ARCHIVES OF CIVIL AND MECHANICAL ENGINEERING 16 (2016) 553–563

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/acme

Original Research Article

Proper matrix-reinforcement bonding in cast metal matrix composites as a factor of their good quality

Katarzyna Gawdzińska, Leszek Chybowski *, Wojciech Przetakiewicz*

Maritime University of Szczecin, Faculty of Marine Engineering, 1-2 Wały Chrobrego St., 70-500 Szczecin, Poland

ARTICLE INFO

Article history:
Received 16 September 2015
Accepted 28 November 2015
Available online 23 March 2016

Keywords:
Composite quality
Composite castings
Bonding of the structure
In situ
Ex situ

ABSTRACT

The mechanism by which the matrix connects the reinforcement (bonding of the composite structure) affects the quality of metal matrix composites. This article describes and documents the impact of metal matrix on various types of reinforcements of in situ and ex situ composites, by reviewing the relevant literature and making use of various analytic methods: optic microscopy, scanning electron microscopy and X-ray microanalysis. The reinforcement formation in the matrix of in situ composites has been described. The infiltration process of composite reinforcement has been discussed. The three basic composite classes have been presented. The reactivity of selected composite components has been pointed out.

1. Introduction

New technologies developed in the foundry engineering industry in recent years have extended the applicability of cast products, which in turn has led to the introduction of new materials and bonding technologies. Possibilities of reducing mass and dimension tolerance, and raising the quality of castings are continually broadening, spurred by new engineering and economical requirements satisfied by cast metal matrix composites (MMCs). Quality control of MMCs may only in part be performed as it is in case of traditional castings because of problems due to the complex structure of these composites. They consist of the matrix, commonly a technical alloy, and the reinforcement that may have various forms and shapes.

The quality of MMC largely depends on how good the bonding between the two components is. According to one definition [1–5] it is also important that the distribution of reinforcement phase be possibly uniform through the whole volume of the product matrix. Therefore, this article analyzes the bonding of the matrix and reinforcement, looking separately at the technological process of in situ and ex situ composites. The description of structural defects of these castings is based on optical and scanning electron microscopy and on X-ray microanalysis.

2. The research material

By the manufacturing technology, metal matrix composites can be divided into in situ and ex situ composites [1]. In situ

* *Corresponding author*. Tel.: +48 91 480 94 12.
E-mail addresses: k.gawdzinska@am.szczecin.pl (K. Gawdzińska), l.chybowski@am.szczecin.pl (L. Chybowski), w.przetakiewicz@am.szczecin.pl (W. Przetakiewicz).
http://dx.doi.org/10.1016/j.acme.2015.11.004
1644-9665/

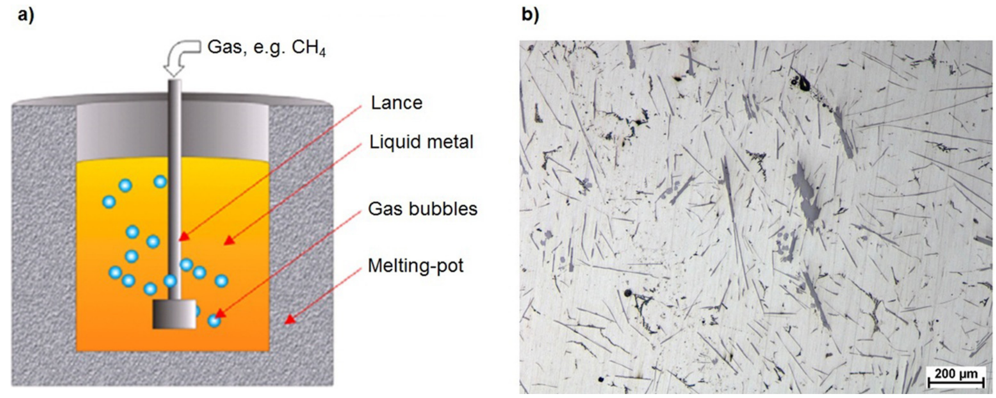

Fig. 1 – A composite obtained from the liquid–gas arrangement: (a) schematic diagram, (b) optical microscopy image of in situ composite (courtesy of Silesian University of Technology, M. Dyzia).

MMCs are materials in which the reinforcement phase is created within the matrix volume in the composite fabrication process. The reinforcement phase created in this process may have a variety of structures and properties. It may be composed of dispersion particles or fibres, it may be plastic or brittle. The reinforcement may be manufactured from the solid phase (Fig. 1) or liquid phase. The formation of reinforcement from the liquid phase may take place in the process of crystallization (e.g. directional crystallization of eutectic systems), by intensive cooling of supersaturated solutions, or a violent reaction in the liquid phase between the components. Processes based on internal oxidation, reactions of substitution or grinding of reactive components are methods of in situ composite manufacturing using the solid phase [2].

Castings of ex situ composites are obtained by one of two methods. One method consists in mixing a liquid matrix – a technical alloy (Fig. 2) – with solid phase reinforcement (suspension composites). Composite suspension is usually obtained by placing ceramic particles in the liquid matrix of the alloy in a variety of ways: during mechanical stirring, by solving composite concentrate, blowing ceramic particles using a gas or by ultrasonic/electromechanical mixing [3]. The matrix is usually composed of light metal alloys, such as aluminium, magnesium, lithium, titanium, and copper, iron and their alloys. The reinforcement is made of a variety of materials, too: graphite, glass, oxides of aluminium, silicon, zirconium, titanium, cerium, carbides of silicon and titanium, and boron nitride. The reinforcement consists of particles with grain size ranging from a few to hundreds of micrometres or fibres with a diameter $0.2 \div 0.4$ mm and length $0.5 \div 2.0$ mm. Its content in the matrix is up to 30%.

In the other method the porous structure of the reinforcement gets infiltrated with liquid technical alloy (composites with infiltrated reinforcement), usually under a certain pressure (Fig. 3) [6]. Various metals or their alloys may be used as a matrix. Due to technological difficulties, casting temperature and environmental impact may hinder their applications. For these reasons the alloys mostly used as the matrix include those of aluminium and magnesium, some copper alloys, and less common, low melting alloys. The reinforcement of saturated composites may be composed of metal materials, e.g. carbon and alloy steels, or non-metallic materials, such as ceramics (aluminosilicates, graphite), boron, polymers, etc. These materials may have various forms: long ordered fibres, yarn, fabric, mat, short unordered fibres, wools, cellular structures, sinters, etc.

To guarantee good quality of composite materials we have to assure good bonds between the matrix and the reinforce-

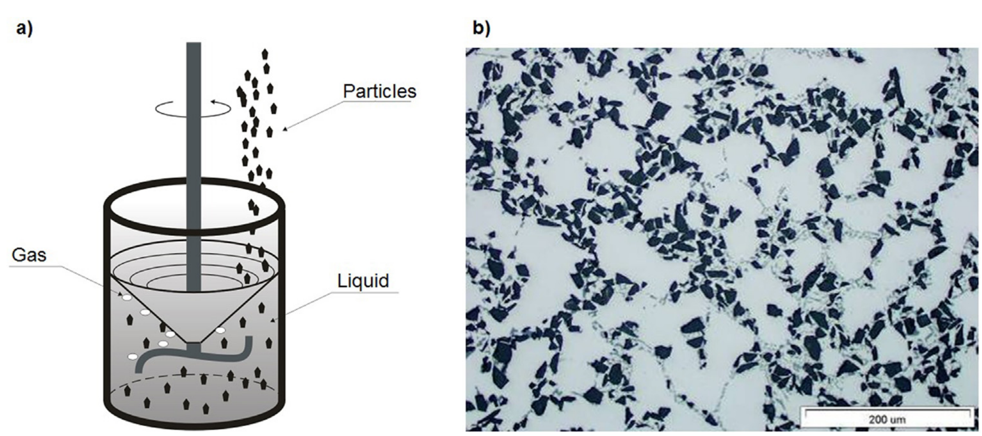

Fig. 2 – Manufacturing of composites by mechanical stirring: (a) diagram, (b) microstructure of ex situ suspension composite, optical microscopy.