https://www.proconference.org/index.php/usc/article/view/usc30-00-011
DOI: 10.30888/2709-2267.2025-30-00-011

ORIENTATION OF CRYSTALLITES AND GRAINS ON THE WELD SURFACE DEPENDING ON THE IMAGE QUALITY

Shtofel O.O.
Candidate of Technical Science (Ph.D.), Senior Research Officer
ORCID: 0000-0003-0965-6340
E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine
Candidate of Technical Science (Ph.D.), Associate Professor
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
37 Beresteiskyi Prosp., 03056, Kyiv, Ukraine
Holovko V.V.
Doctor of Technical Science, Leading Researcher
ORCID: 0000-0002-2117-0864
E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine
Korolenko D.Yu.
Postgraduate Student
ORCID: 0009-0008-8582-5904
E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine

Abstract. *The paper shows a solution to the problem of finding the angle of inclination of crystallites/grains and calculating their sizes. The program is designed to analyse objects of different geometry in an input image and consists of: image processing, object (crystallite) detection, calculation of crystallite parameters, and generation of data files. Further data processing allows to build distributions of orientation angles on a flat structure depending on the number of grains with these angles, to analyse the values of the fraction and the corresponding physical and mechanical characteristics and to correlate them with the fractal dimension of the structure components. The paper also points out the problem of image processing of questionable quality, which impedes further correct data analysis.*

Key words: *structure, gains, weld, fractal, orientation.*

Introduction.

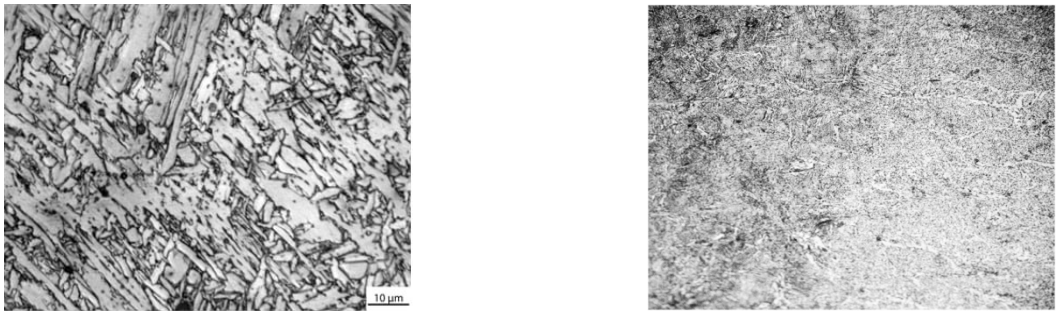
The microstructure directly visible in the plane of the cut only indirectly describes the bulk structure of alloys. The most complete description of the structure can be provided by means of distribution series or curves. The basis for studying microstructure is its morphology, which combines the study of shapes, structures and composition of metal materials. Morphology is based on the understanding that the properties and characteristics of metals will depend on their morphology, i.e. on their external and internal structure, as well as on the components of which they are composed. The main objects of study of metal morphology are metal crystals. The study of metal morphology helps to understand the factors and conditions that influence

the formation of the crystal structure and how it can be changed and controlled. The shape and morphology of a metal plays a key role in determining its properties and behaviour under different operating conditions. They can affect the strength, ductility, fatigue strength and other mechanical characteristics of a metal.

The orientation of the structure has a significant effect on mechanical properties. If the grains are oriented in the longitudinal direction, i.e., when deformed along the crystallographic planes (001), which characterise the direction of grain growth during crystallisation, the ductility, as well as the short-term and long-term strength of the alloy, increase. The orientation of the grains in the direction of maximum stresses eliminates the presence of transverse grain boundaries, so the development of cracks along the boundaries in the longitudinal grain orientation is more difficult than in the transverse or equilibrium structure. In the absence of a predominant grain orientation, the magnitude of stress inhomogeneity is to some extent characterised by the ratio of the maximum and minimum values of the elastic modulus.

Experimental part.

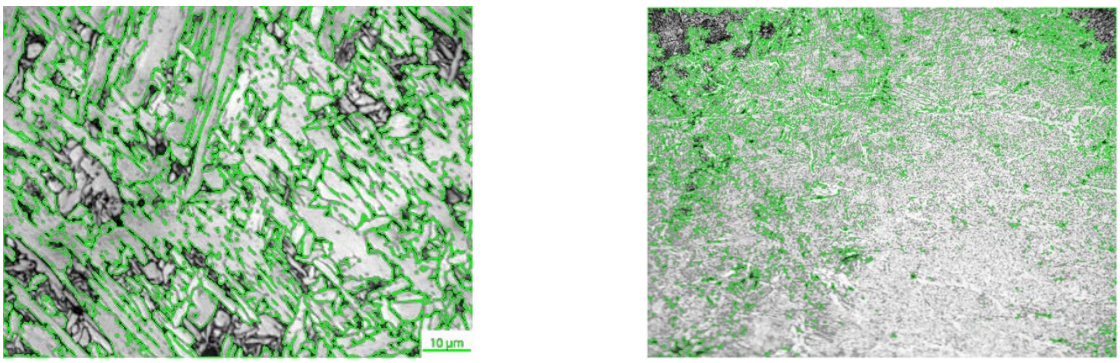
A sample of a welded joint made of 09G2S steel was examined for crystallite orientation at different magnifications (1000 and 200) and image quality.



a **b**

Figure 1 - Sample of a welded joint made of 09G2S steel at magnifications: a - 1000; b - 200.

The software identified the boundaries of crystallites (Fig. 2). As can be seen in Fig. 2b, the image quality significantly affects the identification of crystallite boundaries and some zones, zones of poor image quality, are not calculated by the software (Table 1).



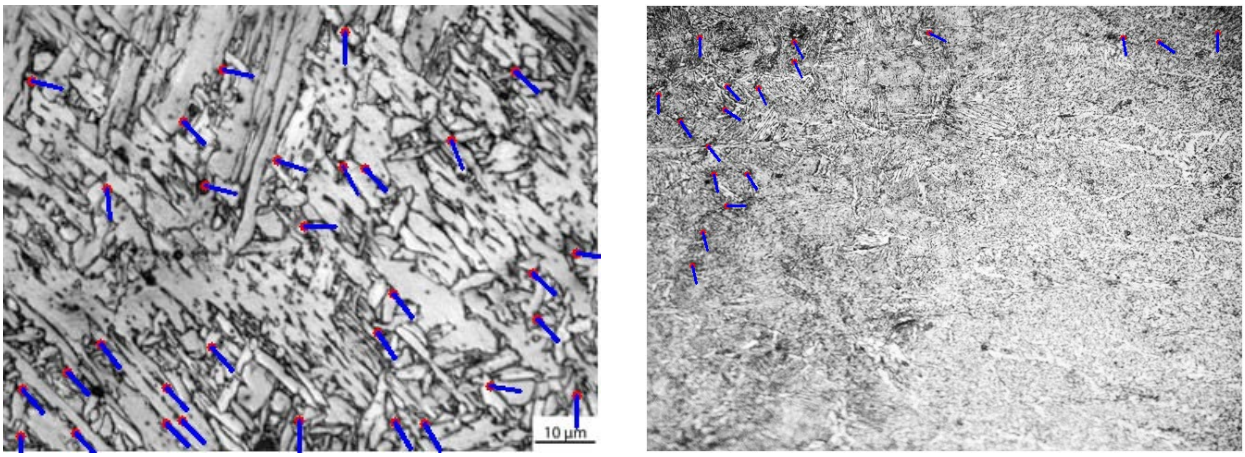
a **b**

Figure 2 - Identification of crystallite boundaries on samples of welded joints made of 09G2S steel at magnifications: a - 1000; b - 200.

Table 1 - Results of identification of crystallite boundaries.

Structure for growth	1000	200
Contours found:	490	5492
Crystallites were found after filtration:	31	18

A similar situation to the identification of crystallite boundaries is observed for the determination of grain orientation (Fig. 3). Data from the samples were obtained (Table 2).



a **b**

Figure 3 - Determination of crystallite orientation on samples of welded joints made of 09G2S steel at magnifications: a - 1000; b - 200.

The built-in method calculates the orientation of crystallite/grain contours (Fig. 4), it calculates the average orientation over the entire image. The minimum value between the absolute angle difference and 360 minus this difference is used, which is standard practice when measuring angle differences, to account for the cyclic nature of

angles. The method focuses on pairs of grains and calculates the orientation without considering the distances between them, which can lead to the analysis of irrelevant interactions between distantly spaced crystallites/grains. In this method, the orientation is calculated between each crystallite/grain and its nearest neighbour. The Euclidean distance between the centroids of the crystallites/grains is used to determine the nearest neighbours, making this approach more relevant for real-world conditions where crystallite/grain interactions occur mainly between nearest neighbours.

Table 2 - Disorientation of neighbouring crystallites/grains

Structure for growth / Disorientation angle	1000	200
0° - 15°	23	18
16° - 30°	2	0
31° - 45°	6	0
46° - 60°	0	0
61° - 75°	0	0
76° - 90°	0	0

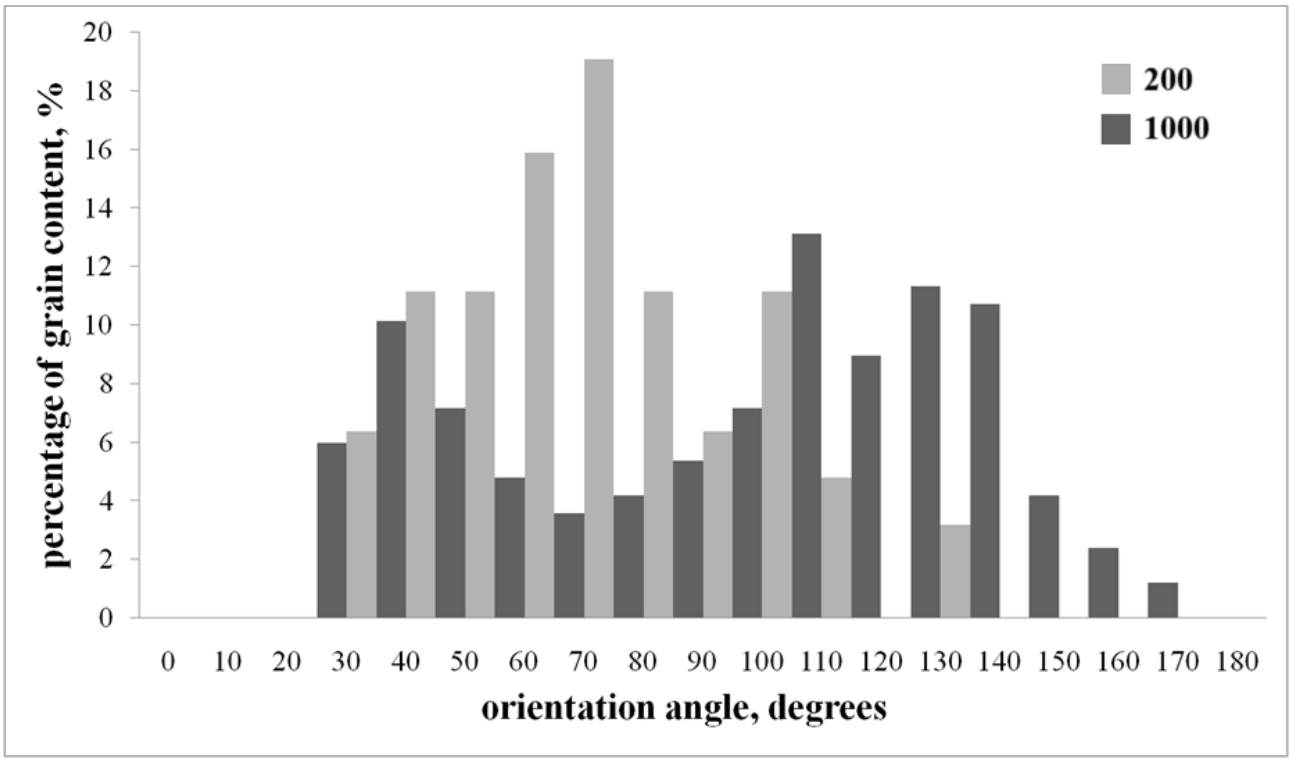


Figure 4 - Distribution of crystallite disorientation on samples of welded joints made of 09G2S steel at magnifications of 1000 and 200.

Table 3 shows additional parameters of the identified contours (Fig. 2), such as the value of a pair of contours, the angle of orientation, and the length of the contours. For example, 23 contours were identified from the sample at a magnification of 1000 after filtering.

Pairs of contours i-k	Orientation, angle[s]	Length of the contour and, px	The length of the contour is k, px
0-1	56.5	116.9	186
...	...	...	...
1-14	117.7	186	687.5
...	...	...	...
2-11	128.2	148.4	231.3
...	...	...	...
3-10	36.8	543.5	665.7
...	...	...	...
20-22	94.97744942	1631.322	2642.079

Summary and conclusions.

To summarise, there are several key factors that are relevant to orientation analysis by computer scanning of photographs:

- ✓ the quality of the photo, first of all, its resolution, is of key importance for computer analysis, because the photo is converted into a binary picture, and if the grain boundaries are outlined by fuzzy contours, the black-and-white analysis will be performed with a large error;
- ✓ for correct software analysis of the grain, its contour, which remains after binarisation, must be closed;
- ✓ the search for the orientation angle should be carried out to a clearly defined axis, because, for the subsequent search for misorientation, this can be a significant problem in terms of the adequacy of the results.

References:

1. Selin, R. V., Shvab, S. L., & Dyman, M. M. (2021). Microstructure and mechanical properties of parts from high-strength titanium alloys produced by WAAM method (Review). Suchasna Elektrometallurgiya (Electrometallurgy Today), (1),

39-47.

2. Diachenko, Y., Fedorov, M., & Liutyi, R. (2024). Effect of heat treatment on the mechanical properties and microstructure of pre-eutectoid steel for hot forming. Materials Processing by Pressure, (1(53)), 197-204. https://doi.org/10.37142/2076-2151/2024-1(53)197

3. Golovko, V. V., Kostin, V. A., & Zhukov, V. V. (2023). Influence of nanomodification on the formation of weld metal microstructure of low-alloy steels. Physicochemical Mechanics of Materials, (6).

4. Bushuev, O., Borodin, E., Bodyakova, A., Zhu, S., & Jivkov, A. P. (2025). Disorientation-based classification of mesostructures in severely deformed copper alloys. Acta Materialia, 286, 120714. https://doi.org/10.1016/j.actamat.2025.120714