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QUALITY FEATURES OF METAL MATRIX COMPOSITE CASTINGS

CECHY JAKOŚCI ODLEWÓW Z METALOWYCH MATERIAŁÓW KOMPOZYTOWYCH

In this paper it is stated, that a set of quality features of metal matrix composite castings differs from the same set for castings of classic materials, although some features are common for both of these material groups. These features (pertaining to a set of quality characteristics of composite castings) have been named as specific, they have not been determined yet and a description of material quality should be performed (according to the qualitology) on a principle of description of quality characteristics of this product. Therefore, this set of features has been determined. It was proposed to add the following characteristics to the set of specific features of composite castings quality: matrix material, reinforcement material, binding between components and porosity of the composite casting. In this set a sub-set of quality characteristics of composite castings was also determined.

Keywords: quality features, casting, metal matrix composites

Stwierdzono, że zbiór cech jakości metalowych odlewów kompozytowych różni się od zbioru cech jakości odlewów z materiałów klasycznych, choć niektóre cechy są zbieżne dla obu tych grup materiałowych. Cechy te (należące do zbioru cech jakości odlewów kompozytowych) nazwano specyficznymi, nie były one dotychczas określone, a opis jakości materiałów powinien odbywać się (w myśl kwalitologii) na zasadzie opisu cech jakości tego wyrobu. Określono zatem ten zbiór cech. Zaproponowano, aby do zbioru specyficznych cech jakości odlewów kompozytowych zaliczyć: materiał osnowy, materiał zbrojenia, połączenie pomiędzy komponentami i porowatość odlewu kompozytowego. W zbiorze tym określono również podzbiór cech jakości odlewów kompozytowych.

1. Introduction

Metal matrix composite materials increasingly replace traditional materials used in building engineering, aeronautics, mechanical engineering and in many other domains. It is related to a possibility of obtaining practically any combination of beneficial properties of the material, e.g. high vibration damping coefficient, high abrasion resistance, high value of the Young's modulus, low specific gravity and low coefficient of thermal expansion [1, 2, 3, 4]. Definition of the composite material, according to Broutman and Krock, contained in publications [3] is as follows: "A composite material is formed by a close combination of at least two chemically and physically distinct materials which should remain separate and distinct while a good and continuous interface between them is maintained; the reinforcing components in the whole volume of the matrix should be as uniform as possible."

This definition describes a perfect composite material, of an ideal structure. In real composites, an imperfect structure is generally present – composite materials contain various defects [5, 6, 7, 8], especially if casted composites are considered. The reason for this is the specific structure of castings, resulting from a course of the manufacturing process. Description of these imperfections allows their unequivocal determination, establishing reasons of their formation and stage of the manufacturing process at which they start to emerge and quick undertaking of preventive measures.

In foundry engineering, a concept of a defect (or unconformity) results from comparison of a present state with an ideal state, which is however not possible to be achieved. Presence of a defect cannot therefore always testify against the casting quality, which is assessed by comparing an existing state with requirements. The last statement forces elaboration of methods for description of an existing state through determination of product quality features, because clear and precise determination of composite castings quality features and existence of a systematic terminology regarding the casting defects facilitates management of quality of their manufacturing. It also makes for a great convenience during the education process, which is confirmed by the author's experience as an academic teacher. Moreover, it is advisable because of possibility of using interactive databases, being presently introduced to the foundry practice (e.g. Simulation DB [9, 10]).

Application of metal matrix composites as material for castings generates new kinds of casting features, unknown because of a specific structure of these composites or being of

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little significance in castings made of traditional materials. The following features can be listed:

– features related to the metal matrix structure, being a result of a crystallization in presence of reinforcement of a nucleus-forming potential;

– quality features related to the quality of the reinforcing phase, i.e. arrangement, quantity, size or shape of the reinforcement;

– composite-specific porosity types, resulting from composite casting density, e.g. occluded gas bubbles.

Up to now, in neither Polish nor foreign sources, there was no unequivocal description of quality features of castings of metal matrix composite materials; hence the author's interest towards this subject.

2. Determination of castings quality

Quality analysis of castings can be performed by tracing the foundry process (through every stage). Beginning from the moment of proposing a concept compatible with the recipient requirements, i.e. the order (where the casting recipient formulates all his demands, expectations regarding the material, shape, machining, finishing etc.), purchase of the input products, through mould preparation, melting of metal, pouring the mould with liquid metal, solidification, till self-cooling and removal of the casting from the mould – during all this time the product quality is being influenced. The product must fulfil quality requirements compatible with the PN-EN ISO 9000:2001 (Quality Management Systems – Fundamentals and vocabulary) and PN-EN ISO 9001:2001 (Quality Management Systems – Guidelines for performance) standards [11, 12]. According to these standards, castings have to fulfil the recipient expectations (they should have an appropriate application), be consistent with recommendations, guidelines and fulfil environment protection requirements, also they should be competitive. Guidelines for orders preparation are described by the standard. The order contains differences between requirements included in the agreement and the offer. The casting manufacturer must specify his capability of fulfilling the requirements contained in the agreement. Level of precision of listed information allows the manufacturer to fulfil the recipient expectations.

Precise planning of production processes has an influence on obtaining a good product. Constant supervision over input materials, equipment, apparatus, personnel etc. is also necessary. Conditions of supervision should comprise documented procedures (if there are none), determining the production methods, application of an appropriate equipment for production, assurance of proper work environment, accordance with appropriate standards and documents, supervision over adequate parameters of processes and product features, criteria of manufacturing and proper servicing of the equipment.

From the above, a conclusion can be drawn that it is impossible to subject the metal matrix composite castings to quality control because of lack of adequate standards and guidelines, describing this type of products (through feature definition). Still, such assessment can be performed using elaborations for castings of classic materials.

Assurance of quality of foundry processes requires fulfillment of a number of conditions, aimed at prevention and detection of all deviations occurring during realization of the foundry processes. Measures precluding recurrence of specific anomalies should also be taken.

Analyzing a structure of the casting as an object, one can determine its quality features and, out of numerous features of the casting, select the ones [13, 14] of a decisive significance (and describing the composite castings, too), i.e.:

1. casting material;
2. casting size, described by its mass or overall dimensions;
3. required minimal thickness of the casting wall;
4. required manufacturing accuracy;
5. required superficial roughness;
6. mechanical properties;
7. other properties (e.g. leak proofness, grindability).

Unfortunately, description of features specific for composite castings using available standards (appropriate for castings of classic materials) is impossible, which is confirmed by papers [1, 3, 4, 15]. It is not possible to unequivocally determine e.g. fractures – damages of reinforcement, homogeneity of arrangement or size of reinforcing phase in the casting space, it is also impossible to interpret the porosity resulting from insufficient saturation of the reinforcing phase with liquid metal of the matrix or other features of composite castings (Fig. 1).

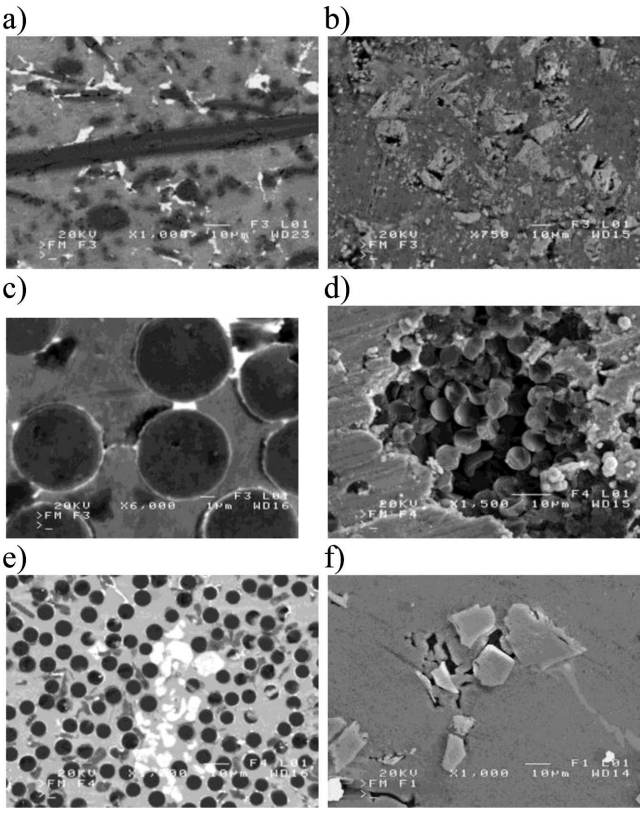

Fig. 1. Microstructure of metal matrix composite castings (SEM): a, b – fractures (damage of reinforcing phase); c, d – insufficient saturation of reinforcing phase with matrix metal; e, f – inhomogeneity of arrangement and size of the reinforcing phase

3. Summary

The answer for stated problems is to enrich the mentioned description with a set of quality features specific for metal matrix composite castings, related to the matrix and the reinforcement, proper connection of these two components and porosity, belonging to the group of quality features describing the casting. A diagram of influence of the quality features on the composite casting has been made and can be found in the figures 2 and 3.

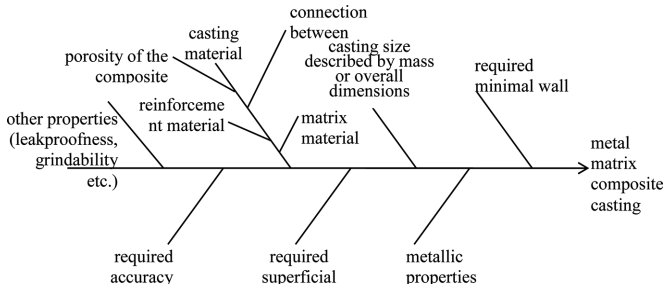

Fig. 2. Quality features describing the composite casting [15]

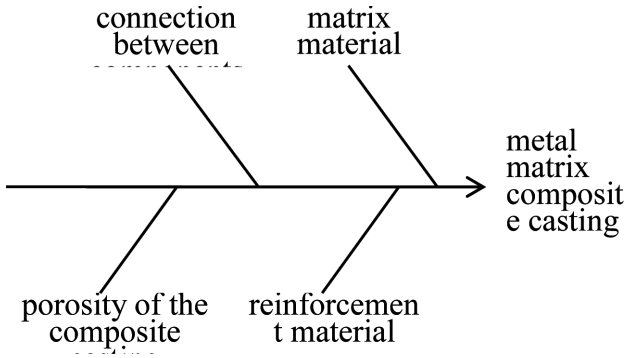

Fig. 3. Quality features specific for the composite casting material [15]

The above considerations were used to prepare the Table 1. It contains features of quality which can be used to describe castings of classic materials (i.e. cast iron, cast steel, non-ferrous alloys) and metal matrix composite castings. In case of quality feature no. 7 (according to Table 1), a feature description "casting material" was proposed to be changed into "matrix material", which seems logical considering the subject of the work. The "–/+" designation means that not all sub-features of this set are equivalent to sub-features of castings of classic castings (i.e. matrix material can have a different structure in area of connection between components).

A conclusion from above is that there is a set of specific quality features, describing metal matrix composite castings. In this set, on the basis of analysis of a production process of composite castings (presented in work [15]), a subsets of quality features of composite castings were defined (Fig. 4).

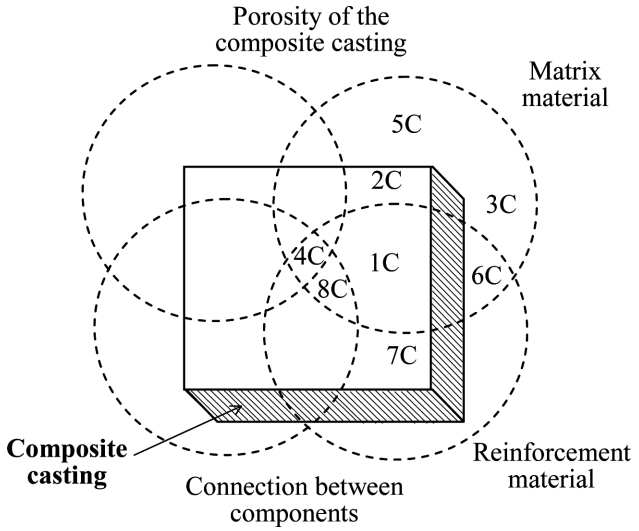

Fig. 4. Set of specific quality features of metal matrix composite castings: 1C – homogeneity of reinforcing phase arrangement in the casting, 2C – homogeneity of reinforcing phase shape in the casting, 3C – homogeneity of reinforcing phase size in the casting, 4C – porosity of the composite castings, 5C – reinforcement structure, 6C – fraction of reinforcing phase in the casting, 7C – matrix structure, 8C – interfacial surface structure

TABLE 1

Quality features of castings of classic materials and specific features of metal matrix composite castings

No.	Feature describing the casting	Casting type		
		cast steel, cast iron, light metal alloys	metal matrix composites	
			„in situ"	„ex situ"
1	Casting size, described by its mass or overall dimensions	+	+	+
2	Required minimal wall thickness	+	+	+
3	Required manufacturing accuracy	+	+	+
4	Required superficial roughness	+	+	+
5	Mechanical properties	+	+	+
6	Other properties (e.g. leak proofness, grindability etc.)	+	+	+
7	Matrix material	–/+	+	+
8	Reinforcement material	–	+	+
9	Matrix and reinforcement connection	–	+	+
10	Porosity*	+	+	+

+ description of casting possible using the quality feature, – description of casting impossible using the quality feature, –/+ look above for description, * further named composite casting porosity.

4. Conclusions

Description of quality of castings (including composite ones) should be conducted using quality features of these castings and not like it was done to date – using the defects. That is why it was necessary to define composite casting quality features so far not described in literature. A description of metal matrix composite castings quality features proposed in this paper allows to:

- complement the quality features of castings of traditional materials with a group of quality features specific for castings being a subject of interest in this work;
- unequivocally determine quality features characteristic for castings of studied composites;
- complete the proposed description with possibly not included quality features, thanks to its open character.

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