New decisions in the organization of the procedure for setting norms in standards on the example of metal products

Marina Polyakova¹, Eduard Dryagun²

¹ Nosov Magnitogorsk State Technical University, 38, Lenin Avenue, Magnitogorsk, 455000, Russia
² OJSC Magnitogorsk hardware and sizing plant “MMK-METIZ” 5, Metiznikov street, Magnitogorsk, 455002, Russia

Corresponding author: m.polyakova@magtu.ru

Abstract. Standard contains the full set of requirements to the product, its production, control and acceptance. A customer and a manufacturer assess one and the same object of standardization in different ways. The function-target analysis makes it possible to find out the relation between the customer functions and the object properties. Application of this developed method results in a network graph reflecting the connections between the main useful function and individual functions as well as the properties providing these functions. The developed approach of assessment of similarity of the customer and the manufacturer positions in the process of development of standard technical requirements is based on the mathematical description of an S-curve. The proposed method makes it possible to take into account the peculiarities for setting norms in standards of metal products.

1. Introduction
One of the most important elements of innovative development is standardization [1 - 3]. It involves both development and setting of requirements to various products; the objects of standardization are operations, processes, services and methods of control and analysis. Standardization can be defined as setting and application of rules in order to normalize activity in certain fields for the mutual benefit and with the participation of all the parties concerned, in particular, to achieve overall optimal saving at the same time meeting all performance conditions and safety requirements. In spite of the obvious achievements in the field of standardization, the process of development and acceptance of specifications of standards is quite controversial.

One of the most important activities in the technological advancement is the development of standards for industrial products. Standardization fulfills different functions at different stages of product life cycle. At the stage of product development, standardization sets the requirements to the quality of the final product on the basis of complex standardization of qualitative characteristics of this product as well as raw materials, semi-finished products and components; besides, standardization makes it possible to develop a unified system of product quality indices depending on the product designation and operating conditions. At the production stage, standards must take into account the nature and characteristics of the final product; they specify the requirements to the control tools and methods and requirements to assessment of the product quality. At the stage of marketing and sales of the product, standardization sets the requirements to package, preservation, transportation and storage.
At the stage of consumption and operation, standardization specifies the unified requirements to maintenance and repair of the product as well as the standards for its utilization. Analysis shows that the current practice specifies only organizational and legal aspects of the problem of standard development [4 – 6]. However, the development of the list of requirements covered by the standard is an important stage because the level of the standard itself is formed at that very stage.

A standard is the result of teamwork. The standard is developed on the basis of the decision made by the developer (manufacturer) or upon request of the customer of the product and it contains the full set of requirements to the product, its production, control and acceptance. In mass production conditions, the standard becomes a precondition of the exchange of goods. That is why it must express the interests of all the parties of the exchange. In other words, the standard is formed on the basis of the balance of interests of the parties. In practice, this balance is achieved in the negotiation process and in the process of comparison of capabilities and needs of the parties. The main aim here is to ensure the mutual understanding between developers, manufacturers, marketing specialists and customers of products and services. Standards can be a means to achieve this understanding.

However, a customer and a manufacturer assess one and the same object of standardization in different ways. The customer is interested in meeting his needs, that is, in his opinion the product must fulfill certain functions. In practice, the customer makes a choice of the product from the product range, which is on offer in the market. However, he or she is motivated by the need to provide the fulfillment of specific functions. The manufacturer has to make sure that the product possesses certain characteristics in the production process. He considers the product as a set of measurable parameters specified by the standard. The manufacturer has certain equipment, production facilities and production practices. All these factors, to a greater or lesser degree, will limit his capabilities. That is the nature of the conflict of the parties taking part in the development of the product specifications [7 – 9].

At present, the requirements imposed on the object of standardization do not take into account all the needs of the interested parties, and as a result, one of the main principles of standardization is not met, that is, some obstacles to the production process and product handling arise. To solve this problem, it is necessary to formalize the procedure of coordination of views of the interested parties in the process of standard development, which will make it possible to give quantitative assessment of the gap between the positions of the customer and the manufacturer.

2. Methodology

The interaction of the customer and the manufacturer in the process of coordination of the standard requirements to the product can take place in two ways: before the mass production of the product and after the start of the mass production (Figure 1).

The first way of interaction between the customer and the manufacturer means that the coordination of the requirements of the parties takes place before the mass production of the new product; later, these requirements are formalized in the standard. The characteristic feature of this way of interaction between the parties is that the customer and the manufacturer state and coordinate the requirements of the conceptual product, which has never been manufactured before. The second way of interaction between the customer and the manufacturer involves adjustment of requirements and characteristics of the product, when they are specified in the standard.

As a rule, the requirements specified in standards are the result of a number of negotiations between customers and manufacturers leading to agreement about the requirements of the standard, which is a trade-off between the parties. A particular standard is negotiated as the optimal combination of customer requirements and manufacturer capabilities. In the present paper, the manufacturer requirements are defined as the requirements and capabilities expressed in quantitative terms and characterized by unit parameters of the product. Customer requirements are defined here as the requirements made by the customer to the product; in the opinion of the customer, these requirements must ensure the product quality corresponding to the functional purpose of the product. That is why it
is necessary to choose the method, which will make it possible to establish the links between the product functions and the properties, which provide the fulfillment of these functions [10 – 15]. The analysis shows that most of them are based on the combination of the well-known methods which are used in quality management.

![Figure 1. Ways of interaction between the customer and the manufacturer in the process of standard development.](image1)

The function-target analysis can be used as the such method [16, 17]. The characteristic property of this method of analysis is that the analysis of the object is carried out from the moment when it acquires the corresponding customer functions and through the whole customer useful phase of the product life cycle without focusing on the method or characteristics of production of this object. The customer useful phase is defined here as the period of time from the date of manufacture of the product to the end of its operation. In other words, this is the period of time when the product is capable of fulfilling its customer functions. Then the process of coordination between the two parties can be divided into two stages: determining the structure of links between the customer functions and the product quality (structural coordination), and the choice of the level of quantitative characteristics providing the coordinated position of the parties (parameter coordination). In this case, parameter coordination can be achieved by maximizing the complex assessment of product properties as a contraction function of property evaluation. Figure 2 shows a scheme of the structural link between the customer functions and product properties.

![Figure 2. Structural relationship between the product properties and functions.](image2)

It is obvious that the customer and the manufacturer specify their requirements in the form of some range of values. Let us consider now the possible variants of overlapping of the ranges of values specified by the customer and provided by the manufacturer. We introduce the following conventional symbols:

- $F$ is the range of requirements or capabilities of the manufacturer;
The range of customer requirements. 

The following principles were used to develop the mathematical model of the degree of similarity between the positions of the parties:

1. If the requirement of the customer $U$ cover totally the capabilities of the manufacturer $F$, then the degree of similarity of the positions of the parties $M$ is equal to 1.

2. If the ranges of values of requirements specified by the parties do not overlap at all, then the degree of similarity is equal to 0.

3. If the range of requirements of the customer and the manufacturer have some common points the degree of similarity $M$ is located in the interval between zero and one $0 \leq M \leq 1$.

One can mathematically express it in the following way

If $F \subseteq U$, then $M = 1$.  

If $F \cap U = \emptyset$, then $M = 0$.  

If $F \cap U \neq \emptyset$ and $F \not\subseteq U$, then $M = \frac{V(F \cap U)}{V(F)}$, $0 < M < 1$.  

where $M$ is assessment of the degree of similarity between the positions of the customer and the manufacturer, $V(X)$ is a certain quantitative measure of the set $X$, that is the length of the interval of values of the requirements.

Proceeding from this condition, let us define the assessment function of the interval measure $M(V(F \cap U))$ in the general case. It will define the following calculation algorithm for the rate of assessment change as a function of the parameter value

If $V(F \cap U) = 0$, then $M(0) = 0$.  

If $V(F \cap U) = V(F)$, then $M(V(F)) = 1$.  

If $\frac{V(F)}{2}$, then $M\left(\frac{V(F)}{2}\right) = \frac{1}{2}$.  

If $0 \leq V(F \cap U) \leq \frac{V(F)}{2}$, then $M(V(F \cap U)) = \frac{2 \cdot V(F \cap U)^2}{V(F)^2}$.  

If $\frac{V(F)}{2} \leq V(F \cap U) \leq V(F)$, then $M(V(F \cap U)) = 1 - \frac{(V(F) - V(F \cap U))^2}{V(F) \cdot (V(F) - \frac{V(F)}{2})} = 1 - \frac{2 \cdot (V(F) - V(F \cap U))^2}{V(F)^2}$.  

By substituting different values of discrepancy between the ranges of the customer $U$ and the manufacturer $F$, we can obtain the quantitative assessment of the degree of similarity of the positions of the parties $M(V(F \cap U))$ for arbitrary values of $V(F \cap U)$.

3. Interpretation, results and discussion

Let us consider the application of the developed approach using high-strength reinforcement for reinforced-concrete structures as an example. Reinforcement is an important component of reinforced concrete, that is why it has to meet the following requirements: it must show good performance characteristics in combination with concrete at all stages of the structure useful life; it must be used to
the yield point in case when the bearing capacity of the structure is exhausted; it must provide operating convenience of reinforcement installation and provide the possibility of its mechanization. Then, in accordance with the function-target analysis, the relationship between the useful functions and the properties of high-strength reinforcement at various stages of its useful life can be represented in the form of a network structure (Figure 3).

However, one should take into account that in the process of negotiating the requirements of the standard for the product, the customer and the manufacturer can express their initial requirements in different ways. In the first case, the customer expresses the requirements clearly, that is, he is fully aware of the functions which must be fulfilled by the product. In this case, one can establish the links between the customer functions and the properties at once. However, in some cases, the customer can form the requirements, which are not specific. In other words, he specifies only the necessary property, and it is not clear how the manufacturer can provide this property. For example, the high strength of reinforcement can achieved by making use of certain chemical composition, by special processing modes or by nanostructuring of the semi-finished product. One more variant is possible, when the customer specifies the properties of the product, which further determine the customer properties. On the basis of the developed principles of mathematical assessment of the similarity of positions of the interested parties and taking into account the continuity of the process, one can represent it in the form of an S-curve (Figure 4) diagramme.
This curve can be described mathematically, because it has two characteristic sections: the sections of accelerated and slow growth \[18-20\]. The bending point is the moment when the rate of growth is equal to the rate of slowing down of the process development. Then this curve can be represented in the form of the following set of formulas

\[
\begin{align*}
0, & \quad \text{when } V(F \, I \, U) = 0. \quad (9) \\
0.5, & \quad \text{when } V(F \, I \, U) = V(F_b). \quad (10) \\
M(V(F \, I \, U)) & = 1, \quad \text{when } V(F \, I \, U) = V(F). \quad (11) \\
\frac{(V(F \, I \, U))^2}{V(F) \cdot V(F_b)}, & \quad \text{when } 0 \leq V(F \, I \, U) \leq V(F_b). \quad (12) \\
1 - \frac{(V(F) - V(F \, I \, U))^2}{V(F) \cdot (V(F) - V(F_b))}, & \quad \text{when } V(F_b) \leq V(F \, I \, U) \leq V(F). \quad (13)
\end{align*}
\]

The developed approach can be used to form technical requirements of the standard for the product. Then the main stages of this process can be stated as:
1. Selection of the set of unit quality parameters of the product (manufacturer requirements).
2. Defining the customer functions of the product (customer requirements).
3. Matching the customer functions to the unit quality parameters of the product (function-target analysis).
4. Coordination of matching the customer requirements and the manufacturer requirements.
5. Determining the overlapping of ranges of values of product quality parameters specified by the customer and provided by the manufacturer.
6. Plotting an S-curve and calculation of assessment of similarity of the customer and manufacturer positions.
7. Calculation of group assessment of similarity of parties’ positions (if necessary).
8. Calculation of integrated assessment of similarity of the parties’ positions (if necessary).

4. Summary
1. The developed approach of assessment of similarity of the customer and the manufacturer positions in the process of development of standard technical requirements is based on the mathematical description of an S-curve. The proposed method makes it possible to take into account the peculiarities of regulatory activity of product properties in the form of interval values. Application of mathematical tools makes it possible both to define accurately the positions of the customer and the capabilities of the manufacturer and to find the mutually acceptable way of regulating the unit quality parameters of the product in the process of standard development; the decision-making time is reduced too.
2. The main methodological principles of standardization are the structural and parameter coordination of the customer and the manufacturer positions. This approach allowed us to develop a mathematical model of coordinating the technical requirements of the standard in the form of optimization problem with the target function of the integrated assessment of quality. Close-cut separation of the customer and the manufacturer positions makes it possible to indicate the ways of promotion for new promising products.
3. The developed principles of structure and parameter coordination are the basis of all the common methods and principles of standardization, such as unification, balance of interests, consistency and others. The concept of advanced standardization complies with principles too. At present by advanced standardization we understand standardization, which sets up higher level of standards and
requirements as compared with the one already achieved in practice, and according to forecasts, these higher standards and requirements will be appropriate in the near future. However, this definition implies changes only in parameters. Structural development of standards is another promising way of advanced standardization. In our opinion, the developed approach to the process of standardization offers a new scientific foundation for developing of this process.

5. Acknowledgments
The reported study was funded by RFBR according to the research project №18-58-45008 IND_a..

References
[1] R. H. Allen and R. D. Sriram: Technological Forecasting and Social Change Vol. 64 (2–3) (2000), p. 171 – 181
[2] Yu. Sered and Y. Reich: J Comp-Aided Design Vol. 38 (5) (2006), p. 405-416
[3] K. Blind and N. Thumm: Res Pol Vol. 33 (10) (2004), p. 1583-1598
[4] M.B. Spring: Int J Standard and Res Vol. 14 (1) (2016), p. 34-44
[5] K. Blind and A. Jungmittag: J Product Analysis Vol. 29 (2008), p. 51-60
[6] G. Dobrescu and Y. Reich: J Comp-Aided Design Vol. 35 (2003), p. 791–806
[7] M.G. Filho and E.V. Saes: Int J Adv Manuf Tech Vol. 64(5) (2013), p. 1177–1191
[8] C-C. Chen and W-Y. Cheng: Int J Adv Manuf Tech Vol. 34 (2007), p. 1236-1245
[9] W. Dai, P.G. Maropoulos and X.Q. Tang: Proceedings 36th Int MATADOR Conf (2010), p. 145-148
[10] Y. Yao, L. Zhao and Y. Qin: Appl Mech Mater Vol. 37-38 (2010), p. 905-909
[11] Z. Sener and E.E. Karsak: Int J Adv Manuf Tech Vol. 48 (2010), p. 1173-1184
[12] Z. Jiang: Appl Mech Mater Vol. 263-266 (2013), p. 839-842
[13] L. Jun, K. Shulin and L. Pengyu: Key Eng Mater Vol. 467-469 (2011), p. 2103-2108
[14] Z. Yu and J. Zhou: Adv Mater Res Vol. 214 (2011), p. 612-617
[15] R. Schmitt, S. Stiller and B. Falk: Enabling Manufacturing Competitiveness and Economic Sustainability (2014), p. 309-314
[16] M.A. Polyakova, G.Sh. Rubin, G.S. Gun and Yu.V. Danilova: CIS Iron and Steel Review Vol. 12 (2016), p. 45-48.
[17] M. Polyakova and G. Rubin: AIP Conf Proc Vol. 1858 (2017), At. no 040005.
[18] G. Rubin, M. Polyakova and G. Gun: Proc 2015 Int. Conf. on Modeling, Simulation and Applied Mathematics Vol. 122 (2015), p. 178 - 181
[19] M. Polyakova, G. Rubin, G. Gun and Yu. Danilova: Int J Quality Res Vol. 12(3) (2018), p. 573-592
[20] G. Rubin, M. Polyakova, G. Gun: Vestnik of Nosov Magnitogorsk State Technical University Vol. 1 (2015), p. 70-75