CHAPTER V

CONCLUSION

5.1 CONCLUSIONS

5.1.1 Rubber is an effective modifier for toughening epoxy resin. Both solid NBR and liquid CTBN can be applied for toughening epoxy resin.

5.1.2 The greater the amount of the rubber, the higher is the toughening effect, as is evident in the impact energy, the falling weight energy and the fracture energy. With more rubber, there is larger interfacial area between the matrix and the rubber phase. Crack in the matrix tends to deviate through the matrix and along the interface. Hence, greater fracture energy is required to break the rubber-modified epoxy systems.

5.1.3 At the same concentration, the liquid CTBN gives better toughening efficiency than the solid NBR. This is possibly due to two reasons. The first one is that the CTBN tends to solidify to form finer rubber particles ranging from 1 to 20 μm while the NBR particle size ranges from 100 to 200 μm. The finer particles achieved in the CTBN system means that there is greater interfacial area between the rubber particles and the epoxy matrix. The second reason is that the liquid CTBN is partially compatible with epoxy matrix, as is evident in the reduction in the T_g of the epoxy matrix. Consequently, greater interfacial bonding is anticipated in the CTBN-modified systems. Thus, it is more difficult for crack to propagate through the CTBN-modified system and greater energy is required for failure to take place.

5.1.4 The greater of the acrylonitrile content in the CTBN, the more effective the toughening efficiencies. This is because the more acrylonitrile content leads to improving the compatibility between the rubber phase and the epoxy matrix. This was verified by the SEM photographs. The fracture surface of the epoxy filled with CTBN which has an acrylonitrile content of 30% is much rougher and have more deformation than the epoxy filled with CTBN which has an acrylonitrile content of 15%.

5.1.5 Titanate treated NBR yields slightly better toughening effect than the untreated NBR, as is apparent in the impact energy, the falling weight energy and the fracture energy. This is the effect imparted by the titanate coupling agent which was used to improve the NBR surface. The SEM micrographs also illustrates the fracture surface of the treated NBR system to be rougher than that of the untreated NBR one.

5.1.6 The density of the NBR or the CTBN-filled epoxy systems follows the *Rule of Mixture*.

5.1.7 The fracture surface of the epoxy-filled with CTBN which has the acrylonitrile content of 30% exhibits the most deformation. The fracture surface of the epoxy filled with CTBN which has the acrylonitrile content of 15% still shows some plastic deformation but not as much as that in the CTBN with 30% AN system. Both the untreated NBR and the treated NBR rubber particles exhibit less deformation on the fracture surface. This implies that the liquid CTBN can toughen more effectively the epoxy resin than the NBR-filled ones.

5.2 RECOMMENDATION FOR FURTHER STUDY

5.2.1. Other types of titanate coupling agents can be applied to compare their efficiencies in the rubber-filled epoxy systems.

5.2.2. Methods to produce rubber particle as small in size as possible and/or with surface modifications for better rubber particle distribution should be explored.