Application of ultrasonic guided waves for investigation of structural components of tidal power plants

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NDT&E of Composite Materials CompNDT 2011
The example of tidal power plant (PS 100)

In service

http://www.itpower.co.uk/node/151
The example of tidal power plant
(Pulse tidal PS1200)

http://www.itpower.co.uk/Projects/UK?view=955

Inspection of so complex object is a great challenge for conventional non-destructive testing (NDT) techniques!
The objective

To determine the most critical regions of hydrofoil to be tested, to select the modes of ultrasonic guided waves to be used and to determine the parameters of their excitation, propagation along the sample and interaction with non-homogeneities.
The work done

- The multi-layered composite structure and the critical regions of hydrofoil to be tested were defined;
- The modes of guided waves propagating in the hydrofoil are identified and their parameters are estimated;
- The mock-up sample of hydrofoil was investigated.
The expected types of possible defects inside hydrofoil

- Delamination between the skin and the adhesive layer;
- Delamination between the main spar and the adhesive layer;
- Adhesive joint failure between the skins along the leading and the trailing edges;
- Internal multiple delaminations or splitting between the layers of the skin and the main spar.
The expected defects (hydrofoil)

**Skin (GFRP)**

- Internal delaminations inside skin or main spar

**Main spar (CFRP)**

- Delamination skin-adhesive-main spar

**Upper shell**

- Internal delaminations inside skin or main spar

**Monitoring directions using ultrasonic guided waves**

- Leading edge
- Trailing edge

**Foam-filled**

- Delamination skin-skin

**Lower shell**
The optimum arrangement of transducers (along the sample)

- Transmitters
- Receivers
- Boundaries of the region being inspected
- Beam divergence of single transmitter
- Direct beam of multiple transmitters
- Upper shell
- Lower shell
- Main spar
- Leading edge
- Trailing edge
The optimum arrangement of transducers (across the sample)

Measurements across the sample, but it is proposed to avoid the boundary between the skin and the main spar.
Calculated dispersion curves in skin (SAFE)

Total thickness of multi-layered GFRP composite is 4 mm

**Diagram:**
- 0°, along the sample
- 90°, across the sample

**Graph:**
- $V_{ph}$, m/s
- $f$, kHz
- $S_0$
- $SH$
- $A_0$
Calculated dispersion curves in skin + main spar (SAFE)

Total thickness of multi-layered GFRP+CFRP composite is 40 mm

Interpretation of the multiple modes is very complicated!
Experimental investigation of the mock-up sample of the hydrofoil

Measurements on the shell base (GFRP):

• Duration of excitation pulse: 11 µs;
• Scanning step: 1 mm.
Investigation of the shell base (GFRP) only

B-scan

2D FFT and SAFE

Selected region for 2D FFT calculation
Experimental investigation of the mock-up sample of the hydrofoil

Measurements on the spar cap (CFRP):
- Duration of excitation pulse: 11 µs;
- Scanning step: 1 mm.
Experimental investigation of the mock-up sample of the hydrofoil

B-scan

2D FFT and SAFE

Selected region for 2D FFT calculation
Conclusions

- The geometry, material type, properties and the critical regions of the hydrofoil that should be tested were identified;
- The testing of the main spar should be performed in longitudinal direction and other parts of hydrofoil along longitudinal and perpendicular directions;
- The propagating modes in the complicated structure of the hydrofoil (multi-layered, CFRP, GFRP) were investigated by numerical modelling (SAFE) and experiments;
- It was estimated, that in order to use the fundamental modes, the frequency of operation below 100 kHz should be used for inspection of the skin and even lower for inspection of the main spar.
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Thank you for attention!

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