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Methodology of classification of internal damage the steels during creep service

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Methodology of research

ABSTRACT

Purpose: of this publication is to present the methodology of computer assisted method for analysis of the metallographic images obtained in the scanning electron microscope (SEM) from the elements after long time creep service.
Design/methodology/approach: Stages in development of internal damage involving intercrystalline cavitation cracking were discussed and illustrated with micrographs. The method based on analysis of images, shape coefficients and neural networks was proposed as a tool to evaluate the internal damage classes of materials used for the high-pressure installations elements working in creep conditions.
Findings: Combining of several methods making use of the image analysis, shape coefficients, and neural networks will make it possible to achieve the better efficiency of class recognition of damages developed in the material.
Practical implications: The presented method can be use in industrial practice for evaluation and qualification of creep-damage of power station boiler components operating in creep regime (e.g., steam boilers, chambers, pipelines, and others).
Originality/value: Original value of the work is applying the artificial intelligence method for the classification of internal damage in the steel during creep service.
Keywords: Images analysis; Steels; Creep service; Internal damage

1. Introduction

In most of the power units of the power rating up to 200MW the constructional elements working in creep conditions are made from low-alloy chromium steels with molybdenum. Results of investigations and own observations are presented below, in the area of forming and generating of internal damages, in the chromium–molybdenum steels after varying service periods in the power station boiler components. Obtained results of the structural examinations in connection with the creep test results after their long-time service made it possible to work out the classification of the internal damage growth, depending on the extent of life exhaustion [2-4,14,15].

Computer applications and artificial intelligence method are often use as the forecast support tools to make the engineering tasks easier and to improve their efficiency [6-12]. The goal of the paper is the development of the computer assisted method employing image analysis, shape coefficients and neural networks for the automatic classification of damages of materials used for power systems in creep service. They are the continuation of the own research on developing internal damage classification method [1-4].

2. Material

Material for investigation was acquired from collectors and chambers of the pressure part as well as from the main and crossover steam pipelines of the power station boilers operating in creep regime. Elements were made from the 1Cr-0.5Mo steel and their working conditions were as follows :

- operating temperature 520-560°C
- real stress 35-120MPa
- working time 60000-250000h

The chemical composition of this steel is given in Table 1. The photos were taken employing the scanning electron microscopy (SEM) and converted to the digital format with 256 levels grey scale. The database of standard images with the development phases of the damage processes was created.

2. Investigation of the structure of the Cr Mo steel with internal damages

The structure changes during elevated temperature acting and stresses are the proximate causes of internal damages creating and their growth processes in elements working in creep conditions. At the beginning singular voids generated as the result of slide acting on the grain boundaries (Fig. 1).

Table 1
Chemical composition of 1Cr- 0.5Mo steel

Range	Mass chemical composition [wt.%]							
	C	Mg	Si	P	S	Cr	Mo	Al
Min	0.11	0.40	0.15	0	0	0.70	0.40	0
Max	0.18	0.70	0.35	0.04	0.04	1.00	0.55	0.02

In most cases voids are nucleated on the boundaries of the grain situated by the angle of 45° or 90° to the stresses axis (Fig. 2).The next step in cavitations creep is the growth of the voids as the result of diffusion and deforming mechanism. Than on the grain boundaries occur the chains of voids and they are connecting one another as the result of coalescence (Fig. 3). As in consequence of this phenomena the initiation of small surface intercrystalline crevices are observed. At the beginning they are observed only in one grains, than they are widen to some grains creating microcracking (Fig. 4). The simultaneously acting of internal damages in different area leads to macrocracks. The presence of internal damages, independent the degree of structure changes, decides the possibilities of the element exploitations was made. Based on the investigations carried out, the observation of the internal damages growth and the literature studies the classification of damages versus the degree of material exhaust were made (Fig. 5) [2]. The additional 0 classes with no internal damages of the structure is introduced.

The classification of internal damages were simplified to 5 main classes to meet the needs of neural network model. The model is under construction and it will be improved with used all the classes in the future.

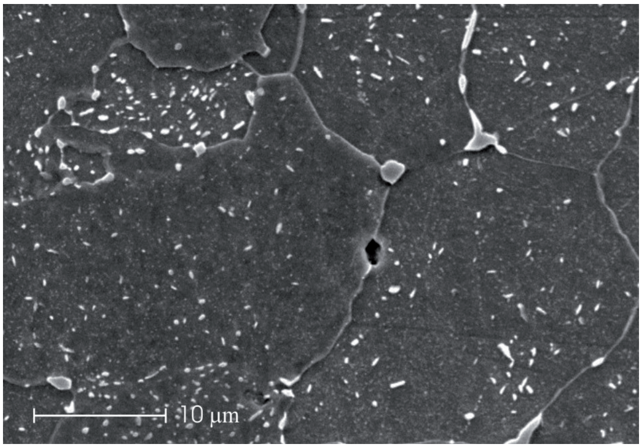

Fig.1. Singular voids irregular displaced on the boundaries of ferrite grains (SEM)

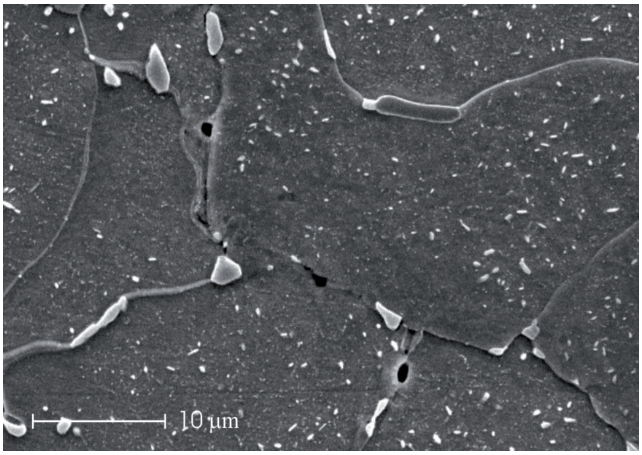

Fig.2. Voids oriented by the angle 45° or 90° to the stresses direction acting axis (SEM)

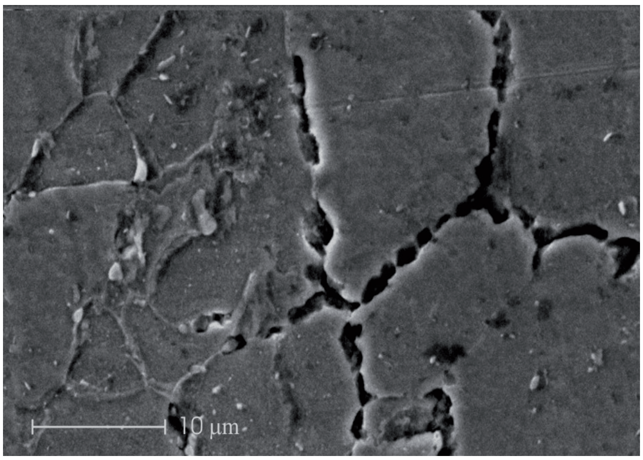

Fig.3. Coalescence of voids (SEM)

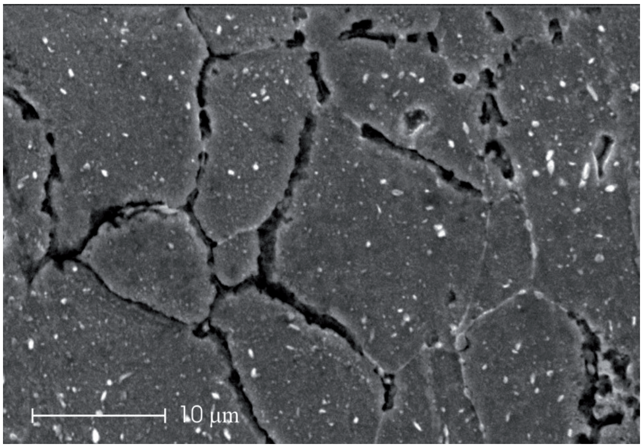

Fig.4. Intercrystalline crevices occurring on gains a dozen or so grains (SEM)

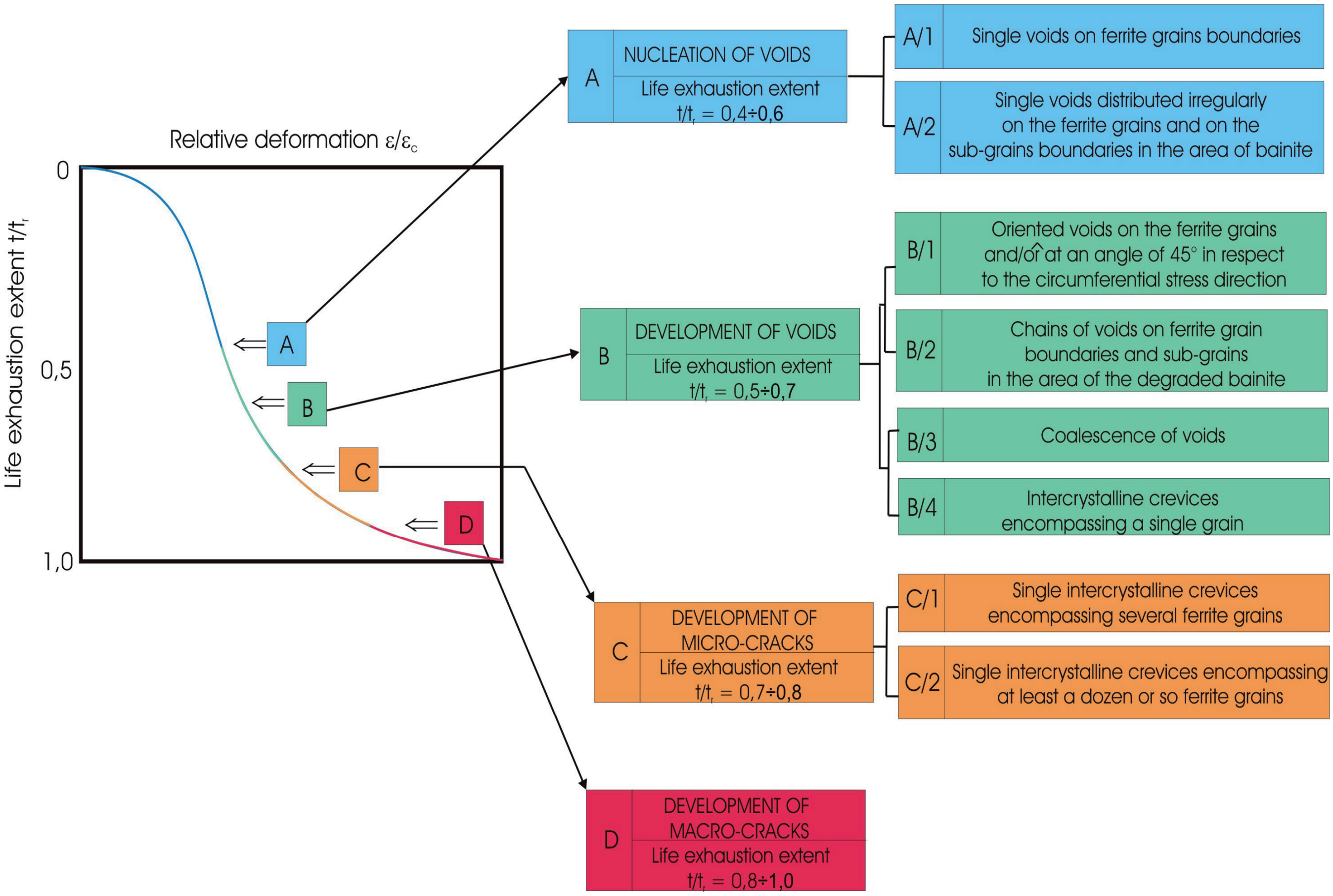

Fig. 5. Development of the internal defects after creep service for the Cr - Mo steel.

Table 2.
The parameters of the best network used for the classification of internal damage

Input vectors	Network structure	Training method	Number of training epoc
minA, maxA, mA, mC, mcR, Mc, mcC1, mcC2, mmD	Multilayer Perceptron 9-6-5	Back Propagation	3500

4. Computer classification of internal damages

To solve the problem of internal damages classifications in steels working in creep conditions, the metallographic structure photos from scanning electron microscope were used and the following methodology was applied :

- initial processing of images (unification of format, contrast and resolution),
- binarisation (the threshold was chosen experimentally),
- median filtration,
- binary erosion,
- calculation of area (A) and circumferences of chosen elements (C),
- calculation of minimum distance between objects (minDis),
- evaluation of shape coefficient of circularity1 (R_{c1}), coefficient of circularity2 (R_{c2}), Malinowska coefficient (WM coefficient of roundness (WK) [13],
- application of neural networks to degree of internal damages classifications.

For recognition of the material damaged classes neural network were use. The data set employed in the model development process using the neural network was split into three subsets: training, validation, and the test one. The parameters of the best network are presented in Table 2.

The task of the development of a neural network required to determine the following quantities: type of the neural network, the size of hidden layers and the number of neurons in individual layers, the type and form of the activation function, variable scaling procedure, function of error and neural network training technique and parameters.

All the parameters mentioned above were selected after the analysis of their influence on the assumed quality coefficients The number of neurons in both the input (9) and output (5) layers were established. The neural activation level in the input layer was made dependent upon the: minimum area (minA), maximum area (maxA), mean area (mA), mean circumference (mC), mean coefficient of roundness (mcR), Malinowska coefficient (Mc), mean coefficient of circularity1 (mcC1), mean coefficient of circularity2 (mcC2), mean minimum distance (mmD).

A single neuron within the output layer meant the five classes of internal damages. A multilayer perceptron (MLP) network with a six hidden layer and bipolar continuously activation function were chosen. The neural network was trained using the Back Propagation algorithm for the next 3500 training epochs.

5. Conclusions

Computer classification of the internal damages can be used with success as forecast support tools in engineering practice. The accuracy and the dependability of this method vastly depends on the place choosing to take the metallographic structure, the proper interpretation of observed metallographic structure and the need of engagement of expert with sufficient practical knowledge.

Results of investigations show that computer assisted method of metallographic structure images classifications of element working in creep conditions based on image analysis shape coefficients and neural networks is a useful tool for internal damage classification.

Connection of all these methods will allow to obtain greater effectiveness in recognition an classification of material internal damages.

References

[1] L.A. Dobrzański, J. Dobrzański, J. Madejski, J. Zacłona, The conception of a computer aided decision making system connected with the residual life of the elements of power installations in the conditions of creep, J. Mat. Proc. Tech., Vol. 56, pp. 718-728, 1996

[2] J. Dobrzański, Internal damage processes in low alloy chromium–molybdenum steels during high-temperature creep service, J. Mat. Proc. Tech., Vol. 157-158, pp. 197-303, 2004

[3] J. Dobrzański, The classification method and the technical condition evaluation of the critical elements' material of power boilers in creep service made from the 12Cr-1Mo-V, J. Mat. Proc. Tech., Vol. 164-165, pp. 785-794, 2005

[4] J. Dobrzański, Material diagnostics in evaluation of the state and extended service time forecast in addition to the computational life of pipelines in creep service, Power Engineering, 12, 2002, pp. 937- 943 (in Polish).

[5] L.A. Dobrzański, Fundamentals of Materials Science and Physical Metallurgy Engineering Materials with Fundamentals of Materials Design, WNT, Warszawa, 2002 (in Polish).

[6] L.A. Dobrzański, M. Krupinski, J.H. Sokolowski, Computer aided classification of flaws occurred during casting of aluminum, J. of Mat. Proc. Techn., Vol. 167, Is. 2-3, 2005, pp. 456-462.

[7] L.A. Dobrzański, M. Kowalski, J. Madejski: Methodology of the mechanical properties prediction for the metallurgical products from the engineering steels using the artificial intelligence methods, J. of Mat. Proc. Tech., Vol. 164–165, 2005, pp. 1500–1509.

[8] L. A. Dobrzański, W. Sitek, M. Krupiński, J. Dobrzański, Computer aided method for evaluation of failure class of materials working in creep conditions, J. Mat. Proc. Tech., Vol. 157-158, pp. 102-106, 2004.

[9] B. Tyler, App. Surf. Sci., Interpretation of TOF-SIMS images: multivariate and univariate approaches to image de-noising, image segmentation and compound identification, Vol. 203-204, pp. 825-831, 2003.

[10] H. Zheng, L.X. Kong, S. Nahavand, Automatic inspection of metallic surface defects using genetic algorithms, J. Mat. Proc. Tech., Vol. 125-126, pp. 427-433, 2002.

[11] L.A. Dobrzański, W. Sitek, Application of neural network in modeling of hardenability of constructional steels, Journal of Materials Processing Technology, 78 (1998) 59-66.

[12] L. Miaoquan, Ch. Dunjun, X. Aiming, Li. Long, An adaptive prediction model of grain size for the forging of Ti–6Al–4V alloy based on fuzzy neural networks, Journal of Materials Processing Technology, 123 (2002) 377-381.

[13] R. Tadeusiewicz, P. Korohoda, Computer assisted image analysis and processing, Development in telecommunication Press, Cracow 1997 (in Polish).

[14] A. Hernas, J. Dobrzański, Life-time and Damage of Boilers and Steam Turbines Elements, Silesian University of Technology, Gliwice, 2003 (in Polish).

[15] J. Dobrzański, A. Hernas, Relationship between micro-structure and remanent life-time of low alloy Cr–Mo steels, in: Proceedings of the Sixth International Conference on Creep and Fatigue, London, 1996, 451-461.