Chapter 6 FaBCoM TeSt Experimental Setup and Testing

6.1. *Experimental Procedure*

Tests were done for an adjacent positioned blades damage for blades #3 and #4 on the FaBCoM TeSt for 5 different levels of damage on both blades in order to obtain a 5x5 damage condition matrix as shown in Figure 6-1. The labels in the matrix correspond to the damage case labels. Figure 6-2 gives a key for the damage case labels:

Blade #3 Damage Level	0%	12.5%	25%	37.5%	50%
50%	4e2	4e3	4e4	4e5	4e6
37. 5%	4d2	4d3	4d4	4d5	4d6
25%	4c2	4c3	4c4	4c5	4c6
12. 5%	4b2	4b3	4b4	4b5	4b6
0%	4a2	4a3	4a4	4a5	4a6

Blade #4 Damage Level

Figure 6-1: Adjacent Positioned Blades Damage Case Matrix

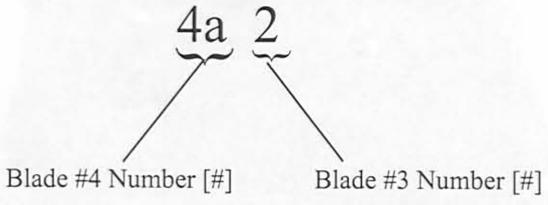


Figure 6-2: Damage Case Label Key

The test procedure will involve measuring for the undamaged case. After that, a certain blade will be damaged at a certain level after which measurements will be taken. This will be repeated until that blade has been damaged to a pre-determined extent. Then that blade will be replaced with an undamaged blade after which an adjacent blade's damaged will be incremented. This whole procedure will be repeated until both blades have reached the pre-determined damage level. Figure 6-3 gives a flow chart for the test procedure.

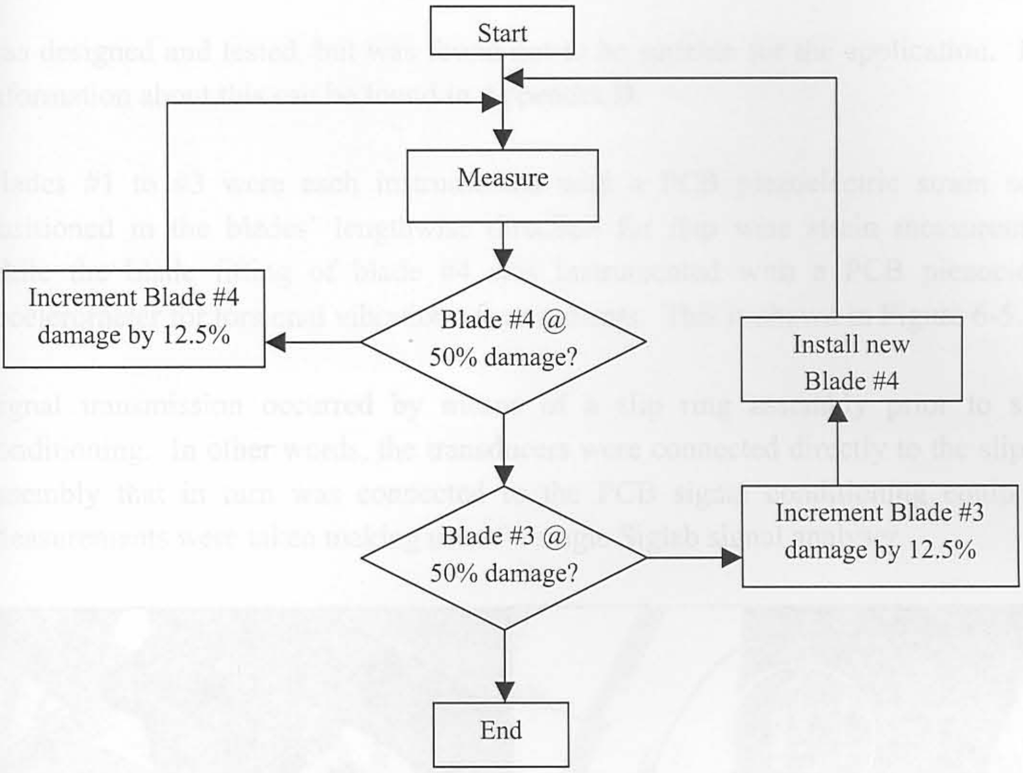


Figure 6-3: Test Procedure Flow Chart

Damage will be simulated in the FaBCoM TeSt by means of hack saw cuts into the blade roots as shown in Figure 6-4. This is the same procedure used by Smit [45].

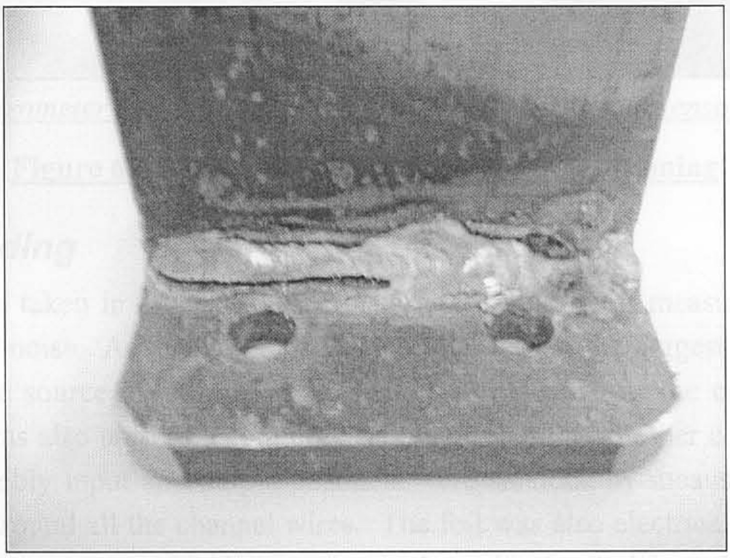


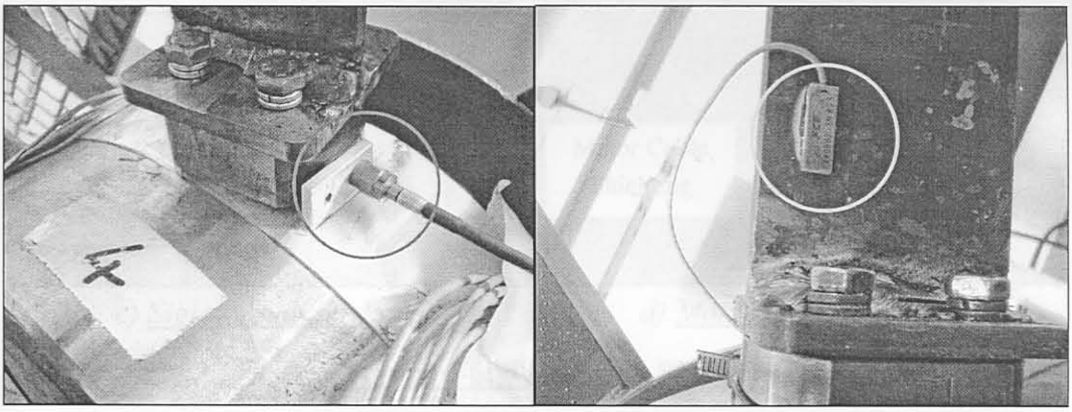
Figure 6-4: Experimental Blade Damage Simulation

6.2. Telemetry

Initially, it was decided to make use of normal strain gauge rosettes as transducers as they are commonly used in industry. However, no equipment was available for bridge excitation and amplification of the strain gauges for the 2000 Hz measurement bandwidth of interest. For this reason, a 4-channel strain gauge half bridge amplifier was designed and tested, but was found not to be suitable for the application. More information about this can be found in Appendix D.

Blades #1 to #3 were each instrumented with a PCB piezoelectric strain sensor positioned in the blades' lengthwise direction for flap wise strain measurements, while the blade fitting of blade #4 was instrumented with a PCB piezoelectric accelerometer for torsional vibration measurements. This is shown in Figure 6-5.

Signal transmission occurred by means of a slip ring assembly prior to signal conditioning. In other words, the transducers were connected directly to the slip ring assembly that in turn was connected to the PCB signal conditioning equipment. Measurements were taken making use of a single Siglab signal analyser.



a) Accelerometer Orientation *b) Piezoelectric Strain sensor Orientation*

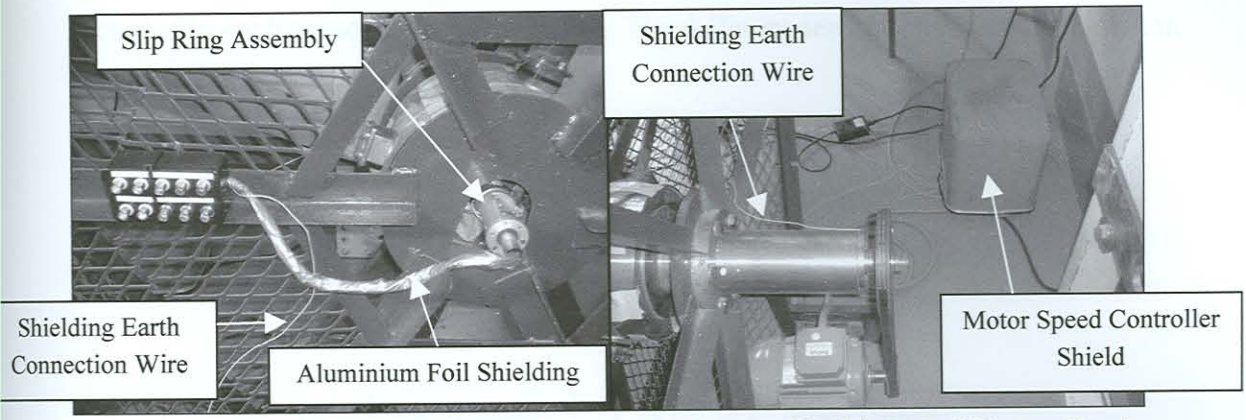
Figure 6-5: Transducer Orientation and Positioning

6.3. Shielding

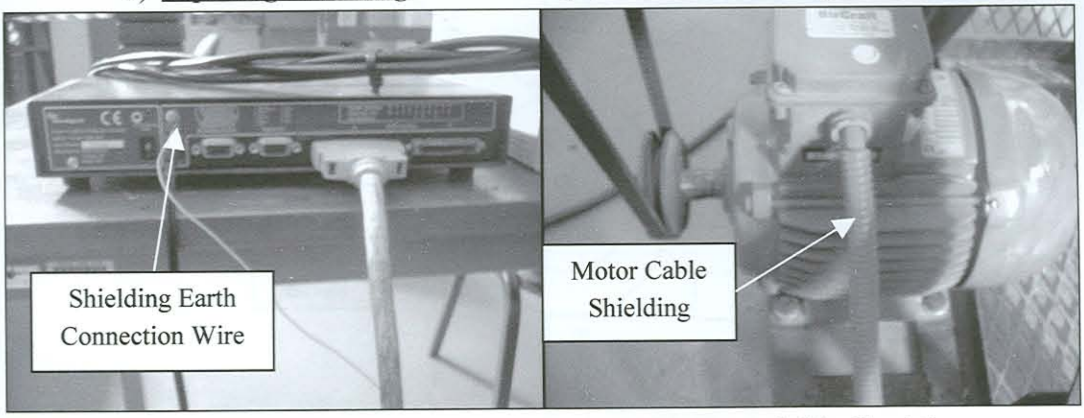
Great care was taken in order to obtain maximum shielding of measurement signals from electrical noise. As the motor speed controller was of the biggest concern for an electrical noise source, a hollow metal shield was placed over the controller. The metal shield was also used as a common shielding earth for all other equipment. The slip ring assembly input and output channels were shielded by means of aluminium foil wrapped around all the channel wires. The foil was also electrically isolated and connected to the common shielding earth together with the Siglab analyser, FaBCoM TeSt frame and motor cable shield as shown in Figure 6-6. Figure 6-7 shows the effect of shielding. It is clear from this figure that the noise to signal ratio is significantly reduced.

6.4. Measurements

As already discussed in section 6.2, simultaneous recording was done of strain signals on blades #1, #2 and #3 as well as the torsional acceleration signal from the fitting of



a) Slip Ring Shielding *b) Common Shielding and Frame Earth*



c) Siglab Analyser Earth *d) Motor Cable Shielding*

Figure 6-6: Test Setup Shielding

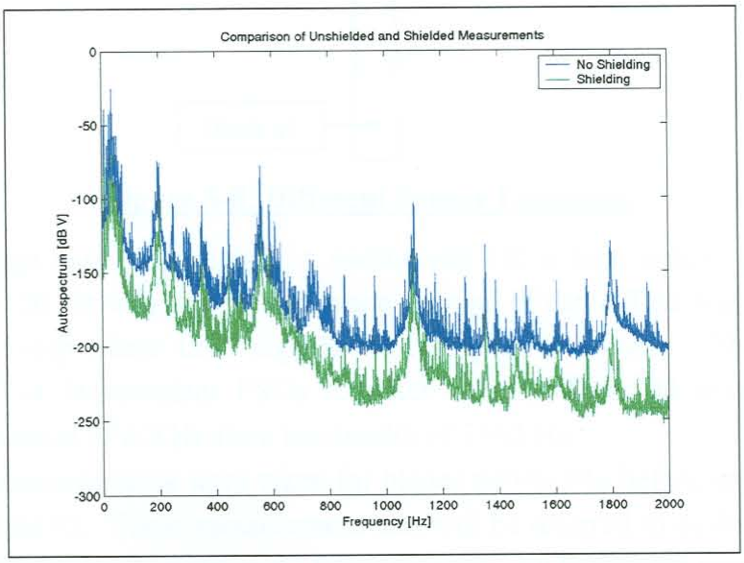


Figure 6-7: Comparison of Unshielded and Shielded Measurements

blade #4. This was done in order to simulate three different strain sensor location scenarios with regard to damage location namely Sensor Location (SL) #1, SL #2 and SL #3, where the sensor location number refers to the blade number on which the strain sensor is installed for that particular sensor location. The accelerometer is included in each sensor location scenario. The different sensor locations are shown in Figure 6-8.

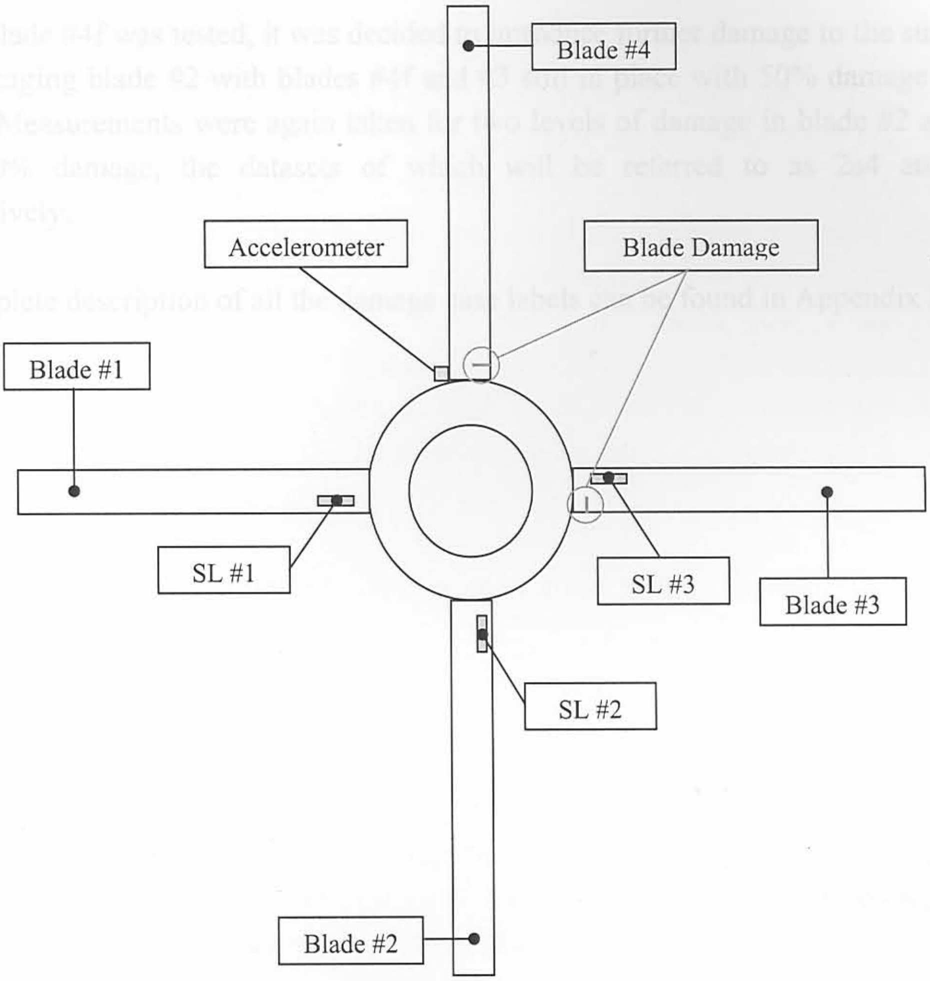


Figure 6-8: Different Sensor Locations

For each damage case (Figure 6-1), a continuous 192 s time sample at a sampling frequency of 5120 Hz was recorded for each channel of data. This was done in order to obtain 24 independent time signals with lengths 8 s each. This allows the calculation of 24 independent PSDs for each channel from 20 averages using a frequency resolution of 2.5 Hz for a bandwidth of 2560 Hz.
Additionally, measurements were taken for blades #4b to #4e before any damage was inflicted on blade #3. These measurement sets will be referred to as 4b1 to 4e1. The reason why these measurements were taken was to see whether the methodology that will be developed is robust in terms of blade manufacturing and installation variables such as weld seam quality and blade attack angle. These two variables will differ from blade to blade due to manufacturing tolerances.

Also, it was discovered that the strain sensor on blade #2 came loose during testing of blade #4e. The sensor was installed at the same position on blade #2 again, after which the same tests that were performed on blade #4e, were performed on an additional blade named blade #4f. The dataset labels for blade #4f ranges from 4f2 to 4f6.

After blade #4f was tested, it was decided to introduce further damage to the structure by damaging blade #2 with blades #4f and #3 still in place with 50% damage levels each. Measurements were again taken for two levels of damage in blade #2 at 25% and 50% damage, the datasets of which will be referred to as 2a4 and 2a6 respectively.

A complete description of all the damage case labels can be found in Appendix E.