LAST DEVELOPMENTS IN NOVEL PRODUCTION PROCESSES FOR METAL MATRIX COMPOSITES

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1 General Introduction

New applications are continuously demanding new advanced materials. Traditional materials can often neither reach the new requirements nor work at extreme environments and offer a low performance and/or competitiveness limiting in many cases their viability for new developments and applications.

Metal Matrix Composites (MMCs), already available from several decades ago, can overcome many of these difficulties and their suitability has already been demonstrated for many applications. Despite being commercialized for a large range of sectors (automotive, aerospace, electronics, etc.), many of the developments in MMCs have not been used, or have been limited to very special applications, just because of being non-suitable from the economic point of view.

In this sense, INASMET-Tecnalia focuses its research on MMCs in the development of low cost alternatives with the aim of facilitating the introduction of this high performance kind of materials for new and conventional applications. This paper shows two examples of low cost processes to manufacture MMCs developed at INASMET and, also, a summary of the achievements in the field of developing low cost nano-reinforced MMCs, which can represent in the near future a new generation of materials suitable for very high demanding applications.

2 Low cost MMCs manufacturing solutions

2.1 Infiltration techniques

The main conditions to produce a competitive MMC based component are:

- To use low cost raw materials.
- To use conventional manufacturing processes (avoiding large investments in new equipments or facilities).
- To obtain net or near-net-shape components (avoiding as much as possible expensive machining).

Infiltration techniques, consisting on the infiltration of porous ceramic preforms with molten metal, meet all these conditions. Moreover, these techniques can be easily implemented in conventional foundries without the need of large investments in new facilities.

Two main technologies suitable for infiltration can be distinguished: pressure infiltration and pressure-less infiltration.

Pressure infiltration technologies consist on the infiltration of a ceramic porous preform with molten metal thanks to an external pressure applied onto the metal. Preforms can be made of ceramic fibres or particles, forming the reinforcement of MMCs. Among other techniques, High Pressure Die Casting (HPDC) has been used as a low cost, easy to be implemented technique, for producing locally or fully reinforced MMCs components. As an example, aluminium reinforced automotive clutch discs have been manufactured using this technique obtaining high performance at competitive prices compared with the conventional cast iron solutions [1] .

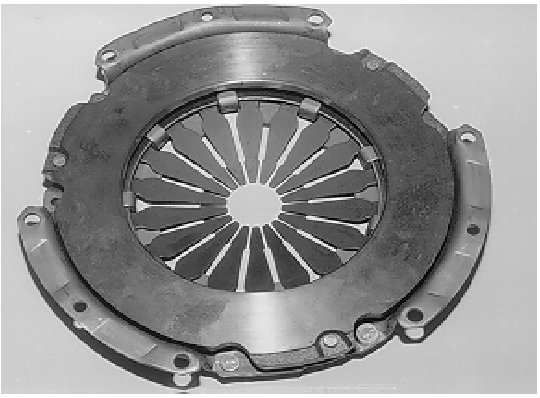

Fig. 1. Automotive aluminum reinforced clutch disc manufactured by preform infiltration by HPDC.

In the case of pressure-less infiltration, a preform is also used, but the molten metal infiltration occurs by capillarity thanks to an special treatment that promotes a good wetting between reinforcement and molten metal, without any need of external pressure. In this way, simple gravity casting moulds can be used. This technique, known as PRIMEX^{TM}, proprietary of LANXIDE and licensed to INASMET-Tecnalia, allows to obtain MMCs with a large variety of matrices and reinforcements. Many components have been already developed and commercialized using this technique, ranging from the automotive, electronic and military to aerospace markets.

2.2 In-situ technologies

In-situ technologies are referred in MMCs to those technologies where reinforcements are generated within the own molten metal thanks to, generally, a chemical reaction between different additives and the molten metal.

A number of different alternative processing techniques have recently evolved in an effort to optimize the structure and properties of in-situ ceramic phase reinforced MMCs [2]. New activities in this field have been focused on combining the Self-propagating High-Temperature Synthesis (SHS) technique for producing highly reinforced titanium based MMCs with conventional foundry techniques. SHS consist of a solid chemical reaction where, through an optimized selection and composition of raw materials, ceramic or intermetallic reinforcements can be generated within a metallic matrix. The new manufacturing approach consists on the use of SHS techniques to produce a kind of "master alloys" consisting of highly reinforced MMCs, which are used as additives in the preparation of the melt in a conventional foundry. In this way, the reinforcement content can be tailored to meet the targeted requirements in function of the amount of master alloy added during a conventional foundry process. The combination of a cheap and easy way to produce master MMCs, such as the SHS, and conventional foundry techniques, enables a rapid and low cost path to industrial production without the need of additional investments.

Following this patented process, a new generation of low-cost titanium matrix composites is currently under development with promising properties for aeronautic and automotive engine component applications. Other low cost iron based MMCs components for the tooling industry have also been patented and are under industrial production. Current developments in this field are also being focused on aluminum and magnesium based composites for the automotive sector.

2.3 Low cost / high performance nano-composites

Due to its excellent mechanical and thermophysical properties, Vapour Grown Carbon Nanofibres (VGCNFs) are one of the most promising reinforcing materials for metal matrix composites in multiple applications, like those for thermal management of high power electronics. Carbon nanotubes (CNTs) exhibit the best mechanical, thermal and electrical properties of any known material, furthermore the continuous manufacturing process of VGCNFs enables an immediate availability and excellent performance-to-cost ratio for the mass production of industrial components.

Copper/VGCNFs composites with excellent thermophysical properties for power electronic applications have been manufactured as follows [3]: In a first stage, composite powders are obtained by dispersing and coating VGCNFs with copper through an electroless plating technique. The poor interaction between copper and carbon makes it necessary to engineer the interface by the incorporation of suitable reactive elements. Two conventional industrial processes such as tape casting (TC) and metal injection moulding (MIM) are being implemented to produce green components. These are further consolidated by either hot-pressing (HP) or spark plasma sintering (SPS).

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