Structural Health Monitoring

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Motivation

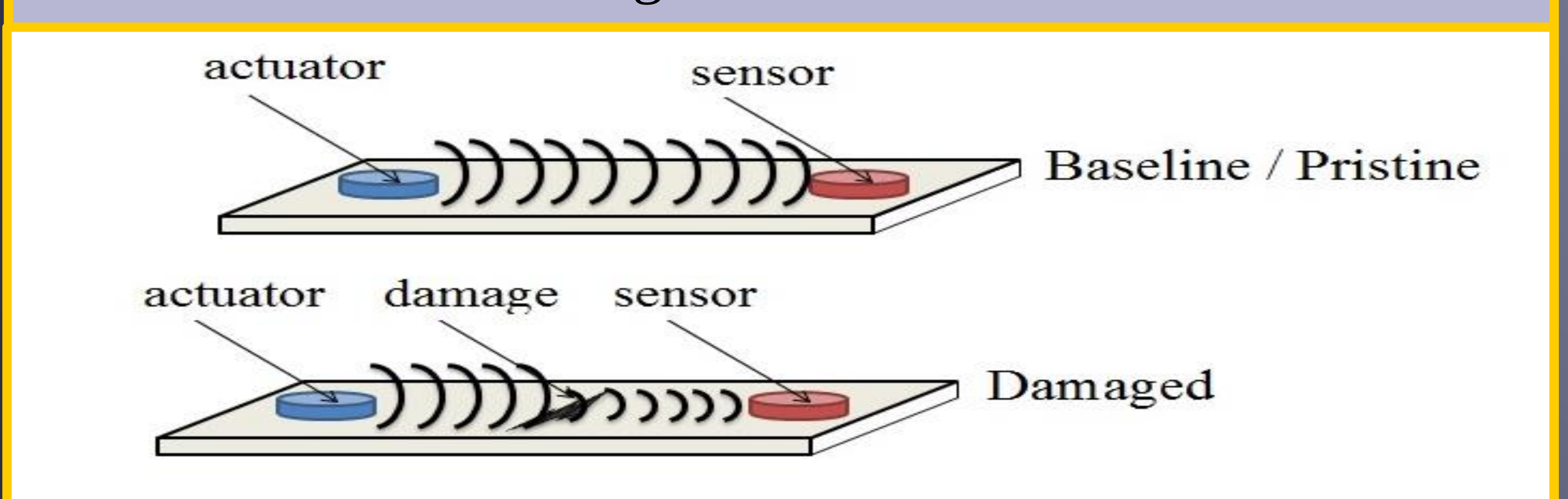
Structural Health Monitoring can detect damage in structures in real time alerting users before failure occurs.

An example of an incident that may have been prevented by SHM is the 1988 Aloha Airlines Flight 243 where undetected fatigue cracks led to a weakened structure. 20 minutes into a flight, at 24,000 ft altitude, the roof of the aircraft ripped off, injuring 65 people and killing one.

Background

Ultrasonic Structural Health Monitoring (SHM) works by inspecting changes in ultrasonic waves, propagated through a structure, to detect:

- if damage exists
- where it exists
- what kind of damage is present
- how severe the damage is



A typical setup, as shown in the picture above, consists of a piezoelectric actuator that generates ultrasonic waves, which propagate through the structure, and a piezoelectric sensor that detect the waveforms. Damage causes changes in the waveforms.

Waveforms are Important

The shape of the actuated waveform is important for detection:

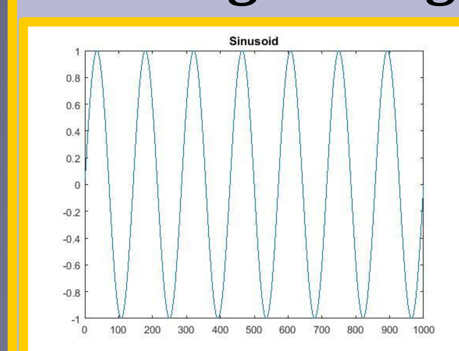
- Limits on time and frequency support analysis
- Changes and distortions in waveforms through propagation can indicate different stimuli

Experiment

Create a 7 peak Hann windowed sinusoid and attempt to detect simulated damage.

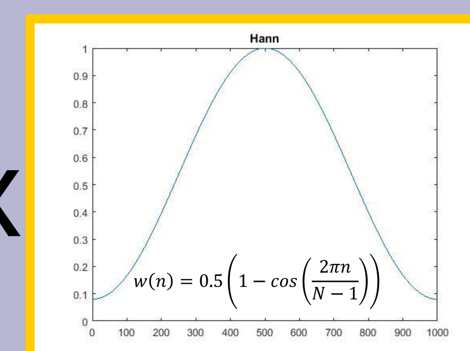
- The hann window has low aliasing; there is a low level of distortion when used and limits the time period of the waveform
- A continuous sinusoid has one frequency

Creating the Signal:



Sinusoid

X



Hann Window

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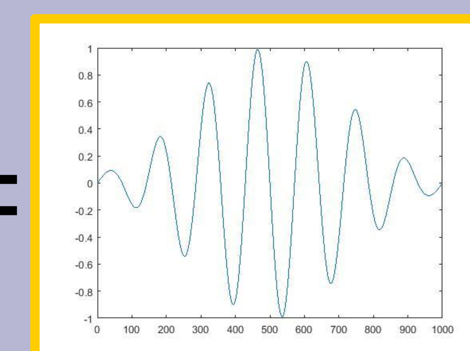


7 peak Hann windowed sinusoid

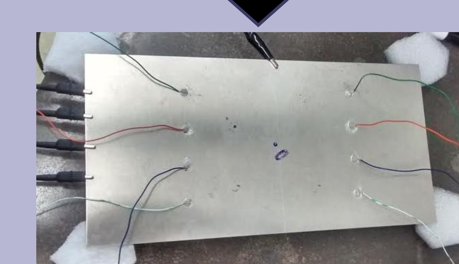
Experiment:

The waveform was actuated with a waveform generator and fed through an amplifier creating a ±50 V signal with a center frequency of 350 kHz. The piezoelectric translates the voltage into strain waves that propagate through the Specimen and another piezoelectric translates the propagated strain into electrical potential which is measured by the oscilloscope. 2 specimens were tested and the data compared to a baseline, one kept pristine, the other with a sticky patch added to simulate damage. The difference between a baseline and test signal gives a "scatter" signal. The signal energy of the scatter can be calculated according to:

$$\sum(scatter^2) * \sum(time) = scatter\ signal\ energy$$

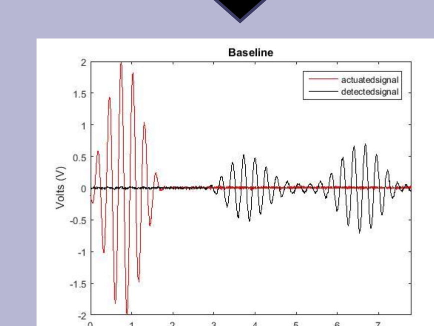
Waveform Generator

Amplifier



Specimen

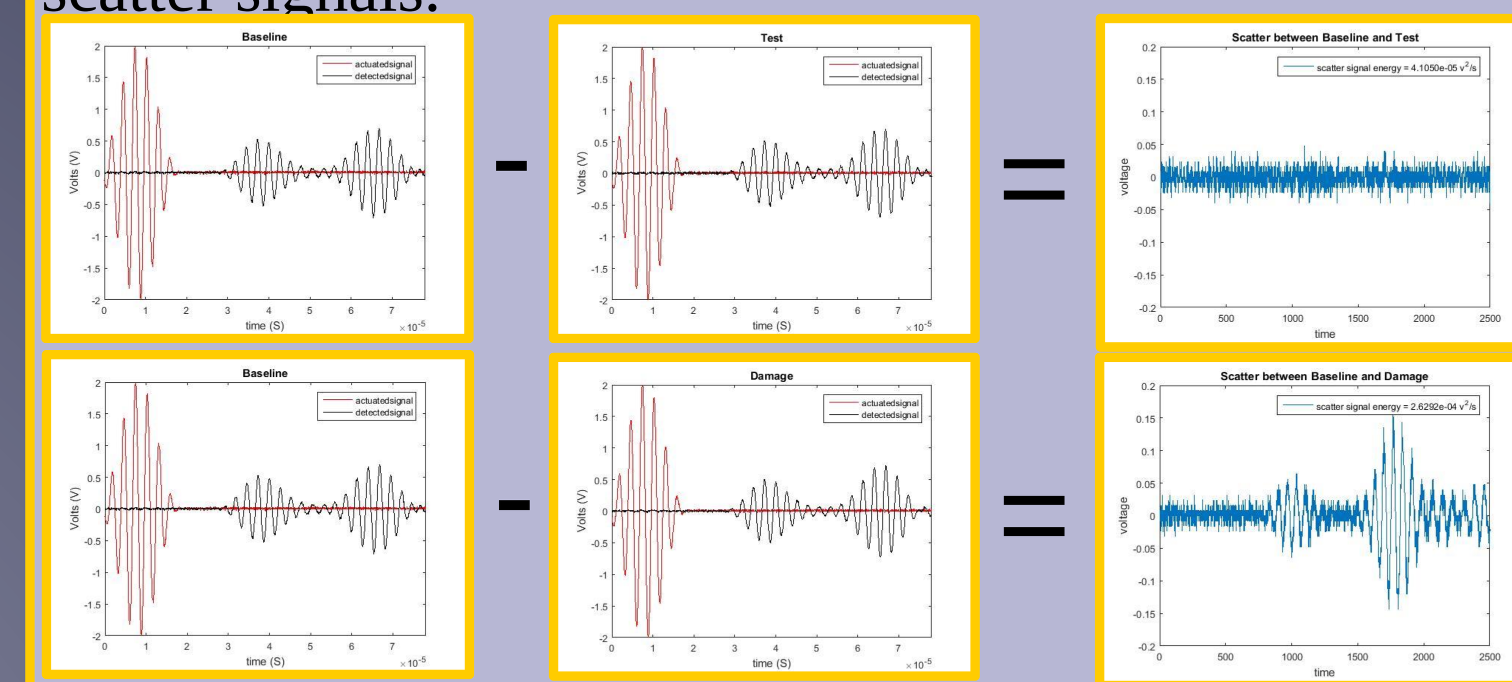
Oscilloscope



Data

Results

There is a visually obvious difference between the scatter signals.



The calculated signal energies indicate a greater change in the signal when damage is present.

- The pristine scatter signal energy was 4.1050e-5 V^2 S
- The damage scatter signal energy was 2.6292e-4 V^2 S

The scatter signal energy of the "damaged" specimen is an order of magnitude greater than the undamaged specimen, indicating damage as distinctly detectable.

Challenges

- The wave's shape changes/fades over distance and time complicating analysis
- accurately modeling wave propagation is extremely challenging, therefore experimental approaches are preferred
- Damage is defined relative to the baseline waveform. If the baseline signal itself contains damage, then the second signal will show no change and such damage can go undetected.
- Damage can be confused with other factors such as temperature

Future Work

- Signals can be altered to improve accuracy and simplify interpretation:

Conclusion

- As a result of my involvement, I learned to use Matlab and was introduced to its coding and uses in the world of SHM. I also learned about the fundamentals of SHM and research being done to change our world for the better.