CHAPTER VI

CONCLUSIONS

The suitable matrix alloy composition based on benzoxazine, and urethane resins for Kevlar™ fiber-reinforced composite armor was determined. The criteria for the evaluation of the optimal resin mixture composition were thermal stability, mechanical properties and ballistic impact resistance of the obtained composite materials.

From DSC experiment, the resin mixture curing reaction was found to occur at higher temperature with an addition of the urethane prepolymer. The fully cured condition of the prepregs could be achieved at 160°C for 2hrs, 180°C for 2hrs and 200°C for 2hrs. Synergism in the glass transition temperature can be observed in Kevlar™-reinforced BA/PU alloys confirming our previous finding. This phenomenon caused by the addition of urethane prepolymer was attributed to improve crosslinked density of the matrix alloys. The glass transition temperature of the BA/PU composites, obtained from peak of loss modulus (G") in the dynamic mechanical characterization, was found to be in the range of 178-235°C with the increasing amount of the urethane from 0-40% by weight. The degradation temperature at 5 % weight loss of our composites decreased with increasing the PU in the matrix alloys. The residual weight at 800°C of our composites in the range of 0 to 40% by weight of the PU fraction in the alloys was ranging from 44.5 to 35.6%

In dynamic mechanical property measurement, the increase of the PU content significantly lowered the stiffness of the composites. The storage modulus of the Kevlar™-reinforced BA/PU composite decreased from 16.4 GPa of polybenzoxazine matrix to 2.8 GPa of 60/40 BA/PU alloys.

The ballistic test results of the 20-ply Kevlar^{TM}-reinforced BA/PU composites tested using a 9 mm handgun with standard lead projectiles having lead outer-coating, revealed that 80/20 mass ratio of BA/PU matrix alloy exhibited outstanding ballistic impact resistance in comparison with other compositions of the BA/PU alloys as well as of the polybenzoxazine. The storage modulus of the composite armor having bullet penetration resistance was found to be in the range of 10-15 GPa. In addition, the corresponding density of the 80/20 BA/PU composites was approximately 1.29 g/cm^3.

SEM observation showed various fracture surfaces due to ballistic impact including fiber breakages, matrix cracking, delamination, interply cracking, and translaminar fracture in the thickness direction of the 80/20 BA/PU composites. The extent of the delaminated damage and interfacial fracture were observed to change with the composition of the matrix alloys.

The studies of specimen's thickness and the arrangement of the composite panels revealed that the suitable thickness having 30 piles of the Kevlar^{TM} cloth can protect the ballistic impact at level II-A. Whereas the 50 ply-thick composite was able to protect the ballistic impact of NIJ level IIIA. Finally, the arrangement of composite panels was also found to significantly affect the ballistic performance of our composites with the thicker and stiffer panel should be placed in the front face of the composite panel assembly to yield best ballistic resistance.