deviation on the roundness of samples that were made using a lathe is presented.

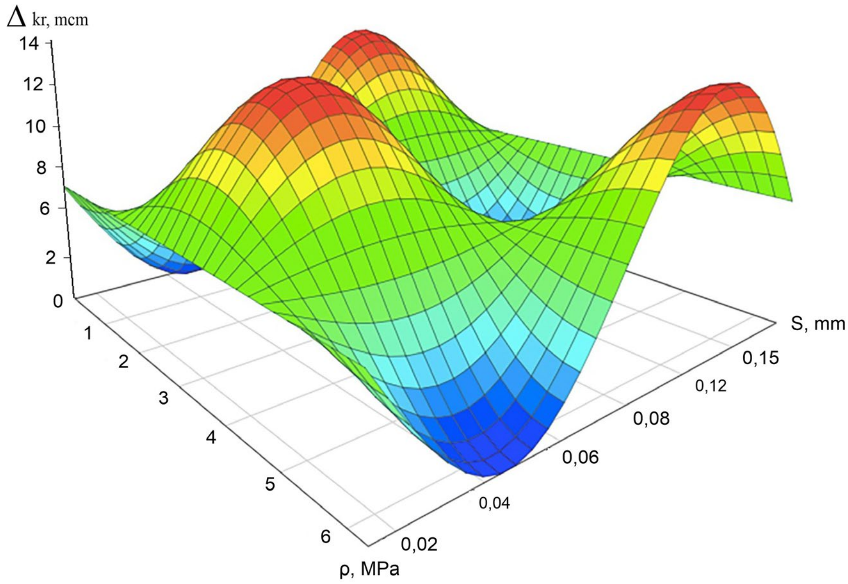

Fig. 6. Dependence of the deviation on the roundness of samples, which is shown using the finite element method

Analysing the presented dependence, which is shown in Figure 6, it can be concluded that with an increase in the gradual cutting depth, there is a slight deviation from the roundness of the treated surfaces of samples that were made of grade 45 steel. This is due to an increase in the cutting force, on which the elastic deformations of the elements and the vibration activity of the upgraded spindle assembly depend. It should also be noted that the resulting deviations lie within the permissible error and are equal to ± 1,5 %, which fully corresponds to the technical conditions of production.

3 Conclusion

Thus, we can conclude that with the help of the process of modelling a lathe, it is possible to improve its design. It should be noted that the level of natural vibrations of individual nodes and the control system as a whole is low. These deviations lie within the permissible limits of ± 1,5 %, these are normal indicators for machines of normal accuracy class. Based on the upgraded spindle unit, we developed a typical lathe speed scheme, and also by increasing the speed, we were able to achieve the desired cutting speed, which increased by 2-2,5 times. Typical layout schemes generally allowed us to record a small deviation that occurs on the treated surface of samples. The deviation occurs due to an increase in the cutting force.

It should also be noted that the constructed dependence of the deviation on the roundness of samples by the finite element method allows us to predict the following main parameters:

1) feed – S;
2) spindle speed – n;
3) cutting depth – t;
4) static imbalance – D_{CT};
5) initial and final pressure – P.

An important point is that the analytical results allow us to establish the main regularities of the formation of the accuracy of this lathe, and also the statistical imbalance of the rotating elements of the lathe can be controlled (if any) by the accuracy indicator.

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