CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

In this research work the wear and friction, erosion and mechanical behavior of pure epoxy and epoxy/MWCNTs with various weight percentages were investigated. The worn and eroded surface morphologies were studied for the mechanism of material removal process. The numerical simulation is also carried out for the prediction of wear with the experimental results. According to the results the following conclusions were drawn.

1. Tribological behavior is greatly improved in epoxy/MWCNTs nanocomposites with the effect of homogeneous dispersion of MWCNTs in epoxy matrix and interfacial strength of nanocomposites.

2. 0.1 wt.%, 0.5 wt.% & 1.25 wt.% MWCNTs nanocomposites exhibited considerable improvement in wear resistance. However, 1.25 wt.% MWCNTs showed remarkable wear resistance than pure epoxy and moreover the mechanism of material removal was ductile.

3. The addition of MWCNTs into epoxy matrix decreases the coefficient of friction due to the exposed reinforced material in the sliding surface and the self-lubricating property.
4. Erosion resistance is greatly improved in 1.25wt.% epoxy/MWCNTs nanocomposites with 60° impingement angle due to the effect of homogeneous dispersion of MWCNTs in the host matrix. From the investigation, the erosion mechanisms are in close relationship with the impingement angles.

5. The erosion rate of nanocomposites decreases with increase of MWCNTs 0.1wt.%, 0.5wt.%, 1.25wt.% and 2.5wt.% contents in the epoxy. However, 1.25wt.% MWCNTs exhibited remarkable erosion resistance and also the mechanism of material removal was semi-ductile nature.

6. Furthermore addition of 2.5wt.% and 5wt.% MWCNTs nanocomposites did not improve the wear and erosion resistance due to excessive addition of MWCNTs which formed localized bundle in the epoxy matrix.

7. There is a significant improvement in the ultimate tensile strength and it was observed in 1.25wt.% of MWCNTs nanocomposites. Similarly, considerable enhancement in breaking load, peak load and stress than the pure epoxy are occurred.

8. Thus the fabricated nanocomposites acted as super performance materials which seek many immediate applications leading mechanically robust, tough and strong goods such as fishing gears, safety belts, conveyor belts, sewing thread, protective clothing, man mad fiber and cement paste.
9. Four widely used artificial neural networks were used to predict the specific wear rate of pure epoxy and epoxy/MWCNTs nanocomposites with the function of load and sliding time. The GRNN architecture shows excellent capability of predicting wear properties of epoxy/MWCNTs nanocomposites.

10. The ANN prediction accuracy dependence on number of training datasets are used to train the network and also well trained neural network provides useful data from relatively minimum experimental datasets.

11. The investigation could provide considerable saving of time and costs, which could benefit the organization to develop more particular and general data base of new composite material properties.

12. The satisfactory agreement between ANN and experimental results were obtained from general regression neural network. Hence, it can be effective prediction technique in the field of tribology in composite materials.
5.2 LIMITATIONS

There are several limitations associated with the material preparation and experimental work of this research investigation. The first limitation involves the CNT dispersion and measurement. The assessment of the dispersion of the CNTs within the solution was difficult and not precise since it depended on the visual evaluation, including the TEM images, which gives qualitative information at a very small scale and may not entirely represent the microstructure of the nanocomposite as a whole. It was even more complicate and difficult to measure the dispersion of the CNTs within the epoxy composite, as the SEM images only covered a small area and depth on the dispersion of the CNTs within the epoxy volume. The final length of the CNTs was not measured after the ultrasonication process. The breakage of the CNTs could effectively change the actual aspect ratio of the CNTs assumed before the ultrasonication process.

Another important limitation concerning the testing involves the size of the specimens like pin and square shape. The small diameter cross-sectional area of the specimens made them very sensitive to micro defects, like bubbles and air voids. These micro defects significantly affected the tribological and mechanical behavior of the composite. In addition, the limitation pertaining to the neural network is the ANN prediction accuracy dependence on number of training datasets used to train the network and also well trained neural network provides useful data from relatively minimum experimental datasets.

Furthermore, the difficult manipulation and lack of process ability in the host matrix have imposed great limitations to the use of CNTs in various applications. Finally, previous research has revealed that un-functionalized sidewalls produce poor adhesion between the nanotubes and the polymer matrix.
5.3 FUTURE WORK

More explorations are required on the dispersion of CNTs within the solution by examining the amount of surfactant needed, the concentration of the CNT/epoxy ratio and the ultrasonication duration and power needed to improve the dispersion rate without damaging the CNTs.

More examination and process ability are required for preparing bulk volume of epoxy/MWCNTs nanocomposites with high MWCNTs loading. Measuring distribution and dispersion of these nanofilaments is needed in order to apply sequential mixing procedure to effectively utilize the CNTs within the epoxy matrix.

Further investigations are needed on the tribological and mechanical properties of epoxy/MWCNTs nanocomposites of the various weight percentage from between 0.1wt.% and 1.25wt.% and also to performing the wear and friction tests by varying the factors like sliding speed and distance and in same way the erosion tests can be carried by changing the impact velocity and size of the erodent particle. The orientations of MWCNTs into the epoxy matrix significantly affect the mechanical properties because of their high aspect ratio. A systematic and comprehensive study of the nano particle orientation is recommended in the future to control the nano particle orientation and reveal its influence on the mechanical properties of composite materials.

Finally, performing finite element analysis for the epoxy/MWCNTs nanocomposites is needed to validate the experimental results, verifying and understand the mechanism of material removing and strengthening of the matrix caused by the existence of CNTs.