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A Choice of Description Methods and Measures for the MMC Quality Features

K. Gawdzińska

Maritime University of Szczecin, 70-500 Szczecin, Wały Chrobrego 1–2, Poland
Corresponding author. E-mail address: k.gawdzinska@am.szczecin.pl

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Abstract

This study proposes a procedure for the choice of description methods and the determination of measures and corresponding values of quality features used in examining metal composite castings. The procedure is herein applied to a selected feature of these materials, namely reinforcement phase distribution of the casting. The proposed procedure can be successfully used for describing quality features of such common materials as cast iron, cast steel, light metal alloys and composite materials.

Keywords: Casting, quality features, Choice of methods and measures

1. Introduction

Casting quality is largely affected by such features as casting material, size of casting, that is its mass or size, required minimum thickness of casting walls, casting accuracy, surface roughness, mechanical properties, others (e.g. tightness, grindability etc.). However, in case of composite castings the description needs to be extended with a set of specific quality features of these materials, relating to porosity, matrix and reinforcement of the composite, appropriate bonding of the two components, where we additionally distinguish the homogeneity of distribution, shape and size of the reinforcement phase in the casting and its content fraction [1]. The above quality features of composite castings have been examined in view of their possible description. Some of these features, and methods of identification (understood as a description of composite structure by research methods), have been widely investigated and described in the literature, particularly in publications on traditional castings [2], [3], [4], [5], [6], [7], [8]. Other features have not been subject to research yet, or research results have not brought sufficient data necessary to assess the applicability of the methods. This article focuses on one quality feature of composite castings in order to propose a relevant description procedure. Quality features description, including their measures and valuation, may utilize images obtained by the mentioned methods, as set forth in Table 1.

Table 1.
Research methods used for a description of the metal composite casting structure

Non-destructive methods	Destructive methods
X-ray defectoscopy	Light microscopy
	Confocal microscopy
	Scanning electron microscopy
	Atomic force microscopy
Ultrasound defectoscopy	X-ray microanalysis
Computer tomography	Mercury porosimetry
Acoustic emission	X-ray diffraction

Computer image analysis is used in case of images produced by light, confocal, scanning electron, atomic force microscopy, mercury porosimetry or computer tomography for calculating quantitative parameters [1], [7], [8], [9], [10]. For numerical description of specifically prepared parameters (Fig. 1) quantitative metallography [11] and statistical methods [9], [12] are utilized.

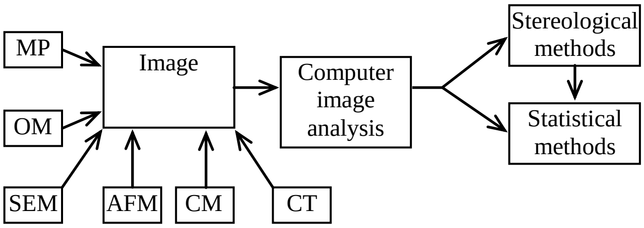

Fig. 1. Schematic procedure for the identification, description and valuation of features defining the quality of metal composite castings with reference to description tools. Image obtained by: CT – computer tomograph, CM – confocal microscope, AFM – atomic force microscope, SEM – scanning electron microscope, OM – optical microscope, MP – mercury porosimeter [ ]

2. A description of a quality feature of composite casting

Each casting quality feature should be allocated an appropriate method of description, based on the matrix diagram. An example graphical outcome of such description is given in Figure 3, according to the data obtained from an analysis – Table 2. The optimization of research methods (optimization is understood as the choice of a method for obtaining the best solution from the viewpoint of a specific quality criterion, e.g. costs, efficiency [12], [13]) for a specific quality feature has been estimated in view of these component criteria: 'research costs' (dependent on the price of measuring equipment, servicing costs, operating materials costs, including labour) and 'research quality' (dependent on method effectiveness, type, duration of the tests). According to [14] a conventional three-grade assessment scale has been here adopted for the component criteria (Fig. 2).

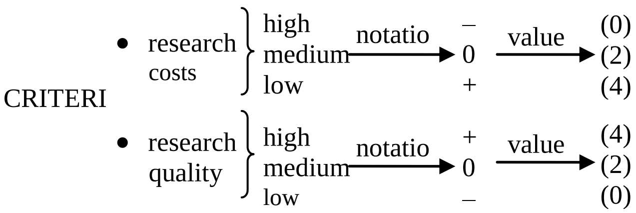

Fig. 2. Conventional assessment scale (as per [14]) used in making the matrix diagram for component criteria: research costs and research quality

It follows from Table 2 and Fig. 3 that the optimal method for the considered feature (distribution of reinforcement phase in a casting), having the lowest 'research cost' (lowest point value on the ordinate axis – Fig. 3), and ensuring an appropriate quality of the research (highest point value on the abscissa axis – Fig. 2) is the optical microscopy method. The feature description, determination of measures – qualitative and quantitative variables, given in Table 3, may be done by means of a computer-based image analysis, using stereological principles (e.g. SKIZ procedure [1], indicator of distribution inhomogeneity, systematic scanning method [9] etc.) and properly selected statistical methods.

Table 2.
An example of a matrix-based relationship, illustrating the optimization of research methods for a specific quality feature: homogeneity of reinforcement phase distribution in a casting accounting for the criteria 'total research costs' and 'research quality'

Criterion	Notation		
Price of measuring equipment	0	–	–
Costs of equipment maintenance	+	0	–
Costs of operational materials and labour at research	0	0	0
Research costs	Point value		
	8	4	2
Research method	OM	SEM	CT
Method effectiveness	+	+	0
Non-destructive method	–	–	+
Duration of research by the method	0	0	–
Research quality	Point value		
	6	6	6

OM – optical microcopy, SEM – scanning electron microscopy, CT – computer tomography.

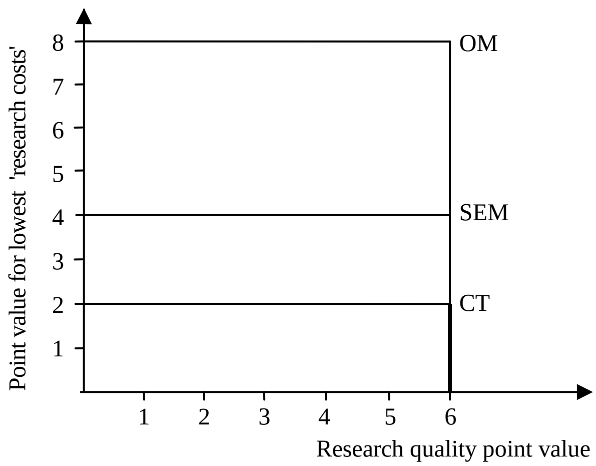

Fig. 3. Graphical result of matrix analysis of data (as per Table 1). The optimized research method for the feature 'homogeneity of reinforcement distribution in a casting'

Table 3.
Determination of identification methods and description of quantitative and qualitative variables (and their valuation) for the feature: homogeneity of reinforcement phase in a casting

Method	Microscopy		Computer tomography
	Optical	SEM	
Effectiveness of identification	high	medium	low
Qualitative variables	*	*	–
Quantitative variables	• systematic scanning, • analysis of variance, • geometric parameters of objects obtained by SKIZ procedure, • indicator of distribution inhomogeneity, • Kruskal-Wallis test.		• voxel, • distance to nearest neighbour, • volume percentage [%], • variance coefficient (depending on standard deviation from mean value in a sample), • indicator of distribution inhomogeneity, • characteristics of object spatial distribution based on the coordinates of centres of gravity of reinforcement phase, • geometric parameters of objects obtained by SKIZ procedure.

* Description of a structural feature, e.g. according to a composite structures atlas [15].

3. Conclusions

The proposed procedure of selecting description methods and valuation measures, based on an example quality feature of composite castings (homogeneity of reinforcement distribution in a casting), may contribute to better description of metal casting quality [16].

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Dobór metod opisu i miar cech jakości metalowych odlewów kompozytowych

W niniejszej pracy zaproponowano postępowanie dotyczące wyboru metod opisu oraz określania miar i wartości cech jakości odlewów z metalowych materiałów kompozytowych na wybranej cesze jakości tych tworzyw tj. jednorodności rozmieszczenia fazy zbrojącej w odlewie. Zastosowanie proponowanej drogi może być z powodzeniem stosowane do opisu cech jakości odlewów z materiałów klasycznych tj. żeliwo, staliwo, stopy metali lekkich, jak i materiałów kompozytowych.