PET 섬유의 유전가열 접착에 전도성 섬유의 영향

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Effect of Conductive Fiber on the Polyester Fibers Bonding by Dielectric Heating

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1. Introduction

For the common drier and heaters, the heat gradually transfers from exterior to interior in the materials, as it generally adopts radiant or/and convection heat. However, by using microwave, both the interior and exterior of fiber materials can be evenly heated simultaneously. Thus, microwave heating offers processing advantages over conventional methods for its ability to provide rapid and volumetric heating to the fibrous medium. The application of microwave system for textile processes has the results of remarkably enhancing productivity and improving working environment owing to no air pollution.

From literature survey, there was a few results related to microwave heating the surface of materials. About thirty years ago, industrial engineers have developed the microwave heating technique that overcome some limitations of conventional heating. In particular, there was no research for the thermal bonding method of fibrous materials by microwave heating.[1)]

In previous study, we obtained that permittivity must be high in order to generate much heat-quantity.[2)] But, high melting point fiber such as PET fiber could not be melted. Thus, in this study, microwave bonded PET fibers using conductive fibers as bonding media have prepared and their morphological structures and bonding force have investigated with different treatment time.

2. Theoretical Consideration

For typical conditions of many dielectric heating applications, the electronic power converted to heat medium was related to the frequency, the permittivity and the electric field strength as the described the equation(1). Thus, to improve the power densities can be achieved by increasing permittivity of materials and electric field strength. But in the study, the frequency and electric field strength of a microwave system have constant values of 2450MHz and 220V, respectively. Meanwhile, permittivity can be controlled so as to increase the heat-quantity of emitted samples.

$$P = 2\pi f \varepsilon_0 \varepsilon'' E^2 = A f \varepsilon_p \tan\delta \, E^2 \quad (1)$$

In AC electromagnetic field, electric and magnetic fields are sinusoidally changed with time. And the effective permittivity expressed by complex variables is related to electric conductivity of materials like equation(2).

$$\varepsilon_p = \varepsilon\left(1 + \frac{\sigma}{jf\varepsilon}\right) \quad (2)$$

P: power converted to heat per unit volume(W/m³) A: constant $\tan\delta$: loss tangent
E: magnitude of electric filed(V/m) ε_p: effective permittivity ε'' : loss factor
ε_0: Permittivity of free space(F/m) ε : relative permittivity σ : electric conductivity

3. Experimental

3.1. Sample preparation

Raw materials were used the PP/PE bicomponent fiber, regular PET fiber and bicomponent PET fiber(Conju®) produced by Huvis Company. Table 1 shows fundamental properties of raw materials. To bond these fibers by microwave heating, Bonding media are used conductive fiber(ELEX®) made in Hanil Synthetic Co..

Table 1. Fundamental properties of raw materials.

Properties / Fibers	T_m(℃)	T_g(℃)	Linear Density (denier)
PP/PE	163/130		9
PET	258	77	4
Conju®	258	77	25

The bonding sample by microwave heating system was produced in our laboratory as shown in Figure 1. The fiber bundles to be bonded were constituted ten fibrous end. Crossing point between two bundles was put conductive fiber(0.1g). The fiber bundles prepared were put between two heat-resistant glass plates and treated in the specially designed microwave system(2450MHz) with 0.75gf/mm² of applied load.

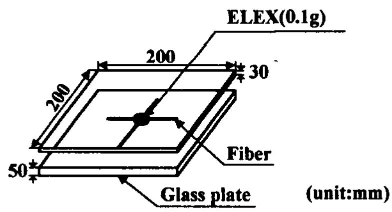

Figure 1. Schematic diagram of sample preparation.

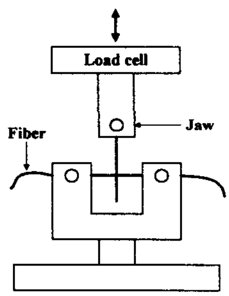

Figure 2. Sample holder for the bonding force measurement

3.2. Bonding force

In order to investigate bonding characteristics of prepared samples, bonding force was measured by tensile tester(model: Instron 4467). Figure 2 shows sample holder for the bonding force measurement by using a tensile testing machine. Crosshead speed used was 4mm/min, and load cell used 50kgf.

4. Results & discussion

4.1. Morphological structure

Figure 3 shows morphological structure on bonding region of PET fiber with different microwave treatment time. As shown in Figure 3, the bonding area of PET fiber increased with increasing treating time. This is the fact that PET fiber was melted indirectly by heat generation of conductive fiber. Photograph (c) shows that melted PET fibers are combined conductive fibers. Similar trend showed PP/PE bicomponent fiber and bicomponent PET fiber.

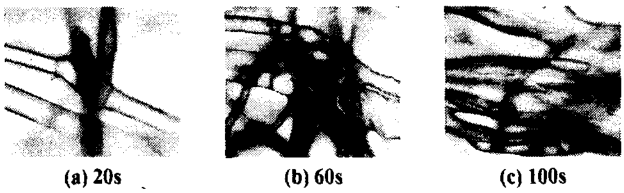

Figure 3. Photographs(×200) of microwave bonded PET samples with treatment time.

4.2. Debonding behavior

Figure 4(a) shows load-displacement curves of PP/PE bicomponent fiber with microwave treatment time. As treatment time increased, debonding load increased. And, when treatment time was increased up to 60sec, fracture occurred at bonding region. On the other hand, above 60sec, fracture started from fiber near the bonding point. This indicated that PP/PE bonding part had higher than PET fiber on bonding force above 60sec. Load-displacement curves of PET fiber with microwave treatment time are shown in Figure 4(b). The debonding behavior was similar to the PP/PE bicomponent fibers.

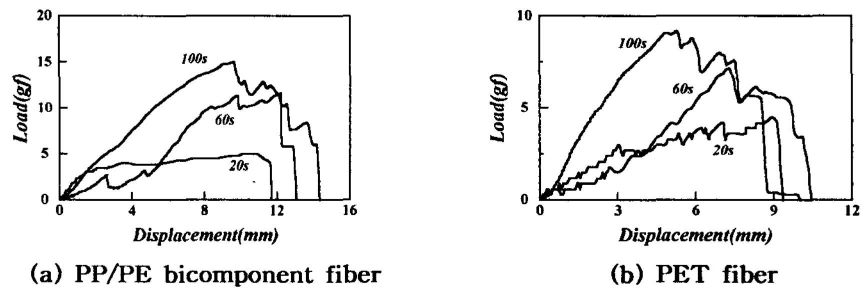

Figure 4. Load-displacement curves of microwave bonded samples with treatment time.

4.3. Bonding force

Figure 5 shows the bonding force of bonded PP/PE bicomponent fibers using organic solvents(EG, DEG) with different treatment time. As the treatment time was increased up to 400sec, bonding force was gradually increased. Above 400sec, bonding force was decreased. That is due to occurrence of fracture at minimum fiber diameter in vicinity of the bonding point.

The bonding force of samples bonded using conductive fibers with treatment time is shown in Figure 6. As treatment time increased, bonding force increased. That is due to strong interaction of PET and conductive fibers by melting of PET fibers.

It found the fact that treatment time can reduced about 1/4 when bonding media was used conductive fiber rather than organic solvent. When organic solvent was used, the melting of PET fibers was impossible because of low boiling point relatively. On the other hand, when conductive fiber was used, the melting of PET fiber was possible. The reason is that conductive fiber chemically combined Cu ion with high conductivity represented high permittivity.[3]

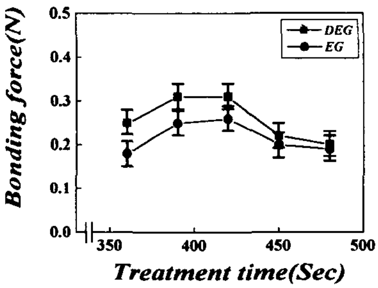

Figure 5. Effect of treatment time on bonding force of PP/PE sample bonded by microwave heating.

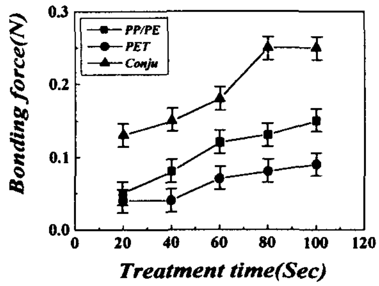

Figure 6. Effect of treatment time on bonding force of sample bonding by microwave heating

5. Conclusion

(1) In fiber-bonding using microwave heating, the treatment for PP/PE fibers time was shorter than organic solvent when bonding media was used conductive fiber. Also, the microwave bonding of PET fibers could not achieved by using organic solvents, but by the application of conductive fibers, the microwave bonding of PET fiber was possible.

(2) When treatment time was increased up to 60sec, fracture occurred at bonding region. On the other hand, above 60sec, the fracture started from fiber near the bonding point.

(3) Generally, the bonding force of fibers increased with increasing treatment time. Thus, we obtained treatment time of 100sec for the best microwave bonding condition with conductive fiber in this study.

6. References

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