Improvement of the machine determining technological capabilities method

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Abstract. The article presents the method of determining the position of the modules of surfaces that manufactured on the machine in its working space. The method is based on the use of rectangular coordinate systems of the machine working space, the module of surfaces and establishment of dimensional connections between them.

One need to know the technological capabilities of the machine when forming the enterprise production program, determining the possibility of performing individual orders for production, purchasing machines, as well as developing technological processes for manufacturing parts. The technological capabilities of the machine is a list of items of production, which are the surfaces, manufactured on the machine, with certain ranges of dimensions, level of accuracy and roughness, with certain dimensions of the parts. The technological capabilities of the machine should be reflected in the assignment wording. Assignment wording analysis of machines with different degrees of universality showed that they do not have sufficient information about what surfaces can be made on these machines and with what characteristics. As an example, table 1 shows the assignment wording of a screw-cutting lathe and a milling machining center with an indication of their shortcomings.

Table 1. The assignment wording of a screw-cutting lathe and a milling machining center.

| Machine | Assignment wording | Remarks |
|---------|--------------------|---------|
| Screw-cutting lathe model CDE6140A | Designed to perform a variety of turning operations, including cutting metric, inch, modular and pitching thread, allows usage of modern high-speed processing modes with coolant-cutting fluid and with usage of advanced tools and accessories. | − there is no list of surfaces manufactured on the machine; − the sizes of the produced surfaces, the level of their accuracy and roughness are not indicated; − range of dimensions of manufactured parts is not specified |
The high-precision milling machining center with a tool changer, interchangeable heads and an additional 4th coordinate has wide technological capabilities when performing milling, drilling, countersinking, reaming and threading operations. The machine consists of a rigid bed, along which the work table moves in the longitudinal direction. A column is rigidly connected to the bed, along which the console moves. In the transverse direction of the console moves the headstock. At the end of the headstock spindle head is rigidly fixed.

Analyzing the assignment wording of other machines, it was found that the higher the machine versatility, the greater the formulation uncertainty of its technological capabilities. The most complete information about the technological capabilities of the machine is given in the assignment wording of the specialized and operational machines used in large-scale and mass production.

Thus, in the assignment wording of the machines the technological capabilities are represented vaguely. The uncertainty in the description of the machines technological capabilities makes it difficult to choose machines when designing technological processes for manufacturing parts, purchasing new machines, causes difficulties in conducting a technological audit of an enterprise’s machine park, assessing the possibilities of executing a production program and orders.

The problem of the machine technological capabilities describing was to choose the subject of production. In the existing machines assignment wording as the subject of production is taken a surface, a set of surfaces or a part. However, the part as an object of production is characterized by an almost unlimited variety of possible designs and its characteristics. The combination of surfaces is characterized by a large variety of surfaces forming it and their characteristics. Surfaces also have almost unlimited variety of geometric shapes, sizes, and accuracy.

In order to eliminate these shortcomings, it was proposed to adopt the module of surfaces as a subject of production. The module of surfaces (MS) is a combination of surfaces united by the joint performance of the service function of a part [1]. The main advantages of MS are their limited variety and consistency of structures. According to the classification, all MSs are divided into three classes: basing, working and binding. Each MS has its own number of standard designs, and each design has its own classification by size, accuracy, and roughness.

When using MS as an object of machine production, the wording of the machine technological capabilities will change, and will contain a list of manufactured MSs with ranges of dimensions, accuracy and surface roughness, overall dimensions and material of the parts being manufactured.

To determine the MSs manufactured on the machine, a special method was developed [2], the initial data of which are the processing methods implemented on the machine, the processing tool used and the technical characteristics of the machine. The method includes the following steps:

1) Determination of surfaces manufactured on the machine;
2) Determination of MS by the composition of the surfaces manufactured on the machine;
3) Determination of the surfaces positions compliance in the MS construction with their positions in the machine working space during manufacture;
4) Determination of the size ranges of MS, obtained on the machine;
5) Determination of achievable accuracy of MS manufacturing on the machine.

For the correct choice of machine for technological operation the great importance has the position of the MS surfaces in the machine working space during manufacture. It is so because the MS construction is a combination of surfaces having a certain relative position. After installation of the workpiece on the machine according to the technological bases, a situation may arise when one of the MS surfaces takes a position relative to the tool in which it cannot be made. To avoid such cases,
when determining the technological capabilities of the machine, each MS is checked for positions compliance of the surfaces in its structure with the positions of the same surfaces in the working space of the machine during manufacture.

The disadvantage of such a test is that it does not take into account the possible positions of the entire MS structure in the machine working space. This may lead to the fact that the MS as the composition of the surfaces can be made on the machine, but after the workpiece is based on the machine, the MS structure may take such a position in the working space of the machine that its manufacture will be impossible. The following is an example of such a case: after basing the shaft on a lathe mod.16A20Ф3, the MSB312 module that consisting of a cylindrical surface produced on this machine, is offset from the axis of the centers and cannot be manufactured on this machine.

Therefore, it is necessary to determine not only the conformity of the surfaces positions in the MS structures and in the working space of the machine, but also the permissible position of the entire MS structure in the working space of the machine.

To solve this problem it is necessary to develop a method which would help to determine the admissible MS structure position in the machine working space. The basic data are: the scheme of machine working space and the MS structure, which in terms of the composition and the location of the surfaces can be produced on the machine.

The initial stage will be constructing of a rectangular coordinate system of the machine working space on the working body surface, on which the workpiece is based. For example, in a milling machine, this is the surface of the working table, in a lathe - the spindle flange and the axis of the centers, etc. In some cases, like with a lathe, it is necessary to first install possible basing patterns of the workpiece on the machine, and then build the coordinate system of the machine working space for each scheme.

The second stage is constructing of a rectangular coordinate system on the MS. For example, if the MS consists of cylindrical and flat surfaces, then one of the axes is located on the cylindrical surface axis, and the second is on a flat surface.

The admissible position of the MS structure in the machine workspace will be determined by three linear and three angular dimensions that bind the machine coordinate systems and the MS. Therefore, the task is to establish admissible values of six sizes that bind two coordinate systems. In connection with the above, the following method is proposed for determining the MS structure permissible position in the machine working space:

1. Construction of a rectangular coordinate system on the MS.
2. Construction of a rectangular coordinate system of the machine.
3. Determination of permissible values of three linear and three angular dimensions that bind the machine coordinate systems and the MS.

Using the proposed method one can determine the allowable position of the MSB212 module, consisting of the threaded outer surface and the end face in the working space of a 16A20Ф3 lathe while basing the workpiece in the cartridge.

First, we construct the coordinate system on MSB212. The 0_MX_M axis will pass through the axis of the threaded outer surface, and the 0_MZ_M axis will pass through the flat outer surface (Figure 2). The
$0_{XC}$ axis of the lathe mod.16A20$\Phi$3 coordinate system, when basing the workpiece in the three-jaw chuck, is located on the rotation axis of the cartridge, and the $0_{ZC}$ axis - on the right end of the cartridge (Figure 3).

Figure 2. The MSB212 coordinate system.

Figure 3. The MSB212 position in the coordinate system of the lathe model 16A20$\Phi$3.

The position of the MSB212 coordinate system in the coordinate system of a lathe mod.16A20$\Phi$3 is described by three linear (X, Y, Z) and three angular coordinates (Figure 3). The angular coordinates include:

- $\varphi_{M}$ - the MSB212 rotation coordinate around the $0_{XC}$ axis;
- $\psi_{M}$ - the MSB212 rotation coordinate around the $0_{YC}$ axis;
- $\theta_{M}$ - the MSB212 rotation coordinate around the $0_{ZC}$ axis.

If one analyze the shaping movements of the machine, one see that the $\psi_{M}$ angle can have two values: $0^\circ$ and $180^\circ$, the $\varphi_{M}$ angle can vary from $0^\circ$ to $360^\circ$, and the $\theta_{M}$ angle is zero. The linear coordinates Z and Y must also be zero. The value of the linear coordinate X (Figure 3) can vary in the range from 0 to 900 mm.

The relative position of the MSB212 coordinate system parameters in the lathe mod.16A20$\Phi$3 coordinate system are summarized in Table 2.

Table 2. Dimensional relations of coordinate systems.

| MS coordinate system | Machine coordinate system | X   | Y   | Z   | $\varphi$ | $\psi$ | $\theta$ |
|---------------------|--------------------------|-----|-----|-----|----------|--------|--------|
| X_M$\varphi_M$Y_MZ_M | X_C$0_{XC}$Y_CZ_C        | 0-900| 0   | 0   | 0-360    | 0, 180 | 0      |

In a similar way, the required positions of the other MS structures that manufactured on a lathe mod.16A20$\Phi$3 are determined.

Thus, the proposed method, based on the construction of the machine coordinate systems and the MS, allows definitely determine the parameters of the possible MS parts position in the machine working space during manufacture.

References
[1] Bazrov B 2001 Modular technology in mechanical engineering (Moscow: Mashinostroenie) p 368
[2] Bazrov B and Sakharov A 2016 The technological capabilities determination of the enterprise machine park Stankoinstrument number 2 pp 29-34