AFFORDABLE SIC-FIBRE REINFORCED METAL MATRIX COMPOSITE FOR HIGH TEMPERATURE APPLICATIONS

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1 Introduction

Titanium matrix composites (TMCs) reinforced unidirectionally with continuous silicon carbide fibres are considered to be attractive candidate materials for structural components in future jet engines. TMCs show superior mechanical properties (such as tensile, creep and fatigue) compared to unreinforced titanium alloys [1]. However, the serial application of titanium matrix composites is still very limited due to cost reasons and processing difficulties.

Potential applications may be found in aircraft engines where high specific strength and stiffness are needed in combination with heat resistance. Current processes are using unidirectional or hot isostatical pressing for the consolidation of the composite material [2]. The pressing of the material leads to shrinkage, distortion and fibre breakage in the worst case. To diminish these difficulties a pressureless process has been developed for the production of SiC-fibre reinforced metal matrix composites for high temperature applications. Especially for ring applications where the fibres are in hoop direction a process without shrinkage and distortion offers many advantages.

2 Preparation of the specimens

The specimens were produced by three different kinds of silicon carbide fibres. The base fibre material is the SiC-fibre SCS-6 from Specialty Materials Inc. with a diameter of 142 µm and an outer carbon coating. (i) The fibres were coated with a 5 µm thick layer of Ti-6Al-2Sn-4Zr-2Mo and (ii) the fibres were coated with the same titanium alloy and a thickness of 34 µm. (iii) The fibres were used in the ‘as delivered’ condition without any additional coating.

The fibres as specified before were put into an 80 mm long tube of the heat resistant titanium alloy Ti-6Al-2Sn-4Zr-2Mo (wt.-%). The inner diameter of the tube is 3.5 mm and the outer 12 mm. The tubes were fixed in vertical and the lower ends were closed by a plug. A funnel was placed at the upper end in which material of a low melting alloy was put. Ag-30Cu-10Sn (wt.-%) was used as low melting alloy (melting range 680-730°C). This configuration was placed in a high vacuum furnace. At a pressure below 10^{-5} mbar the specimens were heated up until 780°C. The holding time of the temperature was 30 minutes and the molten Ag-Cu-Sn-alloy infiltrated the fibres supported by the gravity and the capillary effect.

After cooling down the specimens were removed from the furnace and machined to a final shape with a gauge length of 12 mm and a gauge diameter of 4 mm. Threats of M10 were applied at both ends for the fixature in testing machines.

3. MMC microstructure

The microstructure of the infiltrated material with 34 µm coating can be seen in figure 1. The SiC-fibres with the carbon coating are dark. The titanium alloy is grey and the infiltration alloys is bright. It can be seen that the fibre distribution is fairly homogeneous.

The infiltration material reacts with the titanium alloy and forms several phases. Most of them are likely to be intermetallic phases. At the points where two titanium layers are in contact, metallic diffusion zones are growing together forming a local bonding with melting points above the infiltration temperature.

The composite using 5 µm thick titanium layers showed cracks within the titanium coating. EDX-scans of the cracked layers identified copper which was diffused through the whole thickness of the coating and formed brittle titanium copper intermetallics.

The composite produced with uncoated fibres was not fully infiltrated; in some locations no infiltration material was found. The reason is the poor wetability of the carbon surface of the fibres by the infiltration alloy. This leads to a reduction of the capillarity effect and thus a poor consolidation.

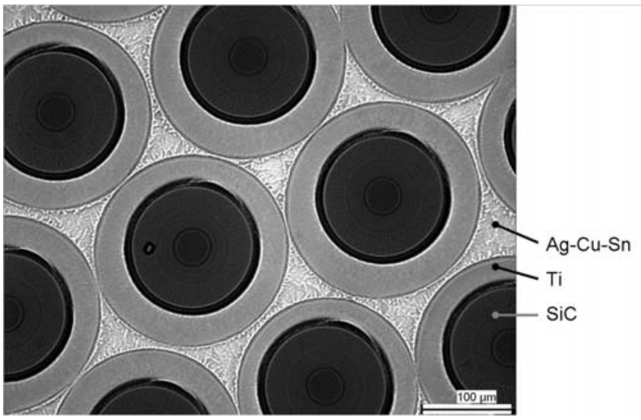

Fig. 1. Cross section of the SiC-fibre reinforced metal matrix composite.

4. Test results

The specimens described before were tested by a servo-hydraulic tensile testing machine. A summary of the test results is given in table 1. Specimen number 1, 2, and 3 were produced by the infiltration process. Specimen number 4 indicates a reference produced by the conventional hot isostatic pressing procedure with the same fibre volume content as specimen number 2. The titanium alloy volume content considers the titanium coating of the fibres as well as the remaining cladding material of the outer titanium tubing.

The ultimate tensile strengths (UTS) of specimens 1 and 3 are very low compared to specimen 2 and the reference. For specimen 3 it is caused by the poor wetting of the fibre material as described before. Specimen 1 with the thin titanium coating shows an exceptional high Young´s Modulus but the UTS and maximum strain is relatively low. The excessive formation of intermetallic phases may be the reason for this.

UTS as well as Young´s Modulus of specimen 2 are even a little above the values of the reference specimen. The maximum strain is comparable. This specification seems to be most promising.

5. Conclusions

A new consolidation process for SiC-fibre reinforced metal matrix composites has been developed. The choice of the right thickness of the titanium coating seems to be important to obtain satisfying properties. Mechanical properties of the new MMCs are at least comparable to these of titanium matrix composites processed by conventional routes. The formation of intermetallic phases in-between the titanium alloy and the infiltration alloy promises a material suitable for high temperature applications. Further Investigations are necessary to optimise coating thickness, infiltration alloy and the infiltration procedure.

References

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Table 1: Specimens data and results of tensile tests

Specimen number	# 1	# 2	# 3	# 4 (Ref)
Diameter [mm]	3,999	4,022	4,015	3,5
Thickness of titanium coating [µm]	**5**	**34**	**0**	**34**
Fibre volume content [%]	47	25	50	25
Titanium alloy volume content [%]	31	53	23	75
Infiltration alloy volume content [%]	22	22	27	0
Young´s-Modulus [GPa]	**366**	**171**	**296**	**161**
Ultimate tensile strength [MPa]	**1086**	**1690**	**934**	**1570**
0,2% Yield strength [MPa]	1047	1644	795	1320
Maximum strain[%]	0,77	1,21	0,66	1,20