Chapter 5

Conclusion and Suggestion for Future Work

5.1 Conclusion

In this work, a photo-induced process, combinations of UV and various gas species, for modifying polymeric surface was designed and constructed to apply in continuous composite manufacturing. PET fiber/epoxy composite was selected to determine the preliminary effectiveness and feasibility of the process. To reveal those characteristics of the process, chemical and mechanical properties of resulted surfaces and composites were analyzed and discussed in previous chapter. The conclusion of this study can be described as follows:

- A new continuous UV photo-induced apparatus was built for the surface modification of polymer fibers. The apparatus described in this thesis research was found to be suitable method for controlling surface modification of polymeric fibers. The experimental results demonstrated that the treatment resulted in considerable changes in surface composition and mechanical properties of the composite.

- Up to 10 minutes of treatment, the oxygen content of PET surfaces treated at every regime, UV/N_2, UV/air, UV/O_2, UV/air + O_3, and UV/O_2 + O_3, were increased without significantly altered their tensile properties. The most effective regime was UV/O_2 + O_3 treatment which can increase an amount of oxygen on the PET surface to 36.51 % compared to 29.91 % of nontreated PET surface.

- The adhesion between PET fiber and epoxy matrix is poor. However, the adhesion can be improved by photo-induced surface modification of PET fiber. All surface modifications that had done in this study had increased the mechanical properties, i.e. tensile strength, elongation to break, and toughness. The most effective condition was 5 minutes UV/O_2 + O_3 treatment, which can result~~ed~~ in improving 63 % of tensile strength, 175 % of elongation to break, and 325 % of toughness, in comparison to nontreated PET/epoxy composite.

- UV/oxidative gas regimes, i.e. UV/air, UV/O_2, UV/air + O_3, and UV/O_2 + O_3, were responsible for stronger fiber/matrix adhesion, mainly after treatment for 5 minutes, according to observations from the fractography analysis obtained by the scanning electron microscopy. Poor mechanical properties composites were deformed predominantly via fiber pullout mechanism. The failure mode changed from interfacial failure to matrix failure upon increasing treatment to 5 minutes.

5.2 Suggestion for future work

5.2.1 Suggestion for Process development

- The performance and efficiency of the fiber guidance and introducing into and out-off reactor chamber remain inadequately which makes the surface modification rates of the process still not flexible enough for practical application. More effective fiber guidance should be developed to use in the process. In addition, designing of guidance to make it possible to modify various geometries of polymeric surfaces, e.g. ribbon, laminate, and films should be done.

- Inline monitoring devices, e.g. UV intensity meter, ozone/oxygen concentration measurement unit, moisture trap and detector, and CO/CO_2 detector (or gas phase chromatography, GC), should be added to the process to in-depth analysis of modification mechanisms, and to determine conditional profiles inside the reactor chamber.

- Some control units are required to improve the performance, flexibility and reproductivity of the process, e.g. temperature/pressure controllers, heating/cooling unit, control valve, and anti-short-circuit.

- Investigate the capability of the process, in order to estimate the production rate and feasibility for applying the process in practical continuous composite manufacturing.

5.2.2 Suggestion for Further Surface Modification Study and Characterization

- In-depth study of chemistry, morphology and physical properties of fiber surfaces using advanced surface characterization technique to determine actual effects of the treatments to the surfaces. The recommended techniques to examine the surface properties were shown as following:
    - X-ray photoelectron spectroscopy (XPS) and Static Secondary Ion Mass Spectrometry (SSIMS) to investigate chemistry information of outermost surface (1 - 5 nm deep) of the fiber surface.
    - Contact mode atomic force microscopy (AFM) to investigate topology and surface energy of the surface.
    - Wilhelmy contact angle measurement method to investigate surface energy of yarn surface.
- Investigation of the optimum condition, e.g. gas species, treatment time, temperature, UV intensity, ozone concentration, and operating pressure, should be done in order to evaluate the effects of each parameter on surface modification of PET fiber.
- In order to examine the failure mechanism of resulted composite, other mechanical testing techniques are required, e.g. single fiber pull-out testing, flexural strength testing, and photoelastic imaging.