금속섬유의 계면강도에 있어 후처리의 영향

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Studies on the Interfacial Strength of Metal Fibers with Epoxy and PET Resins

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1. Introduction

The unique physical properties of metal fibers have led to their wide application in different fields of machinery and electrical products. Especially, stainless steel(SS) fiber is used to the reinforcement of composites, textile and nonwoven materials for improving strength and electric properties. Since the surface of SS fiber is usually inert, smooth and flat, it is difficult to adhere to matrix resins and binders. In addition, mechanical properties of composites are affected on the properties of fibers and resins, as well as interfacial adhesion.

Thus, the improvement of interfacial adhesion is very important for the composite performance. Various methods for improving interfacial adhesion[1, 2] are focused on the increasing the surface area and chemically active groups of the fiber. In particular, the fiber surface modification by acid treatment[3] and plasma treatment are used for this purpose. The surface change of the SS fiber after the treatment has an effect on its strength as well as interfacial adhesion. In this study, surface structure and interfacial properties of SS fiber by hydrochloric acid treatment and plasma treatment were investigated to determine the optimal SS fiber reinforced composites and chemical bonded nonwovens.

2. Experimental

2.1. Surface treatment condition

The SS fiber was treated by hydrochloric acid solution of 0.2 M/l at 60℃. Treatment time was varied from 0, 20, 40, 60, 80, 100min followed by washing with water and drying in oven. On the other hand, SS fiber was treated by oxygen plasma with a flow rate of 10ml/min at the system pressure of 60mTorr. Plasma treatment time in the reactor was varied with 1, 5, 10, 20min and discharge power was fixed at 20W.

2.2. Surface morphologies

The surface structures of SS fiber were observed by using a scanning electron microscope JEOL(model: JSM 5410).

2.3. Interfacial shear properties

Interfacial adhesion between SS fiber surface and resins was tested through microdroplet test. The matrix used were the epoxy resin 2216 B/A(3M Co.) based on the epoxy resin(diglycidyl ether of bisphenol-A) with the amine terminated hardener(1,3 phenylene diamine) and PET resin. PET resin was used the filament of 300㎛ diameter manufactured in Samyang Co.. In the case of PET resin, it was used by the knot on SS fiber formed by filament of PET resin and then melted PET knot. The interfacial shear strength(IFSS) was tested by Instron 4467 tester with the crosshead speed of 0.5mm/min and gage length of 20mm.

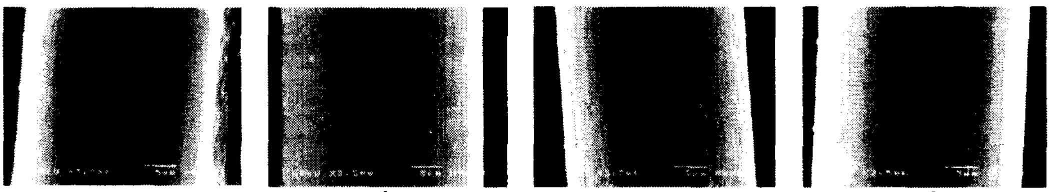
2.4. Contact angle

Contact angles of SS fiber was measured with water(H_2O) and methyleneiodide (CH_2I_2) by DCA 322(Chan Co.) for conatct angle and surface energy properties of SS fiber. At this time, motor speed of DCA was 500㎛/min.

3. Results and discussion

3.1. Surface properties

The SEM photographs of SS fiber surfaces with different after treatments is shown in Figure 1. The surface of untreated SS fiber(a) was flat and smooth. In the case of acid treatment, microcracks were observed on the surface of acid treated SS fiber, and as the result a few microcraters were observed with plasma treatment. On increasing treatment time, the size and number of microcraters and microcracks increased. In acid treatment over 60min, SS fiber(c) was more rough and it did not show large microcrators or taken-off coating of SS fiber on surface. In the case of plasma treatment(d), there were small size and number of microcraters on the SS fiber surface compare to the case of acid treatment.

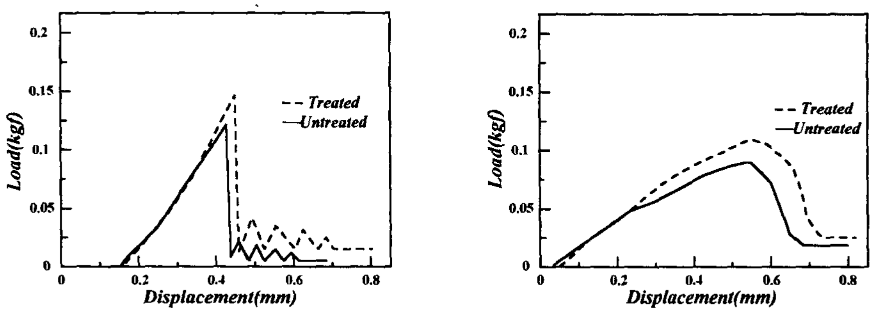


a b c d

Figure 1. SEM microphotographs(3500X) for the surface of SS fibers
(a: untreated, b: acid treated(20min), c: acid treated(60min), d: plasma treated(20W, 5min))

3.2. Interfacial adhesion properties

Figure 2 shows the 2 different resins types of debonding curves obtained by the microdroplet tests. The shear behavior(Figure 2(a)) of epoxy resin and SS fiber showed a linear increase of the debonding load as the fiber strained, because epoxy resin was stiff and hard. The debonding load then drops sharply as bonding droplet occurred the failure behavior of the bond. The residual load and slipping phenomenon after debonding was due to the friction between the bonded droplet and SS fiber as it was pulled along SS fiber. In the case of PET resin(Figure 2(b)), the shear behavior increased gradually and then decreased after debonding because PET resin by comparison with epoxy resin was soft and flexible. And it is due to not physical bonding but chemical bonding with SS fiber and epoxy resin. The bonding force with SS fiber/epoxy is higher than SS fiber/PET resin.



a b

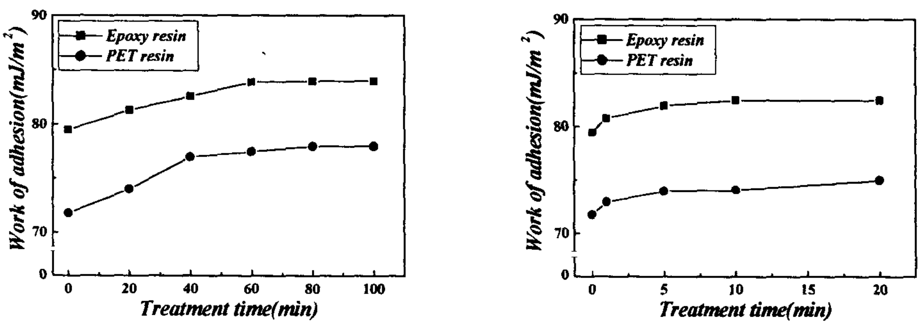
Figure 2. Debonding curves of SS fibers/epoxy and PET resins
(a: epoxy, b: PET)

3.3. Relation between work of adhesion and IFSS

The effects of treatment time on work of adhesion is shown in Figure 3. Work of adhesion between SS fiber and resin(matrix) was calculated by Young-Dupre's equation[4](1).

$$Wa = 2(\gamma_F \gamma_M)^{1/2} \quad (1)$$

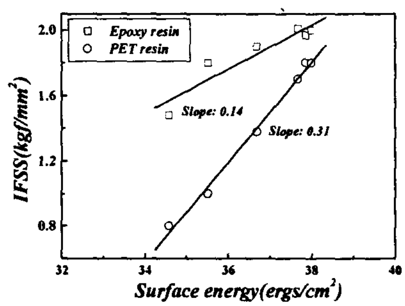
γ_F: the surface energy of SS fiber, γ_F: the surface energy of matrix

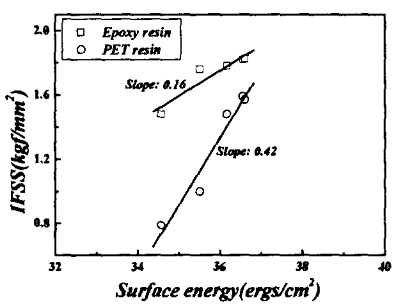


a b

Figure 3. Effect of treatment time on work of adhesion of SS fibers
(a: acid treatment, b: plasma treatment)

The surface energy of untreated SS fiber was 34.5ergs/cm^2 and PET was 37.4ergs/cm^2. Work of adhesion of SS fiber and PET resin was 71.8ergs/cm^2 and was 71.8mJ/m^2, repectively, by unit conversion. Work of adhesion(Figure 3(a)) by acid treatment increased linearly to 40min and did not largely increase over 60min. The effect of surface energy on IFSS was appeared in Figure 4. The difference between epoxy and PET resin was the slopes of regression straight line. The slope was 0.14 and 0.16 for epoxy, 0.31 and 0.42 for PET resin. So, it was concluded that PET resin by surface treatment changed more sensitive than epoxy in IFSS because epoxy resin strongly adhered to untreated and treated SS fiber.





a b

Figure 4. Effect of surface energy on IFSS of SS fibers
(a: acid treatment, b: plasma treatment)

4. Conclusion

The effect of acid and plasma surface treatments on the interfacial strength of SS fiber was experimentally carried out. The results from this study obtained are as follows:

1. Microcraters and microcracks on SS fiber surface were generated by acid and O_2 plasma treatment,
2. IFSS of SS fiber/epoxy increased from 1.5kgf/mm^2 to 2.0kgf/mm^2 with increasing acid and plasma treatment time of SS fiber due to the enhanced interfacial adhesion from chemical bonding and mechanical interlocking, and in the case of PET resin, IFSS increased from 0.8kgf/mm^2 to 1.8kgf/mm^2 and
3. The slope of the regression straight line between IFSS and surface energy of PET resin was higher than that of epoxy resin and more sensitive.

5. References

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