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The effects of low-temperature plasma treatment on the capillary properties of inorganic fibers

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Abstract. Solving the problem of achieving high adhesion between the components in the polymeric composite material (PCM) based on carbon fibers (CF) and basalt fibers (BF) is proposed to use the radio-frequency (RF) plasma under lower pressure by virtue of efficiency, environmental friendliness and rationality of the method. The paper gives the results of studies of the properties of CF and BF after RF capacitive discharge plasma treatment. The plasma modification modes of carbon and basalt fiber were investigated. The efficiency of treatment tool in surface properties modification of carbon and basalt fibers was found, namely capillary properties of CF and BF were researched. The optimal treatment modes were selected. It was found that the method of plasma modification in the radio-frequency capacitive discharge under the lower pressure contributes enhancing the capillary properties of inorganic fibers, in particular carbon and basalt ones. It shows the tendency to increase of the adhesive properties in PCM, and, consequently, the increase of the physical and mechanical properties of the products.

1. Introduction

Technology of creating fibrous polymeric composite materials (FPCM), which are applied in the production of sports equipment and sports cars, includes activation of the fiber surfaces to enhance adhesion between fiber and matrix. Nowadays in the production of reinforced composites fiber is pretreated with chemical solutions which are toxic and aggressive substance, and thus require complex protection systems and disposing of as hazardous waste. The radio-frequency capacitive (RFC) plasma under lower pressure is the perspective treatment tool for materials with different nature [1]. This method makes it possible to treat organic and inorganic materials of various consist and structures. It is especially important to note the fact that the RFC plasma treatment technology is environmentally friendly [2].

Based on the results of previous researches [3, 4] in the study of the low-temperature plasma (LTP) effect on the properties of inorganic fibers and filaments to make materials hydrophilic treatment in RFC discharge under lower pressure in argon atmosphere is carried out.

2. Materials, methods and equipment

As study objects were considered three types of CF with different degree of graphitization and the structure of weaving: high modulus fiber Kulon 500/0.07, carbonized fibers LUP-0.2 and Ural T-2-22r; basalt twisted thread BS10-68Z40-KB-12.

Capillarity was measured by height of fluid lifting with the control and the treated by RFC plasma CF and BF samples.

To modify the fibers it was used the radio-frequency plasma unit of capacitive discharge with plane-parallel electrodes (figure 1).

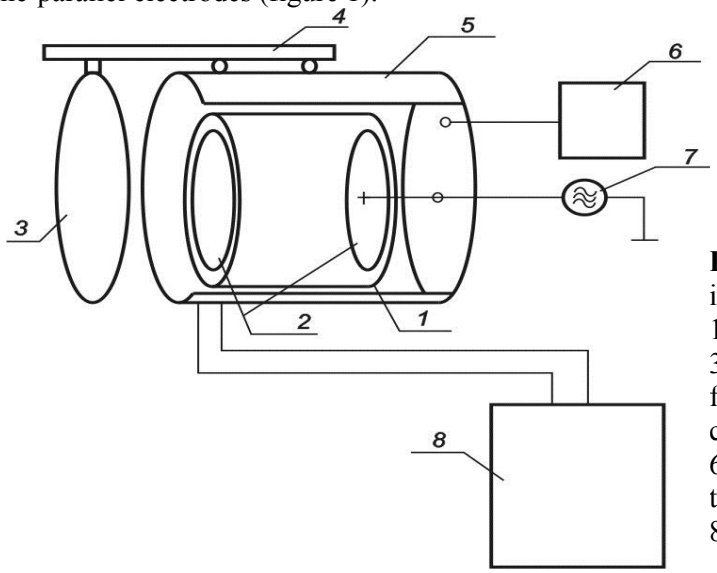

Figure 1. Scheme of experimental-industrial RF plasma unit: 1 - plexiglass drum; 2 - RF-electrodes; 3 - cap of vacuum chamber; 4 - console for opening the lid of the vacuum chamber; 5 - vacuum chamber; 6 - system of supply and regulation of the plasma gas; 7 – RF-generator; 8 - vacuum pumping post.

In this study the input parameters of the unit for CF treatment were set within the following: plasma gas flow G = 0.04 g/s, frequency f = 13.56 MHz, the pressure in the vacuum chamber P = 26.6 Pa, voltages U, amperage I and the treatment time t were varied from1.5 kV up to 5 kV, from 0.3 A up to 0.7 A and from 3 up to 7 min respectively. In the experiments technical argon was used as the plasma gas.

To research the effect of LTP on the capillary properties of BF samples were pretreated in the plasma unit with mode: the plasma gas argon, G = 0.04 g/s, f =13.56 MHz, P = 26.6 Pa, t = 3 min with variable voltage U from 2 kV up to 7 kV and amperage I from 0.3 A up to 1.0 A.

3. Results

After the plasma treatment the carbon fiber samples show the tendency to increase the amount of fluid lifting height. This indicates an improvement wettability of the carbon textile (figure 2).

It is found that at the equal time of plasma treatment t= 5 min in argon atmosphere increase of RF voltage on the electrodes leads to a decrease of the capillary rise of liquid by CF (figure 3).

On the one hand, increase the plasma treatment time at a fixed voltage U=1.5 kV leads to increase capillarity of CF. On the other hand, increase the plasma treatment time at a fixed voltage U=3 kV leads to its decrease (figure 4).

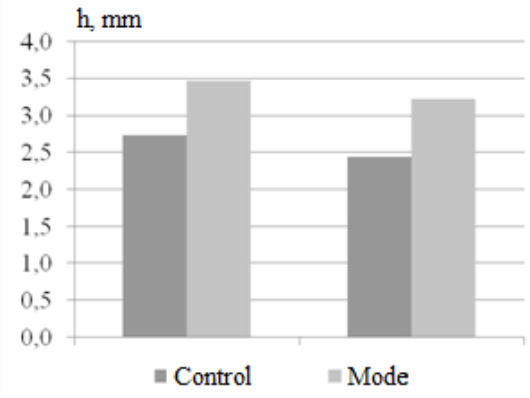

Figure 2. The effect of treatment on capillarity of CF: 1 – CF LUP-0.2; 2 – CF Kulon 500/0.07.

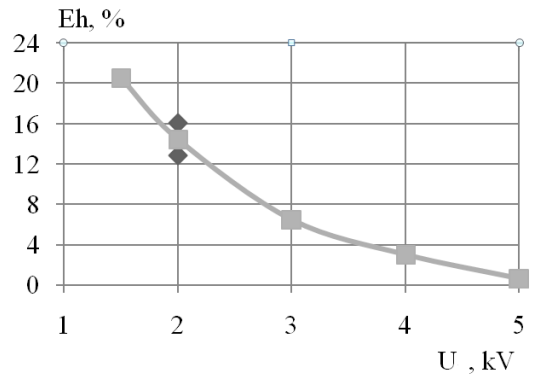

Figure 3. The effect of voltage between the plates on the capillary rise of liquid of CF Ural T-2-22r;

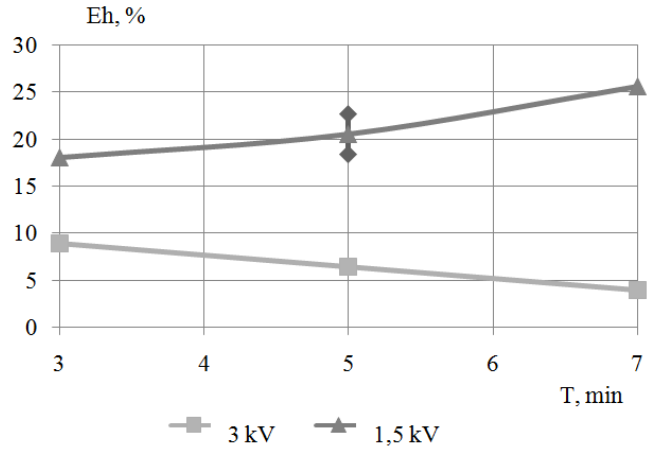

Figure 4. The effect of the treatment time on the capillarity of CF Ural T-2-22r.

The results of BV research are presented in table 1.

Table 1. The dependence of the BF capillarity from modes of plasma treatment

Voltage (U), kV	Amperage (I), A	Capillarity, mm
The control sample		34
2	0.3	60
3	0.4	64
4	0.6	74
5	0.7	67
6	0.85	62
7	1.0	62

Analysis showed that the maximum of capillarity of basalt thread is achieved with following LTP treatment mode: U=4 kV, I =0.6 A, t =3 min, G= 0.04 g/s, f=13.56 MHz, P=26.6 Pa. Capillarity due to this mode increases by 118%.

4. Conclusions

RFC plasma treatment under lower pressure in argon atmosphere enhances the capillary properties of CF and BF.

Accordingly the test results the tendency to increase adhesiveness of these fibers by LTP treatment was found. Projected, it will lead to increase the physical and mechanical properties of polymeric composite materials based on modified fiber.

Acknowledgments

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