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Analysis of regulatory support for accreditation procedures in steel shot production

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Аналіз нормативного забезпечення акредитаційних процедур виробництва сталевого дробу

Abstract. Purpose. *Analysis of DSTU 3184 requirements for spherical steel shot and heat-treated spherical steel shot in the context of ensuring production accreditation procedures.* ***Methodology.*** *The research material was manufactured by SE "STALZAVOD TAS" using the method of steel melting and pouring into rotary nozzles with subsequent atomization of the melt on a water curtain to form shot particles. Metallographic analysis was performed using a NEOPHOT-32 optical microscope.* ***Findings.*** *The analysis of DSTU 3184-95 requirements for spherical steel shot type was carried out with regard to its size distribution, microstructure, unacceptable defects, heat treatment, and chemical composition. It was established that the distribution of steel and cast-iron spherical shot into 10 nominal sizes specified by DSTU 3184 does not correspond to international standards for this type of product. According to DSTU 3184, the chemical composition of the shot is determined by the manufacturer, which decreases the level of regulatory control. The necessity of aligning the regulated microstructure of heat-treated steel shot with its chemical composition was identified. Requirements for unacceptable defects under DSTU 3184 include the ratio of maximum to minimum particle diameter, the area of shrinkage porosity, the length of the largest crack, and the area of the largest cavity; however, they do not take into account such typical defects for this product as gas pores and non-metallic inclusions.* ***Originality.*** *A comparative analysis of the requirements of national and international regulatory documents and technical specifications regarding permissible defect levels in steel shot was performed. The study revealed that DSTU 3184 provisions are inconsistent with modern requirements concerning the regulation of chemical composition and its compliance with the declared microstructure.* ***Practical value.*** *The revision and adaptation of DSTU 3184 regulatory requirements to current technical realities and international standards are substantiated as critical factors for maintaining the competitiveness of domestic products in both national and international markets.*

Key words: *steel shot, regulatory framework, microstructure, defects, particle size distribution, accreditation.*

Анотація. Мета. *Аналіз нормативних вимог ДСТУ 3184 на дріб сталевий сферичний марок ДСС та ДССТ з позицій їх вичерпності для забезпечення акредитаційних процедур виробництва. Методика. Об'єктом дослідження був сталевий дріб марок ДСС та ДССТ виробництва ДП «СТАЛЬЗАВОД ТАС», виготовлений методом плавлення та заливання сталі у обертальні форсунки з подальшим розпиленням розплаву на водяну завісу для формування дробових часток. Металографічний аналіз проводили із застосуванням світлового мікроскопа NEOPHOT-32.* ***Результати.*** *Здійснено аналіз положень ДСТУ 3184-95 щодо дробу сталевого типу ДСС стосовно його фракційного складу, мікроструктури, недопустимих дефектів, термічної обробки та хімічного складу. Встановлено, що передбачений стандартом розподіл фракцій сферичного дробу сталевого та чавунного на 10 номінальних розмірів не відповідає міжнародним вимогам до цього виду продукції. Згідно з ДСТУ 3184 визначення хімічного складу покладається на виробника, що знижує рівень регламентованості. Виявлено необхідність узгодження встановленої мікроструктури термічно обробленого дробу з його хімічним складом. Вимоги до недопустимих дефектів за ДСТУ 3184 охоплюють відношення максимального діаметра дробини до мінімального, площу усадочної пористості, довжину найбільшої тріщини та площу найбільшої раковини, однак не враховують такі характерні для цього виду продукції дефекти, як газові пори та неметалеві включення.* ***Наукова новизна.*** *Виконано порівняльний аналіз вимог національних та міжнародних нормативних документів і технічних специфікацій щодо допустимого вмісту дефектів у сталевому дробі. Показано невідповідність положень ДСТУ 3184 сучасним вимогам до регламентації хімічного складу та його відповідності заявленій мікроструктурі.* ***Практична значущість.*** *Обґрунтовано необхідність перегляду й адаптації нормативних вимог ДСТУ 3184 до сучасних технічних реалій та міжнародних стандартів з метою підвищення конкурентоспроможності вітчизняної продукції на внутрішньому та зовнішньому ринках.*

Ключові слова: *сталевий дріб, нормативне забезпечення, мікроструктура, дефекти, фракційний склад, акредитація.*

Introduction. The foremost objective of modern industry is to ensure high product quality that meets consumer expectations, regulatory and technical documentation, and international standards. In the context of global competition, intensified production processes, and continuously rising customer expectations, enterprises are required not only to maintain stable manufacturing operations but also to implement an effective quality management system across all stages of the product life cycle.

Product quality is a decisive factor in determining an enterprise's competitiveness, reputation, economic efficiency, and market resilience. It is influenced by a wide range of factors – from material selection and

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adherence to technological processes to final output control and post-sale service.

Modern approaches to quality management are based on international ISO 9000 series standards, particularly DSTU ISO 9000:2015, which provide a unified understanding of the term "quality" as the degree to which a set of characteristics of an object meets established requirements [1].

A guarantee of product and service quality is the presence of appropriate certification, confirming compliance with established requirements, technical regulations, and international standards. In today's conditions of globalization, open markets, and rising consumer expectations, certification becomes not only a control tool but also a key element of an enterprise's competitive strategy [2].

Since quality today is viewed not only as compliance with technical specifications but also as a comprehensive indicator including service, reliability, environmental friendliness, and safety, the role of certification goes beyond formal confirmation. It becomes a management tool integrated into all levels of enterprise activity [3].

Product and service certification is carried out through attestation procedures that involve verifying the conformity of the evaluated object to established standards, technical conditions, or regulatory documents. This process includes technical documentation review, testing, production audit, and analysis of the quality management system. Only after successfully completing all stages can an enterprise or organization receive the appropriate certificate of conformity.

It is important that the effectiveness and reliability of certification are guaranteed by the accreditation of certification bodies, confirming their technical competence, impartiality, and compliance with international standards such as ISO/IEC 17065 (for products) or ISO/IEC 17021-1 (for management systems). In Ukraine, accreditation is carried out by the National accreditation agency of Ukraine (NAAU) in accordance with DSTU EN ISO/IEC 17011.

Thus, certification together with accreditation creates a closed trust system between the manufacturer, consumer, and the state, ensuring transparency, legal validity, and international recognition of product and service quality.

Therefore, one of the most crucial steps in ensuring product quality is the selection of adequate regulatory requirements according to which the product is evaluated. Clearly formulated, up-to-date, and technically justified requirements form the basis for objective control, certification, and continuous quality improvement. Without unified regulatory guidelines, the concept of "quality" loses its measurability, and product compliance loses its evidential power.

Purpose and objectives of the research – to establish the validity of the requirements set forth in DSTU 3184 for spherical steel shot and heat-treated spherical steel shot in terms of the completeness of normative characteristics necessary to support accreditation procedures in production.

Materials and research methods. Standard DSTU 3184-95 Steel and cast iron shot. General technical conditions applies to cast steel and cast iron spherical and angular shot intended for technological purposes, shot blasting and shot peening of blanks (castings, forgings, rolled products); for surface hardening of machine parts; for scoring rolls of rolling mills and other technological operations [4].

Spherical steel shot and heat-treated spherical steel shot produced by SE "STALZAVOD TAS" (Figure 1, a) is manufactured by melting and pouring steel into rotating nozzles with atomization of the melt (Figure 1, b) onto a water curtain to create shot particles [5].


a


б

Fig. 1 – External appearance (a) and rotating spray cup (b) of the steel melt of spherical steel shot produced by SE "STALZAVOD TAS" [5]

Microstructural research specimens were prepared using standard methods in accordance with ASTM E3-11 (2007) "Standard Guide for Preparation of Metallographic Specimens" with mechanical grinding [6]. Mechanical polishing was performed on a felt wheel using diamond paste.

Metallographic analysis was conducted using a NEOPHOT-32 optical microscope following generally accepted procedures.

Shot, as a commercial product, according to DSTU 3184, must conform to the following types: spherical steel shot, angular steel shot, heat-treated spherical steel shot, and heat-treated angular steel shot.

Angular shot is obtained by crushing the corresponding spherical shot.

General requirements for steel shot and its testing methods are regulated by the following normative document: DSTU 3184-95, ISO 11124-1:2018, ISO 11124-2:2018, ISO 11124-3:2018, ISO 11124-4:2018, ISO 11124-5:2018, ISO\PWI 11124-6, ISO\DIS 11124-7:2018, ISO 11125-1:2018, ISO 11125-2:2018, ISO 11125-3:2018, ISO 11125-4:2018, ISO 11125-5:2018, ISO 11125-6:2018, ISO 11125-7:2018, ISO 11125-8:2018, DSTU ISO 11125-1:2015, DSTU ISO 11125-5:2015, SAE J827, SAE J2175, SAE J444, DSTU 3185-95, ISO 11125-9:2021, SAE J445.

Research results. Analysis of the requirements of DSTU 3184-95 for spherical steel shot type.

Analysis of the fractional composition of steel shot

According to the requirements of DSTU 3184, the fractions of spherical steel and cast iron shot are divided into 10 nominal sizes.

However, some manufacturers, depending on the intended use of the products, supply steel shot in two fractions with the conditional designations «fine particles» and «coarse» with sizes of 1-3 mm and 3-5 mm, respectively.

At the same time, the standard DSTU EN ISO 11124-2:2022 includes 12 nominal shot sizes [7], and DSTU EN ISO 11124-3:2022 includes 14 nominal shot sizes [8]. Specifications from the Society of Automotive Engineers (SAE), specifically SAE J444, distinguish 20 shot sizes [9].

It is evident that when conditionally designating shot according to the requirements of section 4.2 of DSTU 3184 under the item "shot number," in the case of supply in two fractions from the dimensional ranges mentioned above, this item in the product's accompanying documentation cannot be accurately fulfilled. This is due to a contradiction – the dimensional range, for example, 1..3 mm, according to the National standard DSTU 3184, includes 5 shot fractions. Fractions smaller than 1 mm – three; 3..5 mm – two.

Even when agreeing to supply this product according to the requirements of European, International, or other standards (due to other objective circumstances of interaction between the organization and the customer), the boundaries of the 10 size ranges of shot fractions under the National Standard requirements do not align due to their differing quantities (see above – 12, 14, 20).

Analysis of the chemical composition of steel shot

According to the requirements of DSTU 3184, the chemical composition of the shot is determined by the manufacturer.

The chemical composition of potential low-carbon and high-carbon steels for shot production is regulated by the following normative documents: DSTU 8781:2018, DSTU 7809:2015, DSTU 3833-98, ISO 11124-3:2018, ISO 11124-4:2018, SAE J2175, SAE J827, and the AUREMO Steel and Alloy Handbook. Thus, as noted above, this is the first reason for aligning this technical requirement for steel shot with a standard other than DSTU 3184-95. A key consideration in this case is that such alignment must take into account the possibility of ensuring a clearly defined microstructure of the shot material, which is unequivocally stipulated by DSTU 3184-95 (this issue will be examined in detail later).

Analysis of unacceptable defects in steel shot

The requirements for unacceptable defects under DSTU 3184 include the following categories:

a) the ratio of the maximum diameter of the shot particle to the minimum > 1.7;
b) shrinkage porosity area greater than 40% of the shot particle area;
c) the length of the largest crack greater than 20% of the shot particle diameter;
d) the area of the largest cavity greater than 10% of the shot particle cross-section.

Thus, DSTU 3184 regulates technical requirements for the perfection of the spherical shape of the shot, defects of crystallization origin (shrinkage porosity) in melt droplets (Fig. 2, a), crack formation in products related to thermal expansion/contraction of the material (Fig. 2, b), and casting shrinkage (Fig. 2, c).

At the same time, such obvious inconsistencies as non-metallic inclusions (Fig. 2, d) and gas porosity (Fig. 2, e), from the perspective of the normative document, are not recognized as product defects at all.

As will be shown later, this situation is partially addressed in foreign standards.

Analysis of heat treatment of steel shot

Heat-treated shot is obtained by performing additional heat treatment to relieve residual stresses and improve operational characteristics.

Requirements for the microstructure of steel shot

DSTU 3184-95 establishes the requirement: "The microstructure of heat-treated steel shot must consist of tempered martensite with bainite."

This unequivocal standard provision immediately introduces a correction to the manufacturer's freedom to independently choose the chemical composition of the product material.

Obtaining a martensitic structure in steels with carbon content below 0.3% is problematic without the use of complex and costly production measures, such as cryogenic cooling media for quenching.

For high-carbon steels (hypereutectoid composition), it is necessary to consider the carbide phase (cementite) as an additional structural component, which is not normatively provided.

Discussion of results

General assessment of permissible defect content

Table 1 presents the results of an analysis of the requirements of national and international normative documents and specifications regarding the permissible content of shot with deviations from spherical shape, shrinkage porosity, cavities, and cracks.

Despite some discrepancies in the quantitative characteristics of such defects across different normative documents, they are mostly consistent and all converge in the total number of defective shot particles.

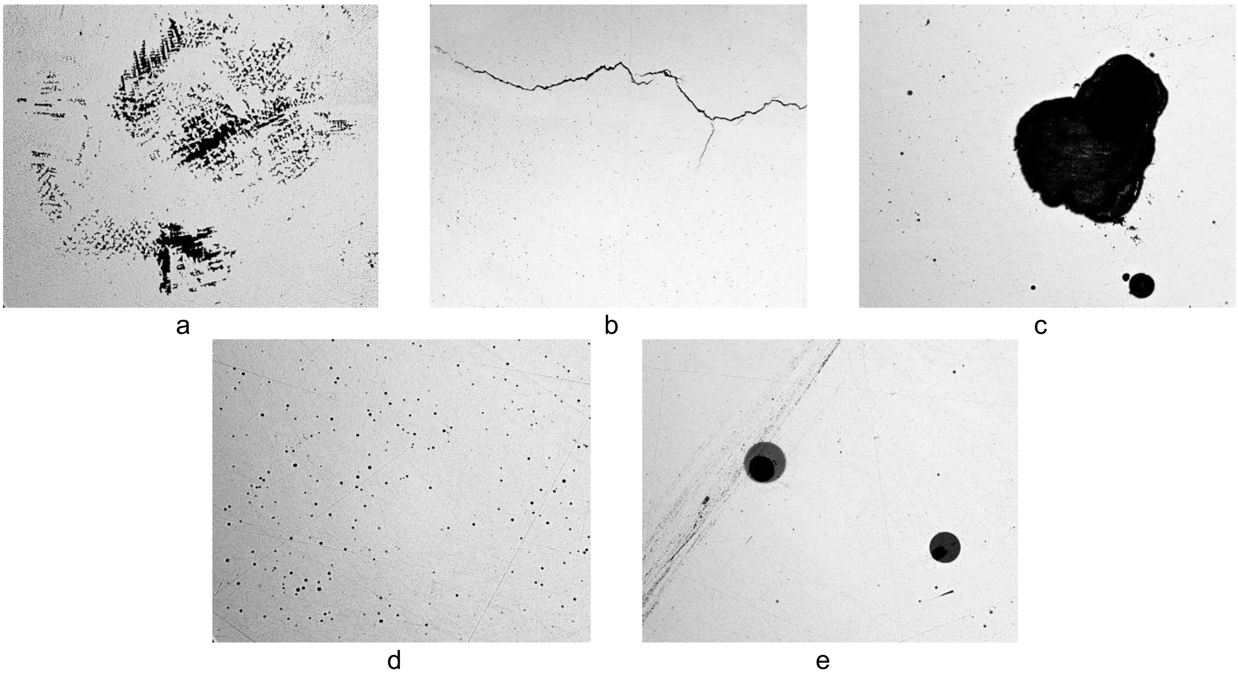


Fig. 2 – Crystallization-related defects in steel shot: a – shrinkage porosity, b – cracks, c – cavity, d – non-metallic inclusions, e – gas pores; ×50

Table 1 – Permissible content of defective shot particles

Normative document	Permissible shot content, %, not more than				Total defective shot content, %, not more than	Foreign inclusions, %, not more than
	with deviation from spherical shape	with shrinkage porosity	with voids	with cracks		
DSTU 3184	10	10	10	10	20	0,5
ISO 11124-3	5	10	10	15	20	1
ISO 11124-4	15	5	15	Not permitted	20	1
SAE J2175	5	10	10	5	20	-
SAE J827	5	10	10	15	20	-

Assessment of structural discontinuity requirements

Unlike DSTU 3184, international standards ISO 11124-3 and ISO 11124-4 include a category of nonconformity – «voids». According to ISO 11124-4:2018 [10], this is defined as «a smooth surface internal cavity considered undesirable when greater than 10% of the cross-sectional area of a particle». Based on the criterion of «smooth-surfaced cavity», at least gas pores (see Fig. 2, e) may be classified as such a defect. With a certain degree of permissibility, this category may also be used to assess the presence of nonmetallic inclusions (see Fig. 2, d) and other defects. However, in these cases, the presence of a smooth internal surface of the discontinuity is not absolutely guaranteed.

Nevertheless, when a national standard is in place, the use of other individual normative technical requirements – even those of international scope – for procedures of attestation, accreditation, and certification of production and products is not permitted.

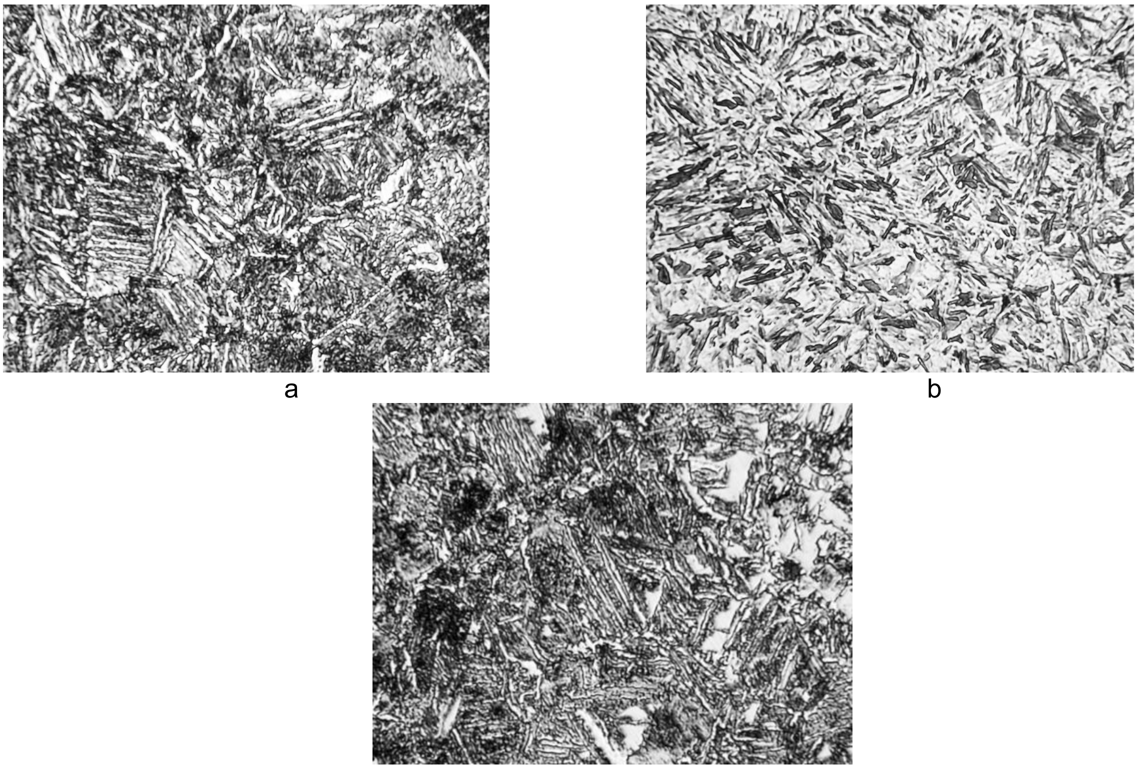
Assessment of chemical composition requirements

The issue of assigning normative requirements to the chemical composition of a specific product on an international scale is resolved through the use of individual standards.

The international standard ISO 11124-4:2018 [10] establishes requirements for the chemical composition and structure of shot, specifically a carbon content of 0.08-0.20%.

Microstructure: bainite (Fig. 3, a) or martensite (Fig. 3, b). Ferrite and pearlite phases along grain boundaries must not exceed 5% in any individual area of examination. This type of structure is essential for ensuring a combination of high hardness and durability. No more than 15% of test specimens may exhibit undesirable microstructure.

The SAE J2175 specification for low-carbon cast steel shot sets the carbon content in the range of 0.1-0.15%. The corresponding microstructure is a transitional structure (bainite) (see Fig. 3, a), defined in the normative document as: "a mechanical mixture of ferrite and cementite" of disordered feathery (upper bainite) and needle-like (lower bainite) types with a small amount or complete absence of free carbides [9].



a b

c

Fig. 3 – Microstructures of heat-strengthened structural hypoeutectoid steel: a – bainite, b – martensite, c – martensite with bainite; a-c – ×1000

Analysis of these normative documents raises questions about how a martensitic structure is achieved in low-carbon (<0.3% C) steel shot. From the standpoint of fundamental principles of modern metallurgy, the transformation of austenite during continuous cooling of steels with carbon content ≤0.3% [11] cannot produce martensite without the use of special, unconventional heat-strengthening techniques.

The chemical composition of hypoeutectoid structural steels with carbon content greater than 0.15% up to 0.60% (grades 15L, 20L, 25L, 30L, 35L, 40L, 45L, 50L, 55L) is regulated by the national standard DSTU 8781:2018 [12].

According to DSTU 7809 [13], stable martensite formation occurs in heat-strengthened steels with carbon content of 0.3-0.6%, i.e., grades 35L, 40L, 45L, 50L, 55L.

Indeed, analysis of thermokinetic diagrams of austenite transformation in medium-carbon steels (Fig. 4) [14] confirms the reliable hardenability of these materials for martensite formation. They exhibit a wide temperature-time range for intermediate transformation with bainite formation and, evidently, phase transformations involving shear and shear-diffusion recrystallization of austenite, resulting in structures combining bainite and martensite.

The recommended heat treatment regime for these steels according to DSTU 7809 is: quenching from 900°C followed by tempering at 200°C, resulting in a tempered martensite structure.

The structural state of steel products with the carbon content currently under discussion, when implementing heat treatment procedures according to the phase transformation diagram during continuous cooling of austenite (see Fig. 4), is presented in Fig. 3. To obtain the desired structure of steel shot, the national standard DSTU 3184-95 provides manufacturers with permission to freely choose the heat treatment regime at their own discretion.

Thus, fulfilling the DSTU 3184-95 requirement regarding the microstructure of tempered martensite and bainite is realistic, but under the normative restriction of the chemical composition of products to specific grades of medium-carbon hypoeutectoid steels according to DSTU 8781:2018.

The international standard ISO 11124-3:2018 [8] establishes requirements for the chemical composition and structure of shot, namely a carbon content of 0.8-1.2%.

Microstructure – martensite and/or bainite, tempered to a degree corresponding to the hardness range (see Fig. 3, c), with fine, uniformly distributed carbides, if present (see Fig. 5, a). Partial decarburization, carbide networks (see Fig. 5, b), and segregation along grain boundaries with products of high-temperature transformation, such as pearlite, are undesirable.

No more than 15% of tested samples should exhibit undesirable microstructure.

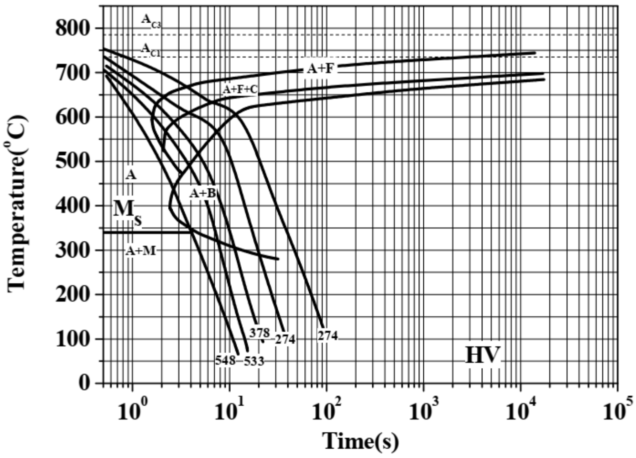
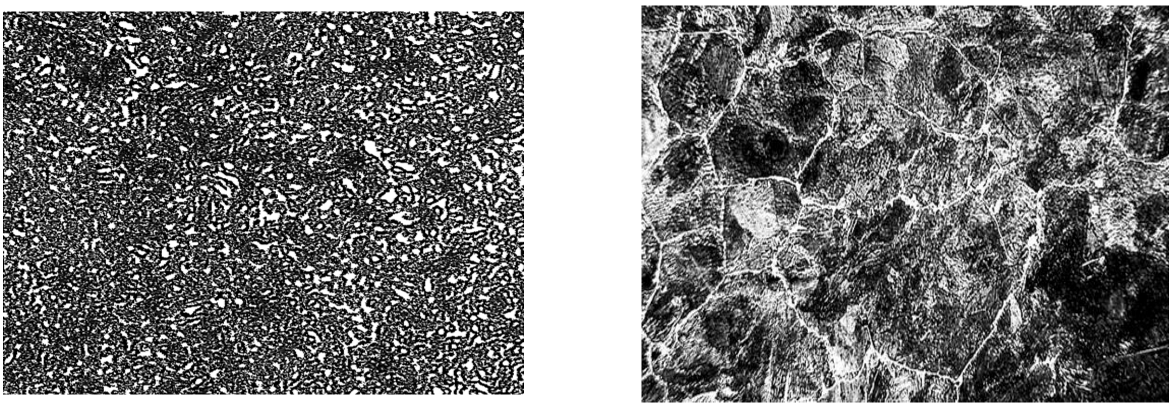


Fig. 4 – Diagram of continuous cooling transformations of AISI 1045 steel [14]



a b

Fig. 5 – Morphology of the carbide phase in high-carbon steel: a – tempered martensite with globular carbides, b – carbide network; a – ×500, b – ×200

The SAE J827 specification for high-carbon cast steel shot also sets the carbon content in the range of 0.85-1.2%. The microstructure of high-carbon cast steel shot must be homogeneous martensitic with fine, uniformly distributed carbides (see Fig. 5, a).

As in SAE J827, the SAE J2175 specification states that a carbide network (see Fig. 5, b), partial decarburization, grain boundary segregation, or pearlite are undesirable. No more than 15% of tested samples may exhibit these defects.

In this case of high-carbon steel, there is an evident inconsistency regarding the microstructure requirement. DSTU 3184 contains no information about carbides, carbide networks, grain boundary segregation, etc.

Conclusions

Based on the research results, the following has been established:

There is an evident inconsistency between the normative requirements of DSTU 3184-95 and the objective presence of defects in spherical steel shot and heat-treated spherical steel shot, particularly in the omission of gas porosity, non-metallic inclusions, and other structural discontinuities.

DSTU 3184-95 is only partially suitable for the purposes of technical auditing of shot production from a limited number of structural steel grades and the corresponding products for their attestation, accreditation, and certification.

The current normative framework imposes certain limitations on the development of the steel shot production sector, which in turn necessitates its revision, adaptation to new technical realities, and integration of international standards. This is critically important for ensuring the competitiveness of domestic products both in the domestic and international markets.

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