APPENDIX J

NWTC /University of Mass 9M known defect Blade fatigue loading to failure test 2011 NASA KSC PZT Health Monitoring System Data

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Purpose/background:

The goal of this test program is to demonstrate the ability of the PZT based NASA KSC Health Monitoring Technology to detect stiffness changes of the 9M test wind blade which has know installed defects and is to be load fatigue cycled to failure. The addition of the NASA system will be on a minimal interference basis, as there are other technologies already planned to accomplish similar goals.

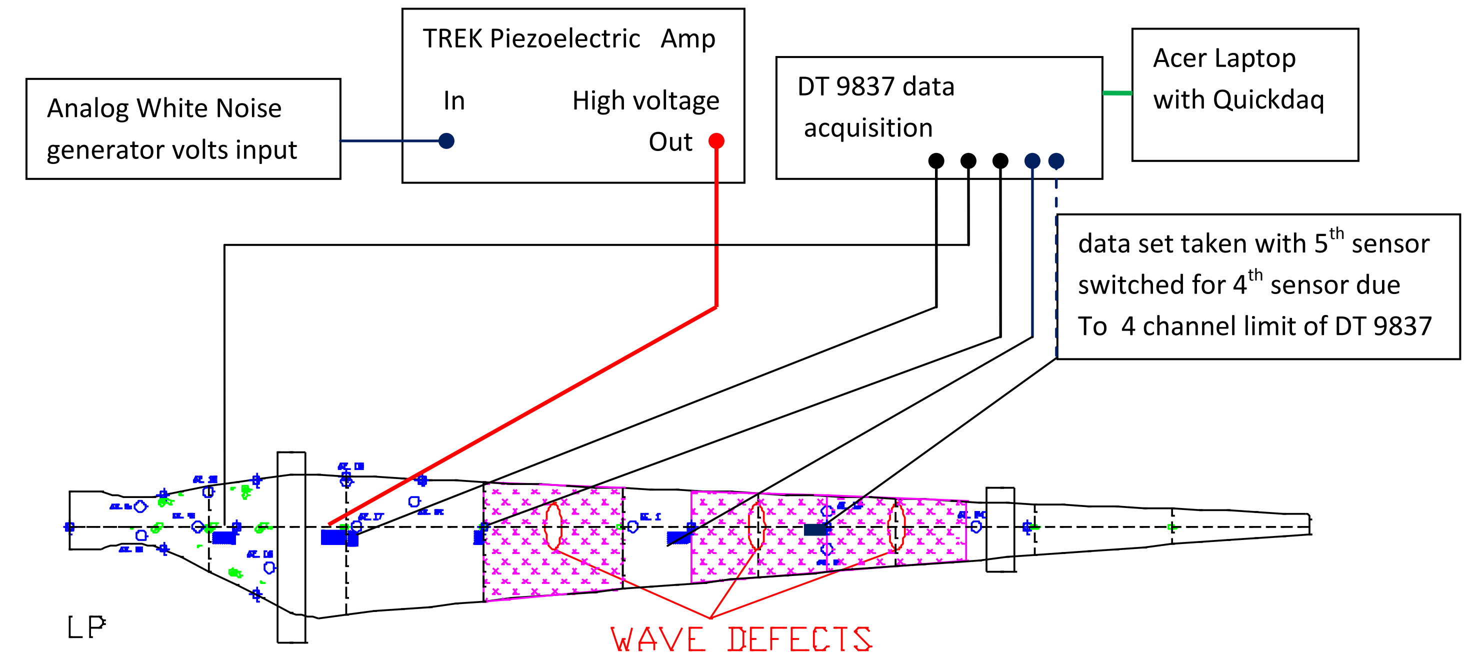
Installation/setup:

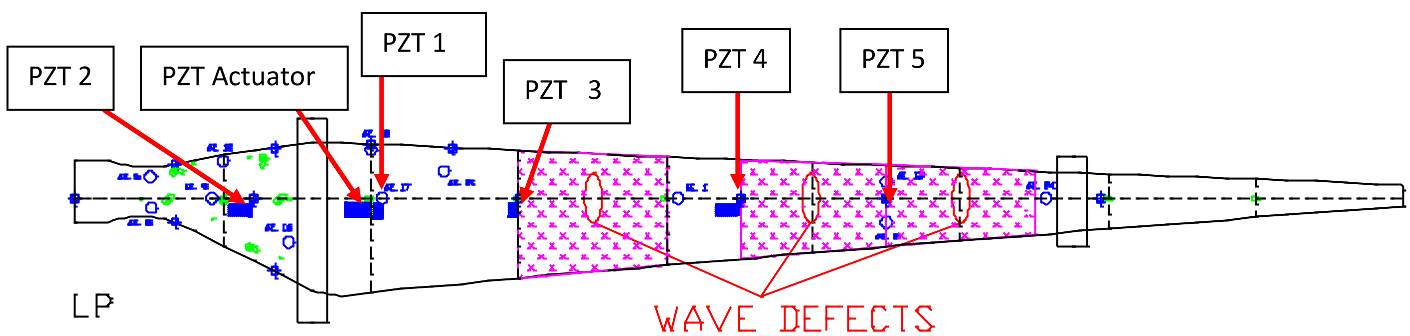
5 PZT sensors and one actuator on the blade top surface were attached to the bottom Low Pressure (LP) side only (I am concentrating on the LP side – bottom surface for access and simplicity). Using the available blade space and considering the other sensors the locations of the PZT sensors are shown below and on the Drawing UMass Defect Blade Instrumentation Plan 110808 rjw.dwg.

Procedure

Sensor data is to be recorded with the actuator energized using the DT quickdaq software at periodic 20 sec long intervals, which will allow averaging of data when the blade is stopped. The white noise input level will be maintained at the same intensity, the intervals correspond to other health monitoring technology data periods with less cycles between data intervals as the blade nears failure. The Data is periodically copied to usb data storage and put on web server at NWTC (same as previous tests)

Wiring block Diagram:





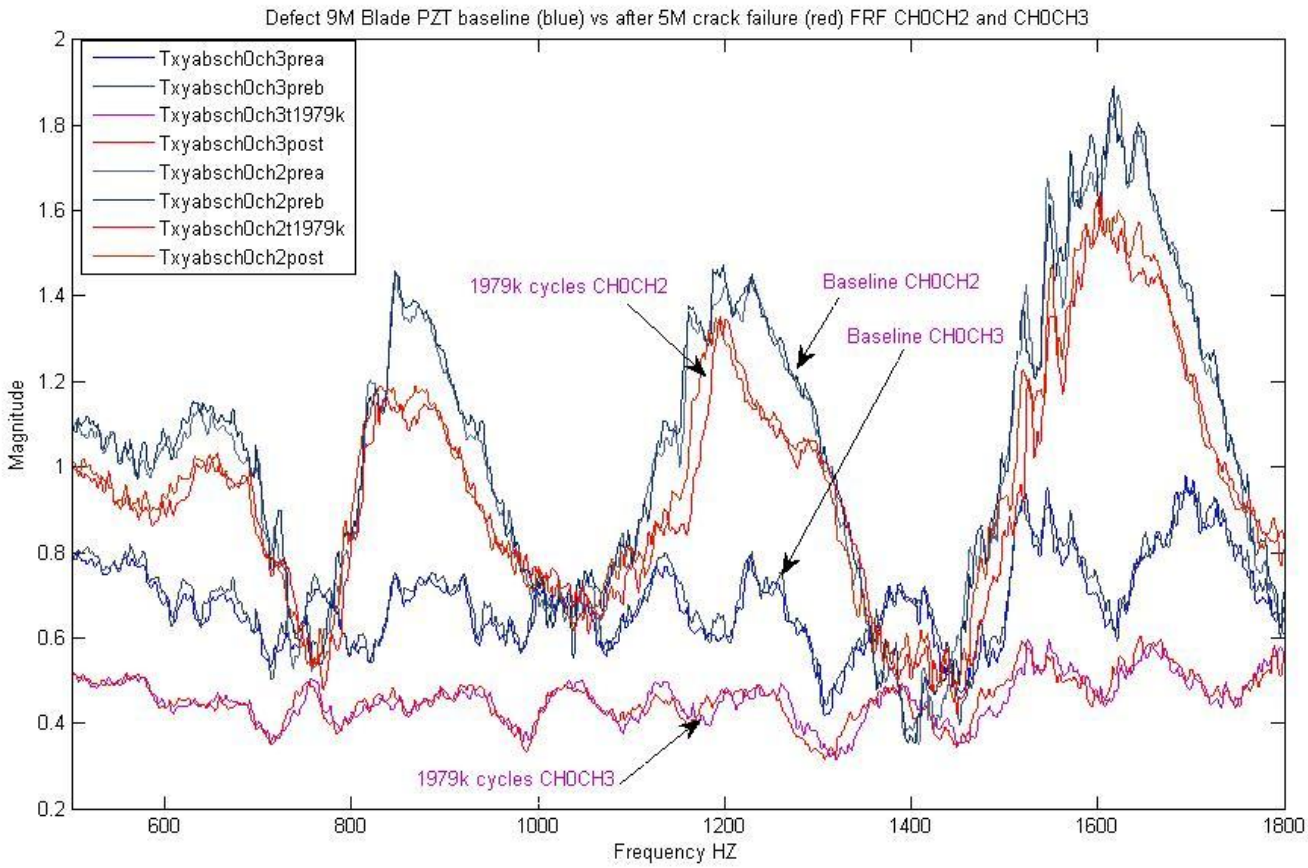
Results:

Limited data Test cell power outages and the Laptop Operating system/Quickdaq software had setup problems which caused a considerable amount of missed data. Full length 20 second data files were only recorded baseline (pre test) and after failure (post test) Short 1.5 sec data files were recorded at 1795, 1803 and 1979 cycles.

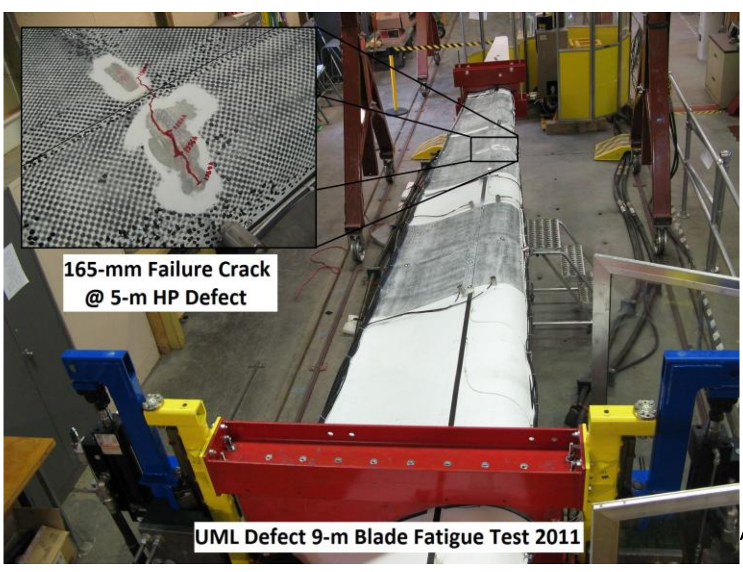
Data files	Date data taken	Number of fatigue cycles (thousands)	Blade condition
20 seconds channels 1-4	12/14/2011	0	No damage
1.5 seconds ch 1-5	2/17/2012	1795	No visible structural cracks
1.5 seconds ch 1-5	2/21/2012	1803	No visible structural cracks

1.5 seconds ch 1-5	2/29/2012	1979	5 M HP crack 165 mm long
20 seconds channels 1-5	3/1/2012	1979	5 M HP crack 165 mm long

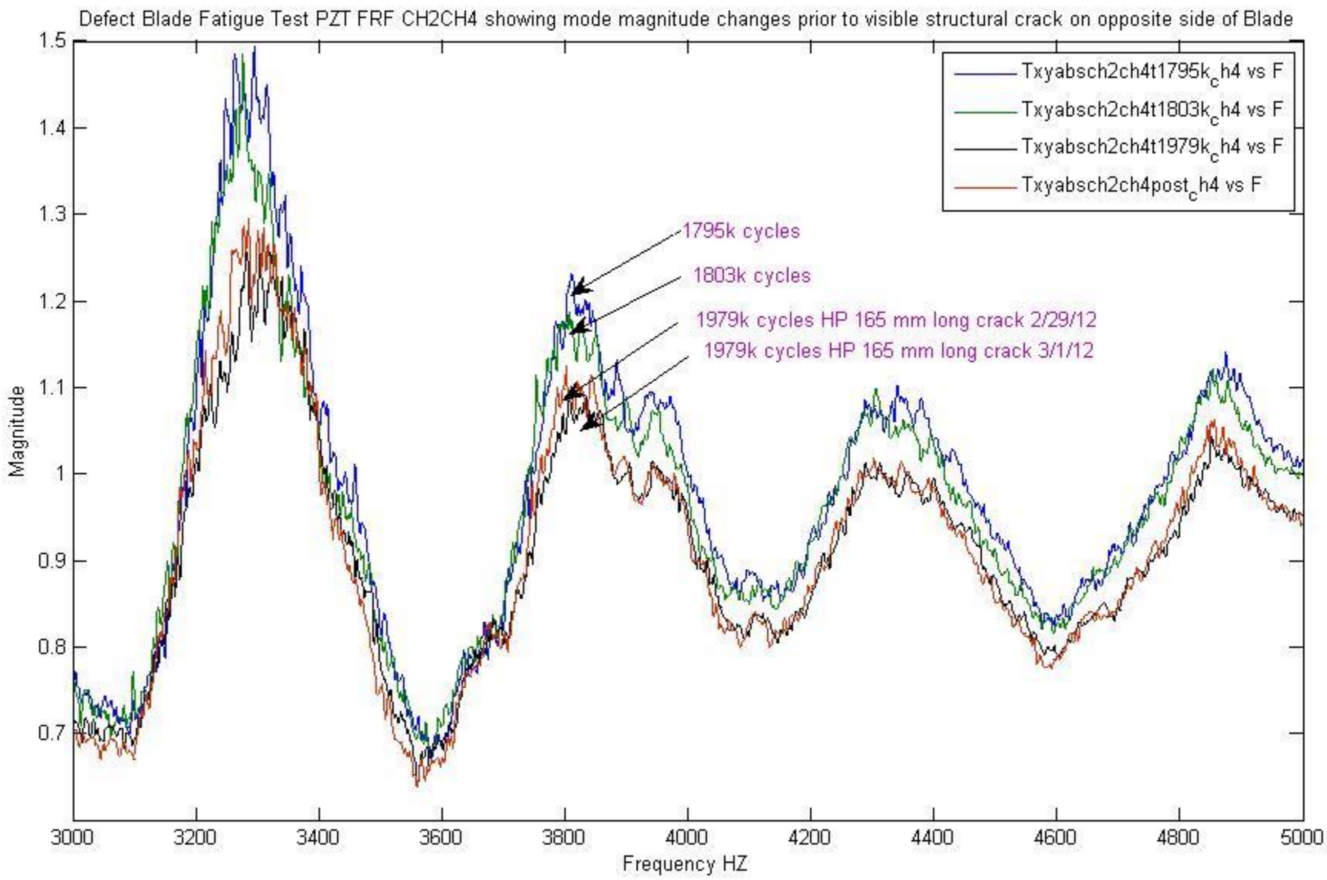
Shown below are the Frequency Response Functions showing differences in modal peaks before and after fatigue crack failure on opposite (LP) side of blade closest to sensor 3. There are two sets of similar data sets shown for the input to response sensor 2 and input to response sensor 3.



Shown below are pictures of the crack on the opposite side of the PZT actuator/sensors which caused failure at 1979 fatigure cycles. Pictures are courtesy of the NREL NWTC Test Team.



Shown below are the Frequency Response Functions of sensor 2 to sensor 4 which span the 5 M 164 mm long crack showing differences in modal peaks before slight trend before the detection of the surface crack. This crack was on the opposite side of the blade from the PZT actuator and sensors which greatly decreased detectability as indicated by relatively small changes.



Discussion:

The structural surface crack at the 5 M location High Pressure side was unfortunate on the opposite side (LP) where my actuator and sensors were attached. The normal plan would be to attach a set of actuators and sensors on both sides of a blade to provide an adequate signal. However, small changes to the stiffness were still detected as shown above. The data is representative, not comprehensive the duration of the data and quantity were unintentionally highly limited, this should not reflect on the NASA PZT health monitoring method.

The following IWSHM paper describes recent fatigue tests using the NASA PZT technology:

PZT Active Frequency Based Wind Blade Fatigue to Failure Testing Results for Various Blade Designs IWSHM 2011, 8th International Workshop on Structural Health Monitoring