CHAPTER V

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

The results of the research from the investigation of thermal behavior and thermochemical conversion by pyrolysis of 30 and 60 wt% glass fiber reinforced orthophthalic, isophthalic unsaturated polyester, vinyl ester, and epoxy cured with amine and anhydride at the temperature of 600, 700, and 800ºC in order to study effect of the pyrolysis temperature and difference of resin matrix such as chemical structure of unsaturated polyester matrix and curing agent of epoxy matrix on the product yield and characteristic of solid, liquid, and gaseous products are summarized into three sections as follows:

5.1.1 The Characteristic of Composite Waste Samples

- The characteristic of each composite wastes such as functional group, chemical composition depended on type of matrix resin which generated from the vibration of carbonyl ester group, aromatic ring, and unsaturated alkene in main chain. Whereas the spectra of epoxy depended on its curing agent. The elemental composition results showed that the amount of carbon, hydrogen, and nitrogen was related to glass fiber content. The increase in glass fiber content resulted in the decrease in carbon, hydrogen, and nitrogen.
- The thermal behavior of composite wastes greatly depended on chemical structure of resin matrix and glass fiber content. Vinyl ester show higher activation energy of decomposition greater than that of isophthalic and orthophthalic polyesters. This is due to the effect of bisphenol A in main chain and methacrylate steric pendant group at the end of vinyl ester backbone which exhibit good thermal stability.

Anhydride (MTHPA) cured epoxy displayed better thermal stability than that of amine cured epoxy due to the presence of benzene ring in anhydride structure. In addition, the presence of higher glass fiber content in composite resulted in lower activation energy. This is because glass fiber content inhibited curing process which led to decrease in degree of cured resin matrix thus lower thermal stability.

5.1.2 Thermal Conversion by Pyrolysis Process

- The product yields are significantly affected by reaction temperature, glass fiber content in composite feedstock, and resin matrix. It was found that the pyrolysis of all composite waste at temperature of 600ºC gave maximum solid and liquid yields. The reaction temperature of 800ºC is the promising condition to produce gaseous products. The liquid and gaseous products generated from pyrolysis of 30 wt% glass fiber composite waste are higher than those of 60 wt% glass fiber composite waste around 30 %) under the same resin and pyrolysis conditions. Orthophthalic polyester matrix composite shows the highest liquid yield due to the effect of phthalic anhydride original monomer. Whereas epoxy cured with amine (MDA) at room temperature can be degraded to form higher liquid product than that of epoxy cured with anhydride (MTHPA) at 150ºC.
- The reaction temperature, resin matrix type, and glass fiber content in composite feedstock do not have prominent effects on characteristic of solid, liquid, and gas in each resin system due to the similar of functional group in polymer matrix which can be degraded and similarly formed liquid and gaseous products.
- Liquid obtained from pyrolysis process of unsaturated polyester and epoxy reinforced with 30 wt% glass fiber at temperature of 600ºC can not be directly used as fuel product due to high composition of oxygenated

compound which can cause to corrosion problem and flash point is lower than conventional fuel product. On the contrary, such oils have the gross calorific value within the range of standard oil and high fraction of gases/naphtha which can be utilzed as gasoline products.

- The gaseous products evolved largely consisted of CO_2, CO, and some amount CH_4 and H_2. The gross calorific value of gas generated from pyrolysis of unsaturated polyester (12-14 MJ/m^3) is lower than that of epoxy composite (17-21 MJ/m^3) due to the larger volume fraction of CH_4 in the later matrix.

5.1.3 Characteristic of Composites Prepared from Original Glass Fiber and Recycled Glass Fiber from Pyrolysis Process.

- Flexural strength of unsaturated polyester resin depended of their chemical structure. The vinyl ester resin had higher flexural strength than isophthalic and orthophthalic polyester resin approximately 9 and 27%, respectively due to the presence of bisphenol A in a main chain and methacrylate at the end of vinyl ester backbone. Similarly, anhydride (MTHPA) cured epoxy resin had higher flexural strength than of amine cured around 20% because of the effect of benzene ring in anhydride structure.
- Flexural strength of both BMC composites with original glass was increased 2-5 %,upon increasing the fiber content 5-10 wt% and tended to decrease 1-2 wt% when original glass fiber was increased to 15-20 wt% . This is due to the agglomeration of original glass fiber .
- In addition flexural strength of both BMC composite containing with recycled glass fiber at 800ºC were clearly lower than that of the BMC composite containing original glass fiber (10- 15%) and recycled fiber 600 ºC (3-7%) with it was increased to 20 wt% because of the presence of fiber pulled out in resin matrix

- The flexural modulus of all BMC composite showed slightly increased, upon increasing of glass content from 5-20 % which depended resin matrix.
- The impact properties vinyl ester resin was greater than isophthalic and orthophthalic polyester approximately 7 and 25 %, respectively due to the effect rigidity structure . Where as cycloaliphatic amine structure of MDA curing agent contributed to better toughness of epoxy approximately 20%
- The addition of 5 wt% glass fiber had no influence on the impact strength of BMC composite. Further loading the glass fiber resulted in the decrease in the impact strength, owing to the agglomeration of glass fiber loading.

Conclusively, the impact properties and flexural properties of composite prepared from recycled fiber obtained from pyrolysis process showed that the recycled glass fiber obtained from pyrolysis of all composite waste at 600°C can be recycled to used as reinforcement up to 5 and 10 wt%, to improve impact strength and flexural strength of resin matrix. While the composite prepared from recycled glass fiber at 800°C showed lower mechanical properties than that of 600°C. because SEM image showed many holes in matrix. This results suggested that the fiber was pulled out during applied load. Indicating of the poor interfacial between fiber and matrix.

5.2 Recommendation

There were some problem that found in this research, which can be mention for further good studied as summarized:

- The pyrolysis system should be continuous process connected with the good flow out of evolution gases to gas analyzer. Because the generated gas during process consisted of the large a mount of oxygenated oxygen. It may cause to explode if the evolution gas are more increased in the system.

- In the step of sample feed should be applied to atomatic controlled feed with the good distribution in to the reactor. This is because of the resin matrix is thermosetting plastic that degrade and cover at the top surface if it is the batch process resulted in the evolution gas can not flow out
- The solid residues which mainly contained with glass fiber should be removed the remained resin or some carbon by oxidizing under room temperature.
- For future study, should study to sample size in order to achieve the large size that can be studied, in fact that the composite waste generated in the manufacturing process or unusable products are in the large size which it can reduce the step of preparation sample and may easier to process.