A new method to create of the plane section standards of grain metal structures

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Abstract. A new method to create of the plane section standards of grain metal structures with a previously known size distribution of 3D grains is proposed. A quantitative analysis of G3, G4, G5 indices of the standard ISO 643:2012 was performed. The stereological modeling method taking into account the polyhedral shape of 3D grains was used to create new versions of plane section standards. Versions of 3D grains structures as the diameter size distributions of 3D grains, plane sections of which correspond to the main quantitative characteristics of existing G3, G4, G5 indices have been created. It was shown that these versions should contain 3D grain more than 1.5 times the mean diameter of the corresponding plane sections. Choosing the diameter size distributions of 3D grains, necessary for the standard, its possible to create a visual index as a picture, as it done on the existing standard, and also to give the parameters of 3D structure, plane section of which corresponds to this standard. Using a new approach to creating standards will increase the accuracy of the grain structure parameters determining.

1. Introduction
Grain metal structure is most often examined on a metallographic section, where it is represented by a system of polygons that are plane sections (let's call these sections 2D grains) of 3D grain-polyhedrons. The methods for determining the grain size presented in the existing standards of DSTU ISO 643: 2009 [1], ISO 643: 2012 [2], allow us to estimate the average size and some other parameters of a set of 2D grains, but do not provide information about the 3D structure, which really affects the properties of the material. Estimation of a 3D structure by its plane section only in studies establishing the influence of structure parameters on the properties of the metal material may give incorrect results.

For such studies it is important not the average grain size only, but also other characteristics: the maximum and modal diameter of 3D grains, the number of grains per unit volume (in 1 mm³), the characteristics of the size heterogeneity – the standard deviation from the average size, the coefficient of variation $K_V$ of the size distribution grains. These characteristics of the 3D structure can be determined by establishing the grain diameter size distribution $P(D_k)$. Information on the distribution of grain sizes may be more important than information on their average size, for example, when predicting the development of a crack in a material and its destruction [3].

In the works [4-6] the distribution $P(D_k)$ was established by the method of successive serial sections, which is considerable laboriousness and leads to the destruction of the sample analyzed, that limits its application.
There are also methods for the stereological reconstruction the distribution \( P(D_k) \) [7-11]. The initial information in these methods is the diameter size distribution of 2D grains \( P_k(d) \) or chords \( P_k(l) \) obtained on a metallographic section. However, these stereological methods and their relations between distributions \( P(D_k) \) and \( P_k(d) \), \( P_k(l) \) are not used to create plane section standards of grain structures. An important obstacle to their use is that most of them are created for spherical structural components [12]. Some studies [13, 14] apply such methods to grain polyhedral structures, however it should be assumed that differences in the shapes of the sphere and polyhedron (circle and polygon, such as plane sections of 3D grains) introduce significant errors in the results of such stereological calculations [15].

Based on the foregoing, a new method to create the plane section standards of grain metal structures proposed in this paper is the method that would provide information on the parameters of a 3D structure, the plane section of which is presented on the standard, and in which the polyhedral shape of the grains would be taken into account.

### 2. Methodology

On the standards [1, 2] the quantitative parameters of 2-D structures are: the number of 2D grains \( m \) per 1 mm²; average grain area \( \bar{a} \), mm²; average grain diameter \( \bar{d} \), mm; average number of grain intersections \( \bar{N}_l \) per 1 mm of the measuring line; average grain intersection length \( l \), mm.

Based on the parameters required and in order to obtain distributions \( P_k(d) \), indices \( G5, G4, G3 \) [1, 2] were analyzed in detail. For that their schemes were created in the Compass program and the area of each 2D grain is measured. Based on the area the diameter of each grain was calculated and distributed on a scale of 10 uniform intervals. The scale was chosen based on the maximum 2D grain visible on the index. The 2D grain diameter was calculated as isometric circle diameter from the equation:

\[
d_s = \sqrt{4S/\pi}.
\]

The obtained distributions \( P_k(d) \) of the indices \( G5, G4, G3 \) are in the Table 1.

#### Table 1. Distributions \( P_k(d) \) of the indices \( G5, G4, G3 \) of ISO 643:2012 on the scale of 10 uniform intervals.

| Size range \( N_0 \) | \( G5 \) | \( G4 \) | \( G3 \) |
|----------------------|---------|---------|---------|
| \( 0\ldots11.7 \)   | \( 0 \) | \( 0\ldots14.9 \) | \( 0 \) |
| \( 11.7\ldots23.4 \) | \( 8.33 \) | \( 14.9\ldots29.8 \) | \( 1.27 \) | \( 22\ldots44 \) | \( 2.63 \) |
| \( 23.4\ldots35.1 \) | \( 13.10 \) | \( 29.8\ldots44.7 \) | \( 7.59 \) | \( 44\ldots66 \) | \( 15.79 \) |
| \( 35.1\ldots46.8 \) | \( 18.45 \) | \( 44.7\ldots59.6 \) | \( 15.19 \) | \( 66\ldots88 \) | \( 13.16 \) |
| \( 46.8\ldots58.5 \) | \( 21.43 \) | \( 59.6\ldots74.5 \) | \( 11.39 \) | \( 88\ldots110 \) | \( 5.26 \) |
| \( 58.5\ldots70.2 \) | \( 19.64 \) | \( 74.5\ldots89.4 \) | \( 16.46 \) | \( 110\ldots132 \) | \( 15.79 \) |
| \( 70.2\ldots81.9 \) | \( 10.71 \) | \( 89.4\ldots104.3 \) | \( 10.13 \) | \( 132\ldots154 \) | \( 15.79 \) |
| \( 81.9\ldots93.6 \) | \( 5.95 \) | \( 104.3\ldots119.2 \) | \( 22.78 \) | \( 154\ldots176 \) | \( 13.16 \) |
| \( 93.6\ldots105.3 \) | \( 1.79 \) | \( 119.2\ldots134.1 \) | \( 6.33 \) | \( 176\ldots198 \) | \( 5.26 \) |
| \( 105.3\ldots117 \) | \( 0.60 \) | \( 134.1\ldots149.0 \) | \( 8.86 \) | \( 198\ldots220 \) | \( 13.16 \) |

To choose the distribution \( P_k(d) \) for the 2D structure standards, the method described in [16] was used. It is based on the reconstruction of \( P_k(d) \) for a structure with a previously known distribution.
By solving linear equations in which the polyhedral shape of 3D grains is taken into account by using shape factors \( \alpha_i \):

\[
P'_k(d) = \alpha_d P(D_k) \sqrt{D_k^2 - D_{k-1}^2} + \alpha_n P(D_{n+1}) \left( \sqrt{D_{k+1}^2 - D_k^2} - \sqrt{D_{k+1}^2 - D_{k}^2} \right) + \ldots
\]

(2)

Researches have shown that the obtained \( P'_k(d) \) should be normalized in accordance with the equation:

\[
P_k(d) = \frac{P'_k(d)}{\sum_{k=1}^{n} P'_k(d)}.
\]

(3)

Since the standards [1, 2] include the method of drawing cut lines on the image of 2D structure and determining the average number of grain intersections \( N_L \) per 1 mm and the average grain intersection length \( I \) (chords), distribution \( P_k(I) \) of chord lengths were reconstructed according to [16] by solving equations in which polygonal shape of the 2D grains is taken into account using shape factors \( \beta_i \):

\[
P'_k(I) = \beta_d P_k(I) \sqrt{d_k^2 - l_{k-1}^2} + \beta_n P_{n+1}(I) \left( \sqrt{d_{k+1}^2 - l_{k-1}^2} - \sqrt{d_{k+1}^2 - l_k^2} \right) + \ldots
\]

(4)

Researches have shown that the obtained \( P'_k(I) \) should be normalized in accordance with the equation:

\[
P_k(I) = \frac{P'_k(I)}{\sum_{k=1}^{n} P'_k(I)}.
\]

(5)

The number of equations (2) and (4) is equal to the number of size intervals \( n \) in the size scale. To obtain a certain distribution \( P(D_k) \) one can calculate the corresponding distributions \( P_k(d) \) and \( P_k(I) \), thus choosing \( P(D_k) \) that gives a plane section with quantitative characteristics corresponding to the required 2D standard structure.

The method to obtain the shape factors is described in detail in the work [17]. It is based on the fact that shape factors \( \alpha_i \) and \( \beta_i \) are intended to account the differences in the distributions \( P_k(d) \) from the sphere and grain of the average shape, and the differences in the distributions \( P_k(I) \) from the circle and plane section of the grain. So, the shape factors were found from the equations:

\[
\alpha_i = \frac{P_k(d)_{\text{grain}}}{P_k(d)_{\text{sphere}}},
\]

(6)

\[
\beta_i = \frac{P_k(I)_{\text{grain}}}{P_k(I)_{\text{circle}}},
\]

(7)

Note that in all calculations by this method the diameter of 2D grain was calculated as isometric circle diameter from the equation (1) and the diameter of 3D grains was taken to be the diameter of an isometric sphere. But on the standards [1, 2] the mean diameter of 2D grain is calculated from the equation:

\[
\bar{d} = \sqrt{a}.
\]

(8)

So, the ratio between \( d_s \) and \( \bar{d} \) is: \( d_s = 1.1287\bar{d} \) and this is taken into account further.
3. Results and discussion

To create the standard index versions, it was suggested that the diameter of the largest 2D grain of the standard is equal to the diameter of the largest 3D grain. Distributions \( P_k (d) \) of \( G_5 \), \( G_4 \), \( G_3 \) indices, modeling distributions \( P(D_k) \), for their versions, corresponding calculated distributions \( P_k (d) \) are presented in Figure 1, 2, 3 and the distribution parameters \( P(D_k) \), \( P_k (d) \), \( P_k (l) \) are presented in Tables 2, 3, 4. It was assumed that the grains of any size interval have the size of the interval middle.

On the \( G_5 \) index the maximum 2D grain has \( d = 117 \) µm. If the 3D structure is represented by grains with a diameter \( D = 117 \) µm only, then on a plane section structure has \( l = 56.4 \) µm, \( \bar{N}_L = 17.7 \) pcs, that is close to the \( G_5 \) index parameters, but it has \( \bar{d} = 65.7 \) µm, that is slightly more than the standard requires \( (\bar{d} = 62.5 \) µm). Because \( \bar{d} \) is the main parameter on the standard, \( P(D_k) \) version are proposed, for which \( \bar{d} = 62.5 \) µm. For them maximum diameter of 3D grains has sizes of 120, 125, 135, 145 µm (see Figure 1, Table 2). For these \( P(D_k) \) options was obtained that 31...48 % of 3D grains have \( D > 117 \) µm (maximum grain diameter on a plane section); \( \bar{D} = 96.7...104.3 \) µm, i.e. 3D structure has \( \bar{D} \), that is at least 1.5 times larger than \( \bar{d} \) on the plane section \( (\bar{d} = 62.5 \) µm), and 3D structure is more homogeneous \( (K_V = 0.11...0.29, \ K_P = 0.40...0.46) \). And version \( d \) \( (D_{max} = 145 \) µm) is most suitable for the \( G_5 \) index parameters.

On \( G_4 \) index the maximum 2D grain has \( d = 149 \) µm. If the 3D structure is represented by grains with \( D = 149 \) µm only, then on a plane section 2D grains have \( \bar{d} = 83.6 \) µm, \( l = 71.8 \) µm, \( \bar{N}_L = 13.9 \) pcs, i.e. this 2D structure is finer-grained than on the \( G_4 \) index (see Table 3), so 3D structure should contain grains with \( D > 149 \) µm. The approximately necessary 2D structure are given by the 3D structure, all grains of which have diameter no less 157.5 µm. Options that also meet the required parameters of the 2D structure are shown in Figure 2 and Table 3. For these options it was suggested that the maximum diameter 3D grains have size of 170, 180, 185, 205 µm. For them \( P_k (d) \) was obtained for which 47...68 % of 3D grains have \( D > 149 \) µm; \( \bar{D} = 139.4...147.6 \) µm, i.e. 3D structure has \( \bar{D} \), that is at least 1.6 times larger than \( \bar{d} \) on the plane section, and 3D structure is more homogeneous \( (K_V = 0.11...0.25, \ K_P = 0.40...0.45) \). And version \( d \) \( (D_{max} = 205 \) µm) is most suitable for the \( G_4 \) index parameters.

On \( G_3 \) index the maximum 2D grain has \( d = 220 \) µm. If the 3D structure is represented by grains with \( D = 220 \) µm only, then on a plane section 2D grains have \( \bar{d} = 124 \) µm, that is close to the \( G_3 \) index, but \( l = 106 \) µm and \( \bar{N}_L = 9.4 \) pcs, that does not corresponds to \( G_3 \) index (see Table 4). So, \( P(D_k) \) versions are proposed, in which maximum diameter of 3D grains have sizes of 240, 250, 280, 300 µm. In these cases received \( P(D_k) \) with 42...63 % of 3D grains, that have \( D > 220 \) µm; \( \bar{D} = 199...208 \) µm, i.e. 3D structure has \( \bar{D} \), that is at least 1.6 times larger than \( \bar{d} \) of \( G_3 \) index and the 3D structure is more homogeneous, than its plane section \( (K_V = 0.12...0.23, \ K_P = 0.40...0.44) \). And version \( d \) \( (D_{max} = 300 \) µm) is most suitable for the \( G_3 \) index parameters.
Figure 1. Distribution \( P_k(d) \) of the \( G5 \) index of ISO 643 and models of the distribution \( P(D_k) \), giving the distributions of plane sections \( P_k(d) \), corresponding to the quantitative characteristics of the \( G5 \) index of ISO 643.

Table 2. Structure parameters of the \( G5 \) index of ISO 643 and version parameters \( P(D_k) \), giving the distribution sections \( P_k(d) \) and \( P_k(l) \), corresponding to the \( G5 \) index parameters.

| Analysis object                        | Structure parameters                           | Values of parameters \( G5 \) index for versions |
|----------------------------------------|------------------------------------------------|-----------------------------------------------|
| Distribution of grain diameters, \( P(D_k) \) | Mean diameter of grains \( D \), \( \mu m \) | \( a \) 104.3 \( b \) 102.5 \( c \) 98.3 \( d \) 96.7 |
|                                        | Mean square deviation from mean diameter, \( \mu m \) | \( a \) 11.5 \( b \) 17.3 \( c \) 26.3 \( d \) 28.3 |
|                                        | Coefficient of variation \( K_v \) of the diameters \( D \) | \( a \) 0.11 \( b \) 0.17 \( c \) 0.27 \( d \) 0.29 |
|                                        | Modal diameter of grains, \( \mu m \) | \( a \) 114 \( b \) 106.3 \( c \) 114.8 \( d \) 108.8 |
|                                        | Maximum diameter of grains \( D_{max} \), \( \mu m \) | \( a \) 120 \( b \) 125 \( c \) 135 \( d \) 145 |
|                                        | Number of grains \( N_v \) per 1 mm\(^2\), pc. | \( a \) 1684 \( b \) 1774 \( c \) 2012 \( d \) 2113 |
| Distribution of plane section diameters, \( P_k(d) \) | Mean diameter of plane grains \( \tilde{d} \), \( \mu m \) | \( a \) 62.5 \( b \) 62.5 \( c \) 62.5 \( d \) 62.5 |
|                                        | Mean diameter of plane grains \( d \), \( \mu m \) | \( a \) 70.5 \( b \) 70.5 \( c \) 70.5 \( d \) 70.5 |
|                                        | Mean square deviation from mean diameter, \( \mu m \) | \( a \) 28.3 \( b \) 29.2 \( c \) 31.2 \( d \) 32.3 |
|                                        | Coefficient of variation \( K_p \) of diameters \( d \) | \( a \) 0.40 \( b \) 0.41 \( c \) 0.44 \( d \) 0.46 |
|                                        | Modal diameter, \( \mu m \) | \( a \) 90.0 \( b \) 81.3 \( c \) 87.8 \( d \) 79.8 |
|                                        | Mean area of plane grain \( \bar{a} \), \( \mu m^2 \) | \( a \) 3902 \( b \) 3902 \( c \) 3902 \( d \) 3902 |
|                                        | Maximum diameter of plane grains, \( \mu m \) | \( a \) 120 \( b \) 125 \( c \) 135 \( d \) 145 |
|                                        | Number of plain grains \( m \) per 1 mm\(^2\), pc. | \( a \) 256 \( b \) 256 \( c \) 256 \( d \) 256 |
| Chords length distribution, \( P_k(l) \) | Mean grain intersection (chord) length \( l \), \( \mu m \) | \( a \) 54.2 \( b \) 54.7 \( c \) 55.9 \( d \) 56.6 |
|                                        | Mean square deviation from mean \( l \), \( \mu m \) | \( a \) 26.0 \( b \) 26.7 \( c \) 28.1 \( d \) 29.1 |
|                                        | Coefficient of variation \( K_l \) of chord lengths \( l \) | \( a \) 0.48 \( b \) 0.49 \( c \) 0.50 \( d \) 0.51 |
|                                        | Modal size intersection length \( l \), \( \mu m \) | \( a \) 66 \( b \) 56.3 \( c \) 60.8 \( d \) 65.3 |
|                                        | Mean number of chords \( \overline{N}_L \) per 1 mm of line, pc. | \( a \) 18.5 \( b \) 18.3 \( c \) 17.9 \( d \) 17.7 |

Structure parameters of the \( G5 \) index of ISO 643

| Analysis parameter | Structure parameters | Values of parameters \( G5 \) index for versions |
|--------------------|----------------------|-----------------------------------------------|
| Mean diameter of plane grains \( \tilde{d} \), \( \mu m \) | \( a \) 62.5 |
| Number of plain grains \( m \) per 1 \( \mu m^2 \), pc. | \( a \) 256 |
| Mean area of plane grain \( \bar{a} \), \( \mu m^2 \) | \( a \) 3900 |
| Mean number of chords \( \overline{N}_L \) per 1 mm of line, pc. | \( a \) 17.7 |
| Mean grain intersection (chord) length \( l \), \( \mu m \) | \( a \) 56.6 |
Figure 2. Distribution $P_k(d)_{ISO \ 643}$ of the $G4$ index of ISO 643 and models of the distribution $P(D_k)$ (a, b, c, d), giving the distributions of plane sections $P_k(d)$, corresponding to the quantitative characteristics of the $G4$ index of ISO 643.

Table 3. Structure parameters of the $G4$ index of ISO 643 and version parameters $P(D_k)$, giving the distribution sections $P_k(d)$ and $P_k(l)$, corresponding to the $G4$ index parameters.

| Analysis object | Structure parameters | Values of parameters $G4$ index for versions |
|-----------------|----------------------|---------------------------------------------|
| Distribution of grain diameters, $P(D_k)$ | Mean diameter of grains $\bar{d}$, $\mu$m | 147.6 146.0 145.1 139.4 |
| | Mean square deviation from mean diameter, $\mu$m | 16.4 21.0 23.5 35.5 |
| | Coefficient of variation $K_v$ of the diameters $D_k$ | 0.11 0.14 0.16 0.25 |
| | Modal diameter of grains, $\mu$m | 161.5 153.0 157.3 133.3 |
| | Maximum diameter of grains $D_{max}$, $\mu$m | 170.0 180.0 185.5 205.0 |
| | Number of grains $N_k$ per 1 mm$^3$, pc. | 594 614 625 705 |
| Distribution of plane section diameters, $P_k(d)$ | Mean diameter of plane grains $\bar{d}_l$, $\mu$m | 88.4 88.4 88.4 88.4 |
| | Mean diameter of plane grains $d_l$, $\mu$m | 99.8 99.8 99.8 99.8 |
| | Mean square deviation from mean diameter, $\mu$m | 40.0 40.9 41.7 45.1 |
| | Coefficient of variation $K_p$ of diameters $d$ | 0.40 0.41 0.42 0.45 |
| | Modal diameter, $\mu$m | 128.5 117.0 120.3 112.8 |
| | Mean area of plane grain $\bar{a}$, $\mu$m$^2$ | 7819 7819 7819 7819 |
| | Maximum diameter of plane grains, $\mu$m | 170.0 180.0 185.0 205.0 |
| | Number of plain grains $m$ per 1 mm$^2$, pc. | 128 128 128 128 |
| Chords length distribution, $P_k(l)$ | Mean grain intersection (chord) length $l$, $\mu$m | 76.7 77.3 77.8 79.9 |
| | Mean square deviation from mean $l$, $\mu$m | 36.8 37.6 38.2 41.0 |
| | Coefficient of variation $K_l$ of chord lengths $l$ | 0.48 0.49 0.49 0.51 |
| | Modal size intersection length $l$, $\mu$m | 93.5 81.0 81.0 92.3 |
| | Mean number of chords $\bar{N}_L$ per 1 mm of line, pc. | 13.0 12.9 12.9 12.5 |

Structure parameters of the $G4$ index of ISO 643

| Analysis object | Structure parameters | Values of parameters $G4$ index for versions |
|-----------------|----------------------|---------------------------------------------|
| Mean diameter of plane grains $\bar{d}$, $\mu$m | 88.4 |
| Number of plain grains $m$ per 1 mm$^2$, pc. | 128 |
| Mean area of plane grain $\bar{a}$, $\mu$m$^2$ | 7810 |
| Mean number of chords $\bar{N}_L$ per 1 mm of line, pc. | 12.5 |
| Mean grain intersection (chord) length $l$, $\mu$m | 80 |
Figure 3. Distribution \( P_k(d) \) of \( G3 \) index of ISO 643 and models of the distribution \( P(D_k) \), giving the distributions of plane sections \( P_k(d) \), corresponding to the quantitative characteristics of the \( G3 \) index of ISO 643.

Table 4. Structure parameters of the \( G3 \) index of ISO 643 and version parameters \( P(D_k) \), giving the distribution sections \( P_k(d) \) and \( P_k(l) \), corresponding to the \( G3 \) index parameters.

| Analysis object                        | Structure parameters                        | Values of parameters |
|----------------------------------------|---------------------------------------------|----------------------|
| Distribution of grain diameters, \( P(D_k) \) | Mean diameter of grains \( \bar{D} \), μm 208 208 200 199 |
|                                        | Mean square deviation from mean diameter, μm 25 25 46 46 |
|                                        | Coefficient of variation \( K_v \) of diameters \( D \) 0.12 0.12 0.23 0.23 |
|                                        | Modal diameter of grains, μm 228 213 210 195 |
|                                        | Maximum diameter of grains \( D_{max} \), μm 240 250 280 300 |
|                                        | Number of grains \( N_k \) per 1 mm³, pc 212 212 239 242 |
| Distribution of plane section diameters, \( P_k(d) \) | Mean diameter of plane grains \( \bar{d} \), μm 125 125 125 125 |
|                                        | Mean diameter of plane grains \( d_L \), μm 141 141 141 141 |
|                                        | Mean square deviation from mean diameter, μm 57 57 62 63 |
|                                        | Coefficient of variation \( K_P \) of diameters \( d \) 0.40 0.40 0.44 0.44 |
|                                        | Modal diameter, μm 180 163 154 165 |
|                                        | Mean area of plane grain \( \bar{a} \), μm² 15607 15607 15607 15607 |
|                                        | Maximum diameter of plane grains, μm 240 250 280 300 |
|                                        | Number of plain grains \( m \) per 1 mm³, pc 64 64 64 64 |
| Chords length distribution, \( P_k(l) \) | Mean grain intersection (chord) length \( l \), μm 108 109 112 113 |
|                                        | Mean square deviation from mean \( l \), μm 52 52 57 58 |
|                                        | Coefficient of variation \( K_L \) of chord lengths \( l \) 0.48 0.48 0.51 0.51 |
|                                        | Modal size intersection length \( l \), μm 132 113 126 135 |
|                                        | Mean number of chords \( \bar{N}_L \) per 1 mm of line, pc 9.20 9.19 8.92 8.84 |
| Structure parameters of the \( G3 \) index of ISO 643 | Mean diameter of plane grains \( \bar{d} \), μm 125 |
|                                        | Number of plain grains \( m \) per 1 μm³, pc 64 |
|                                        | Mean area of plane grain \( \bar{a} \), μm² 15600 |
|                                        | Mean number of chords \( \bar{N}_L \) per 1 mm of line, pc 8.84 |
|                                        | Mean grain intersection (chord) length \( l \), μm 113 |
4. Conclusions
A detailed analysis of the indices $G_5$, $G_4$, $G_3$ [1, 2] using the stereological method showed that 3D grain structure, the plane section of which has the parameters of the standard, should contain 3D grain more than 1.5 times the diameter $d$ of the corresponding index. It can be argued approximately that the 3D structure consists more than 30% of grains with a diameter larger than the maximum 2D grain diameter on the plane section. It is important that the 3D structure is much more homogeneous than its plane section. The new stereological modeling method, taking into account the polyhedral shape of 3D grains, can be effectively used to create of plane section standards with a previously known size distribution of 3D grains. Choosing the distribution $P_k(d)$ necessary for the standard, it's possible to create a visual index as a picture, as it done on the standards [1, 2], and also to give the parameters of 3D structure. Using a new approach to creating standards will increase the accuracy of determining of the grain structure parameters and their effect on properties of metal, including metal structures of railway transport, which experience significant stress during operation.

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