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Parameterization of Microstructures in Material Science and Material Technology

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Abstract: The article deals with possible applications of multi-fractal parameterization of microstructures (MFP) fields of material science and welding. MFP is successfully used for fine selection of microstructures, specification of thermal treatment modes and others. Experimental data were recorded for samples manufactured from steels of austenitic class. The research also comprises data on dependence of grain size upon multi-fractal parameters of uniformity and orderliness got by other authors. The study suggests algorithm of predicting Vickers hardness on basis of multi-fractal parameterization of metallographic specimen by means of calculating the parameters of uniformity and orderliness. Program created on basis of algorithm allows analyze microstructure to determine the grain size.

Key words: Material science · Welding · Parameterization of microstructures · Microstructures · Steel · Welded joints

INTRODUCTION

One of important trends in material science is updating of structure research procedures, testing and determining the physical and thermo-mechanical properties of materials.

To determine reliability of constructions in process of operation, the diagnosis of structural state [1] and material mechanical properties is required, the properties being revealed by traditional methods of metallography and mechanical tests. But in a number of cases, this requires time- and labor-consuming operations. Promising technique to identify parameters of microstructure and predict material mechanical properties is procedure of multi-fractal parameterization (MFP) [2] developed on basis of fractal theory [3].

Method of multi-fractal parameterization of microstructures (MFP) allows detect the state of material with current variance of structures in scope of technology suggested. It becomes possible to select material structure, to discard structures sensitive to loading conditions.

MFP is successfully used to specify optimal conditions of thermal treatment where parameters of uniformity and orderliness are the most information-bearing parameters of canonical spectra. All kinds of «irregularities» of these multi-fractal characteristics during research of thermal treatment modes precede the beginning of large grains formation, their joining up to huge grains. Multi-fractal analysis of microstructures makes possible to specify proper raw materials and appropriate conditions of heat treatment. The sense of multi-fractal parameterization method is mathematical treatment of digitized metallographic pictures of material macro- and microstructures using «MFRDrom» software developed by G.V. Vstovsky [4-6].

Technique. Welded joints in machinery objects manufactured from steels of austenitic class were the objects of research.

Metallographic specimen were got with the help of automatic setup for grinding and polishing. Krupp reactive agent with 20 sec. etching time was used to reveal steel grain boundaries. Recording of microstructure pictures was performed with the help of stationary

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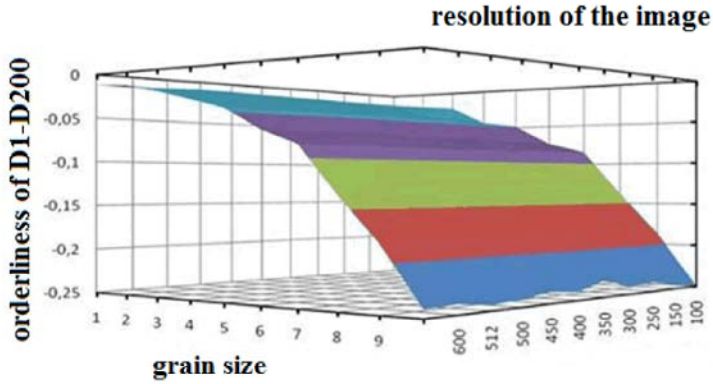

Fig. 1: Dependence of orderliness from grain size and image resolution

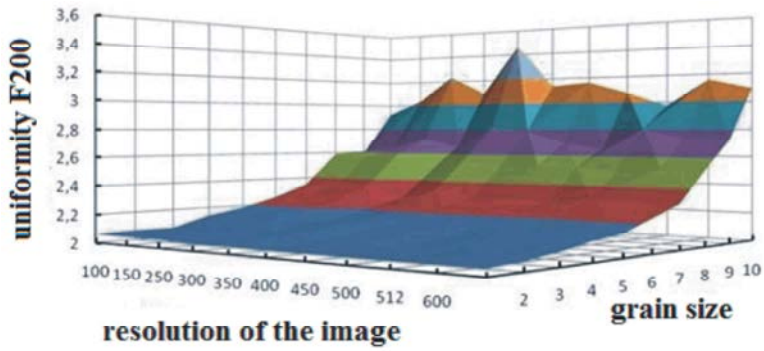

Fig. 2: Dependence of uniformity from grain size and image resolution

1000-power microscope with "AxioCamHR" built-in digital camera to record photos; personal computer with software set: AxioVision, Adobe Photoshop, MFRDrom, MS Excel, MathCAD.

Preliminary preparation of pictures of structures studied supposed the treatment of digital images using computer graphics methods. With this, out of photos in "JPEG" format got from microscope digital camera, 9 zones were cut symmetrically to initial image; then, they were converted to "BMP" bit format with maximum contrast and image resolution of 300pixels/inch by method of "50% threshold". Processing of studied series of microstructures supposed their loading into "MFRDrom" soft, selection of spectrum type (Canon or Pseudo), number of decimal places, main color of structure, surface of coating. Vickers method was used to assess mechanical properties of steel of austenitic class. Characteristics of regularity ?q = D1 – Dq and uniformity Fq were specified as main multi-fractal parameters, they were calculated with the help of "MFRDrom" software by means of screening the design mathematical parameter q which characterized the orderliness of saturation.

Main Part: Authors analyzed data of researches got by A.D.Anvarov (image resolutions 250-512) [7] and acquired their own results. In view of these results, they stated that there exists rather distinct correlation (Fig. 1 and Fig. 2) between grain size, resolution with which image was got and parameters of uniformity and orderliness. This may become basis to determine grain size for its computer-aided evaluation.

In actual conditions, during welding, various defects appear, e.g. hot cracks. Besides, faults in specimen may be caused by their poor preparation. So, calculation of uniformity and orderliness characteristics was performed for proper welded joints and for faulty ones. Crack along welded joint was taken as fault.

For all specimen studied, the following equations were got with approximation and smoothing: cross-section hardness in transverse direction in welded joint; structure uniformity F_{200} and orderliness $D_1 - D_{200}$. Hardness may be predicted by means of specifying the functions, compiling the matrix of planning the complete factor experiment, assessing the uniformity of response function dispersions and calculating the ratios of simulation model polynomial.

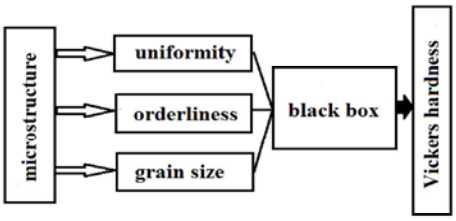

Fig. 3: Algorithm of hardness prediction

Algorithm shown in Fig. 3 includes the following stages:

- Acquisition of sample microstructure.
- At this stage, the corresponding parameters are calculated using «MFRDrom» software: uniformity F_{200}, orderliness $D_1 - D_{200}$ and grain size for various sections of welded joint.
- At this stage of algorithm, approximation of HV hardness, F_{200} uniformity and $D_1 - D_{200}$ orderliness functions is performed, with reference to coordinates of welded joint, i.e. separate sections and zones will have strictly definite values of approximated functions.

CONCLUSION

Authors of article performed adaptation of structural parameterization method [8-10] to study steels of austenitic class, which included preparation of images of welded joint microstructures, various grain sizes for welded joint, zone of heat treatment and main metal, different orientation of grains after grinding and etching, defects of welded joints. The factors specified above influence the uniformity and orderliness of welded joint structure as a whole and of separate zones in particular. During their study, it is crucial to assure proper selection of sites for structural parameterization, number of such sites with correction to possible deviations in modes and etching irregularities, index of microscope power and other factors, i.e. at most similar conditions must be provided for parameterization of welded joints should.

Carrying out of such analysis may be useful to predict hardness in sections of metal of machine parts where for some reason hardness can't be determined during mechanical tests or it is required to restore its values in sections not measured.

Resume:

- Application fields of MFP in material science and welding were revealed.
- On basis of analysis of research data and their own additional study, interdependence of multi-fractal parameters, image resolution of microstructure and grain size in their wide range was formed.
- There was revealed how the specimen and welding defects influence the results of microstructure parameterization. Such defects are as follows: pores, slag inclusions in welded joints, hot cracks. Quality of specimen preparation for micro researches may influence the results of MFP.
- Authors proposed algorithm to predict hardness on basis of calculation of microstructure uniformity and orderliness parameters.

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