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NEW APPROACH TO DEVELOPMENT METHODOLOGY OF REQUIREMENTS OF STANDARDS FOR METAL PRODUCTS

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ABSTRACT

Standardization as a component of control is based on a set of fundamental documents in the field of technical policy and product quality control. Customers and manufacturers put for-ward different requirements to the same kind of product: customers are interested in consumer functions on the basis of the product designation, while manufacturers are governed by quantita-tively measurable parameters, which can be measured and controlled. The novelty of the pro-posed approach is to develop methods of coordination of requirements of the parties concerned using function-target analysis based on correspondence achievement between the requirements of the customer and the capabilities of the manufacturer. The principles of the new science of standardization, protypology are formulated. In accordance with this concept, development of standards can be represented in the form of the following stages: development of customer re-quirements as a set of properties and some measurable parameters, which characterize them; correspondence achievement between the customer properties and the product properties con-trolled by the manufacturer of the product; maximal approximation of differences between the positions of the customer and the manufacturer and development of the standard as the effective trade-off between the parties. On this basis, the procedure of meeting the requirements of the customer and the manufacturer was developed. The first stage consists of comparison of the cus-tomer requirements and the capabilities of the manufacturer, which can be easily represented in the form of a matrix. The second stage is the mathematical assessment of the similarity of indi-vidual quality parameters. Taking into account the principle of continuity in the assessment change as well as continuity of the speed of assessment change, the decreasing S-shape curve was built. The next stage is the function-target analysis of the product which makes it possible to establish relations between the consumer functions of the product and its quality parameters during the course of consumer phase of its life cycle. To calculate the complex assessment, it seems reasonable to make use of qualimetry formulas, which are used to assess the product qual-ity. Thus, perfection of scientific and methodological fundamentals of standardization must be based on the application of mathematical tools to provide correct and rapid setting of require-ments to products, types of work and services.

Introduction

Standardization is one of the most important elements of modern mechanism of product quality control. On the one hand, standardization should be considered as a practical activity, on the other hand, as a part of the control system. Standardization as a practical activity consists of development, implementation and application of regulatory documents and in supervisory control of fulfillment of requirements, rules and norms specified in them. Standardization as a component of control is based on a set of fundamental documents in the field of technical policy and product quality control. Standardization is the most important instrument providing competitiveness of the product [1–3].

Although the practical activity in the field of standardization is well developed, at present time development of its scientific basis is one of the urgent issues [4–6]. In this regard, scientific basis of standardization is viewed here as development and application of fundamentally new approaches in the practice of standardization, making use of mathematical tools rather than just a system of knowledge about standardization [7–9].

Development of standards for products is one of the types of activity in the field of standardization; this activity is based on a series of negotiations between customers and manufacturers. As a rule, each party defends its own points and is interested in including the requirements in the standard, which are important for this party. This state of affairs causes a number of problems [10–12]. This can be explained by the fact that customers and manufacturers put forward different requirements to the same kind of product: customers are interested in consumer functions (usefulness to customers) on the basis of the product designation, while manufacturers are governed by quantitatively measurable parameters, which can be measured and controlled (**fig. 1**).

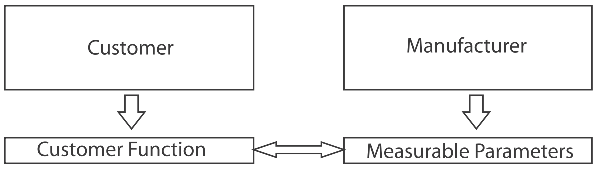

Fig. 1. Interactions in the system "customer — manufacturer" in the process of requirements of the standard for a product

This state of affairs in the field of standardization makes it necessary to develop such an algorithm, which could resolve the differences between the customer and the manufacturer of the product using clear mathematical tools.

Methodology

In order to solve the contradiction between customer demands and manufacturer capabilities, several methods are proposed [13–18]. The analysis shows that most of them are based on the combination of the well-known methods which are used in quality management. But the literature review didn't show the progression in the development of the scientific basics of standardization based on

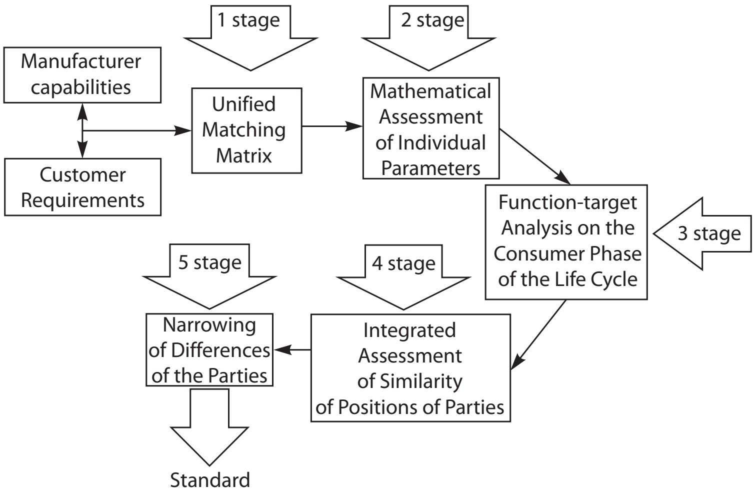

Fig. 2. Stages of requirements development for the standard in accordance with the principles of protypology

	Customer Requirements			
Manufacturer Capabilities	•			•
		•	•	
		•	•	•
	•	•		•

Fig. 3. Compliance matrix of the requirements of customer and capabilities of the manufacturer

Screw Characteristics \ Consumer Functions	Assemblability	Fracture Properties	Resistance Lo Stretching (Compressive) Strains	Resistance to shear strain	Multiple Use	Hardness	Corrosion Resistance	Replaceability	Interchangeability	No Risk of Self-nfastening	Coupling With the Tool	Compactness	Lightweight	Aesthetic Qualities
Dimensional Characteristics of the Screw Head and Design Features								•	•		•	•	•	•
Dimensional Characteristics of the Screw Core and Design Features								•	•	•		•	•	•
Mechanical Properties										•				
Base Material		•		•	•	•	•						•	•
Coating Material		•					•						•	•
Weight												•	•	•
Complete With a Screw-nut and a Washer														

Fig. 4. Compliance matrix of consumer functions (requirements of the customer) and characteristics of the screw (capabilities of the manufacturer)

the mathematical estimation of the standard development procedure.

The novelty of the proposed approach is to develop methods of coordination of requirements of the parties concerned using function-target analysis based on correspondence establishment between the requirements of the customer and the capabilities of the manufacturer. This is one of the principles of the new science of standardization, protypology [19, 20]. The term “protypology” can be translated from the Greek word «ϖρότυϖο» as “standard”. Protypology is a science of standardization; it is a science related with metrology, qualimetry, quality management and optimization theory. In accordance with this concept, development of standards can be represented in the form of the following stages:

1. Development of customer requirements as a set of properties and some measurable parameters, which characterize them.

2. Correspondence establishment between the customer properties and the product properties controlled by the manufacturer of the product.

3. Maximum narrowing of differences between the positions of the customer and the manufacturer and development of the standard as the effective trade-off between the parties.

On this basis, the following procedure of meeting the requirements of the customer and the manufacturer was developed: the procedure consists of a number of successive stages (**fig. 2**). The first stage presents comparison of the customer requirements and the capabilities of the manufacturer, which can be easily represented in the form of a matrix (**fig. 3**). In practice, this form of representation makes it possible to establish interrelations between the customer demands and the specified properties of the product. At the same time, the capabilities of the manufacturer can be considered as both performance criteria (for example, mechanical properties, geometric dimensions, etc.) and individual parameters (for example, tensile strength, corrosion resistance, wire diameter etc.). In **fig. 4** one can see the compliance matrix for one of the most common fastener, particularly, an engineering screw.

Mathematical assessment of the similarity of individual quality parameters (stage 2) is based on the following principles proving its adequacy: when the positions of the customer and the manufacturer achieve maximum similarity, mathematical assessment of individual parameters is equal to one; in the case of the complete discordance of the positions of the parties, the mathematical assessment is equal to zero. Consequently, this can be represented in the form of two parts of a parabolic curve (**fig. 5**), which can be described by well-known formulas. Thus, formulas (1) and (2) describe the part of the curve for the maximum similarity of positions of the customer and the manufacturer (fig. 5, *a*), while formulas (3) and (4) describe the part of the curve for the maximum difference between the positions of the customer and the product manufacturer (fig. 5, *b*).

$$M(p) = -k_1 p^2 + 1 \; ; \qquad (1)$$

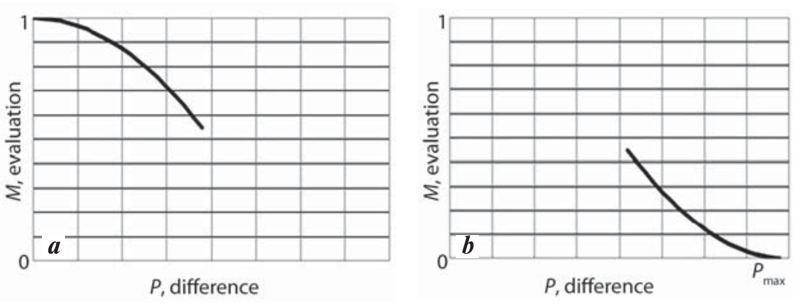

Fig. 5. Mathematical assessment of the customer and manufacturer positions:
a — the part of the curve describing the maximum similarity of positions of the customer and the product manufacturer;
b — the part of the curve describing the maximum difference between the positions of the customer and the product manufacturer

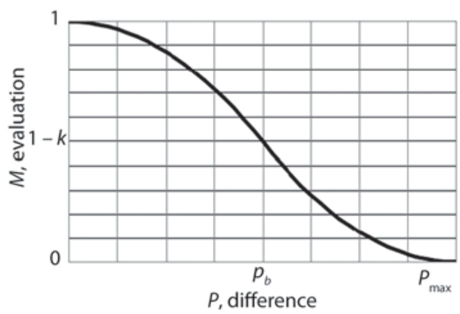

Fig. 6. The form of the decreasing S-shape curve

$$M'(p) = -2k_1 p\,; \tag{2}$$

$$M(p) = k_2 (p_{max} - p)^2\,; \tag{3}$$

$$M'(p) = -2k_2 (p_{\max} - p)\,; \tag{4}$$

Taking into account the principle of continuity in the assessment change as well as continuity of the speed of assessment change, i.e. of the first-order derivative, a decreasing S-shape curve was built, which can be used as a graphical interpretation of the correlation process and the process of meeting of the positions of the customer and the product manufacturer in the course of regulatory document formulation (**fig. 6**).

The principle of continuity helps to achieve the diagram which can be denoted as a decreasing S-shape curve. Usually S-curve diagram is used for forecasting the development of different technological systems [21–24]. It means that one can estimate the parameter level in each point and at every moment of time. Theoretically the S-shape curve shows the development of any process and can be drawn without any empirical data. But in practice when it is used for investigation of the real process or system the mode of this curve will be different: it can be either elongated along the X axis or become nearer to Y axis. The mode of the S-shape curve for the definite process will be dependent on three points: maximum point, minimum point and the point p_b. Meanwhile in point p_b slow decrease changes to slow increase of the assessment value. On this basis, the following relationships can be derived

$$\lim_{p \to p_b - 0} M(p_b) = \lim_{p \to p_b + 0} M(p_b)\,; \tag{5}$$

$$\lim_{p \to p_b - 0} M'(p_b) = \lim_{p \to p_b + 0} M'(p_b)\,; \tag{6}$$

Then coefficients k_1 and k_2 in equations (1) – (4) can be calculated in the following way

$$\left.\begin{aligned} k_1 &= \frac{1}{p_b p_{\max}} \\ k_2 &= \frac{1}{p_{\max}(p_{\max} - p_b)} \end{aligned}\right\}, \tag{7}$$

where $p_{\max}$ is the maximum allowable variation, p_b is the reference point of the second order.

Hence, the decreasing S-shape curve can be described by the following set of equations

$$\begin{aligned} &M(p) = 1 \text{ when } p = 0, \\ &M(p) = 1 - \frac{p^2}{p_{\max} p_b}, \text{ when } 0 \le p \le p_b, \\ &M(p) = \frac{(p_{\max} - p)^2}{p_{\max}(p_{\max} - p_b)} \text{ when } p_b \le p \le p_{\max}, \\ &M(p) = 0 \text{ when } p = p_{\max}. \end{aligned} \tag{8}$$

Application of the decreasing S-shape curve makes it possible to estimate what is the value of the assessment of similarity of positions of parties at any specific time, i.e. in any divergence point.

In accordance with the developed algorithm (see fig. 2), the next stage is the function-target analysis of the product (**fig. 7**). Application of this method makes it possible to establish relations between the consumer functions of the product and its quality parameters during the course of consumer phase of its life cycle.

In **fig. 8** one can see the result of the function-target analysis for an engineering screw.

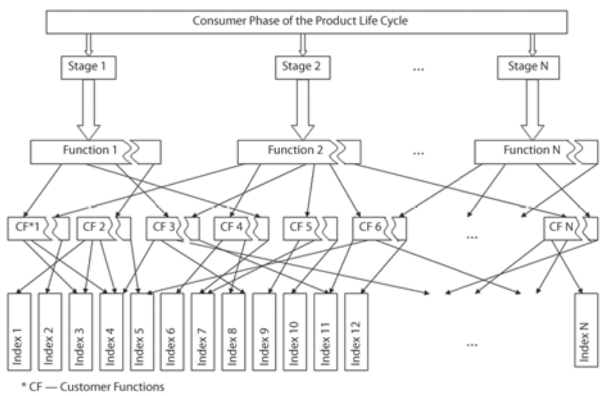

Fig. 7. Generalized scheme of the function-target analysis of the product

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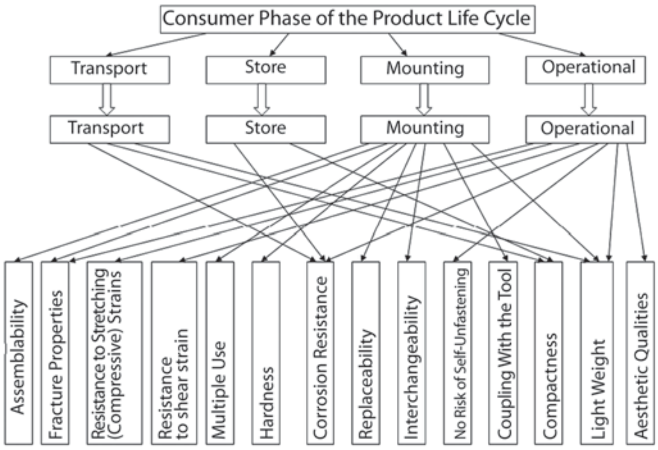

Fig. 8. Consumer functions and quality parameters of an engineering screw in accordance with the function-target analysis

Results and Discussion

To calculate the complex assessment (stage 4, see figure 2), it seems reasonable to make use of qualimetry formulas, which are used to assess the product quality

$$C_j=\frac{\prod_{i=1}^{m} d_i^{1/m}(d_i+1)^{1/m}}{2}, \quad (9)$$

$$C_j=\prod_{i=1}^{n}(k_i+1)^{1/n}-1, \quad (10)$$

$$C=\frac{\prod_{i=1}^{m} d_i^{1/m}(d_i+1)^{1/m}\prod_{i=1}^{n}(k_i+1)^{1/n}}{4}. \quad (11)$$

where C_j is the group estimate for parameters with the dominant or compensated status, d_i are the assessments of dominant individual properties referring to the group, $i = 1, 2, ..., m$; k_i are the assessments of the compensated properties, $I = 1, 2, ..., n$; C is the integrated assessment of the similarity of positions of the customer and the manufacturer.

Thus, the generalized algorithm of the integrated assessment calculation of the similarity of positions of the parties can be represented in the form of a sequence of actions as it is shown in figure 9. This approach makes it necessary to set some threshold value of the integrated assessment. However, if this value is not achieved, it is necessary to continue to narrow the differences of the parties. This algorithm makes it possible to formalize the procedure of coordination the requirements of the product consumer and the product manufacturer. It should be noted that this procedure and this algorithm are universal and can be used for any kind of metal products.

The developed approach makes it possible to solve the problem of creating the methods of transformation the product customer properties into its specified indices. The basic idea of the proposed new methodology of product quality assessment based on function-target analysis is to use the functional principle during the consideration

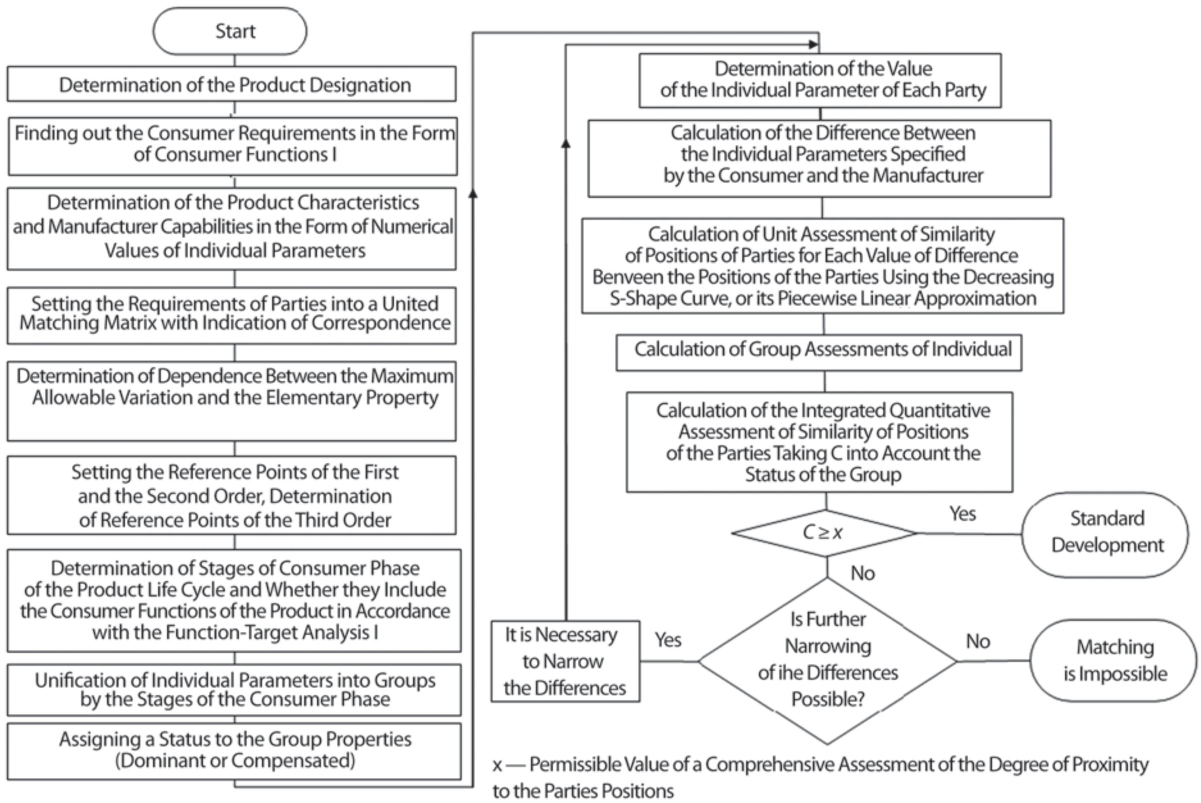

Fig. 9. Generalized algorithm of the integrated assessment calculation of the similarity of positions of the parties during standard development

of the main customer function of the product. Such approach differs from other methods of functional analysis (QFD, Taguchi, FMEA etc.) by more detailed examination of product life cycle stages, multi-level structure of the researched functions, study of one material object as a system of properties which can become apparent in various ways depending on the product consumption targets. From this point of view the process of complying the customer and manufacturer positions can be formalized as a problem of optimisation in the space of product properties with complex quality assessment as an objective function.

Conclusion

Considering protypology as a self-consistent science makes it possible to focus all the efforts of scientists and all the developed engineering solutions on their efficient application in the theory and practice of standardization. The developed concept of coordination the requirements of the customer and the capabilities of the manufacturer is based on the quantitative assessment of the similarity of positions of the parties in the process of standard development. The suggested approach to the description of dependence of similarity of positions of parties on positions of the consumer and the manufacturer offers an opportunity to use a decreasing S-shape curve. Thus, perfection of scientific and methodological fundamentals of standardization must be based on the application of mathematical tools to provide correct and rapid setting of requirements to products, types of work and services.

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