Features of the modular principle of constructing and manufacturing tools

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Abstract. This article presents the modular principle in tool manufacturing, which allows to distribute the entire range of metal cutting tools currently used in engineering, into eight main modules. A limited range of modules should provide many different instrumental layouts through a variety of combinations and module positions.

The modular principle has long been widely used in various industries (the production of machine tools, technology, etc.), but its scientific foundations have not yet been developed. There is almost no strict methodological apparatus, in the scientific literature you can find a variety of concepts that often contradict each other module, modular principle, etc., there is no classification of modules, etc. All this makes it difficult to implement the modular principle in tool production and requires scientific research in this area. Under the modular principle, we understand the construction of various technical systems with various characteristics by assembling them from standard modules of a limited nomenclature.

Metal-cutting tools represent a wide range of tool modules that are structurally and functionally complete units.

The development of tool modules will make it possible to design metal-cutting tools with a significant reduction in time and labor intensity, increase the reliability of the metal-cutting tool due to the refinement of the component elements of the module, as well as reduce the variety of cutting tool designs, which will lead to improved operating conditions and maintainability of the metal-cutting tool.

The tool module must be a component of the process module, as shown in figure 1, only in this case will the highest effect be achieved from the application of the modular principle in machine-building production. This implies that the modular principle will permeate all the components of the production chain, starting with the product and ending with the organization of the production process.

**Figure 1.** Block diagram of the process module.
Production efficiency depends largely on the level of the production chain: product – technological process-technological system – organizational form of the production process. At the same time, the efficiency of production is affected not only by the level of development of each link, but also to a lesser extent by the uniformity of their development. As practice shows, the development of each link is largely independent of each other. This creates great difficulties in the implementation of the production chain.

The modular principle in tool production will allow distributing the entire range of metal-cutting tools currently used in mechanical engineering into eight main modules, as shown in table 1.

| Modules                                      | Component Tool                                                                 | Cutting Tool Design      |
|----------------------------------------------|-------------------------------------------------------------------------------|--------------------------|
| Tool module for processing planes            | Cylindrical and end mills, cutting turning tools, planing cutters, flat broaches, etc. | One-piece, component and prefabricated |
| Tool module for processing cylindrical surfaces (shafts) | Turning tools, milling cutters, etc.                                           | One-piece, component and prefabricated |
| Tool module for hole processing              | Drills, countersinks, counterbores, reamers, boring tools, internal broaches, firmware, etc. | One-piece, component and prefabricated |
| Instrumentation module for the machining of gear surfaces | Worm gear cutters, chisels, tooth-cutting tools, tooth-cutting heads.             | One-piece, component and prefabricated |
| Tool module for processing slotted surfaces  | Worm slotted cutters, chisels, planing tools, etc.                             | One-piece, component and prefabricated |
| Tool module for processing shaped surfaces   | Turning shaped cutters, shaped cutters, axial tools, etc.                      | One-piece, component and prefabricated |
| Tool module for machining threaded surfaces  | Taps, dies, threaded turning tools, etc.                                       | One-piece, component and prefabricated |
| Instrument module for surface treatment by PPD method | Knurling heads, rollers, flat dies, chipless taps, etc.                     | One-piece and prefabricated |

However, due to the fact that the cutting tool processes parts with different accuracy, performance and is used in a large range of sizes, it was decided to divide the main tool modules into submodules, according to the above characteristics, as shown in figure 2.

As an example we consider a tool module for processing threaded surfaces. It includes thread-cutting tools, which according to submodule №1, in accordance with GOST standard 3449-84 can be divided into 3 accuracy classes:

- 1st class-designed to get a thread on the quality of 4H or 5H (5G);
- 2nd class-designed to get a thread on the quality of 6H or 7H;
- 3rd class-designed to get a thread on the quality of 8H and coarser.
Properly selected and applied tools allow you to achieve high performance, use all potential resources and make any operation cost-effective. High performance is guaranteed with a high degree of reliability. Therefore, submodule №2 includes a thread-cutting tool with stability:

\[ T_1 = 20 \text{ – } 35 \text{ min}; \]
\[ T_2 = 35 \text{ – } 50 \text{ min}; \]
\[ T_3 = 50 \text{ – } 60 \text{ min}. \]

The thread on modern fasteners has the following main parameters:

1. A step is the distance between two adjacent threads of a thread. The thread pitch is measured either as the distance in millimeters (direct measurement method) or as the number of thread turns per unit length of the fastener (indirect measurement method). In our country, it is customary to measure the thread pitch in a direct way. During installation, fasteners that have a larger thread pitch (i.e. fewer thread turns per unit length) are screwed in faster;

2. External diameter is the diameter of the mounting element, taking into account the protruding part of the thread turns;

3. Internal diameter is the diameter of the mounting element in the recesses between the threads of the thread;

4. The vertex angle is the angle at the top of the thread turns. If we consider fasteners that cut into the base when installing the thread, the sharper the thread angle, the less resistance to screwing the base material has.

By type, the thread on fasteners can be internal (on nuts, couplings, anchor sleeves, etc.) and external (on screws, screws, bolts, etc.).

In appearance, the thread is metric and non-metric. Often, instead of the last term, the term "inch" is used, contrasting the metric and inch length measurement systems. However, the parameters of both non-metric and metric threads can be expressed in any of the above measurement systems. For this purpose, there are special tables for transferring the parameters of fasteners from one system to another. The need to use such tables arose during the intensification of international trade, because in different geographical markets, different length measurement systems are used; for example, in the United States and the United Kingdom, parameter designations in inches are applied to fasteners, and in continental Europe, in millimeters. For example, so-called "gauges" or "dimensions" are used to indicate the diameter of fasteners in countries with inch length measurement systems:

| Gauge (number, size) indicating the diameter of the fastener in the inch measurement system | The gauge is similar to the inch measure. diameter of the fastening element in the metric system of measures (mm) |
|---|---|
| #5 | 2.9 |
| #6 | 3.5 |
| #7 | 3.9 |
| #8 | 4.2 |
| #9 | 4.8 |
| #10 | 5.0 |
| #12 | 5.5 |
| #14 | 6.3 |

The most common subspecies of thread today are:
1. Wide-pitch thread.
2. Sparse thread.
3. Carving with small steps.
4. Metric thread.
5. Two-way (variable) thread - consists of alternating high and low turns. In fact, these are 2 threads with the same pitch, one of which is applied in the middle between the turns of the other. The height difference between high and low threads is usually between 40 and 50% of the height of the high thread.
6. Shock (umbrella) thread - consists of thick sloping turns with an obtuse angle of the top.

![Image of thread subtypes]

Figure 3. Thread subtypes.

Each type of thread has its own functional purpose. As a result, the suitability of a threaded fastener for use in a particular base material is determined primarily by the type of thread. The denser the base material, the smaller the thread pitch required for high-quality fixing. So, wood screws have a wide-pitch thread, and metal screws have a small-pitch thread or metric. Where the fixed element is mounted in PVC and is subject to the risk of pulling out, two-way threaded fasteners are used. Two-way thread is also used when it is necessary to achieve a strong fixation in heterogeneous materials of the fixed element and the base. Sparse threads are designed to be fixed in soft or porous materials, such as soft wood. Impact thread is used in threaded fasteners, which are installed faster than screwing in the impact method. Removal of fasteners with a shock thread is carried out by the traditional method of unscrewing.

Carving is a constant object of improvement. Thus, the results of the development of modern engineering are:

- various grooves that allow to remove small particles of the base material, which is destroyed during the process of cutting the internal thread in it;
- indentations and notches on the thread that change its shape at the tip of the fastener and allow the fastener to be screwed into relatively soft base materials (wood, chipboard, plastics) without pre-drilling;
- asymmetric thread (the angle between the sides of its turns and the perpendicular drawn from the top of the turn to the axis of the fastener is not the same, whereas traditional types of thread are symmetrical with respect to such a perpendicular). One example of an asymmetric thread is the impact thread;
- applying different types of threads on separate sections of the same fastener.

Based on the foregoing, it follows that a cutting tool designed to cut such threaded surfaces of various designs and sizes should differ in their standard sizes. Therefore, submodule №3 was proposed.
Metal cutting tools are closely interconnected with metal cutting machines, since increasing the productivity of any machine will not be possible without equipping it with modern progressive high-performance cutting tool designs.

The choice of a tool for equipping a metal cutting machine is one of the important issues in the technological preparation of production. A variety of processing options and equipment for their implementation, a wide range of processed materials and other factors make it difficult to choose a cutting tool and make it time-consuming.

Two main approaches to solving this problem are known: the first approach is based on an analysis of the conformity of the technical characteristics of a typical tool with the conditions of various industries, and the second on a set of economic factors.

We can identify the main regulations characterizing the modular principle of constructing and manufacturing tools:

- a module is a structurally and functionally complete unit that is a component part of the overall system of tools;
- modules are characterized by the smallest possible number of links for adding new modules to them;
- a limited range of modules should provide a variety of different tool layouts through a variety of combinations and positions of modules;
- the modular design principle of the tool most fully meets the requirements of solving a specific technological problem; the tools created on this principle do not have excessive capabilities and therefore they are more economical compared to the universal execution tool;
- the time and effort required to design the tool is reduced, since the modular principle allows for more complete use of previously completed developments;
- the reliability of the tool is increased due to the refinement of the modules included in it and the maximum compliance of this module design with the task being performed;
- the variety of module designs and components is reduced that improves operating conditions and maintainability;
- modular design allows creating a new high-performance tool for the best processing of workpieces, rather than customizing the process to fit the capabilities of a general-purpose tool;
- the modular principle provides a real opportunity to replace the outdated form and design methods of new tool structures and their systems.

Ensuring the requirements for the metal cutting tool depends largely on the design methodology of the tool and the adopted technology of its production, and the latter has its own specific features, both at the stage of obtaining workpieces and during subsequent processing.

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