Aviation Enterprises Ltd

Composite

Tidal Turbine Blade Design & Development

Aviation ? – Where we come from

High performance

100 hp – 160 kts cruise

120 kts – 11 ltrs/hr

Range 2000 nm +

Recent experience

More recent experience

Marine Current Turbine's

Seagen

The Problem

- No longer so aimed at aviation safety
- Target now Cost of replacement or repair
  - Same problem
    - Attention to detail
    - Importance of R&D and trying to predict problems

  - Its one thing to design a blade to be strong enough

  - Completely different problem to ensure that it will last for 20/25 years.

    But fatigue testing is not the end of the story, because the quest for longevity then forces deeper investigation to find where the problem will start – the devil is then in the detail.

The Problem – The Power

Details to solve

- Design Reliability (Cost of replacement/repair)
  - Fatigue
  - Fracture Mechanics
  - Materials
  - Details
  - Joints
  - Seawater
- Cost
  - Materials and Labour
  - Fatigue Strength
  - Fatigue performance mismatch

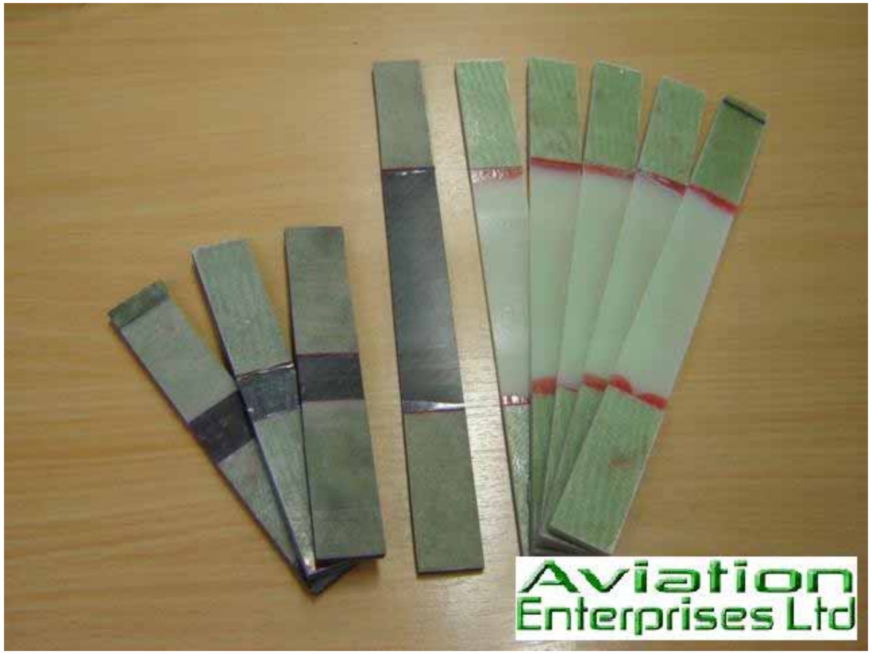
Certification

Certification - Confidence in Allowables & Design Approach

- Testing
  - Lower levels
  - Full scale

- Certifying Authority oversight

Testing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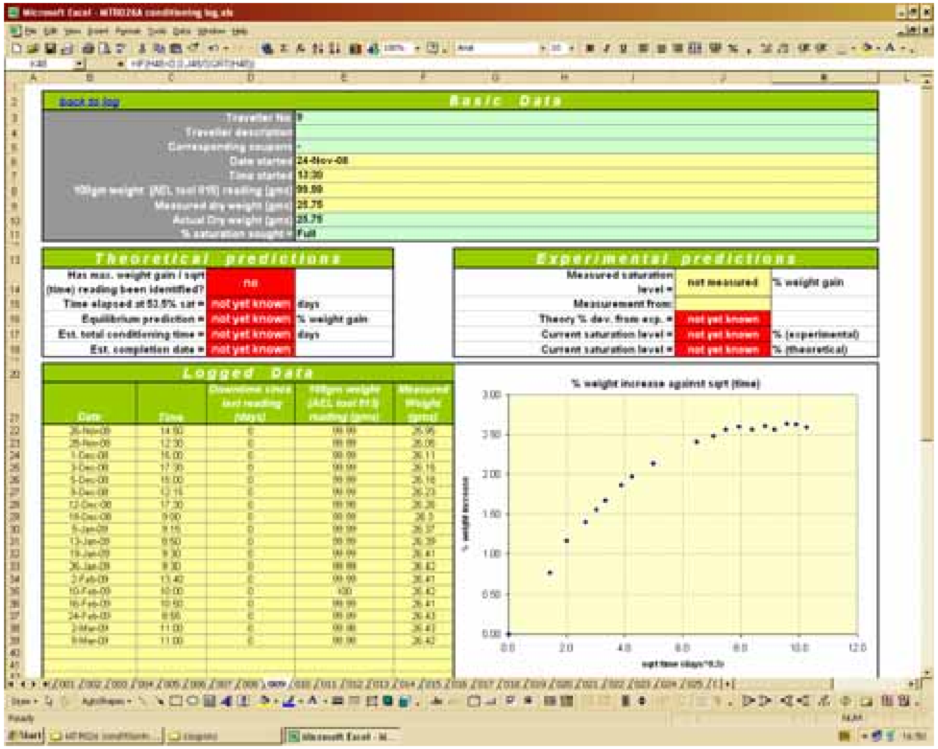
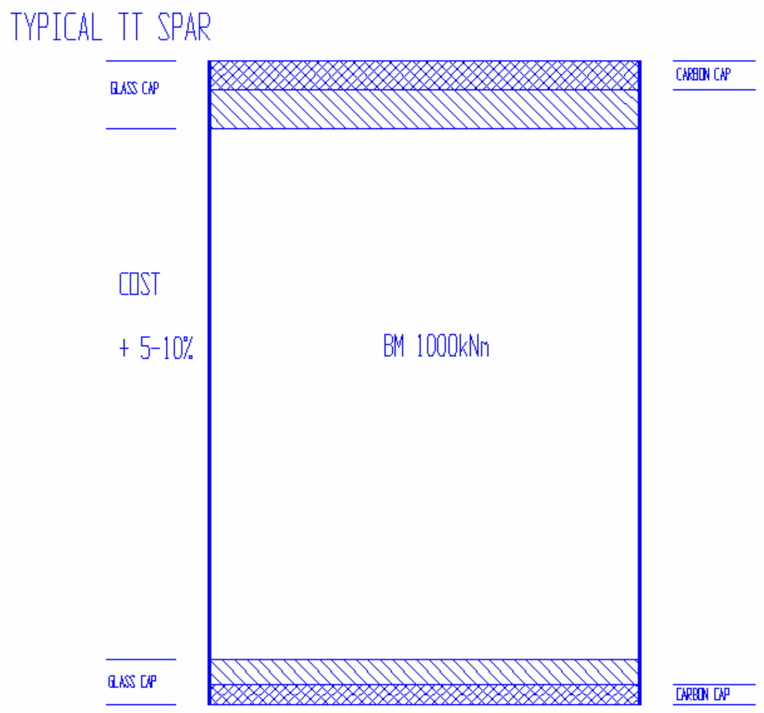

Basic Data
Theoretical predictions
Experimental predictions
Logged Data
% weight increase against sqrt (time)

Materials

- Why composites ?
- Steel
  - Weight plus problems of corrosion & cathodic protection
  - Welded assy to reduce weight
    - But 25% allowable
    - Tooling cost
- Composites
  - Corrosion no problem although water ingress ?
  - Likely to be lighter
  - Fatigue life likely to be much better
  - More easily shaped

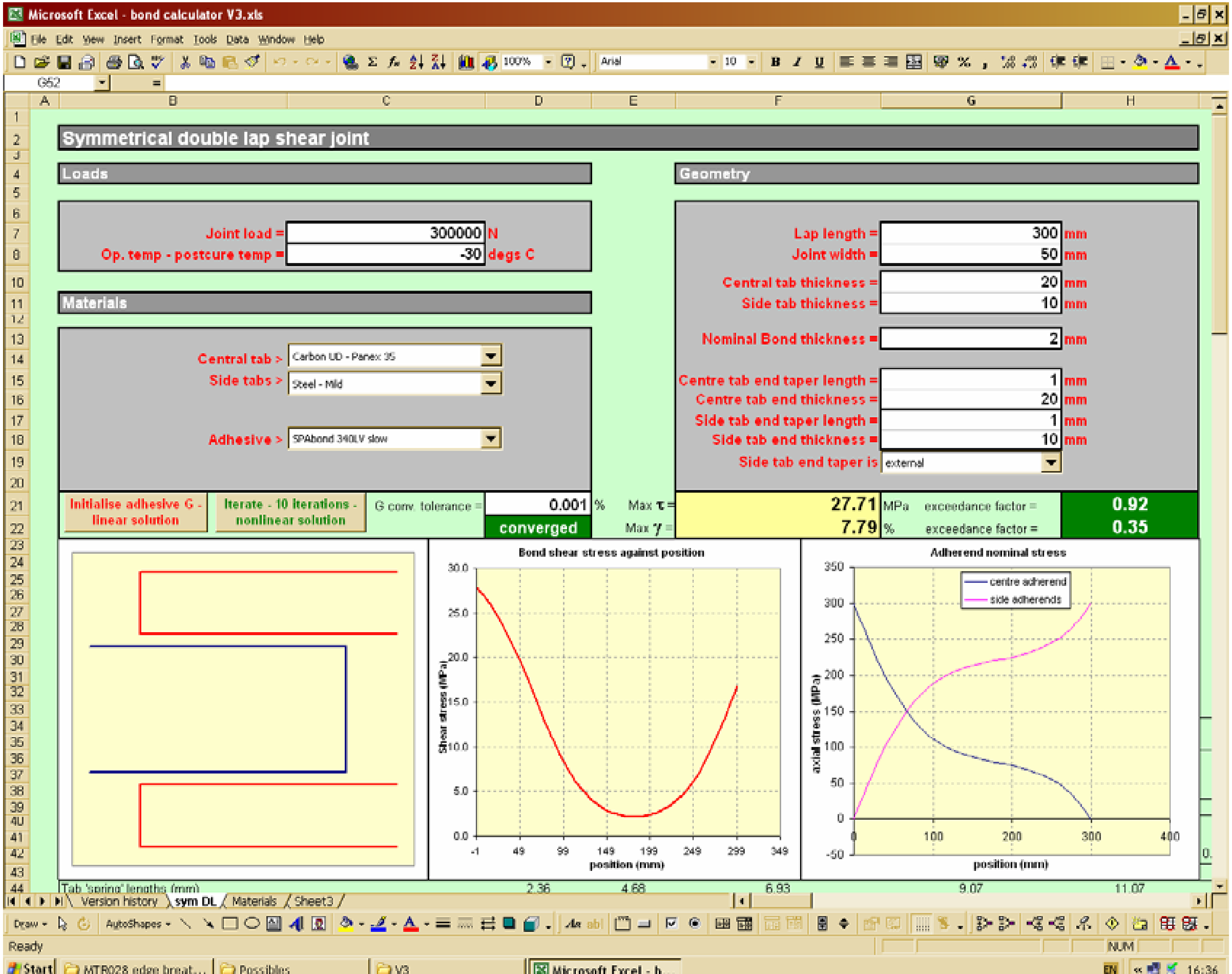
Why Carbon ? – Glass is cheaper !

Typical Spar (Calculated example)



Strategy

- Firm Foundations for materials and details test data.
- Effective materials selection and establishment of a comprehensive materials database. Manufacturers' data is rarely considered definitive and necessitates independent testing.
- Research into the effects of fatigue & long-term immersion in seawater, something that is a relatively new requirement.
- The review of adhesives and surface preparation techniques. Again, reference material for previous work is unlikely to be available.
- Investigating and meeting the standards and safety factors applied by the Certification Authorities.
- Investment in our own suite of numerical tools and production and tooling equipment to minimise costs.
- Strengthen our Fracture Mechanics analysis capability.


Microsoft Excel - bond calculator V3.xls
File Edit View Insert Format Tools Data Window Help
Symmetrical double lap shear joint
Loads
Joint load = 300000 N
Op. temp - postcure temp = -30 degs C
Materials
Central tab > Carbon UD - Panex 35
Side tabs > Steel - Mild
Adhesive > SPAbond 340LV slow
Geometry
Lap length = 300 mm
Joint width = 50 mm
Central tab thickness = 20 mm
Side tab thickness = 10 mm
Nominal Bond thickness = 2 mm
Centre tab end taper length = 1 mm
Centre tab end thickness = 20 mm
Side tab end taper length = 1 mm
Side tab end thickness = 10 mm
Side tab end taper is external
Initialise adhesive G - linear solution
Iterate - 10 iterations - nonlinear solution
G conv. tolerance = 0.001 %
converged
Max τ = 27.71 MPa
exceedance factor = 0.92
Max γ = 7.79 %
exceedance factor = 0.35
Bond shear stress against position
Shear stress (MPa)
position (mm)
Adherend nominal stress
centre adherend
side adherends
axial stress (MPa)
position (mm)
Tab 'spring' lengths (mm) 2.36 4.68 6.93 9.07 11.07
Version history
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Materials
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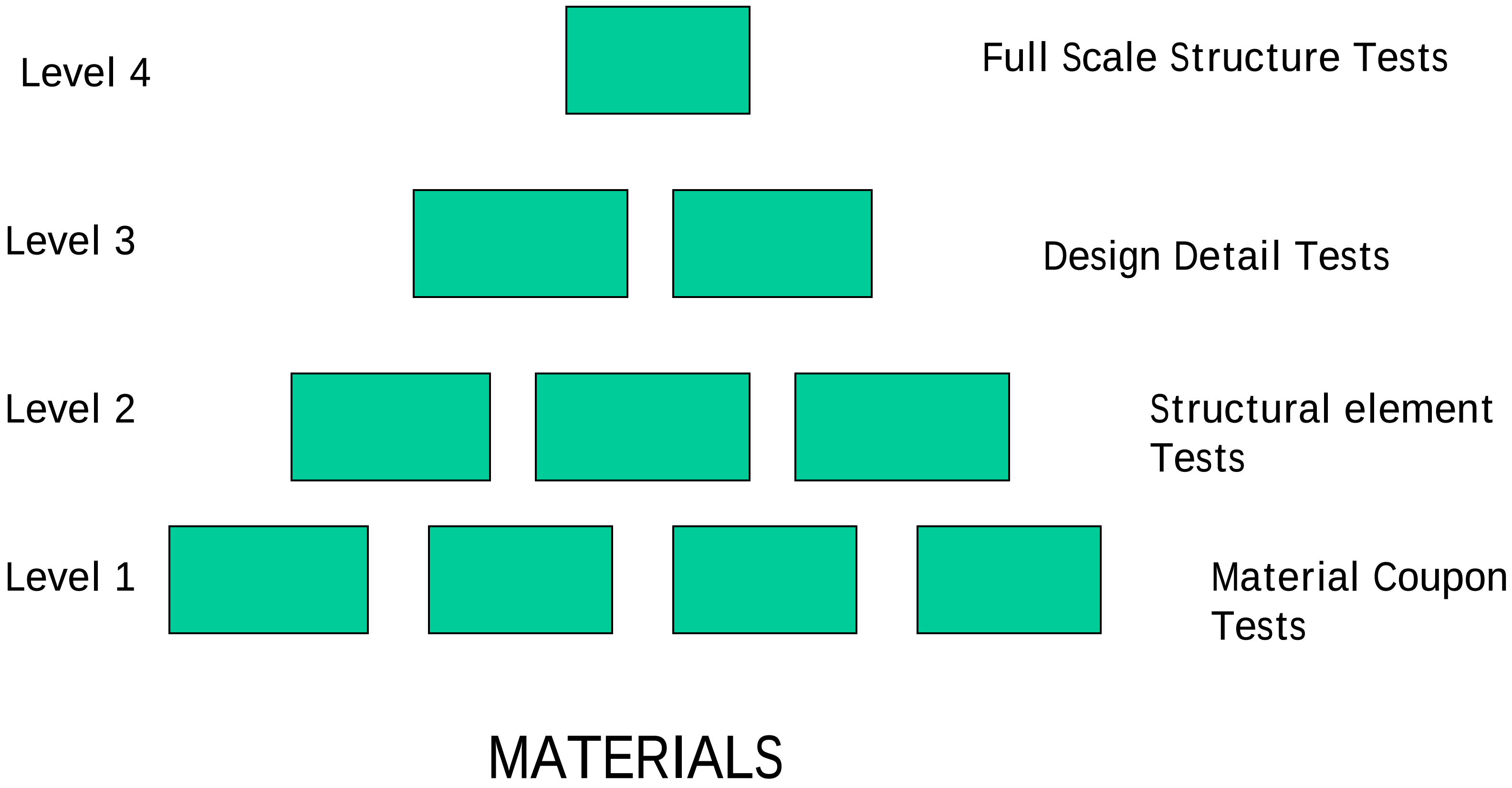
Method

Typical Pyramid approach



Partners & Support

MATERIALS - NEW MMEETT

- Bristol University
- Advanced Composites Group
- Test Houses
- DNV / GL

PYRAMID LEVELS 1, 2 & some 3 - CARBON TRUST PROGRAMME

LEVELS 3 & 4 Watch this space.

Results so far

- Practical fatigue testing backed up be theoretical fatigue & fracture mechanics understanding from Bristol University.
- Blade skin attachments subject to cyclic pressure variation and, therefore, fatigue conditions.
- Materials fatigue database, bonded joint fatigue data,
- Improved/novel blade root fitting designs better suited to the high shear force and bending moments applied to TT blades.
- Development, in collaboration with ACG and any other materials suppliers who are interested, of low risk, prepreg based manufacturing strategies, which will reduce labour content and maximise manufacturing efficiency.
- Establishing the true effect of long term conditioning of carbon fibre composites and bonded joints in seawater.
- Overall cost reduction

The Theory of Fatigue

Collaboration with Bristol (and recently Auckland University)

- Oversight
- Tracking our progress and results
- Advice
- Collaboration leads to Learning and we hope better more useful design tools.

The Future

- Consolidating materials and continuing improvements
- On going monitoring of Design
- Attacking production cost – automation?
  - materials
- Continuing strategy to ensure reliability, reduce cost.
- Hydrodynamic efficiency – lessons from the Magnum which is where we came in.