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Computer aided method for quality control of automotive Al-Si-Cu cast components

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Analysis and modelling

ABSTRACT

Purpose: The technological progress in material engineering causes the continuous need to develop product testing methods providing comprehensive quality evaluation. In material engineering it is the images obtained by various methods that have become the source of information about materials.
Design/methodology/approach: The presented methodology, making it possible to determine the types and classes of defects developed during casting the elements from aluminum alloys, making use photos obtained with the flaw detection method with the X-ray radiation. The tests indicate to the applicability of neural networks for this task. It is very important to prepare the neural network data in the appropriate way, including their standardization, carrying out the proper image analysis and correct selection and calculation of the geometrical coefficients of flaws in the X-ray images.
Findings: In classical computer algorithms even a slight rotation or change in lightning can hinder the proper interpretation and alternation of variable input data. To eliminate this hindrance the programming can be converted by specifying such features of the structure element that remain most significant and affect the similarities of the analysed images. In neural networks this particular feature needs not to be specified – if necessary, the neural network spots it automatically.
Practical implications: The computer aided methodology of the quality control of the light Al and Mg based alloys may be used by manufacturers of subassemblies and elements of car engines.
Originality/value: The value of the applied methodology was to correct identify the casting effects that occurred during the casting process.
Keywords: Methodology of research, Technological process, Al-Si-Cu, Images analysis, Cast defects

1. Introduction

Aluminium alloys have become popular in automotive industry owing to their low weight and some casting and mechanical qualities. The main component of aluminum alloy casting is Si. The eutectic structure in Al-Si casting alloys and Si concentration largely affect the porosity (pore volume) [1-8].

Quality casting alloy may be identified by various research methods including microscopy, thermographic and defectoscopic methods such as X-ray method [9,10].

The images are used in materials examination methods that feature the information source on material's structure, processes taking place in it, and its properties. Images obtained with the flaw detection methods, e.g., radiological or ultrasonic ones, are used for detecting material defects developed on various stages of the technological process [11, 12].

The specific character of images does not always allow using directly the methods and means of the classic image recognition and digital processing theory. The lack of the uniform theory and general approaches renders extremely difficult selection of image processing and recognition algorithms and acquiring the right assessment of their effectiveness. Computer assistance is used more and more often to optimise the image processing task and improve its efficiency. Computer "vision" features the relatively new image technology developing very rapidly. Its main goal is the desire to furnish the computer with the image recognition and processing potential comparable with the living organism endowed by nature with the power of seeing. This stands for furnishing the computer with the artificial intelligence algorithms, whose goal is providing it with the capability of the autonomous use of its own input sensors for detection of the spatial information [13-18].

2. Experimental procedure

Examinations were carried out on the car engine elements' castings, i.e., blocks (Fig. 1) and heads from the W319 aluminium alloy.

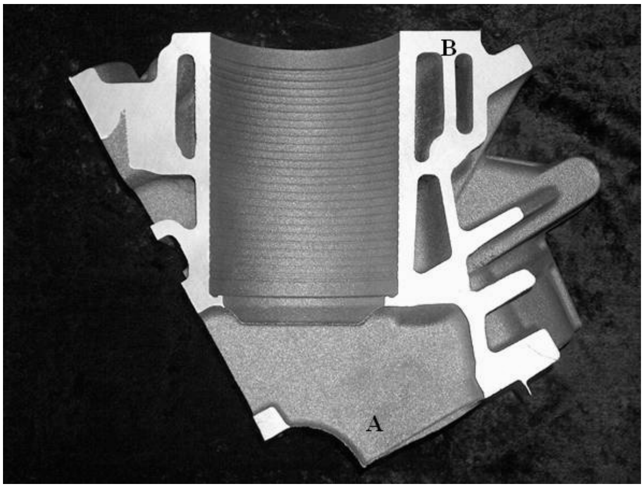

Fig. 1. The fragment of a section of car engine block

Following investigations were performed:

- investigation of the alloy structure and cast defects morphology coming into existence in the aluminium alloy (etching 30% HBF_4) using light microscope MEF4A supplied by Leica. The microscope was connected to an image analysis system Leica-Qwin,
- the defect detection examinations were carried out with the X-ray method for the castings of the six- and eight-cylinders car engine blocks made with the "Cosworth" method" [19]. The examinations were made on the Philips MGC 30 rentgenograph at voltage of 100 kV and current of 10 mA. Exposure time was always 10 seconds. Several hundred electronic photos of the analysed castings of the combustion engines' blocks and heads used for further analyses Classification of casting defects identified in castings of the combustion engines elements was carried out based on the ASTM E155 standard.

Methodology of processing the information contained in images showing the examined castings of the engine blocks and heads, using the developed computer program, includes [20, 21]:

- normalising parameters describing images of castings (size, scale),
- carrying out analysis of digital images showing sections of engine blocks and heads to extract casting defects from the image,
- calculation of areas, perimeters and geometrical coefficients of casting defects,
- calculation of the geometrical values of casting defects, used as independent variable for the neural networks training.

Extracting images of defects consists in such data processing and further applying image analysis methods, so that the defect image is represented in 1-bit format, neglecting the objects which are the technological openings and are not defects (Fig. 2).

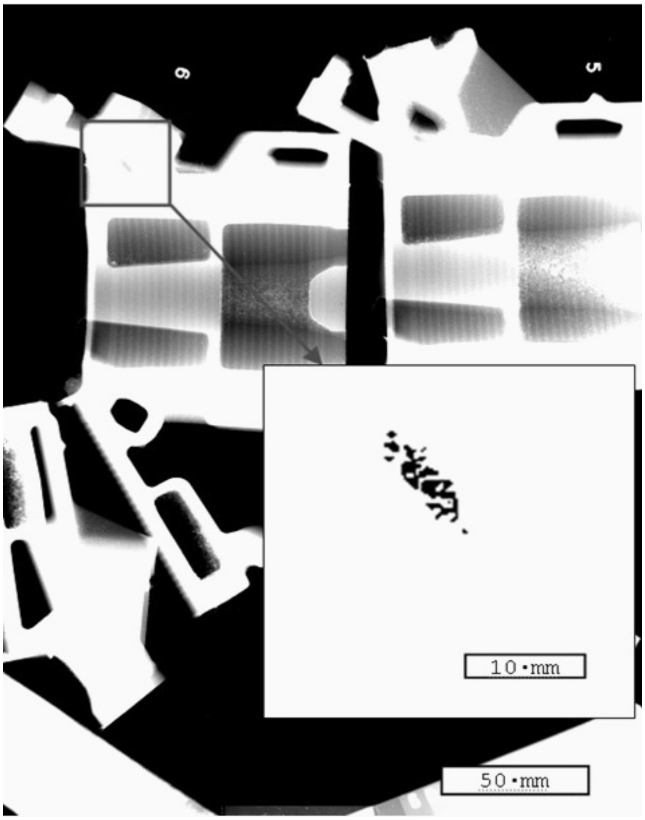

Fig. 2. The fragment of X-Ray picture showing a section of car engine block

3. Discussion of the experimental results

The casts porosity is connected with the solidification rate, because the growing dendrites build a coherent net in the solidified alloy, and the heat in the alloy flow there during the interdendritic space.

Fig. 3. shows the alloy structure of the bering part of the engine block. Fig. 4., on the other side, shows the cylindrical part. The bearing place of the crank shaft has a dendritic structure, due to the difference of the cooling rate of cast wall with variable thickness.

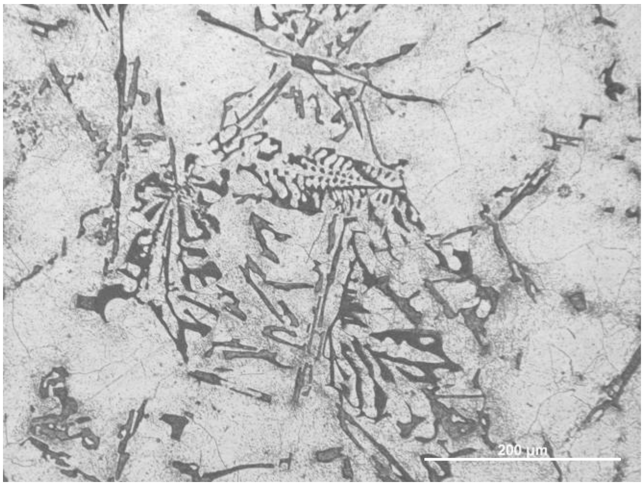

Fig. 3. Light microscope image showing structure of the cast alloy in point A an Fig. 1

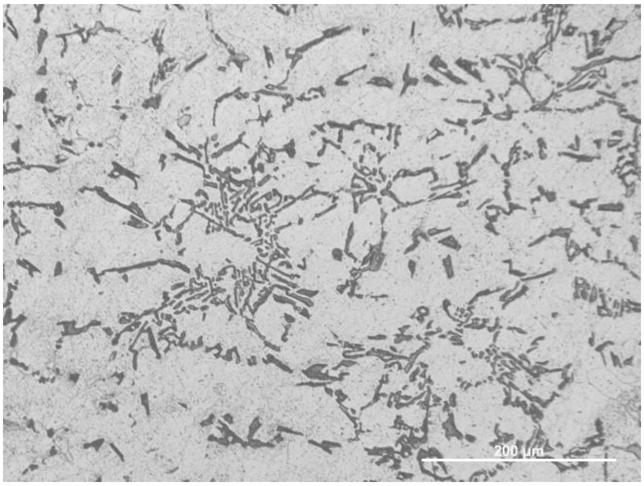

Fig. 4. Light microscope image showing structure of the cast alloy in point B an Fig. 1

The variability of shapes and sizes of casting defects identified by X-ray methods enabled the preparation of methodology based on casting images obtained by defectoscopic research. The class of casting defect calculated by the neural network on the basis of the calculated geometrical parameters in casting defects applied for model construction should be characterised by the proper similarity to the size corresponding to the class of defect of the model included in ASTM E155 standard.

Values of the area and perimeter and of the coefficients calculated using them grow along with the given defect type class. The Feret coefficient, centricity, and the nondimensional shape coefficient assume very close values for different types and classes of casting defects.

From the neural network used for investigations in this work the results of defects classification of the best neural network were presented. Table 1 presents the error values and correct neural networks responses for the validation and test sets.

Table 1
The quality coefficients of the best considered network

Type of neuronal network	Error of learnedly	Error of validation	Error of test	Quality of test
MLP 5-27-108	0,0384	0,0322	0,0551	0,9393

It is not enough to take into consideration only mistake sum square of given cases pointed out by the network mistake in order to evaluate quality of neural networks for classification issues of casting defect worked out in the paper. Because in such a case it is impossible to determine the distribution of mistake classification of particular defect classes. For the classifying neural network used in work, as a quality measure the relation of correctly classified cast defect was used.

Computer program was developed to evaluate quality of castings in the automatic way. In Fig. 5 the image of the analysed casting is shown in the "original image" window and the identified casting defect in the "resulting image" window, as well as the calculated values of the geometrical coefficients of the defect. The defect class calculated using the neural networks is also shown in Fig. 5.

Fig. 5. The programme window for the assessment of class of casting defects

The methodology worked out, aloud it to check the cast quality achieved during the technological „Cosworth" process, because the amount of wrong classified casts defects, using the above methodology or therefore performed computer programs, doesn't pass 6,5%.

4. Conclusions

The computer system, in which the artificial neural networks as well as the automatic image analysis methods were used makes automatic identification and classification possible of defects occurring in castings from the Al-Si-Cu alloys of the W319 type, assisting and automating in this way the decisions about rejection of castings which do not meet the defined quality requirements, and therefore ensuring simultaneously the repeatability and objectivity of assessment of the metallurgical quality of these alloys. Correctly defined quality of products makes further possible such control of the technological process that the number of defects occurring in the castings may be decreased by the relevant process correction. Controlling the technological process basing on the information acquired from the computer system developed for determining the quality of products makes optimisation of this process possible and therefore, reduction of the number of defective casting.

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