7.1 Overall Conclusion

The overall conclusion of thesis is presented in the form of Fault-diagnosis scheme of rolling element bearing. The scheme is developed based upon the work carried out in individual chapters of this thesis (Appendix 1). Fault-diagnosis scheme includes non-linear dynamic modelling, statistical analysis using response surface methodology, intelligent diagnosis using artificial neural network (ANN), and classification of faults using sensor fusion (Vibro-Acoustic).

Following conclusions are drawn from individual chapters presented in thesis.

1] Non-linear dynamic model was developed using six-degrees of freedom to obtain the vibration response due to localized defect. The model proved to be highly relevant in understanding the fault severity due to outer race and inner race defect of rolling element bearing upon rotor dynamic system. The model is validated with experimentation for different fault conditions. The results of the simulation and experimentation are mainly analyzed using CWT. The CWT technique potentially detects the fault by providing the time interval between consecutive amplitudes corresponding to fault frequency.

2] Experimental investigation was carried out to study the effect of input variables such as severity of faults and rotor speed, upon the acceleration response in vertical and horizontal direction of self-aligning rolling element bearing by using response surface methodology. Response surface plots, contour plots and interaction plots are used to determine the effect of change in defect size with change in rotor speed at its high and low level upon the acceleration response in both the directions. The severity of fault assessment is carried out with the help of all these plots which thus provided the clear view of change in vibration response due to the interaction effect of factors as well as individual effect of factors at its low and high level.

3] Expert diagnosis system is developed for diagnosis faults of rolling element bearing. Wavelet transform was used as a significant tool in denoising the signal and extracting the sensitive time domain parameters. ANN and KNN was used to classify the faults by successfully training and testing the data obtained from wavelet transform. ANN model

provides 99% success for classifying OR-IR and CD fault class and 100% for all fault class. KNN classifiers proves to be effective for classifying single point faults (OR-IR fault) and not so effective in classifying the multiple faults (Combined fault).

4] Fault classification is carried out using sensor fusion. Here the data obtained from two different sensors used for monitoring the defective rolling element bearings, are fused together for decision making. Six cases of bearings were tested using sensor fusion and the data obtained from all these cases were feed into K-NN classifier for classification of faults. The results obtained from K-NN proved that fusion of data provides more information about multiple faults as compared to data obtained from Individual sensors.

7.2 Novelty of work

- Multiple fault diagnosis of rolling element bearing using intelligent systems.
- Assessment of fault severity.
- Predicting Capability of transducers.
- Interaction effect between two defects.

7.3 Future Scope

1] Mathematical modelling can be extended for damage occurring naturally. Such a modelling may help the early detection of fault.

2] Statistical analysis can be extended in understanding the interaction effects between multiple localized faults, rotor speed and loading. Such an analysis helps in understanding the impact upon rotor-dynamic system due to the severity of faults.

3] Multiple sensor fusion technique should be enhanced with more advanced machine learning algorithms and signal processing techniques, in order to address the issue of accurate fault diagnosis of particular fault. This area requires enough experimentation with different type of sensors. Thus, it allows researchers to understand the predicting capability of sensor along with choosing right sensor for diagnosis.