Structural Dynamics and Acoustic Systems Laboratory
University of Massachusetts Lowell

DYNAMIC STRESS-STRAIN PREDICTION OF VIBRATING STRUCTURES IN OPERATION

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RESEARCH OBJECTIVE

- Use digital image correlation techniques to measure full-field dynamic stress-strain on a wind turbine blade
- Identify improvement of imaging techniques over traditional strain gage methods for validation/certification testing and structural health monitoring

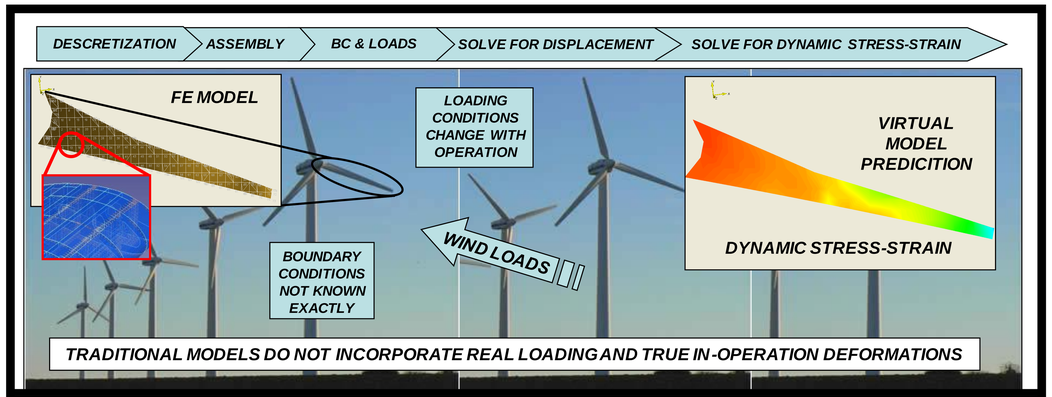
STATIC TEST

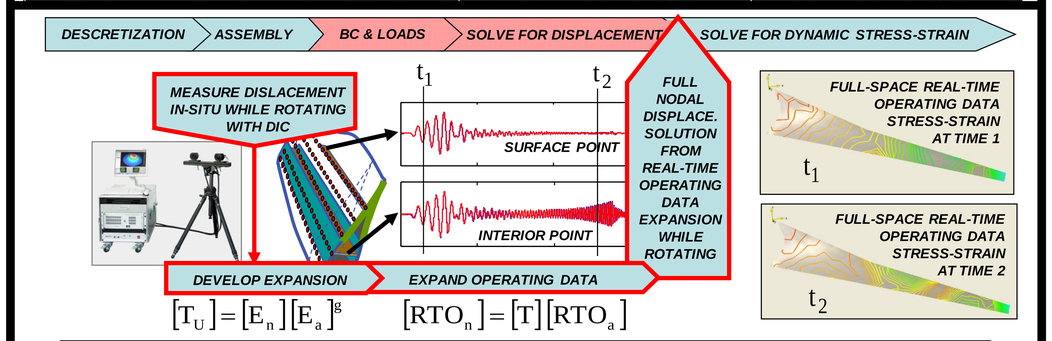
- Perform static load test on a structure to calibrate the system and validate the methodology of testing
- Initial testing performed on cantilever beam, a known structure, to validate results in multiple ways
- Repeat testing on wind turbine blade to ensure that technique has applications on the desired structure. Results obtained using the digital image correlation is compared to traditional strain gages mounted to the structure

DYNAMIC TEST

- Perform dynamic testing that replicates certification procedures for general wind turbine blade applications. Testing consists of a shaker test at the first natural frequency of the system and a pluck test (initial displacement)
- For each test the measurements obtained using digital image correlation is compared to traditional strain gages mounted on the structure.
- Initial testing performed on easily modeled/characterized cantilever beam
- Repeat testing on wind turbine blade to further understand the capabilities of digital image correlation in dynamic testing of structures.

Application for Larger Blades of Interest





RESEARCH OBJECTIVE

- Update and correlate a composite model for the expansion of a limited set of measured location to a full-field dynamic stress-strain
- Develop a damage detection tool for structural health monitoring assessment using the expanded full-field dynamic stress-strain approach

MODEL CORRELATION

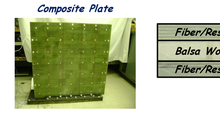
- A model is created using a modeling technique specifically intended to be used for turbine blade applications
- Updating of a modeled and tested panel section is performed to reflect the properties to best represent the panel structure.
- Additional tests are performed with several different perturbed boundary conditions to assure that the updated model has appropriate and realistic properties identified for the model

Tested Panel Section

Composite Plate

Composite Plate Layers

Fiber/Resin Composite	(5 Layers)
Balsa Wood	(Solid Core)
Fiber/Resin Composite	(5 Layers)



Physical Properties

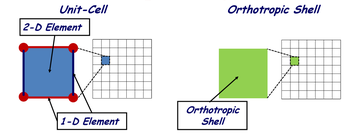
Length	0.865 m
Width	0.865 m
Thickness	
5-Ply layer	0.006 m
Balsa Core	0.006 m
5-Ply Layer	0.006 m
	0.018 m

Mass = 19.5 kg

Stiffer - 0°

Softer - 90°

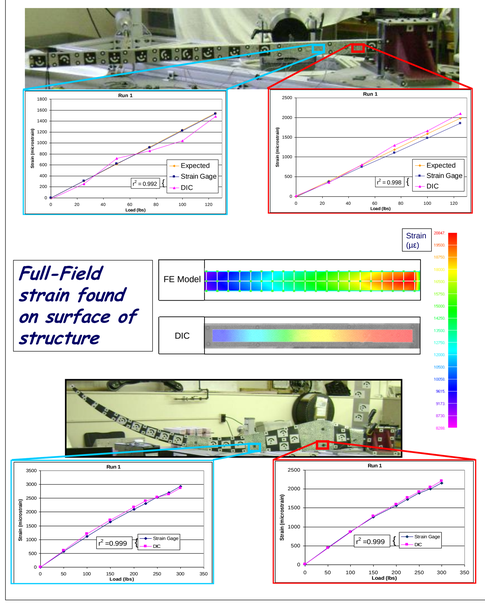
Modeling Techniques



DAMAGE DETECTION

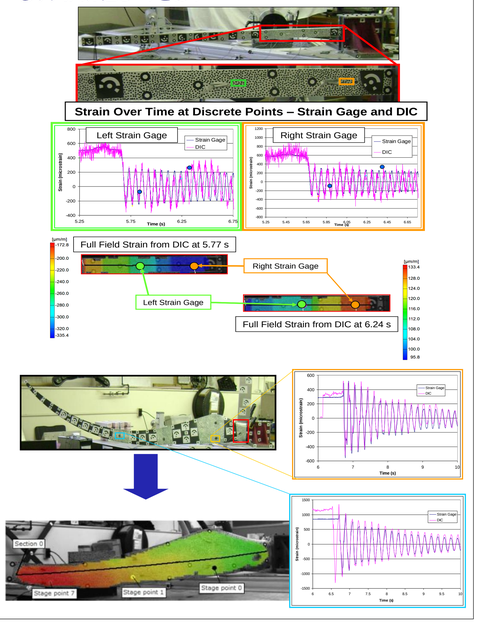
- The current research focuses on the global and local interior and exterior member dynamic interactions to understand the possible loss of structural integrity and fatigue failure of complex composite structures.
- Using some newly developed dynamic stress-strain modeling approaches from limited sets of measured locations, identification of stress-strain distributions will be used as a damage detection tool for structural health monitoring assessment.

STATIC TEST



Full-Field strain found on surface of structure

DYNAMIC TEST



THEORY

- The relationship between the full set of degrees of freedom and a reduced set of degrees of freedom can be written as

$$\{X_n\}=[T]\{X_a\}$$

- The reduced matrices can be formulated as

$$[M_a]=[T]^T[M_n][T] \qquad [K_a]=[T]^T[K_n][T]$$

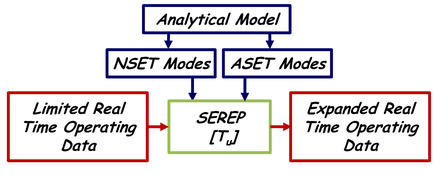
- The SEREP transformation is formed as

$$[T_u]=[U_n][U_a]^g$$

- Equation for expansion of real-time operating data is written as

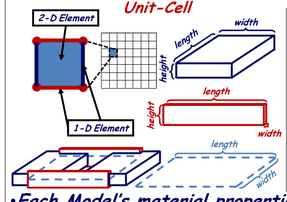
$$[ERTO_n]=[T][RTO_a]$$

- Expanding a reduced DOF system



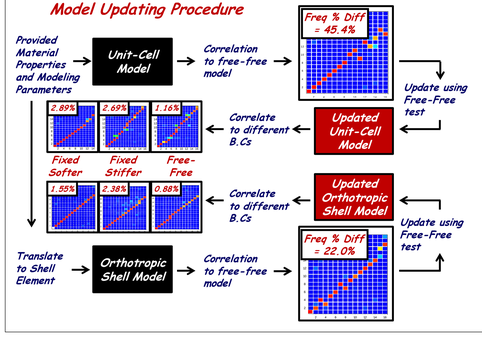
MODEL CORRELATION + UPDATING

- A model of the tested panel section is created using two different modeling techniques

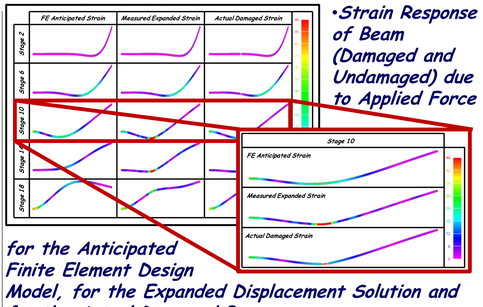


- Each Model's material properties are updated to the desired test frequencies and mode shapes.

Model Updating Procedure

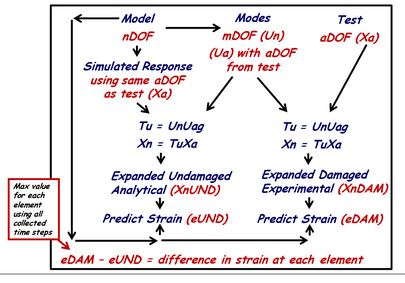


DAMAGE DETECTION



- Strain Response of Beam (Damaged and Undamaged) due to Applied Force for the Anticipated Finite Element Design Model, for the Expanded Displacement Solution and for the Actual Damaged Beam

Damage Detection Procedure



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