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Fabrication technology and material characterization of carbon fibre reinforced magnesium

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Abstract

Carbon fibre and textile reinforced lightweight materials with selected magnesium alloy matrices have been strongly considered nowadays for lightweight applications under complex dynamic and static operating loads, e.g. in automotive engineering. Thereby, especially continuous fibre reinforcement increases the application potential of this novel material group considerably.

The priority objectives of the reinforcement of magnesium are to increase the stiffness and strengths of the material and to reduce its pronounced tendency to creep, whereas the inserted fibre reinforcement effects directional-controlled material properties. The specific development of structures made from new magnesium matrix composites particularly requires adapted fabrication technologies as well as practical calculation and design plans, which realistically consider the anisotrope material behaviour.

Keywords: Magnesium matrix composites; Material characterization; Testing technology

1. Introduction

The technical and economical potential of innovative materials as well as their production and processing has become more and more important for successful competitive strategies of business companies. In addition, it is required to save the limited resources and to reduce the environmental pollution. Due to this, the usage of lightweight metals and reinforced materials gain in importance and their meaning as a basis for new forward-looking developments is increasingly accepted by the science and public.

Thus, big effort on material replacement of conventional materials by lightweight metals like magnesium, aluminium or titanium is done especially by the automotive industry. Nevertheless, the usage of lightweight metals remains limited although they offer a significant weight saving potential, due to their low density. Particularly, the application of magnesium alloys is very low compared to the competing aluminium materials or plastics (Fig. 1).

Magnesium suffers from several material inherent deficiencies like low Young's modulus or low creep and thermal resistance that currently prevent the substitution of steel for highly loaded structural parts. Therefore, for broadening the application of magnesium it is of particular interest to use reinforcements. Especially, selective reinforcement within high loaded areas of structures and components offers the promising possibility to overcome the disadvantages.

Despite high manufacturing costs metal matrix composites (MMC) like carbon fibre reinforced magnesium are interesting materials for components with good wear resistance and high specific strength at low weight and advantageous thermal behaviour. Thereby, a potential field of application would be within robotic high-precision machining tools and positioning systems, textile techniques, aerospace industry and high-performance electronics. Especially, applications that require a minimum of inertia as well as dimensional stability and stiffness would be predestined domain for material replacement by MMCs. In this fact, the development of modern magnesium matrix composites is the basis for innovative lightweight products, due to their various adaptabilities to complex mechanical and functional loads. However, only by the development and optimization of production processes adapted to the material and the ongoing research of micro-structural processes and interfacial reactions fibre magnesium composites will be developed

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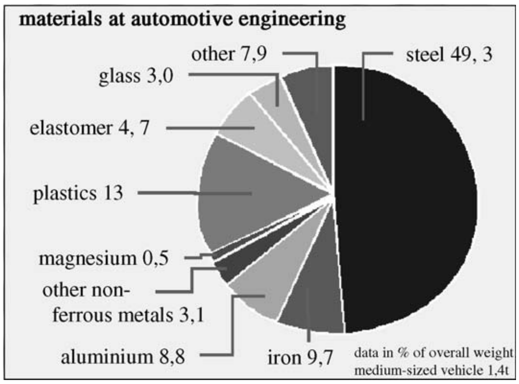

Fig. 1. Materials at automotive engineering [RWTH Aachen/Ward's/BMW/Mercer].

to an interesting alternative to conventional design materials [1,2].

2. Carbon fibre reinforced magnesium (CF–Mg)

MMCs are a rarity compared to fibre reinforced plastics and conventional not reinforced metals like steel or titanium. Compared to conventional metals MMCs offer a lot of advantages like high specific strength and stiffness as well as good wear resistance and an advanced creeping strength.

Compared to fibre reinforced plastics MMCs show good temperature stability, a thermal and electrical conductivity, resistance to radiation and humidity and the possibility of recycling. Besides, there are grave disadvantages by the high costs for the metal matrix compatible fibres and the costly manufacturing process (Fig. 2).

2.1. Magnesium as matrix material

In the group of industrial used lightweight metals magnesium is the material with the lowest density of 1.74 g/cm^3, the Young's modulus is about 40 GPa and the melting temperature is 650 °C. Remarkably low is the viscosity of liquid Mg, which corresponds approximately with the viscosity of water at room temperature.

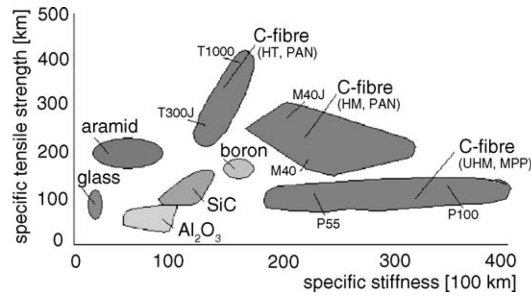

Fig. 3. Specific properties of reinforcing materials [5].

Magnesium is mainly used as cast material. Thereby, it must be pointed out that its behaviour of liquefaction is mainly dependent on the outside pressure. Beside this, liquid magnesium reacts strongly exothermal with oxygen. For this reason, oxygen protection by the use of inert gases is essential during the casting and manufacturing.

For technical applications casting alloys of Mg are classified into two main groups. The first is mainly affected by the alloying addition aluminium, whereas the second is characterized by the addition of zirconium. In connection with carbon fibres aluminium causes an increase of interfacial strength between fibre and matrix. For reasons mentioned above, the magnesium casting alloys AM10, AM20 and an adapted AM0,2 were selected for the fabrication of carbon fibre reinforced magnesium.

2.2. Reinforcing fibres and textile preforms

Compared to other reinforcing fibres like glass or aramid carbon fibres offer a great bandwidth of very high specific strength and stiffness properties (Fig. 3). A distinction is drawn between high tenacity (HT), high modulus (HM) and ultra high modulus carbon fibres (UHM). To reinforce magnesium mainly HT-fibres are used, because these are rela-

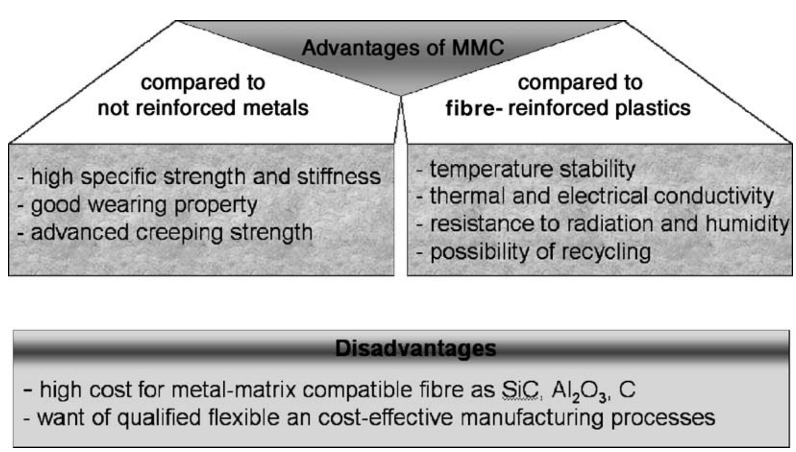

Fig. 2. Advantages and disadvantages of MMC compared to not reinforced metals and fibre reinforced plastics [5].