JOINING MMCS TO METALS

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SUMMARY: Metal matrix composites (MMCs) reinforced with short ceramic fibres (e.g. carbon or Al_2O_3 fibres) or with other metals (such as e.g., tungsten) show numerous advantages since their properties can be programmed by modifying appropriately their composition and technology. A point of considerable importance is the possibility of joining the composites with metals or their alloys. The major problem here is to choose the appropriate joining technique, such that ensures the formation of a high quality joint resistant to the service conditions, avoids the degradation of the composite micro-structure, in particular of the interface layer between the matrix and the reinforcement, and, still, is not expensive [1].

The paper presents the results of experiments on joining the following composites: CuCr1 – based materials containing 20 vol.% of carbon fibres (C_f), CuZr1 – based materials containing 20 vol.% of carbon fibres (these composites were manufactured by volumetric bonding – the kind of PM method) and Cu – based materials with 10 vol.% of dispersed tungsten powder. The CuCr1-C_f and CuZr1-C_f composites were joined with austenitic steel and CuW composite with copper 99.99% purity. The material pairs were chosen so as to take into account their possible applications. Several different joining techniques were examined. This paper discusses the results obtained when using diffusion bonding and vacuum brazing. The morphology and the nature of the interface layer after bonding process between the matrix and the reinforcement and between the MMCs and metal were examined by analysing the interface distributions of the elements, by SEM and by X-ray techniques. The degree of the degradation of the MMCs structure was taken te be described by the coefficient of the relative content of the reinforcing material RCRM = X/B, where X is the percent content of the reinforcing phase in the composite after the joining process, and B is the percent content of this phase in the starting material. The paper discusses how the nature and morphology of the MMCs to metals joints varies with the joining techniques.

KEYWORDS: Carbon fibre–copper composites, Joining MMCs, Diffusion Bonding, Active Brazing

INTRODUCTION :
EXPERIMENTAL PROCEDURE

Materials

The materials used for the experiments were:

- CuCr1 – based materials containing 20vol.% of C_f. These composites were manufactured by volumetric bonding [2]. The fibres (1-2mm long) were produced by the Institute of Carbon Fibres – Poland. The grain size of the CuCr powder ranged from 0 to 160 μm.
- CuZr1 – based materials containing 20vol.% of C_f. The other characteristics of these materials were identical to those given above for the CuCr1-C_f composites [2].
- Cu – based material with 10 vol.% of dispersed tungsten powder. These composites were manufactured by the solid state sintering of mechanically mixed powders [3].

The CuCr1-C_f and CuZr1-C_f composites were joined with austenitic steel and the CuW composite with copper of 99.99% purity. The material pairs were chosen so as to take into account their possible applications.
All the joined materials were prepared in the form of tablets 10 mm in diameter and 2 mm thick.

Joining the composites

The composites were joined with the materials mentioned above using the two techniques: vacuum brazing and diffusion bonding.

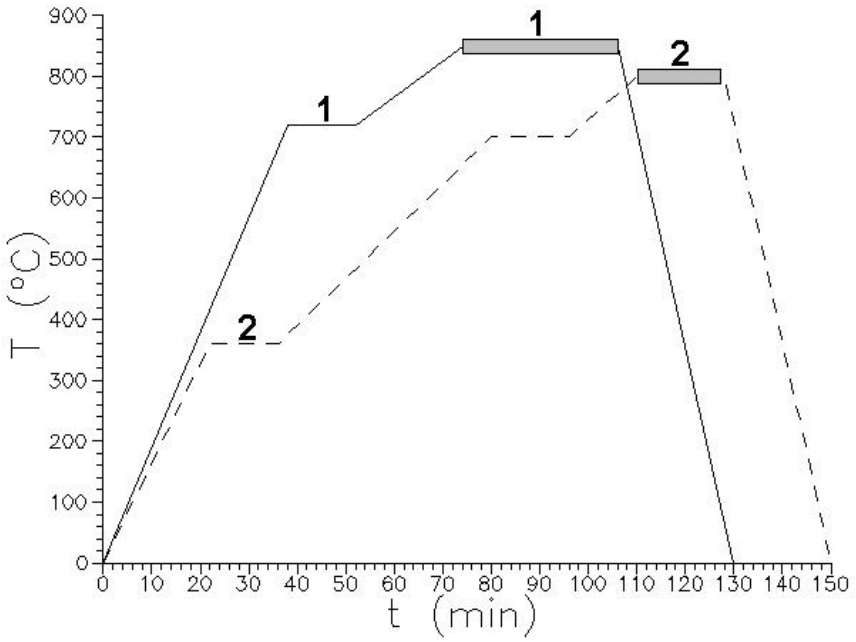

Fig. 1: Scheme of joining of the composites to metals

DIFFUSION BONDING	VACUUM BRAZING
1. CuZr1-C_f - austenitic steel CuCr1-C_f - austenitic steel CuW - Cu Pressure: 6.32 MPa; Vacuum: 2×10^{-5} Torr	2. CuZr1- C_f - austenitic steel CuCr1- C_f - austenitic steel CuW - Cu Vacuum:1×10^{-5} Torr

Vacuum brazing

The CuZr1-C_f and CuCr1-C_f composites were joined with austenitic steel and the CuW composite with copper of 99.99% purity. The materials were brazed using the active braze with the composition: (by weight) 72.5% Ag, 19.5% Cu, 5% In, 3% Ti. The schematic illustrations of the brazing processes are shown in Fig.1.

Diffusion bonding

The material pairs to be joined were the same as those subjected to brazing. The schematic illustrations of the processes are shown in Fig.1.

RESULTS AND DISCUSSION

The mechanical properties of all the joints obtained were good. The average shear strength of the joints obtained by diffusion bonding technique was 120 MPa, and 125 MPa for the joints obtained by vacuum brazing technique.

A thorough analysis of the microstructure of the composites before and after the joining process has shown that the distribution of the reinforcing phase in the vicinity of the joint does not differ from that observed in the matrix [4].

From the analysis made of the thermodynamic conditions of the volumetric bonding process of the composite it was found that when copper powder is admixed with active element additions such as Cr or Zr, the carbides of these elements should form. In the case of the composite containing carbon fibres and CuCr1 matrix, the presence of a Cr_2C_3 phase was clearly revealed by X-ray diffraction [5]. Also, test to detect the presence of unreacted free elements confirmed this results, and showed a concentration of chromium at the fibre-matrix interface, corresponding to the carbide, and a depletion of chromium in the matrix away from the fibres. In the case of the composite containing carbon fibre and CuZr1 matrix, the X-ray diffraction data revealed the presence of ZrC together with a $CuZr_2$ and a unstoichiometric compound of $ZrC_{0.7}$. The figure 2 is proof above statement. The nature of the interface between the matrix (CuCr1 or CuZr1) and the reinforcement was diffusion type.

The morphology and the nature of the interfaces layers between the matrix and the reinforcement in the composite after the joining process and in the starting composite material were similar (Fig. 3). The analysis the surface and linear distributions of the element in the MMCs to metals joints has shown, that the nature of this interface is diffusion type. The Fig. 4 is proof above statement.

On the basis of the above results, I can state, that the interfaces layers witch formed between matrix and reinforcement material, and between MMCs and other material are controlled by the diffusion

phenomena. The elaborated models of the MMCs – other material joints are shown in Fig. 5, 6, 7 and 8.

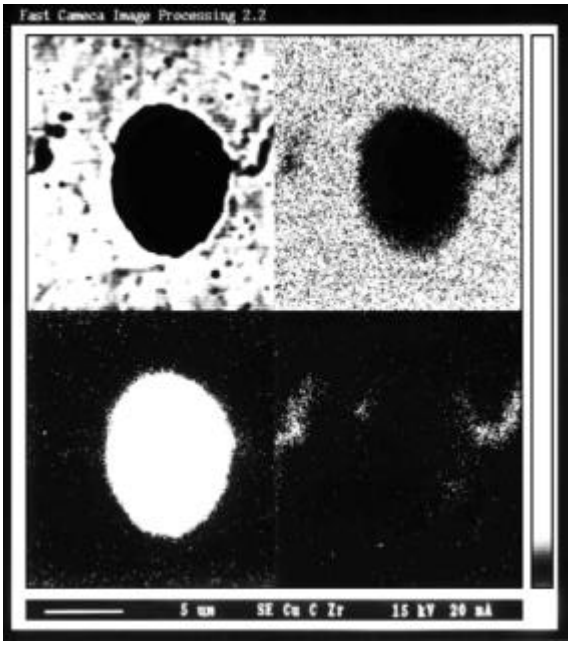

Fig. 2: Surface distributions of C, Cu and Zr in CuZr1-C_f composite

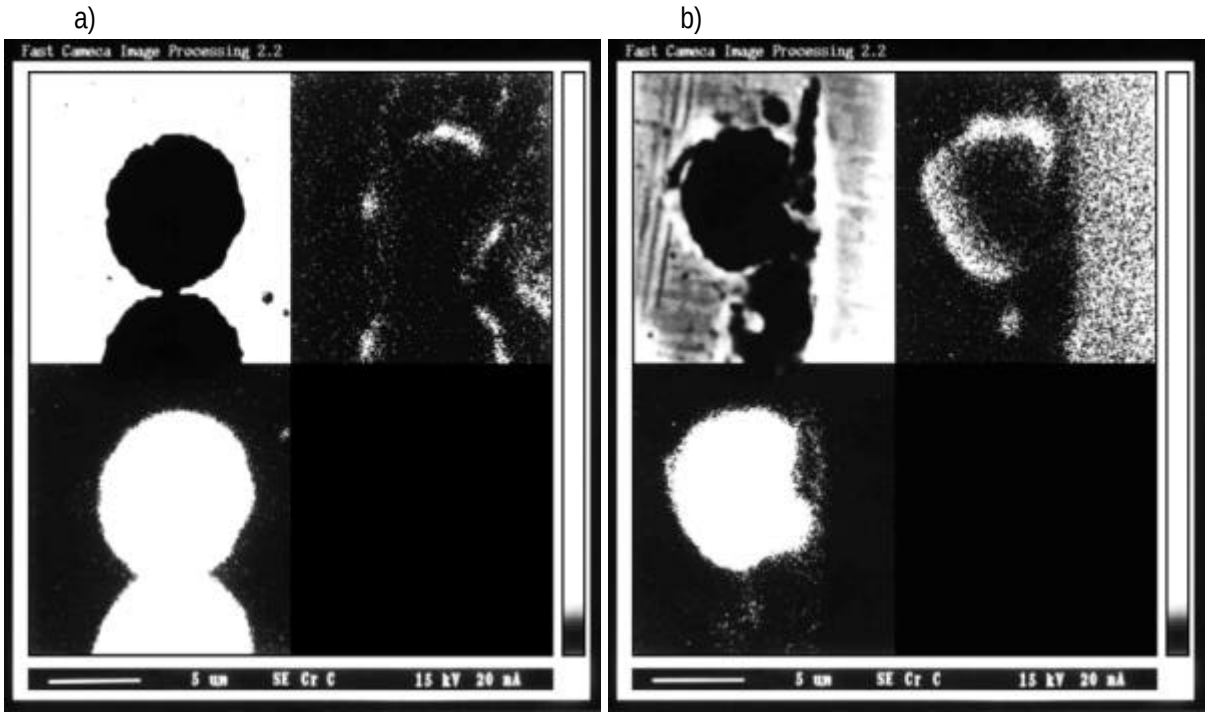

Fig. 3: Surface distributions of Cr and C in CuCr1-C_f composite:
a) before diffusion bonding process
b) after diffusion bonding process

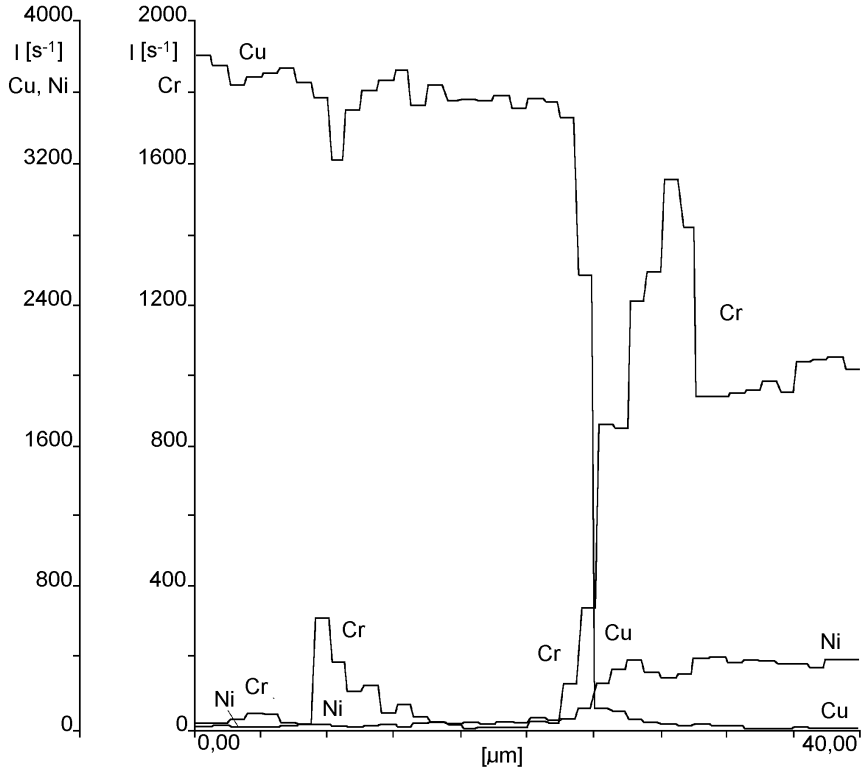

Fig. 4: Linear distributions of Cu, Ni and Cr in the interface layer CuCr1-C_f – austenitic steel, after diffusion bonding process

In conclusion I can state too, that both the proposed techniques can be used to advantage for joining the investigated composites. It should however be remembered that the optimum techniques are those which do not degrade the composite microstructure, and this depends on both the technique employed and the chemical composition of the composites to be joined.

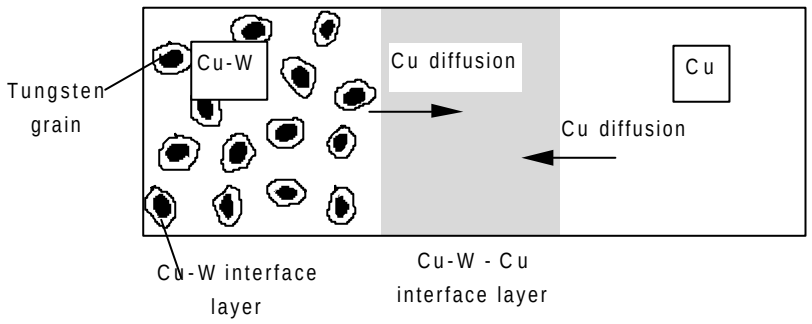

Fig. 5: The elaborated model of the CuW composite to Cu joint formed by diffusion bonding process

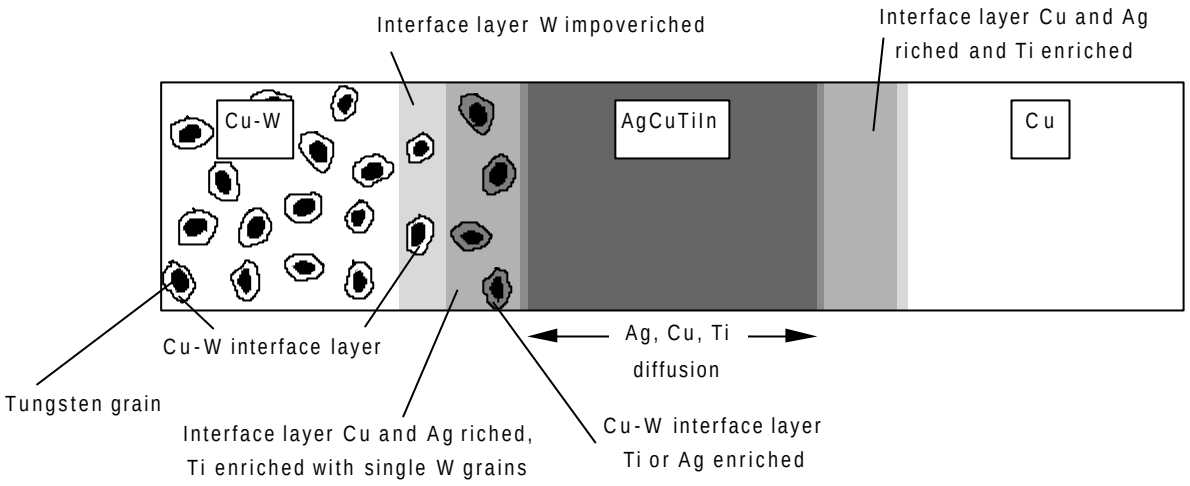

Fig. 6: The elaborated model of the CuW composite to Cu joint formed by vacuum brazing process

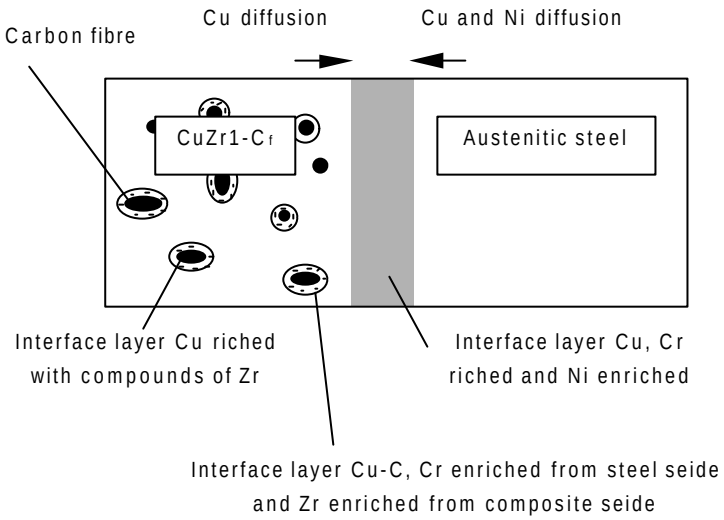

Fig. 7: The elaborated model of the CuZr1-C_f composite to austenitic steel joint formed by vacuum brazing process

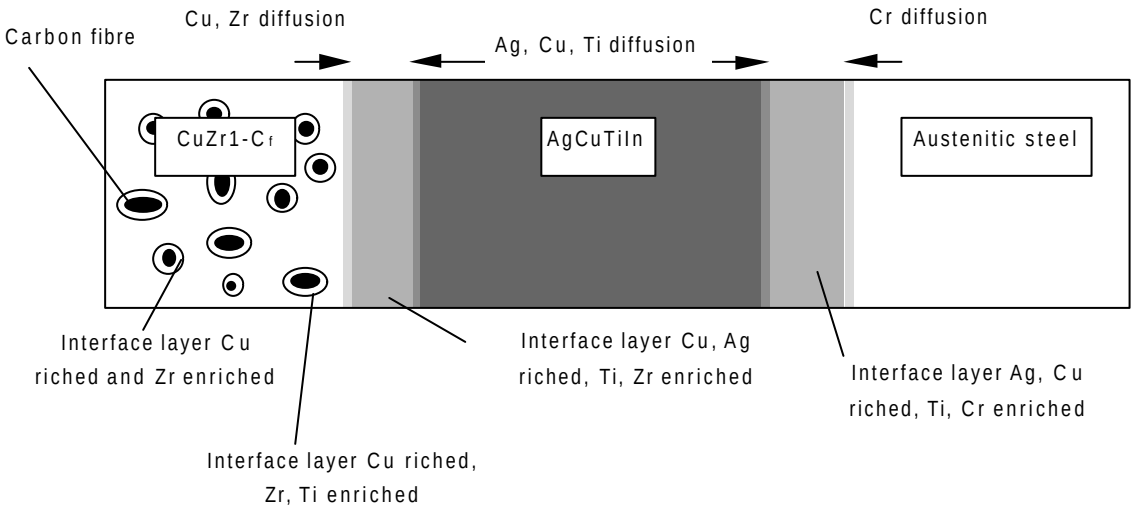

Fig. 8: The elaborated model of the CuZr1-C_f composite to austenitic steel joint formed by diffusion bonding process

Acknowledgements

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REFERENCES

1. Pietrzak K., "Joining of carbon fibre-copper composite to metals", *Adv. in Mater. and Processing Technologies*, Dublin City University, 1995, pp. 315-323.
2. Wnosinski W., Kalinski D., Olesinska W., Pietrzak K., "Carbon fibre-copper composites made by volumetric bonding", *Adv. Comp. Lett.*, Vol. 2, No. 6, 1993, pp. 219-223.
3. Mordike B.L., Kaczmar J., Kienbinski M., Kainer K.U., "Effect of Tungsten Content on the Properties and Structure of Cold Extruded Cu-W Composite Materials", *pmi* vol. 23, no. 2, 1991, pp. 91-95.
4. Pietrzak K., "Joining of carbon fibre-copper composite to metals", *Adv. Comp. Lett.*, Vol. 4, No. 5, 1995, pp. 163-168
5. Wnosinski W., Pietrzak K., Kalinski D., Olesinska W., "Correlation between interfacial microstructure and conditions of bonding in carbon fibre-copper composites", *Adv. Comp. Lett.*, Vol. 4, No. 2, 1995, pp. 57-61.