CHAPTER 9

CONCLUSION

9.1 SUMMARY AND CONCLUSION

Three types of bearing failures have been analysed to identify the potential cause for the failures. From the root cause analysis, connecting big end bearing failures were due to the insufficient internal radial operating clearance and the lubricants used. The tolerance class of bearing was modified to C3 class with high temperature lubricant (Synthetic oil base with thickener) and the same has been validated. No failures have been reported from the field trial compressors. The above solution has been implemented and in the same way, the crankshaft main bearing was analysed and it was concluded that misalignment caused the failure. In order to increase the life of the main bearing, the C3 class bearings with high temperature lubricant was selected, validated and implemented.

The connecting rod small end bearing failures have been analysed and concluded that, a combination of caged needle roller bearing and high temperature grease with synthetic base oil (with thickener) eliminates the failure. The same has been validated and implemented and no failures have been reported from the field validation compressors within the declared life of the bearing.

Design of experiments have been conducted to understand the interaction between the factors contributing the big end bearing failure and it was concluded that the bearing internal clearance followed by grease viscosity are the major factors which determines the life of the compressor.
Finite element analysis has also been carried out to understand the variation of contact stress and fatigue life with internal clearance. It was observed that the fatigue life decreases with increased negative clearance. The analytical calculation revealed that, with higher interference, the life ratio falls off rapidly reaching 0.11 at -0.05 mm of negative clearance. In the modified design, the maximum negative clearance occurred -0.025 mm and the corresponding life ratio is higher than 0.8 and hence the modified design has improved the life considerably.

The failure analyses have been independently carried out for big end bearing, small end bearing and crankshaft main bearing. In case of big end bearing failures, it was evident that, the radial operating clearance was the main cause for the failures. In order to study the effect of the internal clearance on bearing ball load and contact stress the analytical calculation and FE analysis was performed. It was evident that slight increase in radial clearance drastically reduces the life of the bearing. An attempt has been made to estimate contact stress between the contact elements for different radial clearances through FE analysis. It was observed from the metallurgical analysis, the more frictional heat is being generated during failure and isolated fits are formed due to higher negative clearances. The higher contact pressure or contact stress increases the operating temperature of the bearing, which leads to deterioration of the lubricant property. Since, the number of failures happened was more in big end bearings due to insufficient internal clearances, it was considered that the more study on the effect of internal clearance on bearing life is required through analytical and numerical methods, hence above analysis was carried out and explained in chapter 7.

An attempt has been made to diagnose faults in the early stages of the failure in reciprocating compressor using vibration signal. The machine learning methods were used to detect the faults by simulating the defect in
one of the main bearing. The faults were classified using Decision tree (DT) and the same was verified by using Support vector machine (SVM) techniques. The above technique is used to detect the overall faults of the compressor. Since the reciprocating compressor has more noise than rotating machinery, an adaptive noise cancelling method has been used to detect the faulty elements of the bearing through FFT spectrum analysis of the filtered signal. This analysis can be adapted to predict the bearing element faults to detect in advance during testing; hence, the above analysis was carried out and it is described in chapter 8.

QFD analysis has also been carried out to find the importance of the parts characteristics or technical attributes from the system level to the part level. From the QFD analysis, it is found that, more importance should be given to the technical attributes like bearing life, radial internal clearance, lubricant properties and operating temperature range during the initial design stage itself. Since this analysis was performed at the conceptual level and the same is given in Appendix 6.

All the above analyses have been carried out in the oil free reciprocating compressor to eliminate the bearing failures and this analysis is most useful guide for the new designers to overcome the various failure modes of self-lubricated bearings used in compressors.