Application of parametric standardization in the calculation
of rows of hydraulic cylinder diameters

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Abstract. Currently, the ordering of standardization objects and their properties, optimization of
the parameters of standardization objects, normalization of requirements for objects are the most
important areas of standardization as a science. In this regard, the issues of choosing parametric
series are very relevant. In order to increase the level of interchangeability and reduce the range
of products and standard sizes of blanks, overall cutting tools, tooling, productivity, speed, speed,
power, etc., used in a particular industry, as well as to create conditions for effective
specialization and cooperation of plants, reduce the cost of products, the principle of preference
is used in the unification and development of standards. There are two methods for choosing
parametric series: the method of technical justification and the method of economic justification.
The technical method is easier to use and is used to expand the technologies of unification of
standard sizes of parts of homogeneous products. This method was used to calculate a number
of diameters of hydraulic cylinders of broaching machines of the same series based on the
mathematical dependence between the force developed on the hydraulic cylinder rod, which is
formed by the initial parametric series laid down by the designers. As a result of technical
optimization of the choice of the parametric series, a number of diameters of hydraulic cylinders
R20/2(45-224) mm was installed, fully corresponding to the main functional parameter - a
number of forces on the rod of broaching machines R10/2(0.63-16.0) kN.

1. Introduction

Standardization works have acquired great scientific, technical, organizational, and socio-economic
significance in the modern world [1]. They are held at the international, regional and national levels [2].

The most important areas of standardization as a science are [3]: ordering of standardization objects
and their properties (development of methods of systematization, classification and coding);
optimization of parameters of standardization objects (unification, economic and mathematical
modeling and calculation of the most effective parameters of standardization objects); normalization of
requirements for objects (development of methodology).

The theoretical basis of modern standardization is the system of preferred numbers [4, 5]. The
essence of this system is that if you are always guided by a certain, scientifically justified number of
digits when choosing any parameters (power, speed, dimensions, etc.), then the products will correspond
to other related types of products [6].
In 1877...1879, the French engineer Charles Renard applied a geometric progression with the denominator \( q = \frac{\sqrt{10}}{5} \) to normalize the size of ropes for balloons [7]. Based on the series built by Renard, conventionally designated R5, the R10, R20 and R40 series were subsequently built, which were called the Renard series [8, 9].

In order to rationally reduce the range of manufactured parts in order to unify, increase the seriality and develop the specialization of their production, reduce the cost of manufacturing parts, standards for parametric series of various products are being developed. Parametric standardization is the basis for the design of unified assembly units, which are widely used in various mechanical engineering enterprises.

2. General methodology for selecting parametric series

A parametric series is a set of numerical values of the main parameter of products of the same functional purpose and similar in kinematics or technological process, which is naturally constructed in a certain range [10].

The main parameter of the parametric series is the parameter that determines the most important operational indicator of the product and does not depend on technical improvements and production technology. For example: a car with a load capacity of 5 tons, an electric motor with a capacity of 150 kW, a shaft with a diameter of 40 mm. According to the main parameter, a parametric series of the product range is built. The choice of the main parameter and the determination of the range of its values must be technically and economically justified.

The main parameter serves as the basis for determining the numerical values of the basic parameters.

The basic parameters are the values that determine the most significant structural, technological and operational properties of the product. For example, for metal-cutting equipment, these are productivity, accuracy, power, cutting speed, overall dimensions, etc.

The basic parameters are often expressed in terms of the main parameter. For example, the main parameter of a reciprocating compressor is the cylinder diameter, and one of the basic parameters is the performance.

When choosing the main and basic parameters, the following principles are observed:

- the nomenclature of the basic parameters should be minimal;
- the basic parameters must be stable during the constructive improvement of the product;
- the basic parameters should not depend on the manufacturing technology, the use of materials, calculation methods, etc.

The number of main and basic parameters for one product can be different: one, two or more.

The highest and lowest values, as well as the frequency of the series, should be set not only based on current needs, but also taking into account the development prospects.

Standards, along with stable main and basic parameters, should contain parameters that directly or indirectly reflect the development of science and technology. These parameters can include parameters such as performance, weight, connection dimensions, specific energy consumption, fuel and oil.

Auxiliary parameters that depend on the design and production methods of machinery and equipment should be reviewed systematically and much more often than the main and basic ones.

The interval of a parametric series is understood as any bounded sequence of terms of a series, and the range of a parametric series is the maximum interval of a series.

The range of parametric series is determined by the practical need for products of this type. The extreme members are chosen in such a way as to cover a significant part of the needs. Special cases are usually not taken into account.

When choosing a range of parametric series, it is necessary to take into account:

- the growth of production and needs during the period when the predicted parametric series will be used;
• the ability to create and use different product variants based on aggregation;
• the possibility of exporting products that are standardized for this range;
• experience in the production and operation of similar equipment, machines, devices in your country and countries with a high level of this type of production;
• available domestic and foreign standards, recommendations and other documents related to this issue;
• development prospects-to ensure the progressiveness and sufficient durability of parametric series.

For many groups of machines and equipment, there are restrictions when choosing ranges due to:

• the inefficiency of using this product in some intervals of the series and the availability of other, more efficient products;
• inability to use these machines in combination with other equipment;
• features of individual industries and their scientific and technical level;
• methods of production (processing) of products;
• natural boundaries that depend on natural conditions and objective laws, including the influence of natural physical constants;
• precautionary measures.

As a rule, the main and basic parameters of products are set (selected) from the main series of preferred numbers. For example, the rated capacities of electric motors and generators are set in accordance with the R10 series.

In some cases, standard preferred numbers may not be acceptable. The reasons for this may be different: inaccuracy of accuracy, predetermined by preferred numbers; unpreparedness of individual industries to accept preferred numbers, etc. In such cases, the use of more rounded preferred numbers is still more appropriate than disrespectful ones, since this makes it easier to switch to them in the future. When using rounded preferred numbers, of course, it is necessary to strive to ensure that the denominator is the most uniform in the entire series.

When using rounded preferred numbers, do not forget that some rounded values differ from the calculated numbers by up to 5.35% (for example, 1.5 instead of 1.6). In the practice of mechanical engineering, such calculations can lead to significant inaccuracies. For example, an error of 5% in a linear size entails a loss of accuracy by 10% for the second degree (for example, the cross-section and strength of the bolt, the area of the piston and engine power), more than 15% for the third degree (product weight, shaft deflection), more than 20% for the fourth degree (spring stiffness); more than 25% for the fifth degree (moment of inertia).

As a rule, a series with a variable gradation density is optimal. To a large extent, the optimal solution from this point of view depends on the structure of the need, especially in cases where the one-time costs of introducing a new type of product are small, and the consumer's costs are decisive. For example, the design of machine tools is characterized, along with the use of exact series of preferred numbers, by the construction of parametric series of machine tools based on a geometric progression with a variable denominator at different intervals of the series.

There are two main methods for selecting series according to a certain parameter: the method of technical justification and the method of economic justification.

The technical optimization method is used when the mathematical dependence between one parameter that is normalized by a certain parametric series and another parameter whose series is unknown is known.

The method of economic justification is reduced to finding the lowest costs in the manufacture of products in various rows. The method is based on a well-known fact: with an increase in the product release program, its cost price decreases. The manufacturer is interested in increasing the production
program and reducing the product range, and the consumer, on the contrary, is interested in expanding the range.

The method of technical optimization is easier to use, it is this method that we recommend using when choosing a parametric series of products.

3. Application of the method of selecting a parametric series by technical justification for the equipment

Let’s consider the method of choosing a parametric series based on a technical justification. Designers have developed a broaching machine for forming holes in pump housings. In order to unify production, it is necessary to determine a number of values of the diameters of hydraulic cylinders of a broaching machine, if it is known that the main functional parameter - the force developed on the hydraulic cylinder rod has the following standardized parameters:

- series R10/2;
- the first term of the series is equal to 0.63 kN;
- the last member of the series is 16.0 kN.

We identify the elements of the power series on the hydraulic cylinder rod. In accordance with table 1 of GOST 8032-84 "Preferred numbers and series of preferred numbers", we get a series including 8 members:

\[ 0.63 - 1.00 - 1.60 - 2.50 - 4.00 - 6.3 - 10.0 - 16.0 \text{ kN}. \]

The denominator of the progression of this series \( \varphi_p = 1.6 \).

We determine the denominator of the progression of a number of hydraulic cylinder diameters. The force \( P \) is related to the diameter of the hydraulic cylinder \( D \) by the ratio

\[
P = 0.25 \cdot \pi \cdot p \cdot D^2, \tag{1}
\]

where \( p \) is the nominal pressure in the hydraulic cylinder, \( p = 400 \) kPa.

It is known that if the parameter \( A \) obeys the dependence \( A = K \cdot B^n \), where \( K \) is a constant coefficient, then the denominator of the progression is \( \varphi_A = (\varphi_B)^n \). Then, according to dependence (1), we obtain an expression for determining the denominator of the progression of a number of hydraulic cylinder diameters:

\[
\varphi_D = \sqrt{\varphi_P}, \tag{2}
\]

\[
\varphi_D = \sqrt{1.6} \approx 1.25.
\]

This denominator corresponds to the R10, R20/2 and R40/4 series.

We define a number of diameters of hydraulic cylinders. The first term of the series of hydraulic cylinder diameters is determined from the expression (1):

\[
D_1 = \sqrt{4 \cdot P_1 \cdot \pi^{-1} \cdot p^{-1}}.
\]

The diameter \( D_1 \) should be determined using the properties of a parametric series (table 1 of GOST 8032-84 "Preferred numbers and strings of preferred numbers"): the digit 4 has the number 24; the digit 630 has the number 112; the digit 3.15 has the number 20; the digit 400000 has the number 224.

Then the number of the digit \( D_1 \) will be equal to \((24 + 112 - 20 - 224) \cdot 0.5 = -54\), and the value of \( D_1 = 0.045 \) m, which corresponds to the standard value of 45 mm, which is the first of the above rows (in ascending order) found in row R20, so the row R20/2 is taken, 8 terms are counted from the value 45 and the string is obtained: 45 – 56 – 71 – 90 – 112 – 140 – 180 – 224, that according to table 1 of GOST 8032-84 "Preferred numbers and rows of preferred numbers" corresponds to a row of sample R20/2 (45–224) mm.
**Table 1.** The initial series of forces on the rod and the derived series of diameters of the hydraulic cylinders of the broaching machine.

| Number members series | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   |
|-----------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| The magnitude of the force on the rod $P$, kN | 0.63 | 1.00 | 1.60 | 2.50 | 4.00 | 6.3 | 10.0 | 16.0 |
| Diameter of the hydraulic cylinder $D$, mm | 45  | 56  | 71  | 90  | 112 | 140 | 180 | 224 |

By the method of technical optimization, the number of hydraulic cylinder diameters is determined, which fully corresponds to the amount of effort of broaching machines.

4. **Conclusion**

The methodology of choosing parametric series is considered. The simplest method to use is the method of technical justification of the choice of parametric series. This method was used to select a number of diameters of hydraulic cylinders of a broaching machine, based on the mathematical relationship between the force developed on the hydraulic cylinder rod, which is formed by a certain parametric series laid down by the designers. As a result of technical optimization of the choice of the parametric series, a number of diameters of hydraulic cylinders $R20/2(45–224)$ mm was installed, which fully corresponds to the main functional parameter – the number of forces on the rod of broaching machines $R10/2(0.63–16.0)$ kN.

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