CHAPTER 9

CONCLUSIONS

The conclusions of the present investigations based on experimental analysis, theoretical and finite element analysis are presented in this chapter. This chapter is concerned with the contributions of the present investigation, major conclusions and scope for further research.

9.1 CONTRIBUTIONS OF THE PRESENT INVESTIGATIONS

The selection of plain bearing materials used in internal combustion engine is very much important, because the failures of bearing may hamper the life of the component and continued functioning of the automotive engine. The researchers around the world are continuously striving to improve the properties of alloys or materials used for plain bearing. This can be achieved by altering the composition of the conventional bearing alloy material or by adding some of the alloying elements to the base alloy. This research work presents the feasibility of using the bi-metal structure of aluminium-based alloy in the engine bearing applications. The bi-metal alloy is prepared through the cladding process. The two different compositions of the Al-Sn-Si has been selected based on the recent and past research works and found that these materials can replace the conventional bearing alloys because of their good wear and corrosion resistance, low frictional value and better mechanical properties. Here the second composition of the alloy is subjected to special T6 heat treatment process.

The different mechanical properties like hardness, tensile, impact and flexural values have been determined through the experimental tests. The seizure resistance and corrosion rate of the developed alloy material is also
calculated and all the obtained results are compared with the conventional bearing alloy. The tribological studies have been carried out with the help of pin on disc wear tester. Scanning Electron Microscope (SEM) is used to investigate the wear on the surface of the alloy. The tests are conducted under lubricated conditions. The ANN techniques are also used to develop the model with data obtained from the tribological test and this helps to predict the mass loss of the developed alloy. The housing rigidity of the bi-metal bearing structure is also calculated through analytical method which helps to ensure the rigidity of the bearing material fitted into housing. The combined effects of mechanical and thermal loads acting on the engine bearing, working under realistic conditions are also analyzed by coupled-field analysis.

9.2 MAJOR CONCLUSIONS

The aluminium-based alloy material may be effectively used in the industry due to better Mechanical properties like high hardness, maximum tensile strength, good impact strength, high flexural and fatigue strength. The bearing material is also ensured to work well under high temperature, corrosive environments and have better tribological behaviors under oil lubricated conditions. The ANN too is chosen and can be used efficiently as prediction technique in the area of material characterization and tribology. Housing rigidity between the bearing and housing assembly is ensured and the stresses developed in the bearing material due to thermal and mechanical loads are calculated. From the entire studies of the AITSi alloy and AITSiH alloy, the following conclusions are drawn.

1. Microstructure of the Al-Sn-Si alloy consists of $\alpha$ (Al), $\beta$ (Sn) phases and eutectic Si and it belongs to ternary eutectic system. In the ‘peritectic-type’ island structure, the eutectic silicon is surrounded with tin and it is uniformly distributed in the heat treated alloy. So, the combined soft Sn and hard Si
phases in aluminium matrix confirms ‘peritectic-type’ island structure and this gives best microstructure for anti-friction and wear resisting properties.

2. Mechanical properties of the developed alloys are compared with the conventional alloy and the obtained results are discussed below

- Hardness values of the developed alloys are more than the conventional alloy.
- Tensile properties of the developed alloys are better than the conventional alloy. UTS values of the developed AlT Si and AlT SiH alloys are 1.127 and 1.296 times more than the conventional alloy respectively. The reason is due to the addition of high content of silicon and copper.
- Impact and flexural strengths of the developed alloys are superior to the conventional bearing alloy.
- Actual fatigue strength of the developed AlT Si and AlT SiH alloys are 1.238 and 1.512 times more than the conventional alloy respectively. From the S-N diagram, the endurance limit for the developed alloys is calculated at $5 \times 10^8$ cycles as $143.36 \, \text{N/mm}^2$ and $180.38 \, \text{N/mm}^2$.

3. Seizure load for the developed AlT Si and AlT SiH bearing materials are superior to the AlT bearing material. It is also observed that the frictional force and bearing surface temperature increases with the increase of normal loads.

4. Metal loss (ML) and corrosion rate (CR) for the AlT alloy and the developed alloys increase with the increase of concentration value of HCl corrosive solution. The results
showed that the AlT is having high corrosion than the developed alloys in the identical test conditions.

5. The results obtained from the tribological tests under lubricated conditions show that:
   - As the sliding distance increased, the friction coefficient of all tested alloys reached constant level following an initial decrease. Friction coefficient of the developed alloy is less than the conventional alloy.
   - The developed alloy exhibits little wear and mass loss than the conventional bearing alloy. Three different stages of wear curves observed as greater initial wear, comparatively less wear than the initial stage and very less wear to the previous stages.
   - It is found that, a higher wear depth is obtained at a minimum sliding distance by increasing the normal applied load. The wear rate of all the tested alloys also increase with the increase in normal load.
   - From the wear track surface analysis of AlTSi alloy, it is observed that for lower loads, wear track surface is even in character but at higher loads, the material surface is well deformed with deep grooves, craters and delamination. But in the AlTSiH alloy, at higher lower loads, the wear track surface is well deformed with deep grooves and serration marks. The same is not seen at lower loads meanwhile some pits/caves are confirmed on the wear surfaces of the alloy.

6. A model using ANN technique is developed to predict the mass loss of the alloy. Feed-forward backpropagation neural
network is selected and the error between the predicted values and experimental values for both training and testing of ANN is having good compatibility. The overall performance of the model is relatively agreeable and can be used to predict the mass loss with high accuracy.

7. The hoop stress and radial pressure developed in the bearing and housing assembly are calculated through analytical methods and it is found that these are well above the minimum value. This ensures that the bearing can rigidly fit into the housing. The interference between the bearing and housing assembly due to rise in temperature is neglected as it is very small.

8. The limiting load condition for the engine bearing, calculated by using coupled-field analysis, reveals that:

- The maximum load carrying capacity of the developed AlTSi alloy and AlTSiH alloy are 18.31 kN and 88.01 kN respectively.
- The nature of stress variation along the width of the bearing is also examined. Here the maximum stress is generated on the sides of the bearing material, which decreases considerably and remains almost the same in other portions.
- The stress variation and deformation for various ranges of operating oil temperatures reveal that the load carrying capacity of the material is inversely proportional to the temperature of the lubricating oil and obtained stress values are within the permissible limit.
In the combined inertia and gas load analysis, the obtained stress values are found to be within the permissible limits and the deformation of AlTiSi and AlTiSiH alloy are very small and will not affect the reliability of the engine bearing during operating conditions.

From the above findings, it is concluded that the developed aluminium-based bearing materials have less weight, more wear and corrosion resistance, low friction coefficient and high seizure load. Hence, these alloys are better applicant materials for the automotive applications.

9.3 SCOPE FOR FURTHER RESEARCH WORK

- In the present study focus is given only on the lubricated sliding wear properties of the developed alloys. This can be further improved to incorporate the effect of lubricant oil.

- In this study, the two different alloys have been used. The same work can be extended to study the effect of changing of the percentage value of alloying elements like silicon and tin.

- The Finite Element Analysis can be used to develop the mathematical model which could help to study the behavior of fatigue crack growth in bi-material specimen.

- Apart from the laboratory test, a few tests based on real time applications can also be conducted.