CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 SUMMARY

The fracture behaviour of polymer blends is the main topic of this thesis. The blends selected are PP/HDPE and PS/HIPS. PP/HDPE blend was chosen due to its commercial importance and PS/HIPS was selected to study the transition from brittle fracture to ductile fracture. The preparation of PP/HDPE blends and their modification with two different types of modifiers – calcium carbonate and EPDM are described in the first section. The mechanical properties of the blends were measured as function of the modifier content to find the optimum concentration of the modifier to be added. The fracture characteristics and notch sensitivity were also examined.

PP/HDPE blends were prepared at different compositions by melt blending at 180\(^0\)C and fracture failure process was investigated by conducting notch sensitivity test and tensile test at different strain rates. This was done to study the effect of blend ratio on the mechanical properties of the blend system. Afterwards, the effects of two types of modifiers on the fracture behaviour and notch sensitivity of PP/HDPE blends were studied. The modifiers used were calcium carbonate, a hard particulate filler commonly used in plastics and Ethylene Propylene Diene Monomer (EPDM), a soft elastomeric modifier. They were added in 2%, 4% and 6% by weight of the blends. The modified blend samples were subjected to tensile and notch sensitivity tests and tensile parameters were evaluated.

The study shows that PP/HDPE blends form a synergistic system as far as the mechanical behaviour is concerned. The mechanical properties can be
optimized by selecting proper blend compositions. The main thrust of the study was to investigate how the properly selected modifiers could alter and improve the fracture behaviour and notch sensitivity of the blends. It is observed that a particulate filler like calcium carbonate can be used for making the mechanical behaviour more stable at the various blend compositions. The resistance to notch sensitivity of the blends is found to be marginally lower in the presence of calcium carbonate. The elastomeric modifier EPDM produces a better stability of the mechanical behaviour. A low concentration of EPDM is sufficient to effect such a change. The reduction in modulus is only minimal while there is some increase in the elongation at break. EPDM shows the outstanding advantage of improvement in the notch sensitivity of the blends. The study shows that judicious selection of modifiers can improve the fracture behaviour and notch sensitivity of PP/HDPE blends and help these materials to be used for critical applications.

Afterwards, the fracture behaviour of blends containing an amorphous, brittle polymer Polystyrene (PS) and a ductile polymer High Impact Polystyrene (HIPS) were studied. PS/HIPS blends were prepared at different compositions by melt blending at 180°C. Samples prepared by injection moulding were used for conducting tensile, impact and flexure tests. These tests were used to simulate the various conditions which promote failure.

The tensile behaviour of unnotched and notched PS/HIPS blend samples were evaluated at slow speeds. The tests were conducted at speeds 5 mm/min and 10 mm/min. Tensile strengths and moduli were found to increase at the higher testing speed for all the blend combinations whereas maximum strain at break was found to decrease. For a particular speed of testing, the tensile strength and modulus show only a very slight decrease as HIPS content is increased up to about 40% and thereafter show a drastic change indicating changes in the morphology of the blend at this composition. The maximum strain at break show a very slight change up to about 40% HIPS content and thereafter show a remarkable increase. The notched specimens also follow a comparable trend even though the notch
sensitivity is seen high for PS rich blends containing up to 40% HIPS. The notch sensitivity marginally decreases with increase in HIPS content. It was found to increase with increase in strain rate. It is observed that blends containing more than 40% HIPS fail in ductile mode.

The impact characteristics of PS/HIPS blends studied were impact strength, the energy absorbed by the test specimen and impact toughness. The test was conducted in the Izod configuration. Only a slight increase was noted in impact strength as HIPS content was increased up to 40%. Remarkable increase in impact strength was observed as HIPS content in the blend exceeded this value. The energy absorbed by the test specimens and the impact toughness also showed a comparable trend. They show a drastic increase as HIPS content exceeds 40%.

Flexural testing which helps to characterize the load bearing capacity was conducted on PS/HIPS blend samples at the two different testing speeds of 5mm/min and 10 mm/min. The simply supported beam configuration was used with a span of 50 mm. The flexural strength showed higher values at the higher testing speed for all the blend compositions. At both the speeds, remarkable reduction in flexural strength is observed as HIPS content in the blend exceeds 40%. The flexural strain and flexural energy absorbed by the specimens are found to increase with increase in HIPS content. At both the testing speeds, brittle fracture is observed for PS rich blends whereas HIPS rich blends show ductile mode of failure.

Photoelastic investigations were conducted on PS/HIPS blend samples prepared at the various blend compositions to analyze their failure modes. This is used as an experimental method to determine the stress distribution in a material. A plane polariscope with a broad source of light was utilized for the study. The test specimens were placed between the polarizer and analyzer. Plane polarized light from the polarizer was allowed to pass through the test specimens. The optical interference fringes formed as plane polarized light was made to pass through the transparent specimens were observed through the analyzer.
Isochromatic fringes with distinct colour patterns were visible. The fringe patterns obtained on the test specimens indicate the presence of residual stress concentration in the blend samples. The coverage made by isochromatic fringes on the test specimens were found to vary in accordance with the blend composition and it shows a reducing trend with increase in HIPS content. This indicates that the presence of residual stress is a contributing factor leading to brittle fracture in PS rich blends and this tendency gradually falls in HIPS rich blends which lead to their ductile mode of failure.

7.2 CONCLUSIONS

1. The mechanical properties of PP/HDPE blends can be optimized by selecting proper blend compositions.

2. Optimum concentration of particulate fillers like calcium carbonate can make the mechanical behaviour more stable.

3. With the addition of elastic modifiers like EPDM, a better stability of mechanical behaviour is obtained at much lower concentrations.

4. EPDM can further improve the resistance to notch sensitivity.

5. The fracture behaviour of PS/HIPS blends investigated by conducting tensile, impact and flexure tests identifies the various conditions which promote failure.

6. Notch sensitivity is seen higher for PS rich blends, but lower for HIPS rich blends. Marginal increase in notch sensitivity is observed as the strain rate is increased.
7. The impact energy absorbed by the test specimens and the impact toughness increases with HIPS content.

8. Brittle fracture is noted for blends containing upto 40% HIPS. Further addition of HIPS results in a transition from brittle to ductile mode of failure. This is evident from both tensile and flexure tests.

9. Photoelastic investigation indicates the presence of residual stress in PS/HIPS blend samples.

10. The presence of residual stress is a contributing factor leading to brittle fracture in PS rich blends and this tendency gradually falls for HIPS rich blends which lead to their ductile mode of failure.