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FABRICATION OF FIBRE REINFORCED MAGNESIUM ALLOYS

Textile reinforced magnesium alloys as new group of lightweight material offers an interesting property profile. Three different processing techniques for the infiltration of textile preforms are presented. The thixocasting was applied to produce locally reinforced magnesium matrix structures. This technology needs an adapted clamping fixture to locate the textile preform in the form tool. The high pressure die casting technique enables to produce magnesium composite structures with high number of pieces. For the infiltration a BÜHLER real-time operating high pressure die casting machine will be applied. Textile reinforced specimens and structures were fabricated using the pressure infiltration technique, which enables to produce complex shaped magnesium matrix components in a well controllable process.

Key words: **metal matrix composites, processing technique, textile reinforcement**

OTRZYMYWANIE KOMPOZYTÓW MAGNEZOWYCH ZBROJONYCH WĘGLOWYM WŁÓKNEM CIĄGŁYM

Stopy magnezu wzmocnione tekstylnie jako nowa grupa materiałów lekkich oferują interesujące zestawienie własności. Przedstawiono trzy różne techniki infiltracji form tekstylnych. Metodę nazwaną thixocasting zastosowano do produkcji lokalnie zbrojonych struktur w osnowie magnezu. Ta technologia wymaga wykorzystania dodatkowego mocowania półfabrykatu tekstylnego w formie. Wysokie ciśnienie odlewania pozwala wytwarzać struktury kompozytów w osnowie magnezu złożonych z dużej ilości elementów. Specjalnie do tych celów została przystosowana maszyna firmy BÜHLER, pozwalająca w czasie rzeczywistym sterować ciśnieniem w procesie wtrysku. Zbrojone tekstylnie próbki oraz złożone struktury zostały wykonane z użyciem technik infiltracji ciśnieniowej, które umożliwiają kontrolowany odlew skomplikowanych komponentów w osnowie magnezu.

Słowa kluczowe: **kompozyty metalowe, techniki odlewnicze, zbrojenie tekstylne**

INTRODUCTION

Within the framework of the virtual institute „Key Technologies for Advanced Engineering Materials/ Schlüsselwerkstoffe für den Leichtbau", supported by the Helmholtz Association of National Research Centres (VH-VI-021) a carbon textile reinforcement for magnesium shall be developed for industrial scale production. The areas of application for composite materials are many and cover, for example, transport technologies and medical engineering. As a cooperation of national research centres and universities, the fibres and textile preforms are produced in the facilities of the Institute for Lightweight Engineering of Dresden University of Technology (Institut für Leichtbau und Kunststofftechnik, ILK, der TU Dresden) and processed to cast specimen in the Foundry Institute of Aachen University (Gießerei-Institut, GI, der RWTH Aachen) using thixocasting an high pressure die casting and at ILK using gas pressure infiltration. Later the characterization of the material properties shall be done by the GKSS research centre situated next to Hamburg.

CURRENT AND SCHEDULED EXPERIMENTS AT GI

For all experiments the corrosion resistant magnesium alloy AE42 has been chosen. The 2% rare earth and 4% aluminium containing alloy is used for example in aerospace industry and features a high ductility combined with a good creep resistance [1]. The current fields of application of this alloy shall be expanded with the help of the higher mechanical properties reached by the fibre reinforcement.

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Thixocasting

Preliminary experiments have been carried out in thixocasting on the modified BÜHLER high pressure die casting machine at the Foundry Institute. Casting was conducted with a preheated mould featuring a cavity of dimensions 140x70x5 mm. For infiltration one layer of 285 g/m^2 1/4 satin weave made from T300 fibres was fixed by a conical clamping device. Casting properties such as flow ability and mould filling capacity are strongly influenced by the micro structure of the thixo-casting pre-material. These properties can be promoted by using fine and globular grained billets, produced by using RSCT (Rapid Slug Cooling Technology) [2]. The RSCT-billets, also used for the infiltration-trials take advantage of the high temperature gradient occurring when quenching the liquid slug (Fig. 1) in a water bath (Fig. 2), which is underlying forced convection.

Fig. 1. Thixo pre-material [2]

Rys. 1. Półfabrykat Thixo [2]

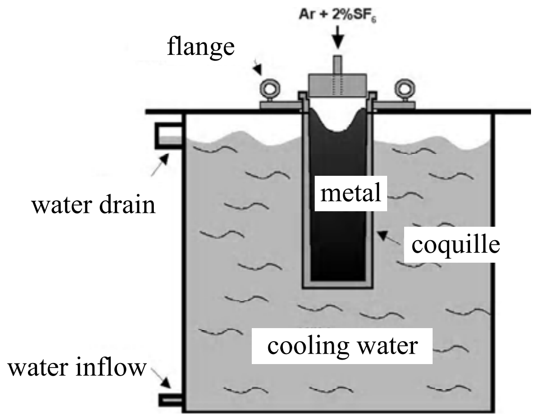

Fig. 2. RSCT Device [2]

Rys. 2. Urządzenie RSCT [2]

The first trials indicated that the preliminary clamping device was unable to ensure a tight fit of the fibres, thus the quality of the casting suffered by dislocated fibres. Due to a loss of friction and surface pressure, the self lubricating carbon fibres were unable to be fixed strong enough to counter-act the force of the incoming melt. Nevertheless the mats of fibres were infiltrated for the most part by the melt resulting in a confident outlook on the coming trials. The casting occurred to be free of included gas and other imperfections, illustrated by the x-ray photographs showing the specimen without (Fig. 3) and with fibres (Fig. 4).

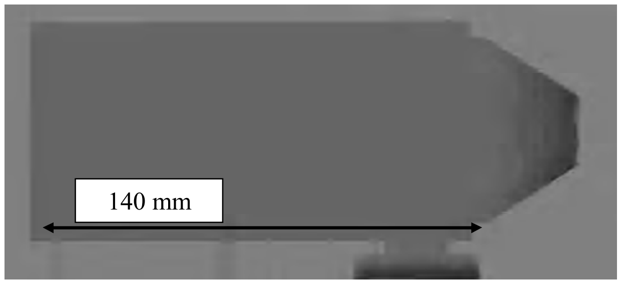

Fig. 3. X-ray image of the not infiltrated specimen

Rys. 3. Zdjęcie rentgenowskie próbki przed infiltracją

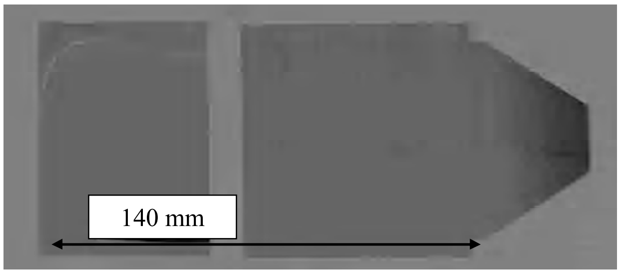

Fig. 4. X-ray image of the infiltrated specimen

Rys. 4. Zdjęcie rentgenowskie próbki po infiltracji

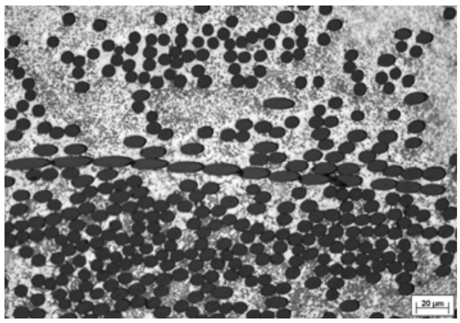

Fig. 5. Cross section infiltrated fibres

Rys. 5. Przekrój przez włókna po infiltracji

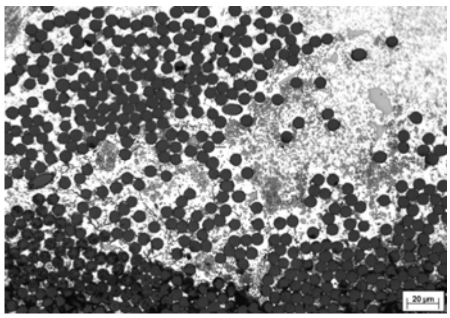

Fig. 6. Cross section infiltrated fibres

Rys. 6. Przekrój przez włókna po infiltracji

The missing part on the x-ray photograph of Figure 4 was taken out for metallographic analyses and can be observed in Figures 5 and 6 for different specimens. The pictures have been taken at a 500x magnification and illustrate infiltrated fibres longitudinal to observation perspective.

High pressure die casting

Coming trials shall be conducted on the BÜHLER real time operating high pressure die casting machine with 725 t clamping force (Fig. 7), available at the Foundry Institute of Aachen University. An elaborate constructed die with a new clamping device shall bring the preliminary experiments forward to the next stage closer to industrial scale. A vacuum assisted mould filling will prevent gas inclusion while filling, and any reactions with the liquid magnesium will be prevented by charging the casting chamber with the protective gas mixture Ar + SF_6.

Fig. 7. BÜHLER real-time operating high pressure die casting machine

Rys. 7. Działająca w czasie rzeczywistym wysokociśnieniowa maszyna odlewnicza BÜHLER

For infiltration, multiple layers of 285 g/m^2 1/4 satin weave T 300J reinforcement, which are stitched together, shall be set in the 210x290x5 mm die and fixed with a special two step clamping device. In the first step a mild tensile force is applied by manually laying the fibres into the mould. In the second step the tension is increased while closing the die halves. Herby the die halves apply a pressure on the fibres and ensure proper fit. It is essential not to shear off the fibres, as the tension must not exceed a critical value. Transferring the clamping force of 725 t on such a small contact surface equates to a high pressure, which can easily exceed the mechanical durability of the carbon fibres.

Once the die is closed and vacuum and protective gas atmosphere is applied, casting can take place. The casted part of the first test geometry shall feature an area of 140x210 mm infiltrated carbon fibre. Thicknesses of the stitched fibre mats are variable from 1 to 5 mm. The weight of the parts with gating and venting system vary, depending on the thickness from 2÷3 kg.

GAS PRESSURE INFILTRATION AT ILK

At the ILK selected 2D and 3D textile structures are infiltrated using gas pressure infiltration technique to fabricate specimens for material tests and first light weight structures. Within comprehensive infiltration tests the optimal temperature of the textile preform and the form tool as well as the infiltration pressure are determined. The determined infiltration parameters a basis for the development of lightweight components made from MMC [3].

Based on the conventional gas pressure infiltration technique (Fig. 8) a modified technology the so-called differential gas pressure infiltration technique (DGPI) was developed at ILK. In comparison to the conventional technique, the DGPI features the advantage of a very small pressure difference between the inside and the outside of the infiltration mould. As a favourable result very thin-walled infiltration tools can be used, resulting in an easier control of the process. This technology allows the production of very complex reinforced lightweight structures.

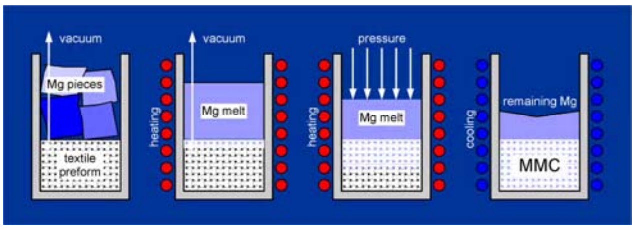

Fig. 8. Schematic diagram of the gas pressure infiltration process [3]

Rys. 8. Schemat procesu infiltracji ciśnieniowej [3]

Fig. 9. High temperature autoclaves for the production of CF-Mg structures

Rys. 9. Autoklaw wysokotemperaturowy do wytwarzania struktur CF-Mg

The gas pressure infiltration techniques requires long processing times what results in costly products. Therefore this technique is mainly applicable for low quantities.

a)

b)

Fig. 10. Graphite form tools (a) and fabricated CF-Mg-tubes (b) [3]
Rys. 10. Formy grafitowe (a) i wytworzone rury CF-MG (b) [3]

A laboratory autoclave, designed for a maximum process pressure of 10 MPa at temperatures up to 1200°C, was initially used for the fabrication of CF-Mg semi-finished plates. The autoclave, which is equipped with two independently controlled heating zones, offers a capacity with a diameter of 140 mm and a height of 300 mm. Larger CF-Mg structures and substructures can be processed in an autoclave especially set up at the ILK. The processing chamber of this autoclave has a height of 800 mm and a diameter of 600 mm and is equipped with three heating zones. Process parameters up to a temperature of 850°C and a pressure of 8 MPa can be reached.

As infiltration tools multi-component graphite moulds were used, which consist of chill and inner mould. Their development and modification were carried out in accordance with specified requirements on the semi-finished sample plates. The moulds allow the production of sample 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.

OUTLOOK

Composite materials offer a wide field of application. Weight saving properties and reduction of moved masses give an outlook for future applications. As an aim of this project, locally reinforced geometries shall be produced to provide higher mechanical properties at highly stressed sections. In the future infiltrated high pressure die casted parts shall fulfill the requirement of a technical practicable solution with advanced mechanical properties.

Acknowledgements

The authors would like to extend his gratitude to the Helmholtz Association for the financial support required to conduct the study. Furthermore the project „Key Technologies for Advanced Engineering Materials/Schlüsselwerkstoffe für den Leichtbau" likes to thank NORSK HYDRO for supply with the alloy AE42.

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Recenzent
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