EFFECT OF PLASMA TREATMENT ON GLASS FIBER/EPOXY RESIN COMPOSITE

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Abstract

In this study, glass fiber mat was used as reinforcement to prepare an epoxy composite. Oxygen and argon plasma were used for surface modification of glass fibers to improve their adhesion to the epoxy resin and enhance the mechanical strength of the prepared composite. Plasma treatment variables were gas type (oxygen and argon), gas flow rate, treatment time, and power. The tensile strength and elongation at break were measured as responses and the effects of different process variables on the responses were studied. The results showed that plasma treatment can enhance the tensile strength of the glass fiber/epoxy resin composite. Increasing in plasma power, increased the tensile strength of the composite samples. Argon plasma was more effective than oxygen plasma.

Key Terms

Glass fiber, Plasma, Composite, Adhesion, Tensile strength.

1. Introduction

Fibrous composites are made of fibers embedded in a polymer matrix. The use of fibers in polymeric composites makes them light-weight and increases their tensile strength. The adhesion between the fibers and the polymeric matrix determines the strength and toughness of the final composite [1]. For reinforcements such as carbon and glass fibers which their surface is smooth and chemically inactive, modification of the fibers can improve the wettability of fiber surface by the resin, resulting in improvement of the interfacial adhesion between the resin and fibers, which is necessary for a good load transfer from the resin to the carbon fibers [2, 3]. Glass fiber (GF) is quite popular as a reinforcement material for polymers due to its unique properties, including high mechanical property, high aspect ratio, good heat resistance, very low cost, etc. It has been found that the properties of glass fiber reinforced polymer composites largely depend on the aspect ratio of fiber, the content of fiber, the dispersion, and particularly, the interaction between fiber and matrix [4]. Due to weakness of glass fiber in wetting and adhesion properties, effective surface modification of fibers is necessary for preparation of composites with high performance characteristics. Several chemical and physical methods have been developed for improvement of surface properties of fibers and increasing their adhesion to the polymeric matrix [5-8].

One of the simple and effective methods for surface modification of fibers is plasma treatment. It can increase the surface roughness of fibers and enhance their wettability and adhesion properties by introducing new functional groups to their surface [2, 3, 9-11]. Plasma modification effects are dependent on several variables such as treatment time, power, type and flow rate of gas, etc. So, investigating the impact of process parameters on the surface characteristics of fibres is essential [3].

In this study, glass fiber mat was surface modified by oxygen and argon plasma and used for preparation of epoxy resin composite. The effect of gas type, gas flow, plasma treatment time and power on mechanical properties of the resultant composite was investigated.

2. Experimental

2.1. Materials
Glass fiber (GF) mat (225 gm^{-2}) was obtained from Iran-Composite co. Iran. Bisphenol F type epoxy resin (EPL 1012) and hardener (EPH 112) were used for preparation of composites.

2.2. Procedures
GF mats were treated in a low-pressure radio frequency plasma equipment (Plasma DEJ, Iran).

Oxygen and argon were used as the process gas and plasma was generated at different durations (1 and 5 min) and powers (50 and 200 W) at two different gas flow rates (20 and 100 Sccm). Table 1 shows the plasma treatment conditions for functionalization of different GF mat samples.

Table 1: The plasma treatment conditions for preparation of GF mat samples

Sample	Power (W)	Time (min)	Gas flow (sccm)	Gas type
1	50	5	20	O_2
2	200	5	100	Ar
3	50	5	20	Ar
4	200	5	20	Ar
5	50	5	100	Ar
6	200	1	100	O_2
7	50	5	100	O_2
8	200	1	20	O_2
9	50	1	20	O_2
10	50	1	20	Ar
11	50	1	100	O_2
12	200	5	20	O_2
13	200	5	100	O_2
14	50	1	100	Ar
15	200	1	20	Ar
16	200	1	100	Ar
17	-	-	-	-

To prepare the composites, the matrix was prepared by mixing epoxy resin and hardener with the weight ratio of 10:2. GF mats were impregnated in the matrix and subsequently were placed into a special mold. Finally, the samples were solidified for 16 h at 25 ^{o} C.

2.3. Analytical Methods
The tensile properties of the composite samples were measured according to ASTM: D3039/D3039M-17.

3. Results and Discussion
The results showed that plasma treatment can enhance the tensile strength of the glass fiber/epoxy resin composite. This is due to the introduction of surface functional groups and increasing the roughness of the fibers leading to improved adhesion between the fibers and resin [12]. When treating the glass fibers with oxygen plasma at 50 W and 200 W, increasing the treatment time from 1 min to 5 min caused a decrease in the tensile strength of the

composite. It may be due to over etching of the fibers due to prolonged exposure to argon plasma, which reduced the strength of the fibers and the composite made of them [3].
In case of oxygen plasma treatment at 50 W, increasing the plasma treatment time from 1 min to 5 min cause a slight increase in tensile strength of the composite. However, when pre-treating with oxygen plasma at 200 W, the tensile strength was decreased when increasing the treatment time from 1 min to 5 min. the reason is the same as the case of argon plasma treatment. Increasing in plasma power, increased the tensile strength of the composite samples. Argon plasma was more effective than oxygen plasma.
Plasma treatment had no significant effect on elongation at break of the composite samples. The changes in elongation at break after plasma treatment are not considerable, however the elongation at break has been increased slightly for argon plasma treated samples.

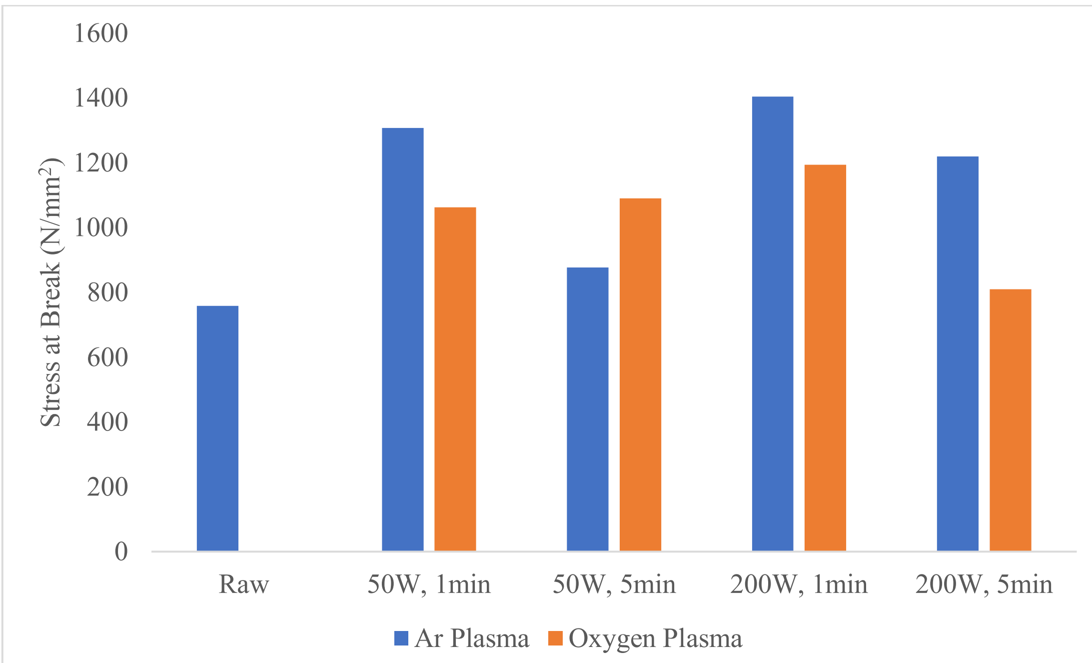

Figure 1: The effect of plasma treatment on tensile strength of prepared composites

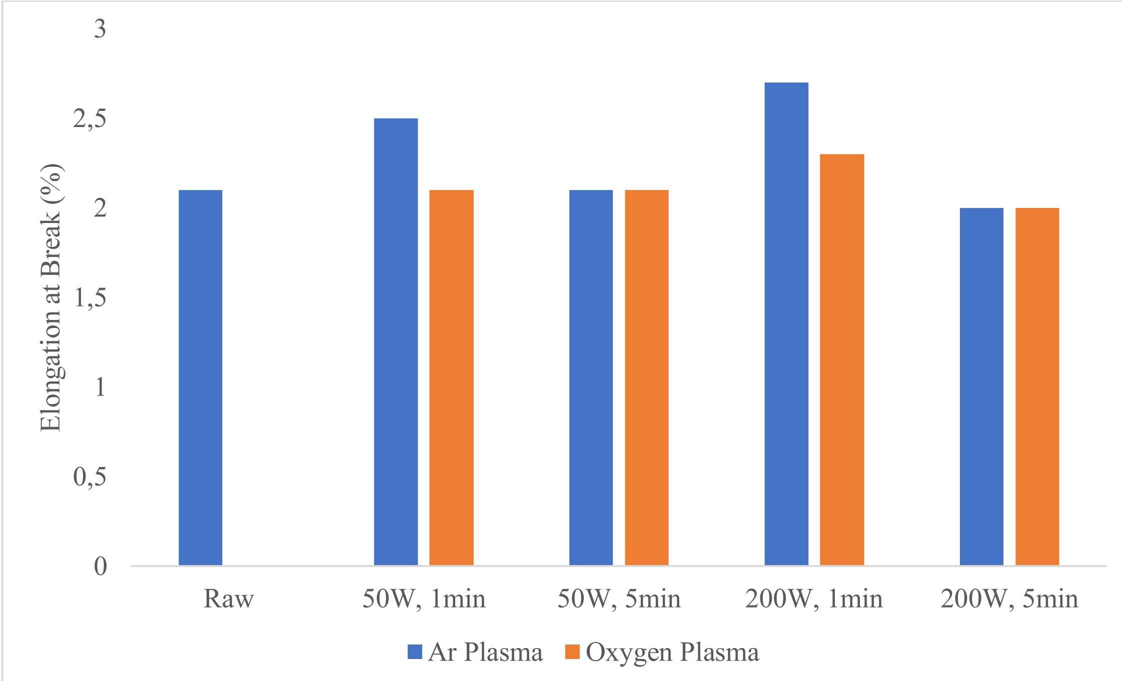

Figure 2: The effect of plasma treatment on elongation at break of prepared composites

4. Conclusions

In this study the effects of plasma treatment on tensile strength and elongation of glass fiber/epoxy composite (under different conditions of plasma treatment) was investigated. The tensile strength was improved for plasma treated samples while it showed no significant effect on elongation of the samples at break. The gas type and flow, treatment duration and power can affect the properties of the resultant composite. The results indicated that treatment of glass fibers with argon plasma for 1 min as the optimum condition of treatment, can improve the tensile strength of the prepared composites.

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