RIGA TECHNICAL UNIVERSITY

International Conference Modern Building Materials, Structures and Techniques 2016 (MBMST 2016)
Vilnius, Lithuania, 26-27 May 2016

Multiple damage identification in beam structure based on wavelet transform

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Problem statement

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Structural failure can lead to tragic consequences

taken from www.eeri.org

Solution

nondestructive structural health monitoring methods

Problem statement

- **We propose a method for damage identification based on transform of structural vibration modes**

$$\Downarrow$$

Continuous Wavelet Transform (CWT)

Algorithm

1. $$W_{s,a} = \int_{-\infty}^{\infty} f(x) \cdot \frac{1}{\sqrt{|s|}} \cdot \psi^* \left(\frac{x-a}{s} \right) dx = \int_{-\infty}^{\infty} f(x) \cdot \psi_{s,a}{}^*(x) dx$$

Generalized CWT

Damage index

Mode shape data

2. $$DI_i^n{}_{CWT} = W_i^n{}_{s,a} = \int_L w_i^n \cdot \psi_{s,a}{}^*(x) dx$$

3. $$DI_i = \frac{1}{N} \cdot \sum_{n=1}^{N} \frac{DI_i^n}{DI_{i,\max}^n}$$

Standardized damage index

4. $$SDI_i = \frac{DI_i - \mu_{DI}}{\sigma_{DI}}$$

Damage estimate reliability

5. $$DER_i = \frac{\overline{SDI_i}(a) \cdot 100\%}{\overline{SDI_i}(a) + \overline{SDI_i}(b)}$$

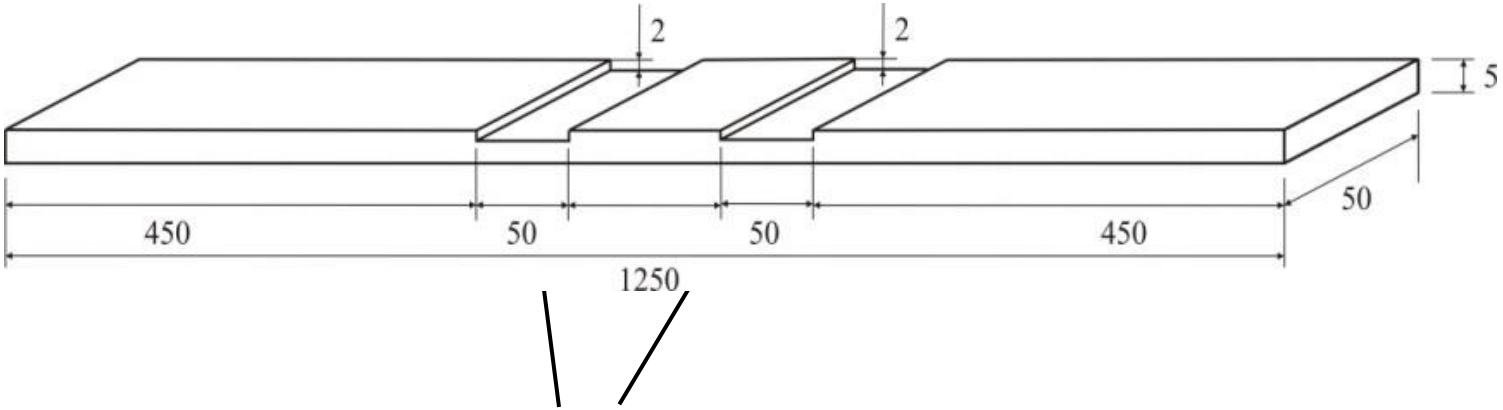
Noise

6. $$w_n'^i = w_n^i \cdot (1 + \delta \cdot (2r - 1))$$

Sharp large amplitude peaks in SDI profiles– zone of damage.

Test specimen

aluminium beam (in mm)

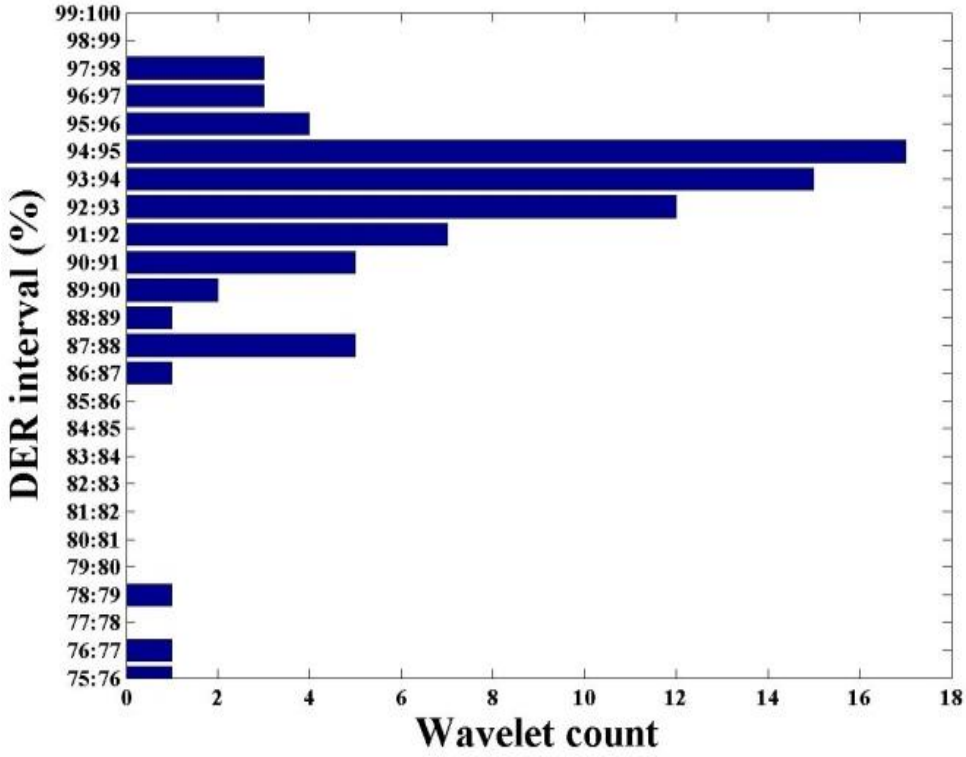


Multiple mill-cut damage sites (depth – 2 mm)

ANSYS model - 2D beam elements with 3 DOFs.

- 148 equal length elements;
- E = 69 GPa, ν = 0.31, ρ = 2708 kg/m^3;
- **Damage -** reduction of flexural stiffness of the selected elements (decrease in element thickness).

DER histogram

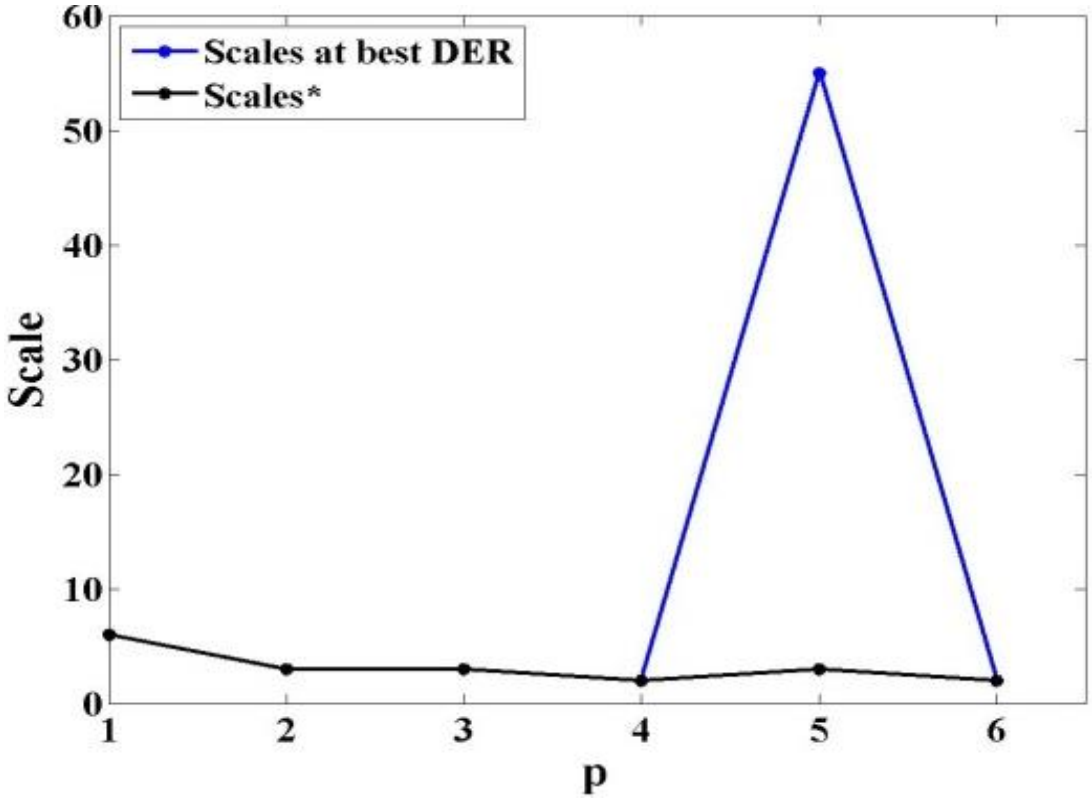


Best wavelet

Complex morlet of order 1-1

DER = 97.71 %

Scale analysis

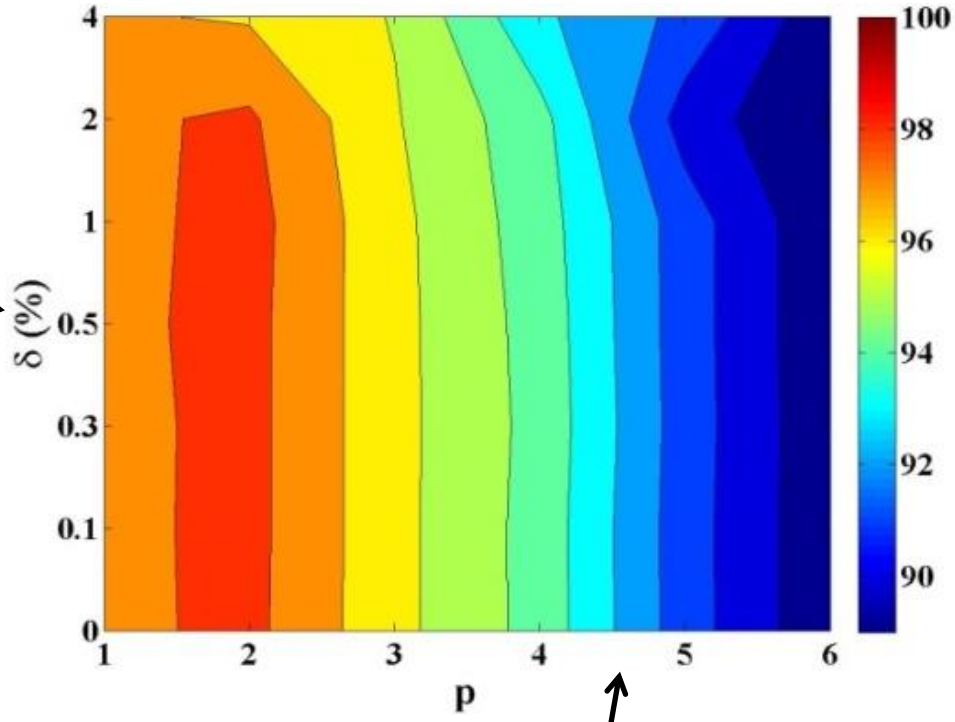


Sensor density

$$\frac{length(w_i)}{p}$$

DER map

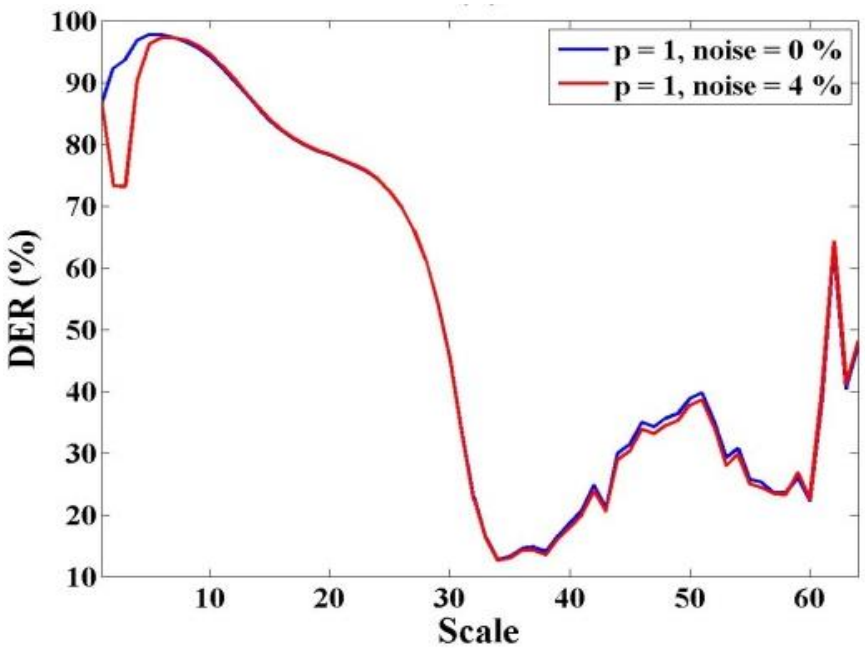
Noise level



Sensor density

increases

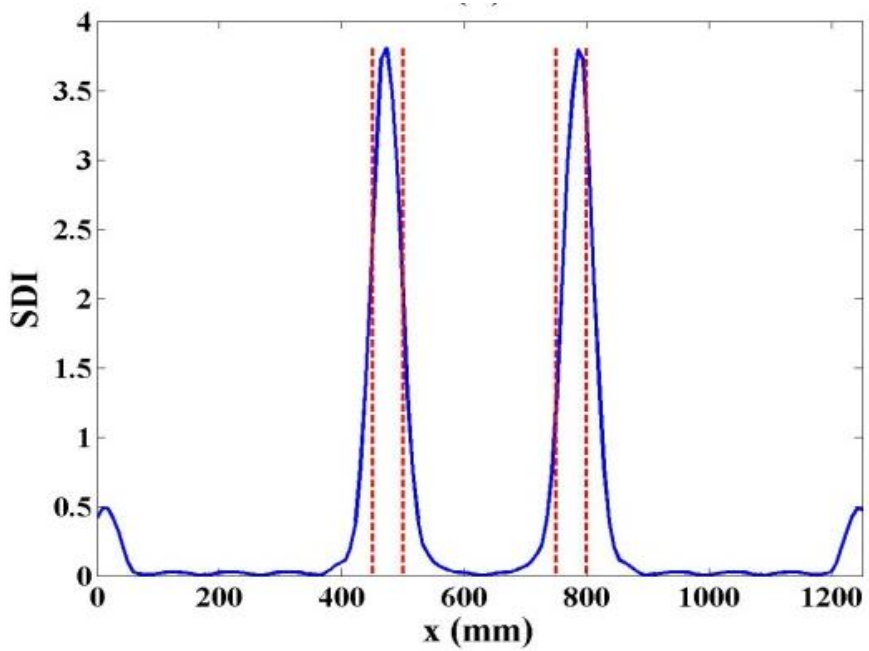
Analysis at $p = 1$



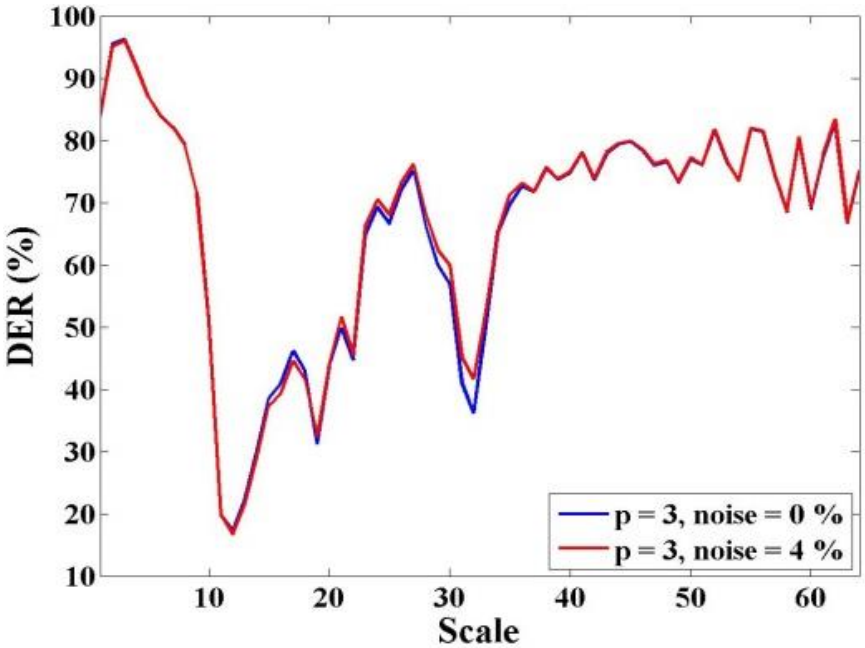
DER vs Scale

Scale = 6 → max DER

SDI vs x



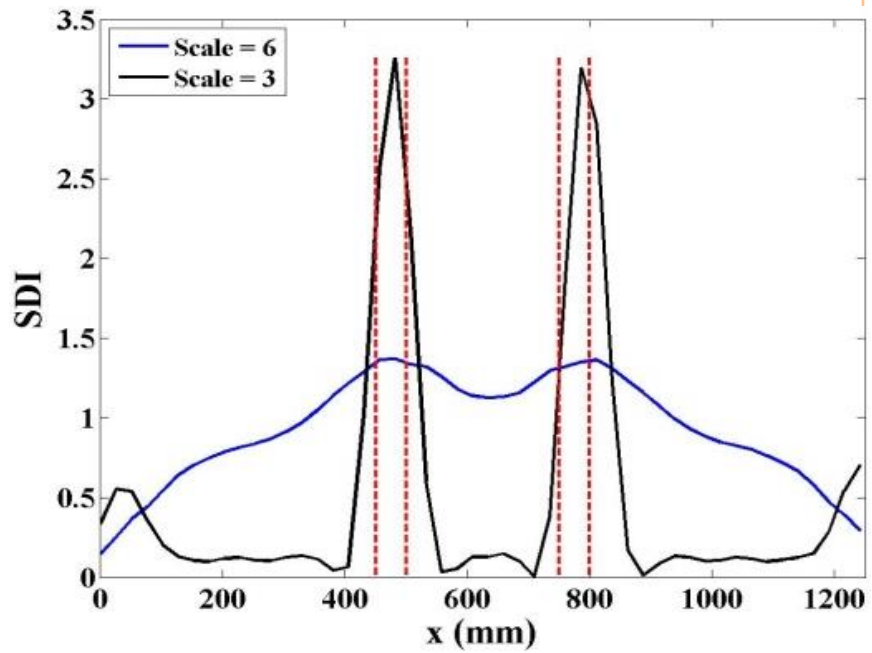
Analysis at $p = 3$



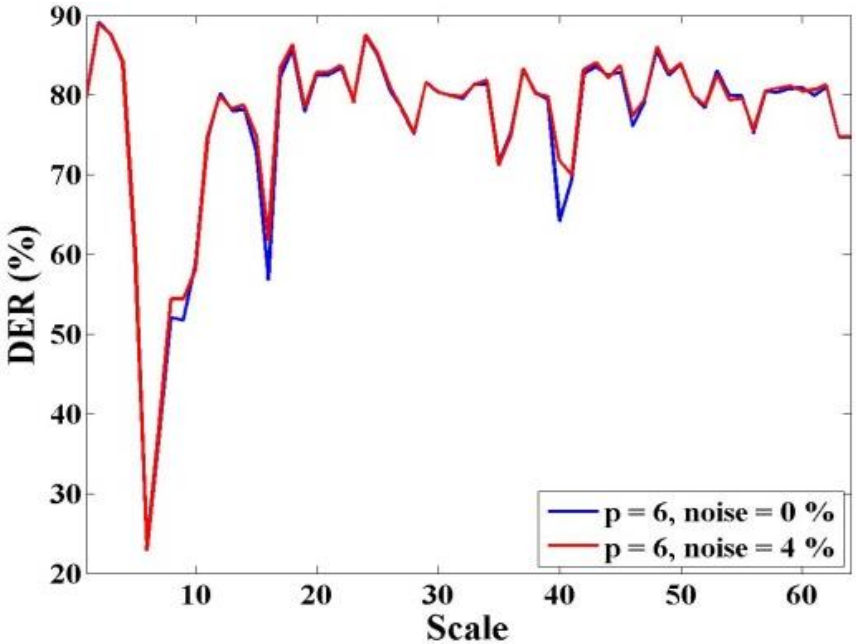
DER vs Scale

Scale = 3 → max DER

SDI vs x



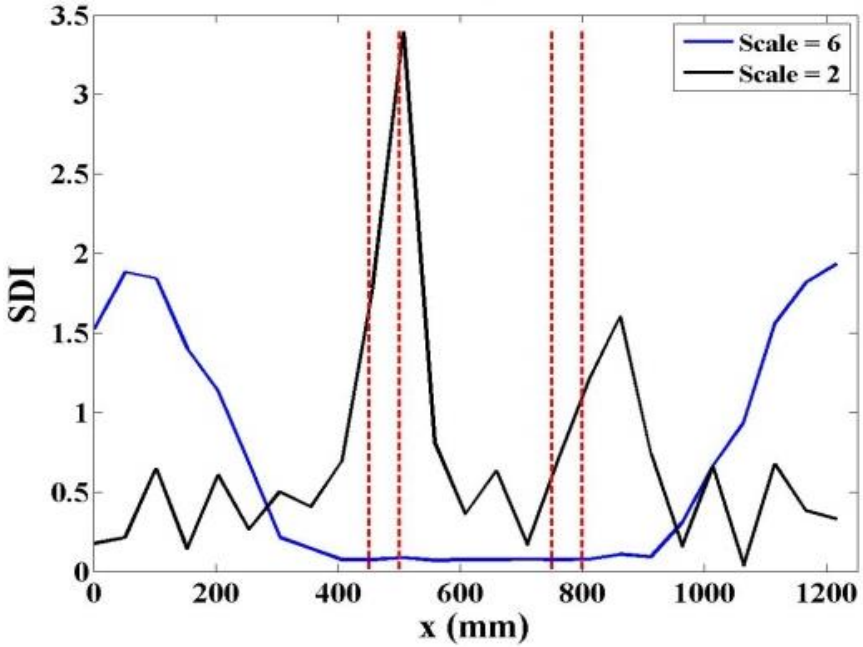
Analysis at $p = 6$



DER vs Scale

Scale = 2 → max DER

SDI vs x



Conclusions

- CWT provides reliable information about the location of multiple damage sites in an aluminium beam.
- Overall, 78 different wavelet functions were tested at scales 1:64.
- Best wavelet - complex Morlet wavelet of order 1-1 with DER = 97.71 %.

Conclusions

- DER maps reveal damage detection reliability at different noise levels and sensor densities.
- DER vs Scale analysis is necessary to determine the appropriate scale.
- As sensor density decreases, the appropriate scales shift to lower values.

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