Chapter 9 Conclusions

This chapter deals with the final conclusions with regards to key aspects of this dissertation including FEM utilization, telemetry identification and developed methodologies.

9.1. FEM Utilization

An extensive FEM of the FaBCoM TeSt was developed for several purposes. As a start, the FEM was used to determine the possibility of using GMSFs to quantify and qualify fan blade damage. Several damage cases and scenarios were used for this study and positive results were obtained. During this study, it was found that some GMSFs were sensitive to added blade mass. This directly influenced the way in which the EMA of the FaBCoM TeSt was conducted. The aim of the EMA was to identify the GMSFs of the FaBCoM TeSt to be used for monitoring during the tests. The EMA was also used to determine whether it would be possible to use torsional vibration measurements for blade damage detection, which proved to be the case.

The FEM was extensively updated before commencing work on the numerical neural network supervision approach. This was done in terms of material properties as well as structural damping assumptions. Making use of EMA results, the first shaft torsional mode frequency of the FEM was tuned to that of the FaBCoM TeSt. A MAC matrix of the FEM was calculated and showed the FEM to be a valid representation of the FaBCoM TeSt.

During testing of the FEM, use was made of a single excitation force with white noise characteristics. Due to the differences between this type of excitation and the more complex distributed excitation forces exerted on the FaBCoM TeSt during operation, it was necessary to normalize features for neural network training.

9.2. Telemetry Identification

Following a thorough investigation into the utilization of different techniques and technologies, it was decided to make use of a readily available slip ring assembly. Available wireless technologies were found to be limited in terms of masses, power supplies and measuring frequency ranges at the time of the investigation. However, several other researchers have already started to address these shortcomings. For industrial application, this technology will be preferred due the low maintenance required as opposed to slip rings.

9.3. Developed Methodologies

In this dissertation two methodologies for on-line fan blade damage detection was presented.

The first methodology entails the training of neural networks using experimental supervision. Using this methodology, neural networks were trained for different sensor locations using one piezoelectric strain sensor signal and one rotational acceleration signal per network. These networks were shown to be able to quantify blade damage on a four-bladed experimental structure for multiple blade damage using only two measurement signals. This methodology will be desirable to use where access to an experimental structure is readily available, or where damage measurements on an operational structure will not involve large cost implications.

The second methodology entails the training of neural networks using numerical supervision. Neural networks were trained for different sensor locations using features obtained from one strain sensor FRF and one rotational acceleration FRF per network. These FRFs were calculated from an updated FEM of the experimental structure. For each FRF, only frequency shifts of two natural frequencies as well as the area underneath the peak of another natural frequency were used as features. Experimental feature normalization constants were calculated only once from a single set of experimental features obtained from a healthy structure. Network committees were used and were found to be able to detect multiple blade damage. This methodology will be more desirable to use than the first methodology where it will be less costly to construct, update and test a FEM than to test an experimental or operational structure by means of damage simulation.