EFFECT OF PRODUCTION PARAMETERS ON THE PROPERTIES OF COMPOSITE WIRES

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ABSTRACT

Nowadays, metal matrix composites have many new areas of application owing to their excellent properties - for example their great tensile strength and high Young's modulus with its relatively low weight.

The aim of this work is the examination of ceramic fibre-reinforced aluminium matrix composite wires made via continuous process. Furthermore, the research will outline the double composite products that are composite wire-reinforced metal matrix composites.

Double composites are examined by tensile tests and bending tests. A lot of experiments have been done on the thermal aging of composite wires and on measuring the impact energy of thermal-aged specimens.

The mechanical test shows us that structures reinforced with the composite wires have a notably higher load-carrying capacity than a structure reinforced directly with fibres or a structure without any reinforcement.

KEYWORDS

metal matrix composite, double composite, thermal aging.

1 INTRODUCTION

The composite wires are fibre reinforced aluminium matrix composites which are made by continuous process. Fig. 1 shows the principal composition of a continuous production process via which wires are made [1, 2]. The reinforcement fibres were drawn through molten aluminium under high pressure via an on-going process. The liquid metal infiltrates into the fibres affected by the high pressure [3] in contempt of incorrect wettability conditions. Thus, the space between the fibres was filled up completely. The molten metal, operating under high pressure, was made to stay in the chamber via a drawing of the fibres. A continuous drawing of the fibres and a suitable speed upwards is required for the process and the liquid metal flow. The main function of the orifice's width is to keep back the molten aluminium. [4]

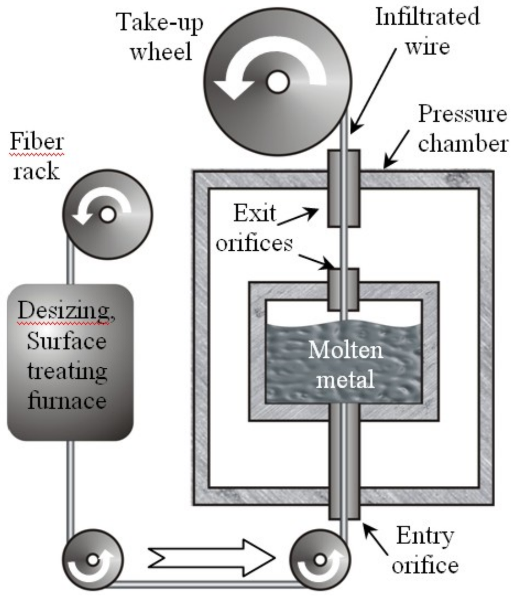

Figure 1. The continuous process

2 THERMAL AGING OF COMPOSITE WIRES

The composite wires were exposed to long term high temperatures (300°C and 500°C). This form of experiment helped us see whether the long-losting high temperatures caused any kind of change in the reinforcement and the interfacing of the fibre and matrix. It often happened that the temperature of the power cables reached 200-300°C due to an overloaded electrical grid. Accordingly, necessary to see the changes brought about by the amount of heat in composite wires. It was observed as well that these effects depend on the temperature and the time duration of the heat treatment. So our specimens were heat treated at both temperatures for 102, 262, 508 and 1155 hours. After the heat treatment impact tests were then applied.

3 ELABORATION OF DOUBLE COMPOSITES

The tensile and the bending specimens are composite wire-reinforced casts [5, 6]. Various matrix materials were used in the experiments. The matrix of the composite wires is aluminium, so one of the double composite's matrix metals is aluminium, too – while the composite wires also had to serve as reinforcing aluminium casts. It was also worth trying other metals as matrix material so as to see the differences among mechanical properties. Utilized metals were chosen with reference to their melting point. After this factor had been considered, the matrix metals were the following: tin (232°C), lead (327°C), zinc (420°C) and aluminium (660°C). All of the mentioned specimens were made by a gravitation casting process.

4 EXAMINATION OF THE COMPOSITE WIRES

Composite wires made via a continuous process have an average 60% amount of fibre, and 1.6-2.5 mm diameters. The composite wires were examined by tensile tests, bending tests, scanning electron microscopy, and EDS-analysis. [7, 8, 9]

The tensile tests of composite wires are complicated, as there is no way to reduce a wire's cross-section when we take into consideration the measured section. Thus, a breaking of specimens at the grip may occur – and any result when a specimen is breaks at the grip will not be acceptable.

In an examination of Nextel 440 fibre (tensile strength 2000 MPa) reinforced wires the average tensile strength was 1350 MPa (the wires were broken in the measured section).

The results of the tensile tests are well approximated by Eq. 1 (Rule of mixture).

$$\sigma_C = \sigma_F \cdot f_F + \sigma_M \cdot (1 - f_{SZ}) \tag{1}$$

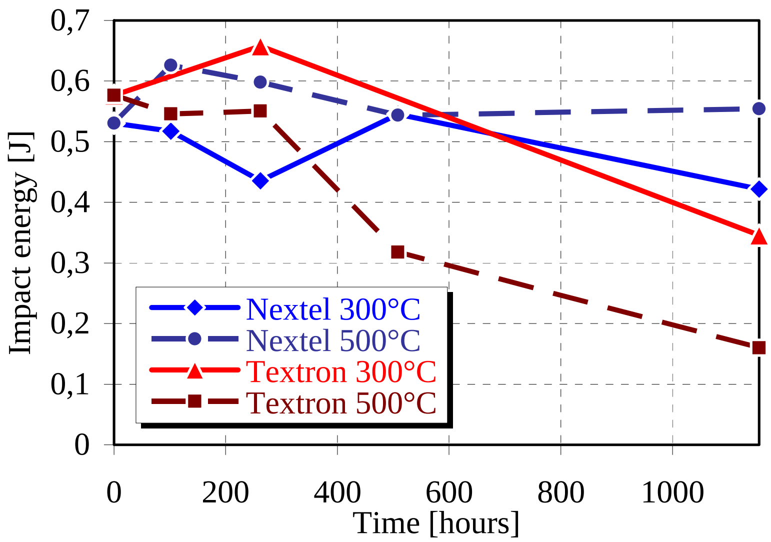

Figure 2. Impact energy of thermal-aged composite wires

Fig. 2 shows the results of the impact tests for thermal-aged specimens. Results of the tests show us that there was not - or was extremely little - fibre or interfacial damage arising which could harden in aluminium-oxide fibre-reinforced composite wires. In spite of this, though, there was notable embrittlement in a case of silicon carbide fibre reinforcement. This phenomenon is presumably connected with the mutual diffusion of the SiC, C and Al solid-solid phases. It was traceable via scanning electron microscopy and an EDS-analysis [10, 11].

The composite wires and the interface between the fibre and the matrix were investigated with a scanning electron microscope and EDS-analysis. Infiltration of aluminium into the composite wire was perfect as the aluminium filled out all of the space existing between fibres. The looked-at wires were Nextel 440, oval cross-section fibre-reinforced Al 99.99 matrix composites [12, 13].

For an examination of reactions at the interface, it is worth investigating, via an EDS-analysis, the changes in components through the cross-section of a filament [14].

5 EXAMINATION OF DOUBLE COMPOSITES

The location of reinforcing composite wires and occurring cavities in double composite casts were examined using an X-ray microscope. There were no ‘failures’ with most specimens. The molten metal flow did not alter wires’ original positions. Discovery of the position of composite wires was difficult, though, due to the tiny differences between the aluminium matrix and such composite wires. Most problems arose in connection with aluminium matrix specimens as its wettability properties are worse than the wettability properties of other metals. Here, many cavities were seen near the wires.

In the tensile tests pure matrix metals were tested first – and, afterwards, came the composite wire-reinforced variant. Fig. 3 displays the tin and composite wire-reinforced specimens after the tensile tests. The strain of pure tin is greater; and, overall, obvious strain marks appeared. So the complete length of the specimen became greater and the strain of the composite wire-reinforced specimen was concentrated in a small area. Thus, the wire with a higher Young’s modulus was loaded and could not affect the other part of the matrix metal until a reinforcing wire failure, with the matrix then carrying the whole load. With lead and zinc there was no great difference between reinforced or pure specimens.

Figure 3. Composite wire reinforced tin matrix specimen (left) and pure tin specimen (right)

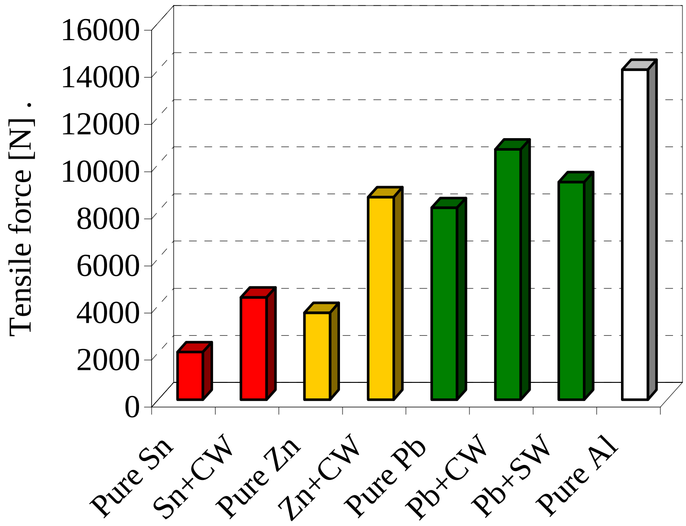

Figure 4. Tensile force of specimens (CW=Composite Wire; SW=Steel Wire)

Fig. 4 gives us the tensile test results. The composite wire-reinforced specimens carried bigger loads than the pure matrix metal specimens. This tells us that a load transfer occurs between the different matrix materials and composite wires. [15]

The results of the bending tests show a similar tendency as that of Fig. 5 concerning tensile tests. With almost all specimens the reinforcing composite wire was able to work together with the matrix. This higher load can be used with the double composites - more than is the case with other specimens (without reinforcement). Exceptions are due to casting faults.

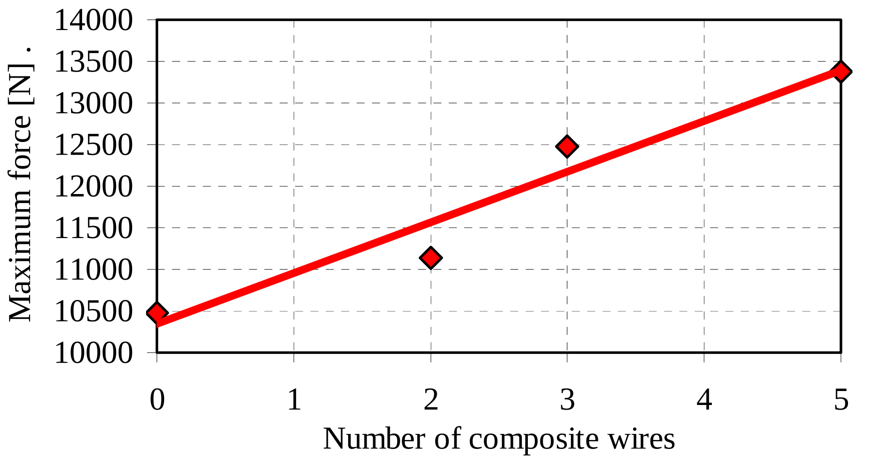

Figure 5. Bending test for square cross-section aluminium specimens

Fig. 5 depicts results coming from square cross-section aluminium matrix double composite bending tests. A regression line related to measured points shows the correlation between the quantity of composite wire and strength. The strength of the double composite structure is a linear function of the composite wires' quantity.

6 CONCLUSIONS

The investigated double composite specimens are reinforced casts with aluminium matrix composite wires. Pb, Sn, Zn and Al were used as a second material for a casted structure.

The cast from Sn fills the mould appropriately and after solidification low imbibitions were noticed and dendritic crystallites were seen on the surface. The Zn cast had crisp imbibitions and a rough surface. Unfortunately, the Pb chilled too quickly, which resulted in the forming of interfaces. The moulding of Al was most difficult, as it filled the mould and the wires poorly (the molten metal did not successfully fill the corners and edges of the chill). Imbibitions measurements were smaller with casts that contained composite wires.

The long-term aging showed a rigidity when it came to lasting and high temperatures. This process was more rapid and more significant for SiC fibre-reinforced composite wires than for Al-oxide reinforced wires. The reason for the rigidity of SiC fibre was that the two main component (Si and C) and Al in the diffusion process with the solid-solid phases reacted with the fibre-matrix interface [12]. So brittle intermetallic phase and aluminium-carbide appeared.

Results from the tensile tests and the rate of the fibre/matrix show us that the strength of composite wires can be reduced 35% when set against theoretical (rule of mixture) results. The reason for this strength lowering is that small pores remained during infiltration of the fibre bundle, where the liquid metal was not able to penetrate; and this phenomenon decreases the cross-section of specimens.

An examination of round cross-section specimens shows us how the presence of the notches and stress concentration places modify strength. Also determinable was the quantity and distribution of composite wires in a volume unit so as not to cause cavities between wires. Our experiments proved that, with specimens, cavities operate as stress concentration locations. Thus, a cross-section decrease does not lead to a major strength lowering – but has a stress concentration effect.

General conclusions are that double composites improve the mechanical properties of products.

During the moulding process composite wires did not move, which is proved via an X-ray microscopic examination – and this points to a minimal amount of fixation needed to hold them in position. In addition it was observed that cavities always formed themselves close to composite wires.

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