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EFFECT OF PLASMA JET ON THE MECHANICAL PROPERTIES OF REINFORCING FIBERS OF COMPOSITE MATERIALS[1])

D. MATEJKA[2]), J. TRČKA[2]), A. MAGNUS[3]), V. I. KALITA[4]), Bratislava

In develoment of a new aluminium alloy based on composite materials the plasma spraying technology is being introduced. Due to thermal and kinetic effects of the plasma jet the properties of reinforcing fibers deteriorate. The work evaluates the effect of some parameters of the plasma torch upon the strength decrease of boron fibers.

ВЛИЯНИЕ ПЛАЗМЕННОЙ СТРУИ НА МЕХАНИЧЕСКИЕ СВОЙСТВА УКРЕПЛЯЮЩИХ ВОЛОКОН СОСТАВНЫХ МАТЕРИАЛОВ

При разработке нового алюминиевого сплава из составных материалов применена технология плазменного распыления. Свойства укрепляющих волокон ухудшаются вследствие термических и кинетических эффектов плазменной струи. В работе вычислено влияние некоторых параметров плазменной горелки на уменьшение предела прочности борных волокон.

I. INTRODUCTION

The aluminium-based composite material reinforced with boron fibers belongs to the materials meeting the requirements of a modern development of structures. The mentioned composite, reinforced material exhibits excellent strength properties, given especially by the low weight of the Al-Mg matrix and boron fibres with a very high strength, used as reinforcement.

Theoretical and experimental experience in this field [1, 2, 3] has provided that the technology of plasma spraying of powder metallic materials in preparation of the matrix-fiber semiproduct, followed by its compaction by some of the ther-

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[2]) Ústav materiálov a mechaniky strojov SAV, Febr. víťazstva 75, 836 06 BRATISLAVA, Czechoslovakia.

[3]) ZŤS — Ústav technológie a racionalizácie, Nevädzova 5, 826 13 BRATISLAVA, Czechoslovakia.

[4]) Institut metallurgii im. Bajkova, AN SSSR, MOSKVA USSR.

mocompression processes (e.g. vacuum pressing), is a highly perspective method providing a number of possibilities in the field of fibrous composite material preparation. The advantages of this method, providing a time limited thermal and mechanical effect of the matrix particles upon the brittle reinforcing fibres, enable to meet the following basic reguirements of the process and technology of preparation of the fibrous composite materials: to preserve the strength of the reinforcing fibers, to ensure a good adherence of fibers to the matrix, a minimum development of diffusion processes resulting in the formation of brittle phases between the matrix and the fibre, to ensure uniform distribution of the reinforcing fibers in the matrix and also their precise orientation.

The aim of one stage of the research work [4] was to determine the optimum parameters of plasma spraying of aluminium matrices [5] and to determine the effect of plasma jet and the sprayed aluminium particles on the strength of the reinforcing boron fibers as the basic conditions for the ensurance of optimum properties of the semiproducts (one-layer) as well as multilayer composite materials of the Al-B fibre type. It is well known [1, 2, 5] that the unfavourable properties of the matrix as well as the reinforcing fibers in the semiproduct lead to a decrease of the quality and the overall strength of the multilayer composite.

II. METHOD OF SOLUTION, USED MATERIALS AND EQUIPMENT

The method of study of the effect of the plasma process on the mechanical properties of the reinforcing fibres was developed from a commercial technological procedure used in our country for the preparation of semiproducts. According to this procedure a metallic cylinder is wrapped with a basic thin aluminium (dural) foil which is then wound with the reinforcing fibre at a precise lead of the individual windings. Upon this system of a layer of the Al-Mg alloy is then plasma sprayed. The plasma-sprayed layer on the system of wound fibres, together with the basic foil are considered as the matrix, fixing element of fibers at their defined distance from the basic foil and also as an interlayer in the diffusion bonding of more systems of semiproducts into the resultant material of the Al-B fibre type.

For comparison of the tensile strength values of original B fibres with those extracted from the composite material matrix a considerable strength decrease of B fibres from the ready made material was observed. Combination of effects of plasma jet heat, kinetic energy of impinging molten particles and oxidation effect of air atmosphere are considered a possible cause of this decrease. In order to prove the first two effects the following procedure of experimental investigation was suggested. On the aluminium sheets the bundless containing 40—50 pcs of boron fibres were fixed. On specimens prepared in such a way, in the first group of experiments the effect of plasma jet was directed. The jet flew from a plasma torch

for a period of 12 seconds, in the first series at the constant torch distance $d = 10$ cm and in the second series at the constant distance $d = 15.5$ cm. With both alternatives the spraying was performed at four different levels of plasma torch outputs: 11.2, 14.4, 18.0 and 22 kW. In the second group of experiments, performed by the same procedure, Al powder was added to the plasma jet and the fibres were affected by the spraying of the Al layer. From the bundles of affected

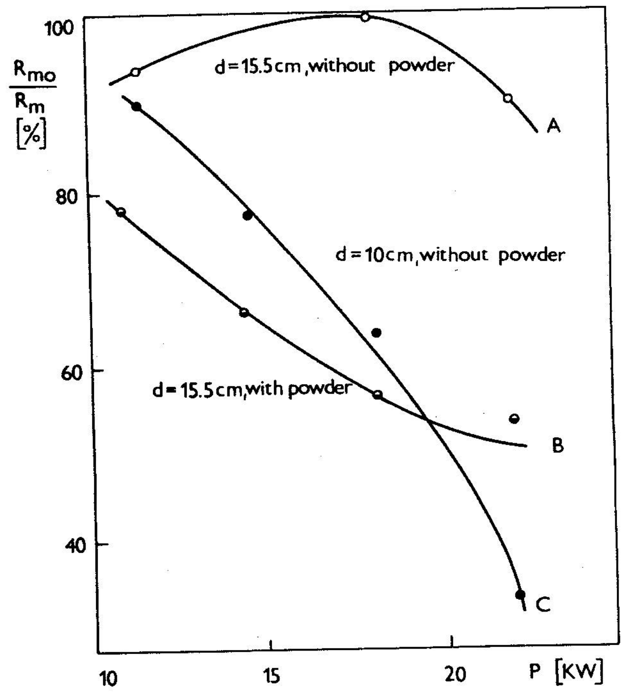

Fig. 1. Strength of fibers in dependence on torch output.

fibres, as well as of the initial non-affected fibres specimens for tensile tests of single fibres were prepared in such a way that for each measured point at least 30 pcs of fibres were available. In case of aluminium sprayed fibres, the fibres were separated from Al in a 10 % solution of potassium hydroxide. Many other experiments have proved that such separation did not affect the strength of the fibres. The strength of single fibres was determined by the tensile tests. After calculation of the mean strength values (from 30—40 measurements) the results were plotted into diagrams in Fig. 1. These diagrams show the dependence of the relative strength of fibre R_{mo}/R_m on the power output and spraying distance, for the plasma jet without powder and/or with powder addition.

Then, from the obtained results of measurements also the graph shown in Fig. 2, expressing the dependence of the relative strength of fibres on the spraying distance was plotted.

For experimental purposes the boron fibre made in the USSR with a diameter of about 0.130 mm was used. It attains 3600 MPa UTS, a 420 GPa elasticity modulus and its specific density is 2560 kg m^{-3}. As the filler metal in plasma spraying the aluminium powder, designated by the CSN Standard as Al 18138 with a 70 μm grain size and 99.0 % purity was used.

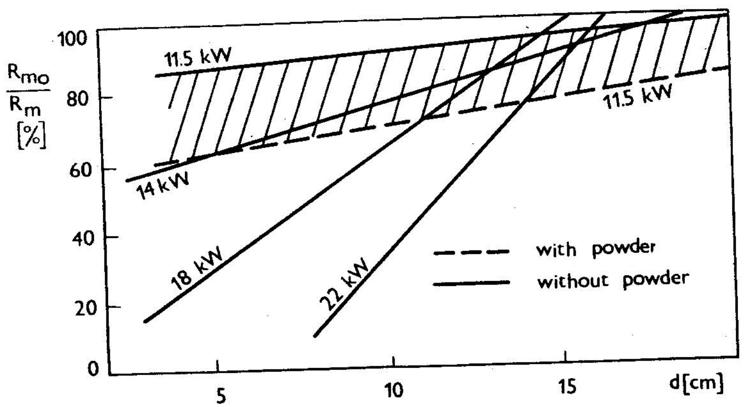

Fig. 2. Strength of fibers in dependence on spraying distance.

The plasma spraying operation was performed on the PLASMATECHNIK spraying equipment with argon-hydrogen plasma. Exit velocity of the plasma jet from the torch type F 4 attains the values of 1000 m/sec. while the velocity of molten particles in plasma is 300 m/sec. The characteristics of the thermal and kinetic effect of the plasma torch were controlled by the power output within the 10—22 kW range at constant flow rates of plasma gases.

Tensile tests of single fibres were carried out on the INSTRON type DT equipment.

III. DISCUSSION OF RESULTS

The dependence of the relative strength of the affected fibres R_{m0}/R_m on the power output P of the plasma torch is plotted in Fig. 1, where the strength values of the affected fibres R_{M0} in relation to the strength of the non-affected fibre $R_m = 3600$ MPa are plotted on the vertical axis. The strength course of the fibers affected by the plasma jet without the filler powder and/or with powder is shown for the alternative spraying distance $d = 15.5$ cm.

The strength decrease in the whole range of the outputs due to the fibers affected by jet without powder (curve A) does not exceed the value of 10 %. At 18 kW output the fiber strength is maintained. A considerably more significant effect on the strength decrease is exerted by the jet with the Al powder addition. According to curve B the strength decrease at the lowest output is 22 %, while it increases with the increasing output up to the maximum value of 46 %. From the course of both curves it follows that with the greater spraying distance the use of minimum output is the most advantageous from the viewpoint of the composite material preparation, because the strength drop in that case is within acceptable limits. With increasing output also the exit velocity of the plasma jet increases, increasing thus also the kinetic effect in the impact of the molten particles of Al on the boron fibre surface. At the spraying distance reduced to 10 cm the thermal effect of the jet on the fibre increases. This is manifested on the curve C (effect of jet without powder) as the strength drop by 10 % at a minimum output with subsequent sudden strength decrease with an increasing output up to 66 % at 22 kW output. From the diagram it is evident that at 10 cm spraying distance, when the jet affects without powder, the strength drop is excessive and this alternative is practically unacceptable. The dependence of the relative strength of fibres affected by plasma jet on the spraying distance d, for all outputs used, is plotted on graphs in Fig. 2. For the alternative of optimum parameters at a 11.5 kW output also the dependence for the effect of the jet with powder is shown. It can be concluded that with a reduced spraying distance the fibre strength decreases. The degree of this decrease is given by the slope of curves, which increases with increasing output. The hatched area between the two lines for the 11.5 kW output represents the portion of the kinetic effect of plasma jet on the total strength decrease of fibres.

IV. CONCLUSION

The experimental results show the percentual strength decrease of boron fibers during the effect by the plasma jet with powder and/or without powder addition. The graphical dependencies show the effects of the main parameters of plasma spraying on the strength properties of composite materials with boron fibers, namely the power output of the plasma torch and the spraying distance. This knowledge can be utilized directly in the determination of parameters for plasma spraying in the preparation of composite materials on the PLASMATECHNIK spraying equipment.

REFERENCES

[1] *Proc. of AN SSSR: Kompozicionnye materialy.* Izd. Nauka, Moscow 1981.
[2] Šoršorov, M. Ch. (Ed.): *Voloknistye kompozicionnye materialy s metaličeskoj matricej.* Mašinostroienie, Moscow 1981.
[3] Kreidler, K. G.: *Metallic Matrix Composites.* Acad. Press New York 1974.
[4] Matejka, D., Trčka, J.: *Správa výskumnej úlohy č. III. 6.5/5* (Research Report) ÚKM SAV, Bratislava 1980.
[5] Matejka, D.: Kovové materiály (Metallic Materials)., *XIII* (1974), 667.

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