The 2012 World Congress on
Advances in Civil, Environmental, and Materials Research (ACEM' 12)
Seoul, Korea, August 26-30, 2012

Water Absorption Induced Impact Value of Thermoplastic Polymers

* Junhua Quan[1)], Naoya Tsuchikura[1)], Shinichiro Nanba[1)],
Masae Kanda[2)] and Yositake Nishi[1,2,3)]

[1)] *Graduate School of Engineering, Tokai University, Hiratsuka, 259-1292, Japan*
[2)] *School of Science, Tokai University, Hiratsuka, 259-1292, Japan*
[3)] *Graduate School of Science & Technology, Tokai University, Hiratsuka, 259-1292, Japan*
[3)] *am026429@keyaki.cc.u-tokai.ac.jp*

ABSTRACT

Although the water treatment (WT) softened the matrix polymers and carbon fiber reinforced thermoplastic polymers, WT enhanced the Charpy impact value of carbon fiber reinforced polymer (CFRP). When additional water molecules, which were mostly free, probably penetrated into interface between carbon fiber and polymer, the impact force easily relaxed, resulting in the boiling water treatment induced enhancement of impact value of CFRTPs as a_{uc} of CFRTP (CF/PA6) at P_f = 0.5 had a big raise from untreated to 100 ks water treated as 15.9% to increase.

1. INTRODUCTION

Carbon fiber reinforced polymers (CFRP) are typical composite materials, and have been applied as light structural materials with high strength. The further strengthening has been always expected to develop high-speed transports with small energy consumption. Carbon fiber reinforced thermoplastic polymers (CFRTP), already applied for automobile bumper and IC substrate, can be easily produced with high productivity for mass production at various forming process. However, it is serious problem that high viscosity of thermoplastic polymer with low wetting to carbon fiber induces the low strength of CFRTP. Homogeneous low voltage electron beam irradiation (HLEBI) often improves the mechanical properties of polymer and carbon fiber. In addition, it is also possible to enhance the interface strength induced by surface activation, which is generated by charging and dangling bond formation.

Since the interfacial area of carbon fiber with 6 μm diameter is extremely large, the enhancement of friction force induces the strength of CFRP. In order to enhance the interfacial friction force, the HLEBI to interface in CFRTP is probably effective. Nylon6 is a thermoplastic polymer with low cost and easy formability for preparing composite materials. In addition, cheap composite polymers with light-metal powders dispersed often feel cold and look shiny, like some metals.

Carbon fiber reinforced polyetheretherketone (PEEK), polyimide (PI), and nylon6 (CFRTP (CF/PEEK), CFRTP (CF/PI) and CFRTP (CF/PA6)) are popular to utilize for practical application.

Figure 1 illustrates the rational formula of PEEK, which has high heat and corrosion resistance. Thus, it is generally applied to interiors and upholsteries of the cabin and parts in airplanes and automobiles. To confirm the basic work for safety design, the water absorption is one of the important factors of CFRTP. Therefore, the influence of isothermal dipping in hot distilled water on Charpy impact value of CFRP has been investigated.

On the other hand, water absorption, which causes softening, is often observed in nylon6. Although water absorption enhances the impact value of nylon6, the influence of water absorption on expansion and softening is a serious problem. Although water absorption also enhances the impact value of thermoplastic polymers and its composites, the influence of water absorption on expansion and softening should be a serious problem. The absorption rate of distilled water is strongly dominated by mass transport, which is generally controlled by both diffusion in the thermoplastic polymer matrix and mass transfer at the interface in thermoplastic polymer composites. In order to evaluate the brittleness and to clear the serious problems of many demands from various markets with high quality controlling, the fundamental data related to impact value has been required.

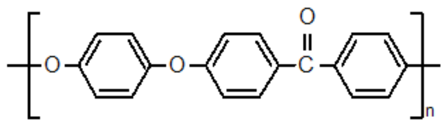

Fig. 1. Rational formula of polyetheretherketone (PEEK).

2. EXPERIMENTAL PROCEDURE

2.1 Sample

The composite polymer was homogeneously mixed with PEEK film (t= 0.025 mm; APTIV 2000-025, Victrexplc), PI (PETI PLATE (HA･10), Ube Industries, Ltd), nylon6 plan (t= 3 mm, Chubu Extron Co., Ltd) and carbon fiber (TR3110M, Mitsubishi Rayon Co., Ltd.). Thereafter, drying was performed for 10 ks at 313 K. The specimen, which shape was JIS K7111, were molded at 608 K, 623 K and 513 K after melting. The volume ratios of carbon fiber in polymers were 50vol%. Average diameter of carbon fiber was 6 μm. Hot pressing to laminate CFRTPs were performed for 600 s at 10 K higher than their molting point. The sample size was 10 mm in width, 80 mm in length and 2 mm in thickness.

2.2 Measurements of mass

Water absorption into thermoplastic polymer composites were performed for 100 ks at 373 K. Mass measurement time was 0, 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10, 20, 50, 100 and 200 ks, respectively. The water absorption ratio was expressed by the following equation (1).

$$C = (m_t - m_0) / m_0 \times 100 \qquad (1)$$

Here, C, m_0 and m were water absorption ratio (%), mass values before and after water treatment, respectively.

2.3 Charpy impact test

To evaluate the impact fracture toughness, the Charpy impact values of the composite polymer were measured using a standard impact fracture energy measurement system (JIS K7111). The Charpy impact value was expressed by the following equation (2). By this measurement, a simple revision method for energy is used at the time of the Charpy impact. Since this method corrects an energy loss, the absorption energy is directly calculated by using the simple blank test angle α'.

$$E = WR\,[(\cos\beta - \cos\alpha) - (\cos\alpha' - \cos\alpha)\,((\alpha+\beta)/(\alpha+\alpha'))] \qquad (2)$$

Here, E, W, R, β, α and α' were impact fracture energy (kJ), hammer weight (N), length (m) of hammer weight point from rolling center, start angle before impact, the maximum angle after impact and the maximum angle of the blank test, respectively. The Charpy impact value ($kJ \cdot m^{-2}$) was expressed by the following equation (3). Charpy specimen

$$a_{UC} = (E / b_N\, t) \times 10^3 \qquad (3)$$

Here, E, b_N (=10 mm) and t (=2 mm) were impact fracture energy (J), sample width (mm) and span distance (sample thickness, mm), respectively. The distance between supporting points was 40 mm. Since the fracture didn't occur, Charpy impact value at room temperature cannot be obtained. Thus, Charpy impact test of CFRTP (CF/PA6) was performed at 77 K.

3. RESULTS&DISCUSSION

3.1 Impact value improvement by water treatment

Evaluating the probability of fracture (P_f) is a convenient method of quantitative analyzing experimental values relating to fracture. P_f is expressed by the following equation, which is a generalized form of the median rank method.

$$P_f = (i - 0.3) / (Ns + 0.4) \qquad (4)$$

Here Ns and i are the total number of samples (Ns = 11) and the order of fracture of each sample, respectively. Here, the order of fracture is the aligned number of fractured samples from low to high impact value. When the i values are 1, 6, and 11, the P_f values are 0.06, 0.50 and 0.94, respectively.

Figure 2 shows changes in Charpy impact value (a_{uc}) of carbon fiber reinforced thermoplastic polymer of CFRP (CF/PEEK), PI and nylon6 before and after water treatment at boiling point for 100 ks against fracture probability (P_f). Influences of water treatment on a_{uc} of CFRTPs are investigated. The water treatment for 100 ks mostly raises the a_{uc}, especially a_{uc} of CFRTP (CF/PA6) at P_f = 0.5 had a big raise from untreated to 100 ks water treated as 15.9% to increase.

When additional water molecules, which were mostly free, probably penetrated into interface between carbon fiber and polymer, the impact force easily relaxed, resulting in the boiling water treatment induced enhancement of impact value of CFRTPs.

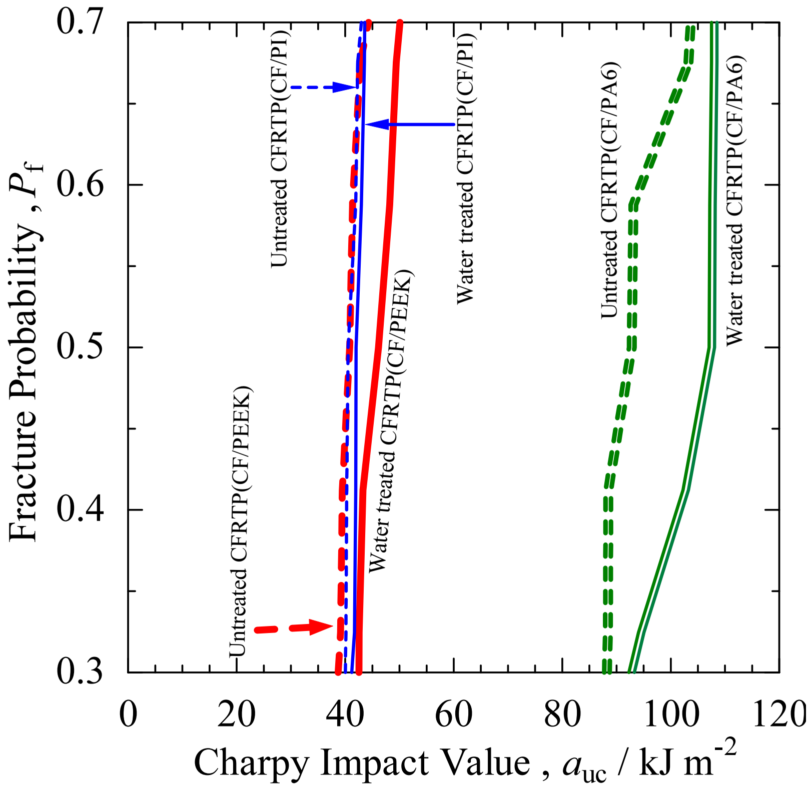

Fig. 2. Changes in Charpy impact value (a_{uc}) of carbon fiber reinforced thermoplastic polymer of PEEK, PI and nylon6 before and after dipping in boiling water for 100 ks against fracture probability (P_f).

4. CONCLUSION

In summary, influences of water treatment (WT) at boiling point on Charpy impact value of the carbon fiber reinforced thermoplastic polymers (CFRTP) were investigated.

1) CFRTP had a mass gain dipped in boiling water.
2) Dipping boiling water enhanced the Charpy impact value of CFRTP.
3) When water molecules, which were mostly free, probably penetrated into interface between carbon fiber and polymer, the impact force easily relaxed, resulting in enhancement of impact value.

REFERENCES

M. Kanda and Y. Nishi (2009). “Effects of Water Absorption on Impact Value of Aluminum Dispersed Composite Nylon6”, *Mater*. *Trans*., Vol. **50**, 177-181.

K. Inoue, K. Iwata, T. Morishita, A. Tonegawa, M. Salvia and Y. Nishi (2006). “Enhancement of Charpy Impact Value by Electron Beam Irradiation of Carbon Fiber Reinforced Polymer”, *J. Jpn. Inst. Metals*., Vol. **70**, 461-466.

K. Iwata, K. Yamada, A. Kadowaki, N. Yamaguchi, A. Tonegawa and Y. Nishi, “Effects of Electron Beam Irradiation on Impacr Fracture Energy for Sosa Glass” *J. Jpn. Inst. Metals*, Vol. **68**, 534-536.