Low-Cost Wind Turbine Blade Structural Health Monitoring

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This project enabled the team to initiate the development of a state of the art acoustics-based structural sensing and health monitoring technique which requires efficient algorithms for operational damage detection from wind turbine blades. The team initially focused on the active acoustic detection aspect of the project. A 9m CX-100 blade has been procured to investigate the acoustic detection rate and the influence of environmental conditions on the diagnostics process.

The "active sensing" approach, which involves mounting an audio speaker (with controlled output frequency and level) inside of the blade to excite the internal cavity acoustics, has been tested under different conditions with different specimen. This study is also complemented by the computational investigations of the acoustics of the blade's internal cavity. A finite element based approach has been used in order to better understand the sensitivity of the technique to damage type, size and location. Ansys, a commercially available computational tool, has been used to model the CX-100 blade section to investigate the acoustic radiation patterns with and without the addition of prescribed damage at different locations of the blade.

The team has also worked on the passive detection part of the project. For this part of the project, UMass Lowell's Wind Tunnel has been utilized to experimentally simulate external wind flow conditions and test the "passive damage detection" technique. This approach leverages the energy caused by the wind/flow-induced noise, exterior to the cavity. It is inexpensive, in-situ, and effective to detect holes, cracks and leading/trailing edge splits in bonded surfaces. The blade can be continuously monitored and when damage is originated, the internal acoustic signature should change due to the changes in the transmission loss (caused by the hole or crack) and/or the distorted acoustic pressure field. The sound field inside the blade should be significantly different when the blade cavity is no longer sealed to the fluid passing over the exterior of the blade. A single microphone inside the blade cavity can be used to track the differential noise component caused by the damage which essentially couples the blade cavity to the exterior airflow (like a Helmholtz resonator or the noise generated by the airflow over a glass bottle).

After the aforementioned initial stages of the project, the team has focused on the active damage detection tests on a full scale wind turbine blade at the Wind Technology and Testing Center (WTTC) located in Boston, MA and developing a suite of preliminary damage detection algorithms that will be used to detect damage under operation. This final report will mostly highlight the results obtained from the active detection tests at the WTTC.
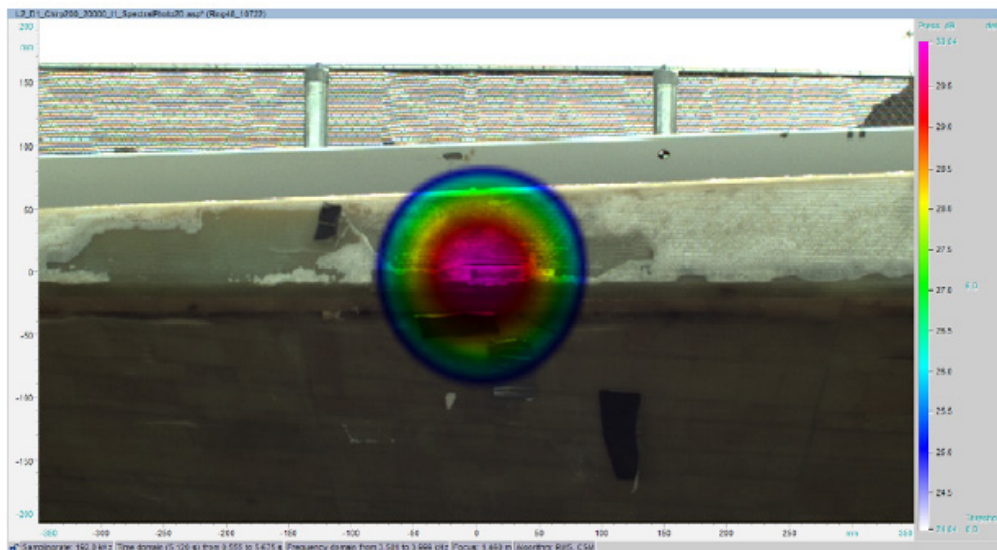
Sound Pressure Map betweeen 3500 and 4000 Hz of the damaged blade during a 200 to 20000 Hz chirp excitation.

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