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Ausferritic Microstructure Phase Analysis in Ductile Iron

W. Trzaskowski *, P. Nawrocki, K. Łukasik, D. Myszka
Department of Metal Forming and Foundry,
Warsaw University of Technology, Narbutta 85, Warsaw, Poland
* Corresponding author: E-mail address: wtrzaskowski23@wp.pl

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Abstract

Image analysis allows to acquire a number of valuable quantitative informations on the observed structure and make appropriate conclusions. So far, a large part of analyzed images came only from light microscopes, where it was a possibility of accurately distinguish the different phases on the plane. However, the problem happened in the case of the observation of images obtained by scanning electron microscopy. In this case, the presence of various shades of gray, and the spaciousness of the image attained. To perform the analysis the matrix images of the ausferritic ductile iron were used. Full analysis was carried out using the computer program MicroMeter 1.03. Results obtained in the analysis were related directly to the results from X-ray diffraction. Obtained as a result of the analysis were related directly to the results from X-ray diffractometer.
The following technique has weaknesses, including the misinterpretation by the operator microscope or program. After all, it was possible to obtain similar results to the result that has been obtained from X-ray diffractometer.

Keywords: Image analysis, Ausferriticductile iron, ADI, X-ray diffraction, Austenite, Ferrite

1. Introduction

The object of the analyzes and observations was the matrix of ductile iron ADI. This material in terms of the numer of publications and various types of research can be considered aspopular. A special interest is in the field of heat treatment. It is worth mention that the share of this material in today techniques is becoming more popular, because of its tensile and mechanical properties. Ausferritic ductile iron can be found in the machine elements such as shafts, wheel hubs and brake pads [1,2].

Due to the main object of analysis crucial is to mention about what is included in the matrix of ductile iron ADI. In this particular case, in the matrix, we can make a distinction between two characteristic ductile iron ADI phases. The matrix is a mixture of austenite and ferrite. On the metallographic images the most visible structure is ferrit in the form of fine needles, which is in fact present in the form of flakes or plates. In contrast, austenite is often visualized as unregular white spaces between ferrite needles. The structure of this type has gain its own name - ausferrite (fig.1) [3,4,5].

Structure of this type can be obtained in the process of withstanding supercooled austenite at a temperature of isothermal transformation. The amount of austenite in ductile iron ADI usually reaches about 40%. Austenite is very desirable component of the microstructure, since under the influence of tension it undergoes a martensitic transformation, which results in strengthening of the material [1,5,6].

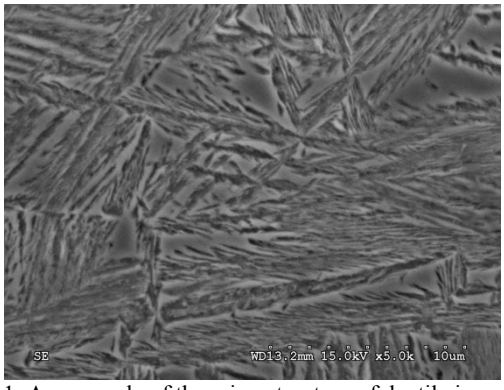

Fig. 1. An example of the microstructure of ductile iron ADI matrix

Figure 2 shows a schematic process of austempering ductile iron as a method to obtain an ADI. In this process it is possible, inter alia, to provide a structure in the nano-scale. For short transformation times (point A on Fig.2), Ductile Iron has a matrix almost fully martensitic, containing a small amount of ferrite plate-shaped precipitates.

This is due to complete transformation at ambient temperature of the thermally unstable austenite. Slightly longer time of the transformation increases ferrite content in the form of packets of plates separated by carbon-rich austenite (point B on Fig.2). The continuation of transformation leads to austenite stabilization (point C on Fig.2). This makes the matrix of ductile iron fully ausferritic with austenite present in two forms, i.e. in the form of layers separating the plates of ferrite and in the form of blocks located between the ferritic-austenitic packets. Very long time of the isothermal transformation usually leads to the formation of typically bainitic microstructure or, in term of very low temperature of austempering, could leads to the nanoausferritic structure (D point on Fig. 2) [11,12]

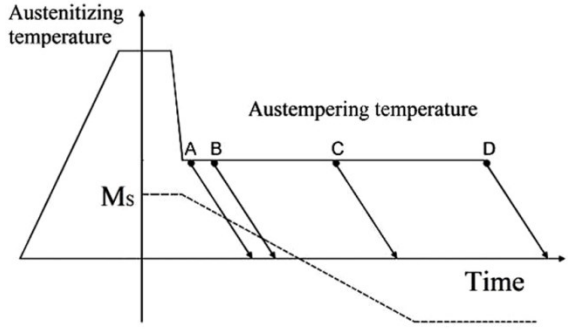

Fig. 2. Schematic representation of isothermal transformation of ductile iron [12]

In the case of knowledge about materials image analysis found a special place in science called stereology. This science focuses, among other things, on the quantitative volume fraction, measuring the surface separating boundaries of the grain or determination of the number and size of individual particle structure parameters [9,10].

In the era of computer technology and digital photography, it became possible to utilization the image analysis of different types of programs. Basically, we can define the image analysis as the process of extracting from the digital image information relevant to the user. To perform a successful analysis one should go through three major research issues (Fig. 3) [7,8,9,10].

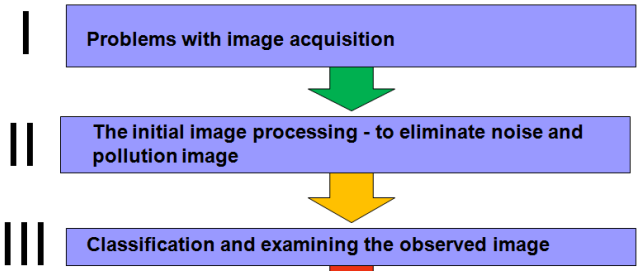

Fig. 3. Computer image analysis - three key research issues

In the case of observation only a single factor or simple images, the research may be carried out automatically. When it comes to such a complex process as metallographic image analysis, despite increasingly sophisticated tools, operator perform a large role. His decisions largely reflected on the results of the analysis.

2. Work Methodology

Image analysis was performed on the metallographic images from electron microscope (SEM). Researches were performed for the six samples of ADI containing different amounts of austenite in the matrix. The chemical composition of ductile iron are shown in Table 1. For the analysis of microstructure the MicroMeter 1.03 program was used (Figure 4).

Innovative issue that appeared in the publication is to develop a methodology of analysis of the structure contains certain amount of nanomaterial and exclusion the misinterpretation from an image the austenite blocks.

Table 1.
The chemical composition of the tested ADI samples

	Chemical composition [%wt]						
	C	Si	Mn	Cu	Mo	Ni	Mg
Sample 1	3,35	3,62	0,18	0,031	0,593	0	0,06
Sample 2	3,35	3,62	0,18	0,031	0,593	0	0,06
Sample 3	3,53	2,73	0,59	0,45	0	0,537	0,05
Sample 4	3,5	2,54	0,16	0,013	0,041	0	0,24
Sample 5	3,5	2,54	0,16	0,013	0,041	0	0,24
Sample 6	3,44	2,32	0,28	1,13	0	0,029	0,05

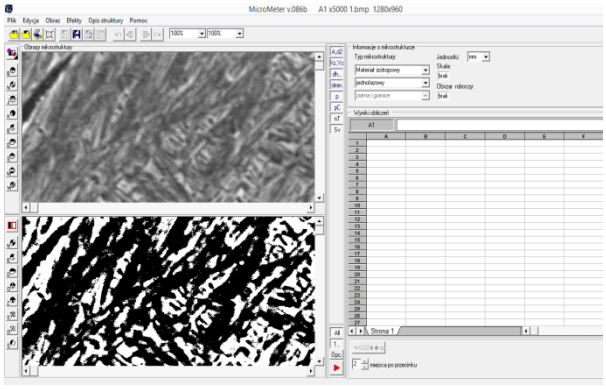

Fig. 4. The interface of MicroMeter 1.03 program

The program offers a range of essential tools for basic image editing. It has features such as contrast, brightness, invert, sharpen and local average. Carrying out the best analysis requires selection of optimal editing parameters. The applicable of the single system processing to all images would be a good solution.

The image obtained from a scanning electron microscope (Fig. 1) usually contains many shades of gray. To bring the image into a form which permits the analysis the binarizatiom process must be carried out.

Binarization (Fig. 5b) rely on converting color or monochrome (grayscale) image into a two-level (binary) image. Most often this process is carried out by thresholding, which is based on determining the threshold value, below which image pixels are classified as object pixels. The remaining pixels are classified as background pixels [9].

a) b)

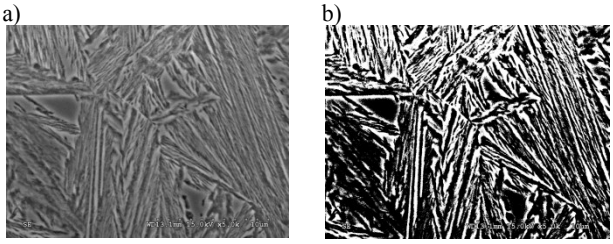

Fig. 5. a) SEM image in shades of gray, b) SEM image after the binarization process

MicroMeter 1.03 program apart from the functions for image processing, has a range of tools by which we can extract from it the necessary information. First, the type of material is defined. Whether it is a material one phase or two-phase and determine the scale of the image. After these arrangements, we can proceed to the correct measurement.

Basically, for the purposes of comparison only one parameter that describes the contents of one of the structural components, ie. Austenite was used. In the program, this information has been concluded under the symbol Vv - the volume fraction of particles.

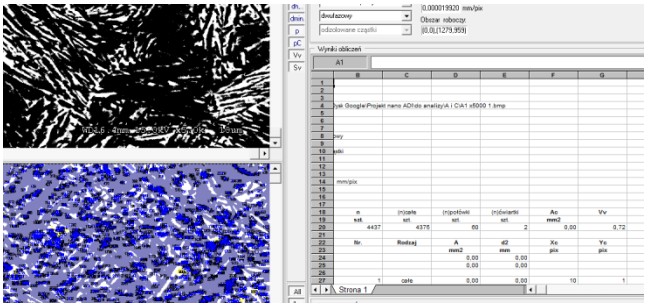

Fig. 6. Workspace image of MicroMeter 1.03 program, on the right is analysis results table

For this type of analysis a very large impact on the results was austenite block. Forparticular images revealed itself as dark spots on a bright background light austenite grain (Figure 7).

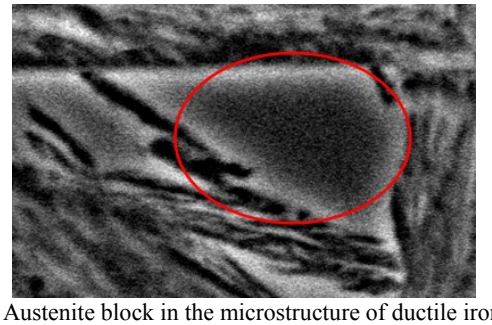

Fig. 7. Austenite block in the microstructure of ductile iron ADI

Image processing and binarization process using standard image editing tools brought no effect. Image editing led primarily to significant abnormal analysis results. Despite the efforts related to the global elimination of austenite block we failed to find fully automatic solution. To obtain meaningful results, efforts associated with manual diagnosis and removal of the image austenite block have been taken. Dark patches of bright austenite grains were cut using a separate program for image processing (Figure 8).

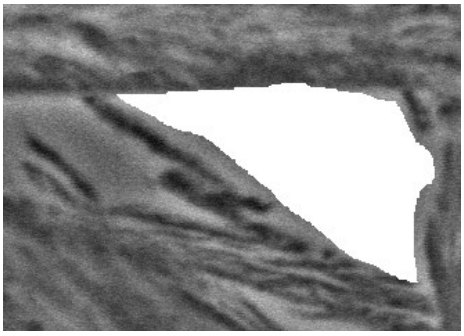

Fig. 8 Elimination austenite block from image

The results obtained in the analysis process were subjected to a comparison with the results of X-ray diffraction

3. Description of results

After determining certain most favorbleparametersfor images from electron microscope,the comparative analysis of the samples was carried out. For each material, three pictures of the same magnification were used. In the case of analyzes magnification was × 5000.

X-ray diffraction studies were performed on diffractometer DRON 1,5. X-ray cobalt anode tube irradiation was used.

Table 2.
The result of image analysis for samples I

	Sample I				Average
Ferrite	**72%**	**75%**	**67%**	**76%**	**72,5%**
Austenite	**28%**	**25%**	**33%**	**24%**	**27,5%**

Table 3.
The result of image analysis for samples II

	Sample II				Average
Ferrite	**77%**	**83%**	**74%**	**67%**	**75,25%**
Austenite	**23%**	**17%**	**25%**	**27%**	**24,75%**

Table 4.
The result of image analysis for samples III

	Sample III				Average
Ferrite	**51%**	**62%**	**71%**	**63%**	**61,75%**
Austenite	**49%**	**38%**	**29%**	**27%**	**38,25%**

Table 5.
The result of image analysis for samples IV

	Sample IV				Average
Ferrite	**73%**	**76%**	**81%**	**75%**	**76,25%**
Austenite	**27%**	**24%**	**19%**	**25%**	**23,75%**

Table 6.
The result of image analysis for samples V

	Sample V				Average
Ferrite	**73%**	**82%**	**76%**	**78%**	**77,25%**
Austenite	**27%**	**18%**	**24%**	**22%**	**22,75%**

Table 7.
The result of image analysis for samples VI

	Sample VI				Average
Ferrite	**65%**	**72%**	**68%**	**74%**	**69,75%**
Austenite	**35%**	**28%**	**32%**	**26%**	**30,25%**

Table 8.
The results of X-ray diffractometer

Number of sample	Austenite	Ferrite
Sample I	**15,75%**	**84,25%**
Sample II	**22,21%**	**77,79%**
Sample III	**34,69%**	**65,31%**
Sample IV	**22,37%**	**77,63%**
Sample V	**21,65%**	**78,35%**
Sample VI	**27,96%**	**72,04%**

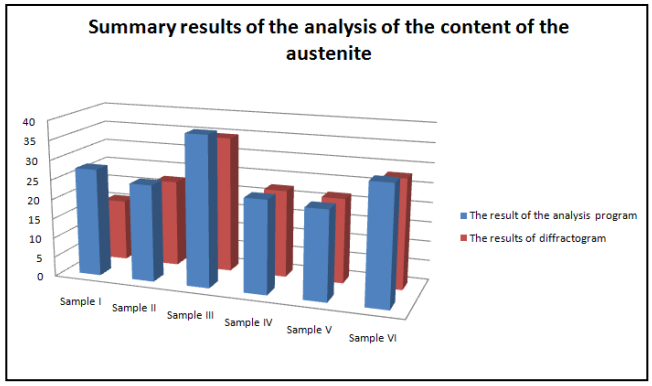

Fig. 9. Chart of the analysis of the contents of austenite for the analysis carried out by the program and the diffraction patterns

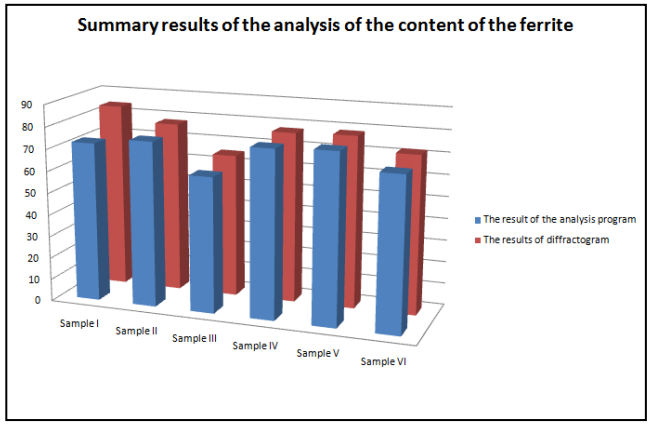

Fig. 10. Chart of the analysis of the content of Ferrite for analysis done by the program and the diffraction patterns

4. Conclusions

As a result of advanced image analysis coming from a scanning electron microscope we was able to get the results of the content of the various phases in the matrix of ductile iron ADI.

The results are similar to the results obtained from X-ray diffraction. However, this results are not perfect.. The results from the image analysis are encumber with a large scatter.

Very important in this type of analysis is the quality of the image as well as the experience and skill of the operator of a microscope and the program.

The presented methodology enables image analysis, however, the final result is a very time-consuming and labor-intensive processes.

Acknowledgements

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References

[1] Kaczorowski, M. (2001). Structure and mechanical properties of ADI cast iron. *Archiwum Odlewnictwa*. 1(1/2), 149-158. (in Polish).

[2] Myszka, D. & Kaczorowski, M. (2001). Structural studies of ADI cast iron obtained by direct isothermal quenching from sand form. *Archiwum Odlewnictwa*. 1(2/2), 263-270. (in Polish).

[3] Ostrowski, D., Gumienny, G. Sikora, M. Kruszyński, B. & Pacyniak, T. (2015). Workability of ADI spheroidal cast iron in the process of sanding external cylindrical surfaces. *Mechanik*. 8-9, 262-265. (in Polish).

[4] Zamit, Z., Abeal, S., Wagner, L., Mhade, M. & Grech, M. (2013). Tribological behaviour of shot peenend Cu-Ni austempered ductile iron. *Wear*. 302, 829-836.

[5] Vedel-Smith, N.K., Rasmussen, J. & Tiedje, N.S. (2015). Thermal disortion of disc-shaped ductile iron castings in verticaly parted moulds. *Journal of Materials Processing Technology*. 217, 262-270.

[6] Benam, A.S., Yazdani, S., Avishan, B. (2011). Effect of shot peening process on fatigue behaviour of an alloyed austempered ductile iron. Overseas Foundary. 331-336

[7] Wejrzanowski**,** T. Lewandowska, M. & Kurzydłowski, K.J. (2010). Stereology of nanomaterials. *Image Analysis and Stereology*. 29, 1-12.

[8] Wejrzanowski**,** T., Spychalski, W.L., Rożniatowski, K. & Kurzydłowski, K.J. (2008). Image based analysis of complex microstructures of engineering materials. *International Journal of Applied Mathematics Computer Science*. 18(1), 33-39.

[9] Woźnicki, J. (1996). *Basic imaging techniques*. Warszawa: Wydawnictwo Komunikacji i Łączności. (in Polish).

[10] Ryś, J. (1995). Stereology of materials. Kraków: Fotobit-Design. (in Polish).

[11] Myszka, D., Skołek, E. & Wieczorek, A. (2014). Manufacture of thoothed elements in nanoausferritic ductile iron. *Archives of Metallurgy and Materials*. 59, 1227-1231.

[12] Myszka, D. (2016). On the structure of ausferrite in ductile iron. Proceedings of the 72nd Wold Foundry Congress, 21-25th May, Japan.