Advanced non-destructive testing (NDT) of manufacturing blade defects

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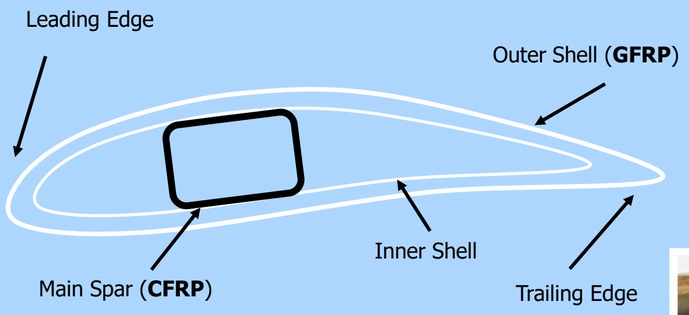
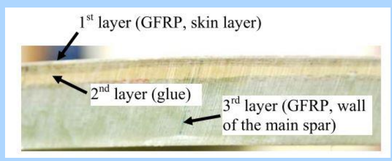
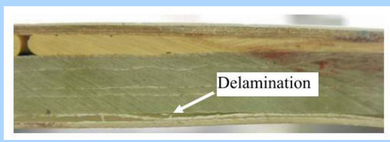
Introduction

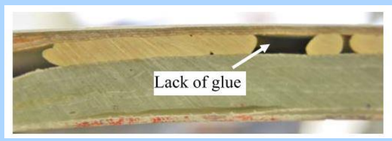
Wind Turbine Blades

- Wind turbine blades are one of the most expensive components of the wind turbine, accounting for around **20%** of the total cost.
- Blades are now approaching 100m in length and are manufactured using **carbon** and/or **glass fibre** reinforced plastic composites (**CFRP, GFRP**).
- Non-destructive testing (**NDT**) methods are utilized to **identify defects** so to reduce operational maintenance costs and extend lifetimes.
- Types of composite defect causing **de-laminations** include: **'kissing' dis-bond**, foreign **object inclusion**, **voids**, areas of increased or decreased **resin concertation**, **ply drops** and **waviness.**



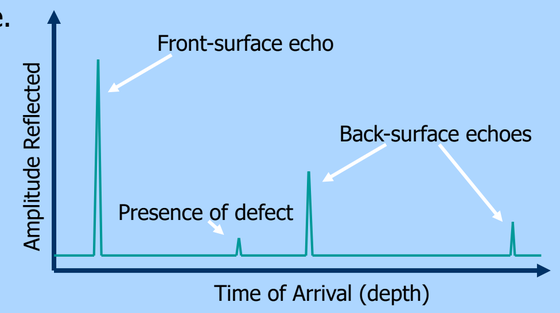




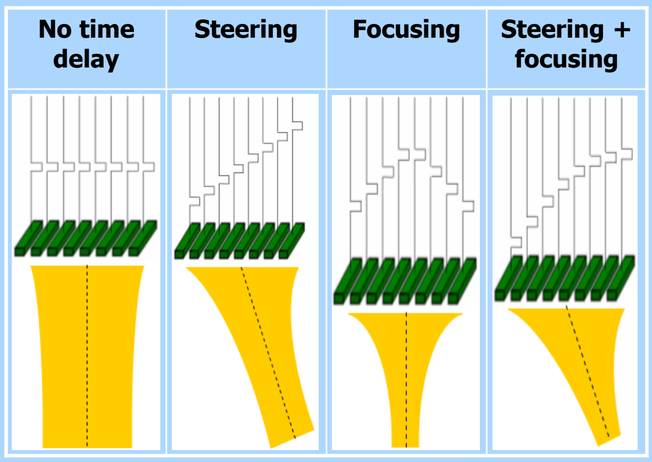


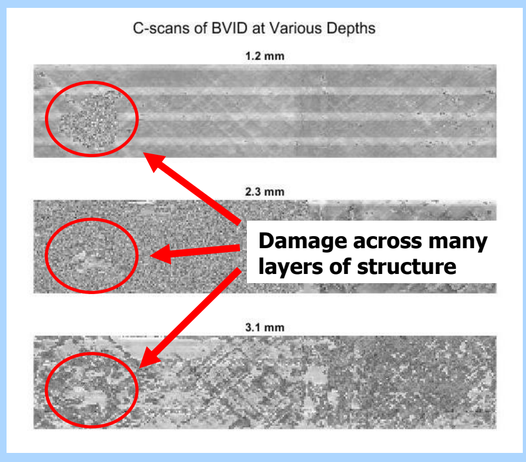
Background on Ultrasound

- **A-scan**: Energy received, as a function of time. Depth of reflector can be found based on the **propagation time.**
- **B-scan**: Cross-sectional view of the specimen. A 2D image at an **orthogonal plane** to the specimen's surface; a '**slice**' through the material formed using a series of A-scans aligned in one axis.



- **C-scan**: Image at a **parallel plane** to the sample surface or the inspection path plane. Formed by applying a **gate** to the A-scans.





- **Phased Array** (PA) ultrasound probes consist of an array of transducers. Can be triggered separately and thus programmable to **steer**, **focus** and **scan** a beam

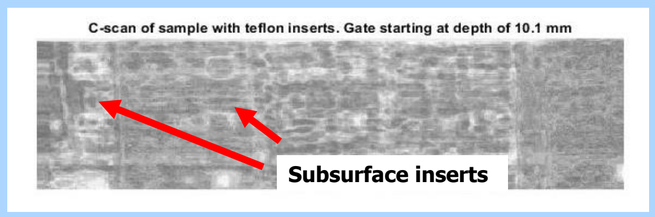
Current Inspection Procedures

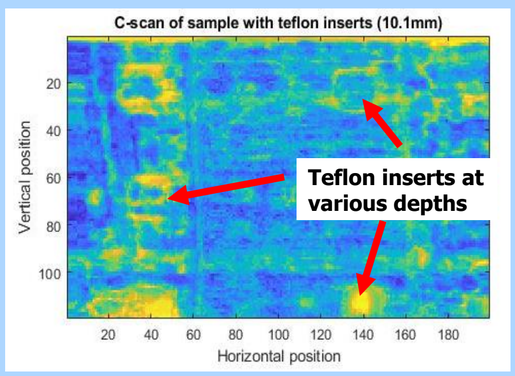
- Ultrasonic testing techniques are used with **semi-automatic modules** and the image/data analysis performed by **trained NDT experts**.
- The aerospace industry now employs improved, **contactless scanning methods**, coupled with smart-detection algorithms and **machine-learning techniques**.
- These techniques are aimed to be adapted and applied to wind turbine blades for a **fully automated set-up.**
- This will enable **more efficient** and **cost-effective inspections** resulting in overall benefits for clean energy production.

Initial Work

Known Defect Samples

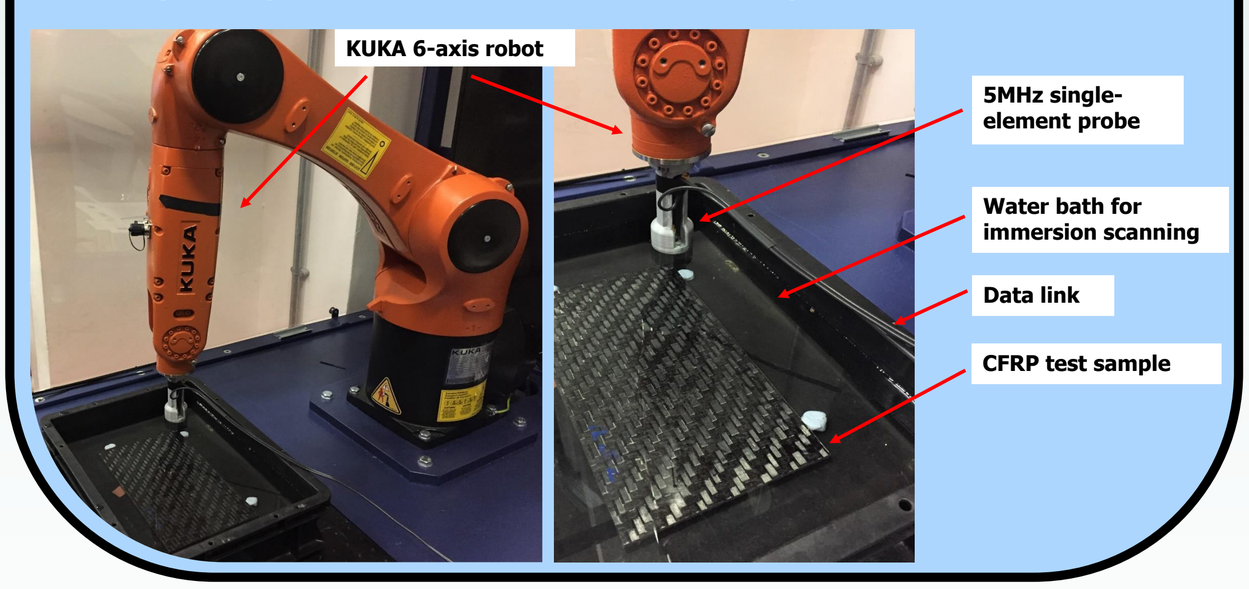
- CFRP samples with **known defects** are scanned using PAUT technology. **Teflon inserts** are often using to **simulate delaminations** within composites. Samples with inserts and **Barely Visible Impact Damage** (BVID).





Practical Set-up Considerations

- Image reconstruction based on chosen **gate position**, **amplitude** and **ToF. Immersion** as well as **air-coupled** procedures possible. Considerations: **coupling, SNR, angular sensitivity,** drawbacks of **water** contact, **practicality** of inspection.
- Transducer frequency a trade-off between **signal strength** and **resolution**. Resolution **increases** with **frequency** but so does **attenuation**.
- Composites are hard to interpret. **Attenuation** higher, internal structure **complex**.
- **Path-planning** of **KUKA robots** based on **CAD drawings** and **MasterCam.**



Structure of PhD

Stage 1

- Review of ultrasound **NDT methodologies**, **composites** and **underlying physical principles**.
- Analysis of **current procedures**, **published literature** and **motivations for improvement**.
- Familiarisation with **equipment**, **software** and **laboratory procedures** necessary for effective testing and data analysis.

Stage 2

- First analysis on **small-scale blade samples** provided by Siemens-Gamesa Renewable Energy.

Stage 3

- **Scale-up** chosen techniques to **full-size blade** components.

Stage 4

- Implementation of **pattern recognition** algorithms and **machine-learning** techniques. Moving towards a **fully-automated** inspection procedures.