Fundamental research and methods of quality assurance of coated abrasive

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Abstract. The article presents the results of the development of scientific and methodological provisions of quality assurance of a coated abrasive (CA) based on the formation of the sets of indicators: technological, performance (existing and newly introduced), reflecting its physical and mechanical properties and economic, which allowed us to classify and evaluate the CA according to their purpose, use it economically and efficiently based on the developed CA design recommendations.

1 Introduction

The vital problem facing the Russian manufacturer is the production of competitive products meeting the world standards. The quality of products, in general, and abrasive tools, in particular, is an objective characteristic of their properties, formed in the process of design, manufacture and operation. The properties inherent in design and manufacture are manifested at the stage of product operation. Therefore, the assessment of the abrasive tool quality should include both an assessment of the tool's operability during operation and an assessment of its performance during manufacture [1].

Both in Russia and abroad, grinding operations using a coated abrasive occupy a significant place in the leading industries at many stages of the technological process of manufacturing parts. Several works studied the influence of the processing conditions on roughness, for example, for the polishing process in the articles of Axinte et al. [2], Huai et al. [3], for polishing and grinding operations in the work of Zhaoetal. [4], for belt grinding – by Bigerelle et al. [5], for grinding – by Kozlov et al. [6] and Karkalos et al. [7]. Many researchers studied the accuracy of processing, for example, of belt grinding – Xiao et al. [8], Li et al. [9], Axinte et al. [10], intragrinding - Pereverzev and Akintseva [11]. Finishing processing of spatially complex surfaces is covered by the works, for example, at processing by robotic belt grinding – Song et al. [12], Zhang et al. [13], at multi-axis processing by CNC belt grinding – Wang et al. [14], Hou et al. [15], with robotic polishing systems – Wang et al. [16], at grinding and polishing – Huang et al. [17]. There are studies dealing with machining mechanics, for example, for belt grinding - the works of Zhu et al. [18], Bratan et al. [19], Stadnik et al. [20]. Much attention is paid to the state of the cutting tool during processing in the works of Pandiyan et al. [21], which studied the tool life (durability) of belt grinding, Kapłonek et al. [22] and Novoselov et al. [23] evaluated the

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active surface conditions of the grinding wheel, Shatko et al. [24] evaluated the influence of the grain shape on the characteristics of a coated tool. The work of Syreischikova and Pimenov [25] presents the results of the development of a method for quality assessment of coated abrasives (CA) using the proposed technological parameter of the elasticity index of the abrasive cloth. The wide spread of grinding operations using a coated abrasive made of a grit paper has determined a high demand for it. The use of a coated abrasive, including grinding belts, is often ineffective due to setting of irrational tool characteristics and grinding modes. Thus, in factories with a similar annual program, the consumption of grinding belts for the same type of operations varies several times at different enterprises [26].

The main reason for the low efficiency of belt grinding operations is the lack of technically sound recommendations on their design and, first of all, on the choice of tool characteristics and cutting modes.

The development of recommendations on the design of belt grinding operations with the selection of the most rational characteristics of belts and cutting modes thereon will create the basis for the coated abrasive quality assurance.

2 Main part

The creation of a basis for the coated abrasive quality assurance formed out of the sets of the tool's technological and performance indicators would allow us to classify the tool according to its purpose, to evaluate its indicators using certification methods on test benches and to use it economically and efficiently. The creation of a basis for the coated abrasive quality assurance using the recommendations on the design of CA operations is a prerequisite for achieving the main goal of the research conducted at the Department of Automated Engineering Technology of the South Ural State University – to improve the efficiency of processing using a coated abrasive.

The studies were carried out based on the main premise that ensuring the design of optimal operations using the CAs is possible when establishing a correspondence between the developed sets of the tool's technological and performance indicators reflecting its physical and mechanical properties and allowing us to control the grinding process.

A coated abrasive (grit papers, grinding belt), like any product and its quality, can be described using an infinitely large number of properties. Complex parameters of the grit paper quality [27] are the resultant values that generalize these properties. In quality assessment, two opposite tendencies are encountered: on the one hand, the desire to describe quality by the maximum possible number of properties, on the other hand, - the desire to reduce the number of the considered properties, in order to reduce labor costs. Therefore, it is necessary to find an optimal number of properties that can reliably assess the quality of the products, in this case - a coated abrasive. For this purpose, when choosing properties, we adhered to the following provisions using the qualimetry methodology:

– the tool's quality properties were considered as a classification system with a hierarchical multi-level structure of properties;

– the basis of the classification was the feature determined by the purpose of the quality assessment;

– the number of quality properties included in the classification had to meet the requirements of necessity and sufficiency.

In a simplified form, the algorithm for assessing the quality level is presented in the form of the following stages in the scheme (see Fig. 1).

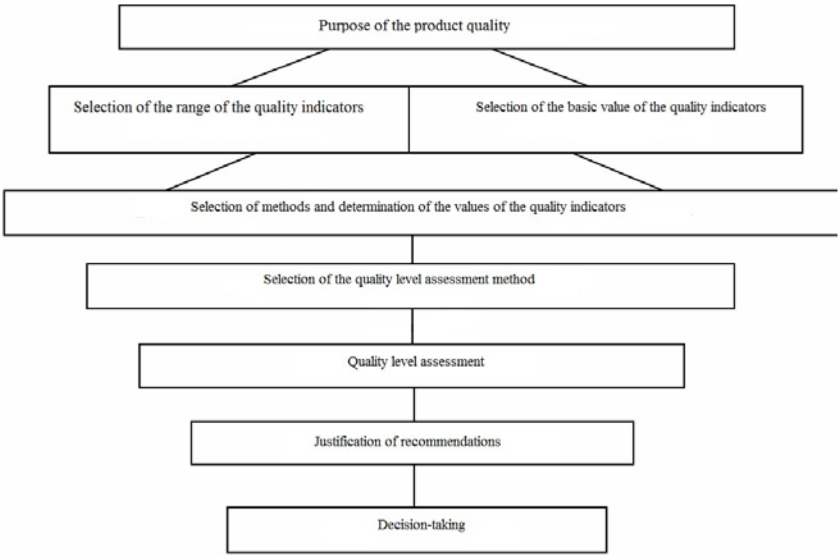

Fig. 1. Stages of the CA quality level assessment.

An analysis of the problem state allowed us to establish a range of indicators for simple and complex properties that determine the quality of the grit paper. The quality index according to [28] is the quantitative characteristic of one or several product properties considered as applied to certain conditions for its creation, exploitation or consumption. The quality indicators were selected and developed for the tool made of a grit paper and are presented in Fig. 2 according to the classification of the indicators as per [1].

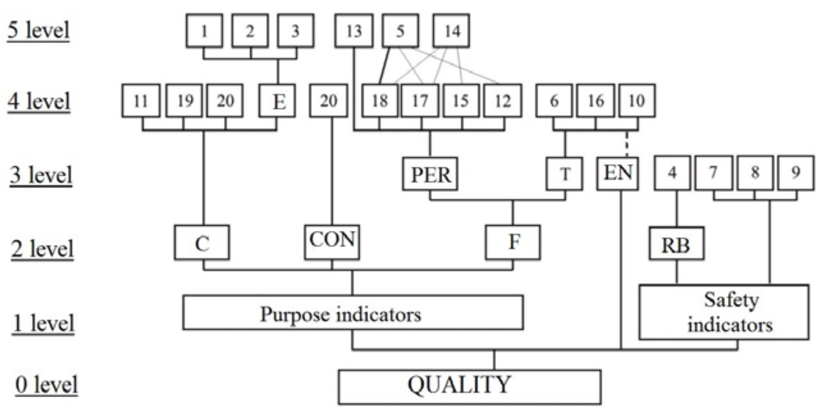

Fig. 2. Hierarchical tree of quality properties for the grit paper tool according to the quality indicator system: C - classification, CON - constructive, F - functional, RB - reliability, E - esthetic, PER - performance, T - technological, EN - economic; 1 - area of defects, 2 - dimensions, 3 – thickness nonuniformity, 4 - strength, 5 - resistance, 6 – relief of the working layer, 7 - content of harmful volatile substances, 8 - electrical conductivity, 9 - ignition temperature, 10 - stiffness, 11 - extension, 12 - reduced cutting ability, 13 - roughness of the treated surface, 14 - material removal, 15 - wear resistance, 16 - bonding strength of the grain, 17 - cutting ability, 18 - grinding coefficient, 19 - water resistance, 20 – moisture content, 21 - coefficient of applying the grinding material.

As it can be seen from Fig. 2, the first level of the hierarchical tree of the quality properties is the purpose indicators characterizing the properties of the grit paper defining the basic functions, for which it is designed and which determine the area of its application. The second level of the hierarchical tree of the quality properties in Fig. 2 is classification, functional and constructive indicators. The first ones characterize the belonging of the product to a certain classification group.

For example, water resistance for grit papers on a synthetic binder or an extension for fabric-based grit papers. The second indicators characterize the useful effect of using or consuming the tool and the progressiveness of the technical solutions laid down in the product (in CAs), for example, the tool's serviceability, the performance of the grinding operation. The constructive indicators characterize the main drawing and design solutions, for example, for the grit paper - this is the type of the working layer (squares, stripes - relief or solid). The third level of the hierarchical tree of the quality properties in Fig. 2 is performance and technological indicators. The indicators that reflect physical and mechanical properties inherent in the grit paper - strength of grain binding, relief of the working layer and hardness of the grit paper (the fourth level of the properties tree) were proposed as specific technological indicators. The indicators introduced into the grit paper standards, for example, wear resistance, and the new ones proposed for inclusion in the set of performance indicators for the grit paper, for example, the reduced cutting ability, are illustrated as specific performance indicators at the fourth level of the property tree (see Fig. 2). The fifth level of the hierarchical properties tree is single natural indicators, for example, the material removal and the tool's operating time, from which the complex performance indicators of the fourth level are formed (see Figure 2). Since it is established that the range of performance indicators is insufficient both quantitatively and qualitatively, a part of specific performance indicators is given in the properties tree.

The third level of the hierarchical properties tree shows the economic indicators that characterize the costs of production, operation or consumption of products. The indicators that determine the prime cost of the grinding operation using a coated abrasive, including the grinding belt, are proposed as specific economic indicators of the fourth level.

The status of many consumer enterprises and manufacturers of abrasive products allows us to suggest that the built scheme for quality assurance of a coated abrasive (CA) should be consistently formed of the following main stages.

The first stage is the establishment of the CA consumer requirements. When carrying out research activities at this stage, we applied one of statistical quality assurance methods - QFD (quality function deployment or quality house) method. The second stage is the creation of the CA characteristic, which most fully meets the consumer requirements. The stage is performed by defining a set of technological indicators formed from the existing and newly developed indicators physically present in the grit paper, reflecting its physical and mechanical properties and determining its operability and application conditions. The third stage is the creation of a set of the tool’s performance indicators that determine its relevance to its purpose and most fully assess the maximum number of the tool’s properties by the criteria of necessity and sufficiency. The fourth stage is the creation of a method, means and procedures for a quantitative evaluation of the developed set of performance indicators. The fifth stage is the establishment of a correspondence between the created sets of the tool’s technological and performance indicators for developing recommendations on the selection of the CA processing characteristics and modes and ensuring the design of optimal operations using the grit paper tool. The sixth stage is the development of economic indicators that assess the effectiveness of operations using the coated abrasive. The seventh stage is the assessment of the quality level of the coated abrasive of domestic and foreign manufacturers and the study of the factors contributing to the obtaining of high quality CAs; application of the quality function deployment technology (QFD method) to enable its planning and development of the domestic grit paper quality plan [29].

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Necessary and sufficient sets of performance indicators are proposed for various types of coated abrasives and CA processing operations (see Figure 3).

A:
- Cutting ability (q) or reduced cutting ability (q_{red})
- Wear (Δ) or reduced wear (Δ_{red})
- Grinding coefficient (C)

B:
- Resistance (τ)
- Roughness (Ra; Rz)

where A – necessary indicators,
(A+B) – necessary and sufficient indicators.

Fig. 3. Necessary and sufficient CA performance indicators.

We formulated the general requirements, which should be met by the sets of performance indicators. We determined the methodological basis of their calculation. We developed the calculation formulas for complex indicators. The comparability of the indicators is achieved by reducing them to the unit spent on the processing of the work. The structural diagram of the formation of the set of indicators of operational properties is shown in Fig. 4.

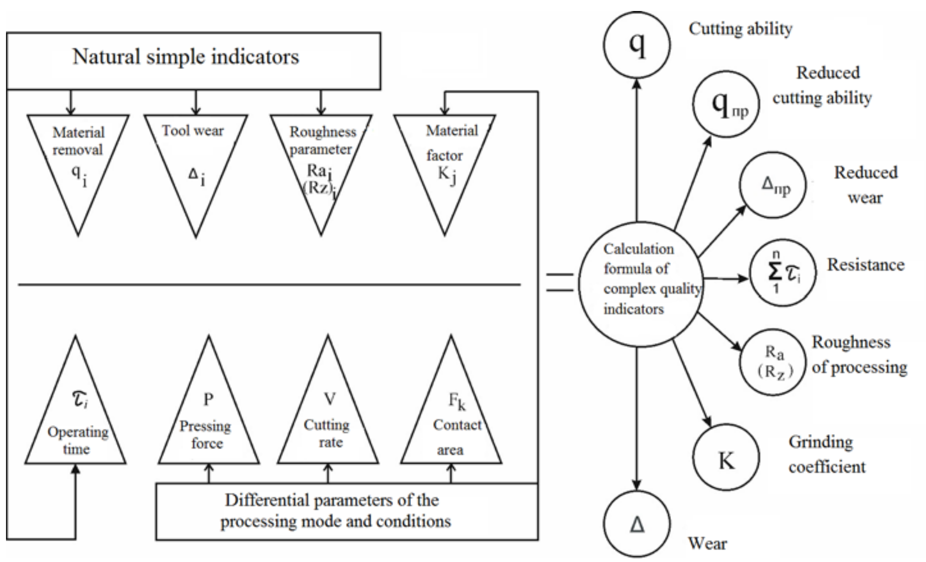

Fig. 4. Scheme of the formation of CA quality indicators.

3 Conclusion

We determined the interrelation of the performance parameters of the CA grinding process on the existing and developed indicators of the tool characteristics, on the main parameters of the cutting modes. The performed studies served the basis for the development of the recommendations on the design of CA processing operations for various steels and alloys, allowing us to increase the efficiency of CA processing and to reduce the tool consumption [1]. The industrial approbation of the research findings showed their high efficiency, ease of use for the technological preproduction and suitability for practical use, which was confirmed by the introduction.

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