CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 SUMMARY

The purpose of this research was to study the tribological performance of the hybrid aluminium nano and micro composites with the potential for use in the manufacturing of automotive engine blocks and aerospace applications. The mechanical properties such as hardness, density and tribological properties such as wear resistance and friction coefficient of hybrid composites were studied using pin on disk apparatus. In an effort to further enhance the mechanical properties of these composites, the effects of hybridisation of sintered compacts were also studied. The microstructures of produced composites were executed using of X-ray diffraction measurements (XRD), Optical Microscopy (OM), Scanning Electron Microscopy (SEM), and mechanical properties were measured through density/hardness tests. The following sections provide summaries of the experimental observations and conclusions derived from the study.

5.2 CONCLUSIONS

The conclusions drawn from this study are summarized as follows:

- AA 2024, Al-SiC, Al-Gr and Al-SiC-Gr composites using micro and nano level powders have been successfully developed by powder metallurgy (PM) technique.
- The microstructure analysis of the composites indicates that both SiC and Gr particles disperse uniformly in the matrix alloy without agglomeration, and orientate randomly in the matrix.

- For all the loads and the sliding velocities studied, the developed composites have exhibited higher wear resistance and higher coefficient of friction when compared with matrix.

- Three wear mechanisms were identified as responsible of the Aluminium hybrid composites wear behavior under the test conditions: oxidative wear, abrasive wear and delamination wear. A transition from delamination to abrasive wear takes place with the increase of SiC particles.

- The incorporation of SiC reinforcement to AA 2024 alloy increases the wear resistance of the composites. The addition of Gr reinforcement in AA 2024/SiC composites increases the wear resistance of the composite. The formation of smooth Gr-rich tribo-layer seems to be a key aspect controlling the wear behavior of the hybrid composites.

- Increased content of SiC reinforcement, leads to higher coefficient of friction. The presence of hard ceramic particularly in high content SiC hybrid composites was found to have influence on the wear properties.

- The wear mechanism operating in hybrid composite with 20% SiC and 5% graphite hybrid composites was found to be delamination and oxidative wear. Wear debris become smaller as the amount of SiC addition increases.
The coefficient of friction values were found to be in the range of 0.15-0.35 for both matrix and hybrid composites. The coefficient of friction was not affected by the sliding speeds. It can be concluded that the increment of SiC levels in the composites affects the wear behaviour of the composites, improving the wear resistance and making it a potential material for aerospace and automotive applications.

Increasing graphite content in nano composites causes density and hardness to decrease.

Wear loss of the composite increases as the amount of graphite addition increases up to 5% Gr addition, then drops to a lower value for 10% Gr addition. The wear resistance of hybrid nano composites was higher than the matrix alloy.

Worn surface observations suggested that the dominant wear mechanism for unreinforced nano AA 2024 matrix alloy has been delaminating wear along with by some oxidative wear mechanism. But, worn surfaces of the hybrid nano composites were smoother and the depth of deformations were smaller than the unreinforced aluminium alloy matrix.

Amount of the graphite released on the wear surface increases as the percentage of graphite addition increases. Moreover, wear debris become smaller as the amount of graphite addition increases. The formation of a lubricating layer seems to be a key factor controlling the wear behaviour of these hybrid nano composites.

From full factorial analysis, the results of ANOVA show that the polynomial models of the wear loss and coefficient of
friction are well fitted to the experimental values. The influence of the wear parameters on the wear loss and coefficient of friction was analyzed by the obtained mathematical model. ANOVA shows that the most significant variables affecting the sliding wear of composites (in terms of their individual percentage contributions) are the sliding distance (56.74%), sliding speed (13.40%), applied load (13.49%), and graphite content in the composite (11.67%), as well as the interaction effect of the load with the sliding speed (2.01%), within the selected range of investigations. ANOVA also shows that the most significant variables affecting the friction behaviour of the composites (in terms of their individual percentage contributions) are the applied load (62.91%), sliding distance (18.71%), sliding speed (7.79%) and graphite content in the composite (1.71%), as well as the interaction effect of the applied load and the sliding distance (2.97%), within the selected range of investigations.

- From Taguchi design of experiments, ANOVA showed that the most significant variables affecting the sliding wear of the composites (in terms of their individual percentage contributions) were the sliding distance (57.12%), sliding speed (12.43%), applied load (13.78%), and graphite content in the composite (11.23%) within the selected range of investigations. ANOVA also showed that the most significant variables affecting the friction behaviour of the composites (in terms of their individual percentage contributions) were the applied load (61.47%), sliding distance (0.86%), sliding speed (8.86%), graphite content in the composite (8.84%) and the inter- action effect of the reinforcement and the load (7.73%).
The optimal control factors were determined in a Taguchi experimental analysis and found to be A2B1C1D3 for wear loss and A2B1C1D1 for the friction coefficient. The prominent testing parameter for the wear of the composites was found to be the sliding distance. However, the applied load, sliding speed and weight fraction of graphite had only a slight influence on wear loss, while the applied load was found to significantly affect the friction coefficient of the composites.

5.3 FUTURE WORK

The future work for this study can be classified into the following research areas:

- Investigate the effects of different reinforcement particle size of both SiC and Gr in AA-2024 matrix.
- Investigate the effect of sintering atmospheres on the composite materials.
- Development of a process for fabricating hybrid composites based on nano-sized particles and fibres.
- Detailed studies on solidification and characterization of the hybrid composites reinforced with nano-sized particles and fibres.
- Investigation in corrosion behaviours of hybrid composites for potential engineering applications.
- TEM investigation in the effect of microstructure of the hybrid composites.
• Study the effect of both SiC and Gr concentration on wear and friction behaviour at elevated temperature.

• Develop Mg-based composite to replace Al-based composites as a further weight reduction applications such as automotive and aero space industries.