POLISH ACADEMY OF SCIENCES - COMMITTEE OF MATERIALS SCIENCE
SILESIAN UNIVERSITY OF TECHNOLOGY OF GLIWICE
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS
ASSOCIATION OF ALUMNI OF SILESIAN UNIVERSITY OF TECHNOLOGY

Conference Proceedings

12th INTERNATIONAL SCIENTIFIC CONFERENCE
ACHIEVEMENTS IN MECHANICAL & MATERIALS ENGINEERING

Precision moulds of graphite for fabrication of carbon fibre reinforced magnesium

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1. INTRODUCTION

In recent years magnesium was established e.g. for automotive engineering due to its high lightweight potential. For a broadening its applications it is of particular interest to use local reinforcements for the transmission of forces. Here, endless carbon fibres (CF) are particularly suitable for the design of load-adapted CF-Mg-composites. In this fact the development of modern magnesium matrix composites (MMC) is the basis for innovative lightweight products, due to their various adaptabilities to complex mechanical and functional loads. However, only by the development and optimisation of production processes adapted to the material and the ongoing research of micro-structural processes and interfacial reactions fibre magnesium composites are developed to an interesting alternative to conventional design materials [1, 2].

2. CARBON FIBRE REINFORCED MAGNESIUM

The characteristic profile of fibre-reinforced magnesium can be controlled by the selection of reinforcing fibres [3] and their interface in a controlled way by the variation of alloy compositions and process parameters during the production of the composite [4]. Since the system magnesium/carbon itself is not reactive (known magnesium carbides MgC_2 and Mg_2C_2 are regarded as endothermic compounds which are not synthesisable from the elements and which are subject to thermal decay at temperatures above 500°C, respectively 650°C) [5], this results in low adhesion between fibre and matrix. Therefore, the selective increase of interfacial surface adhesion is achieved, on the one hand, by the addition of a carbide-forming element – as a rule, aluminium – to the magnesium and on the other hand by the modification of the fibre surface, for instance, by the selection of a special type of fibre or by coating of the fibres.

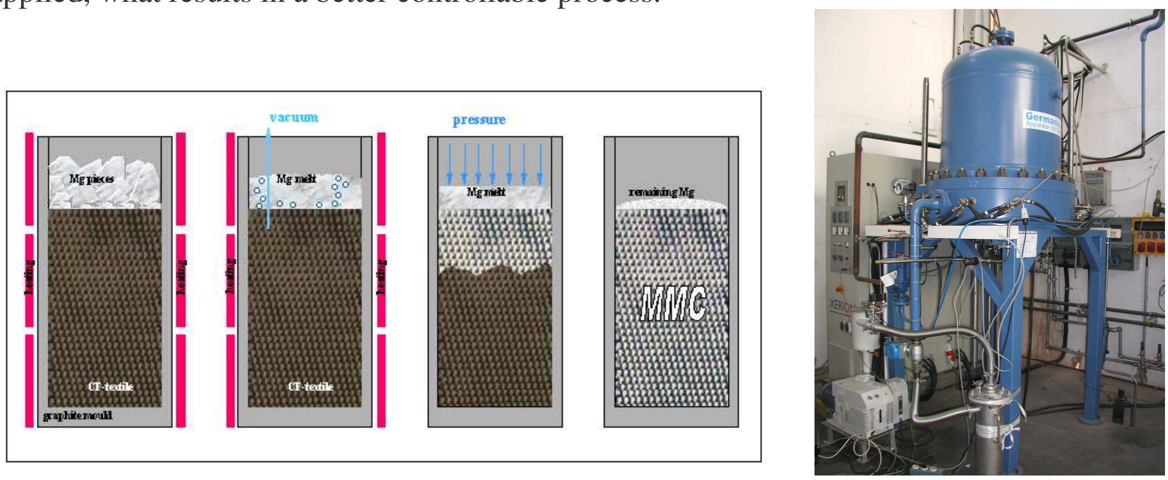
Various different research projects have performed in-depth studies of the connections between the fibre/matrix interface and the micro-mechanical failure mechanisms, such as boundary surface failure (“initial debonding” and “progressive debonding”), fibre fracture and fibre pull out and have thus provided the foundation for the optimisation of compounds of fibre-reinforced magnesium alloys [3, 5].

3. MANUFACTURING OF CF-Mg BY GAS PRESSURE INFILTRATION

Due to poor wetting between magnesium and uncoated carbon fibres, extremely high infiltration pressures are required in the production of carbon fibre magnesium composites. Therefore, gas pressure infiltration techniques have proven to be a particularly effective production process, which allow sufficiently high infiltration pressures at the required high processing temperatures [6, 7].

The fabrication of specimen of the carbon fibre reinforced magnesium was realised with the aid of an advanced differential gas pressure infiltration technique (Fig. 1a), which was developed at the ILK [4]. The advantage of this technique is that, for instance, in contrast to hot pressing, the atmosphere in the fibre preform is reduced during the infiltration. The solidification takes place with a high gas pressure, so that significantly fewer pores are created during the infiltration procedure. Additionally, in gas pressure infiltration the decisive process parameters, such as temperature, pressure and infiltration as well as cooling times can be adjusted selectively, allowing optimisation of the infiltration sequence.

In combination with adapted precision tools of graphite the gas pressure infiltration enables the production of CF-Mg prototypes or low volume serial production with complex geometry close to the final contour. The advantage of the infiltration techniques comparing to conventional techniques like hot-pressing is that very thin-walled infiltration tools can be applied, what results in a better controllable process.



a) b)

Fig. 1. a) Schematic illustration of infiltration process; b) high temperature autoclave

A laboratory autoclave (Fig. 1b), designed for a maximum process pressure of 80 bar at temperatures up to 850 °C, was initially used for the fabrication of CF-Mg semi-finished plates. The autoclave, especially set up at the ILK, which is equipped with three independently controlled heating zones, offers a capacity with a diameter of 600 mm and a height of 800 mm.

The extraordinarily great bandwidth of variable material and process parameters in the production of carbon fibre-reinforced magnesium by means of gas pressure infiltration methods requires a systematic approach in the selection of optimal parameters [4]. In the course of these efforts, the material parameters of fibre type and textile reinforcement and magnesium matrix were varied as were the essential process parameters, such as pre-mould, mould and casting temperature as well as infiltration pressure.

4. PRECISION MOULDS OF GRAPHITE

The fabrication of plain and complex specimens as well as components requires the conception, design and manufacture of precision moulds. Based on adapted requirement specifications a convenient material quality of graphite was selected.

requirement specifications for precision moulds	
material:	geometry:
- low thermal expansion coefficient	- easy handling
- low thermal capacity	- easy assembly
- sufficient stiffness and strength	- low weight
- chemical inactive state with magnesium	- support of directional cooling down
- reusability	- decomposability with optimal component
extraction	

The design of the moulds is based on experiences of first infiltration trials and numerical process simulations, particularly to forecast the transient temperature field throughout the magnesium infiltration and cooling down.

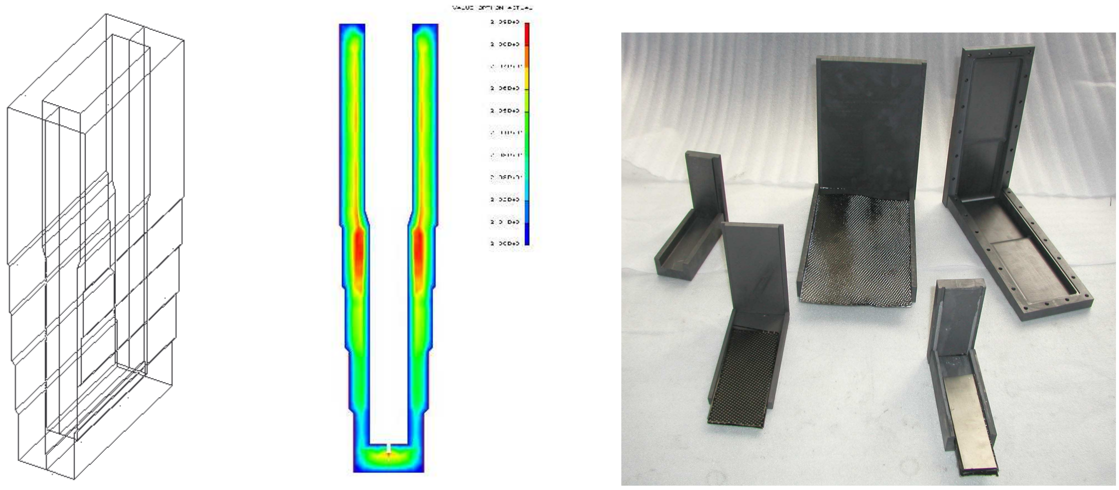


Fig. 2. Lay out design, cooling down simulation, multi component mould for CF-Mg-plates

The developed infiltration moulds are designed as multi-component graphite tools, which consist of chill and inner mould. The moulds for plain specimen (Fig.2) enable the production of plates with a length of 160 to 250 mm, a width of 65 to 150 mm and a thickness of 0.5 to 13 mm. Furthermore, moulds were developed and manufactured for fabrication of curved structures like tubes (Fig.3).

Fig. 3. Multi component mould for tubular CF-Mg-specimen

To characterize the manufactured CF-Mg-specimens (Fig. 4) mechanical studies were performed, e.g. tensile tests for the determination of stiffness and strength data. The determined material properties are used for the optimisation of the infiltration process as well as for analytical simulations.

Fig. 4. CF-Mg-specimen; plates and tubes

5. CONCLUSIONS

The gas pressure infiltration technology enables to fabricate complex carbon magnesium composites with fibre or textile reinforcement using precision moulds of graphite. Thereby, the infiltration technology gives the possibility to vary the processing parameters in a broad range, which allows to produce reinforced magnesium composite with optimal protection of the fibres and matrix materials. Furthermore, special divisible graphite moulds were developed to manufacture samples with different sizes and complex geometry.

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