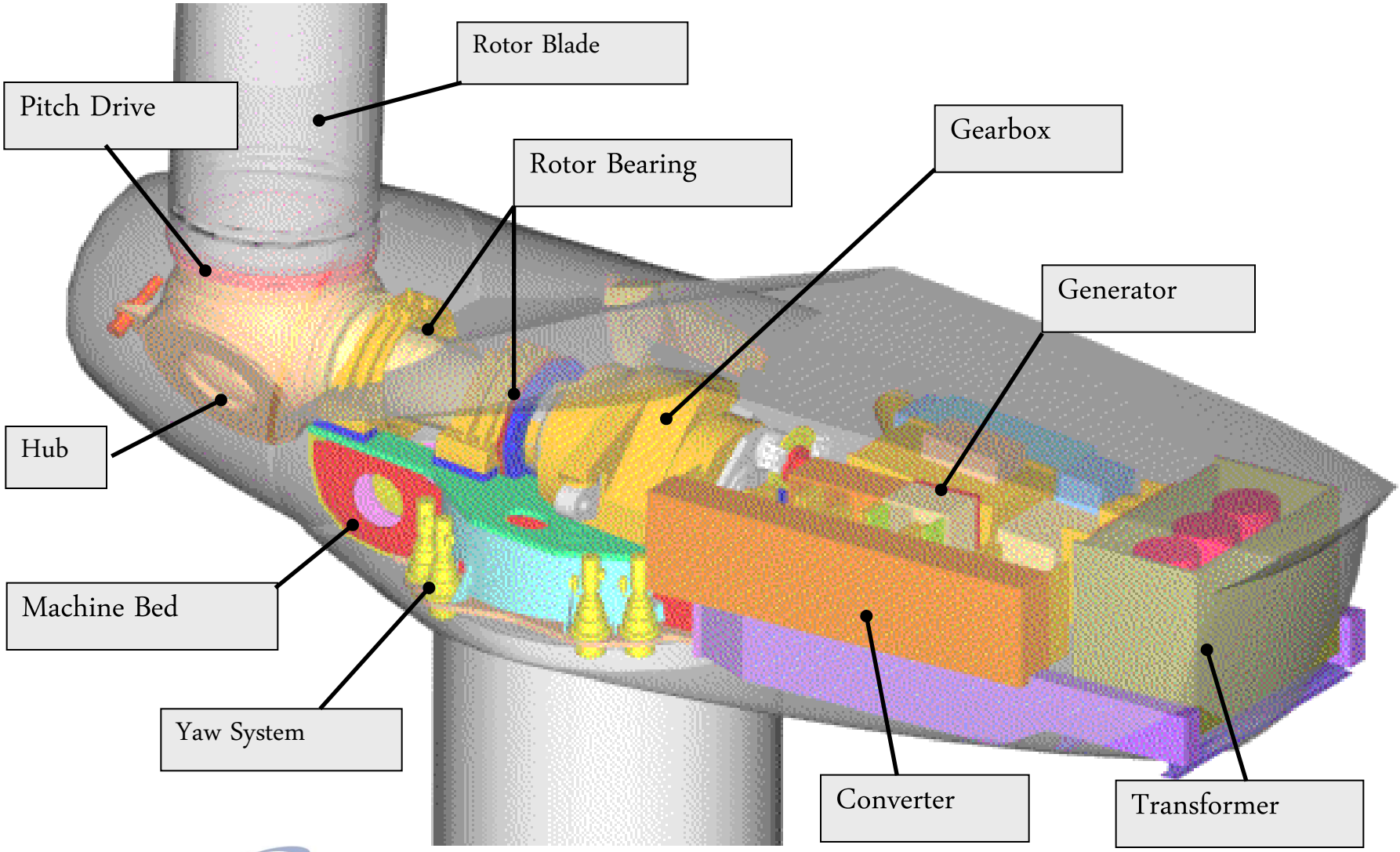
Material Challenges for Wind, Wave & Tidal Energy Systems

Dr Richard Court

Outline of Presentation

- Wind energy
  - Turbine physical dimensions
  - Load cases
  - Materials
  - Needs / challenges
- Marine renewables
  - Device types - tidal and wave
  - Environment
  - Materials
  - Observations and challenges

Turbine Components



Turbine Physical Characteristics

- Increasing mass and physical dimensions increase energy yield, but add to logistics burden

Component	Mass / Sizing
2MW blade, 40m length 5MW blade, 60m length	8 Tonnes 15 Tonnes
Hub (cast steel / iron)	6 to 10 Tonnes
Total head (nacelle) mass	2MW = 200 Tonnes 5MW = 400 Tonnes
Tower for a 2MW turbine	200 Tonnes

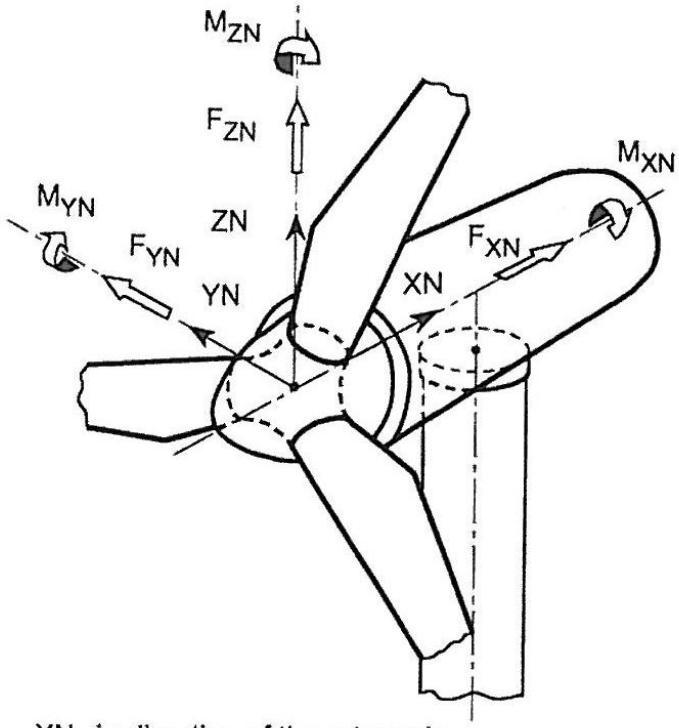
Wind Turbine Load Cases

- Derived from kinetic energy equation and then power:

K.E. = $1/2mv^2$

Power($_{wind}$) = $1/2\rho Av^3$

- Mechanical loads
  - Fx – Axial Force
  - Fy – Radial Force
  - Fz – Radial Force
  - Mx –Shaft Torque
  - My – Moment about y axis
  - Mz – Moment about z axis



XN in direction of the rotor axis

ZN upwards perpendicular to XN

YN horizontally sideways, so that XN, YN, ZN rotate clockwise

Rotor Blade Materials

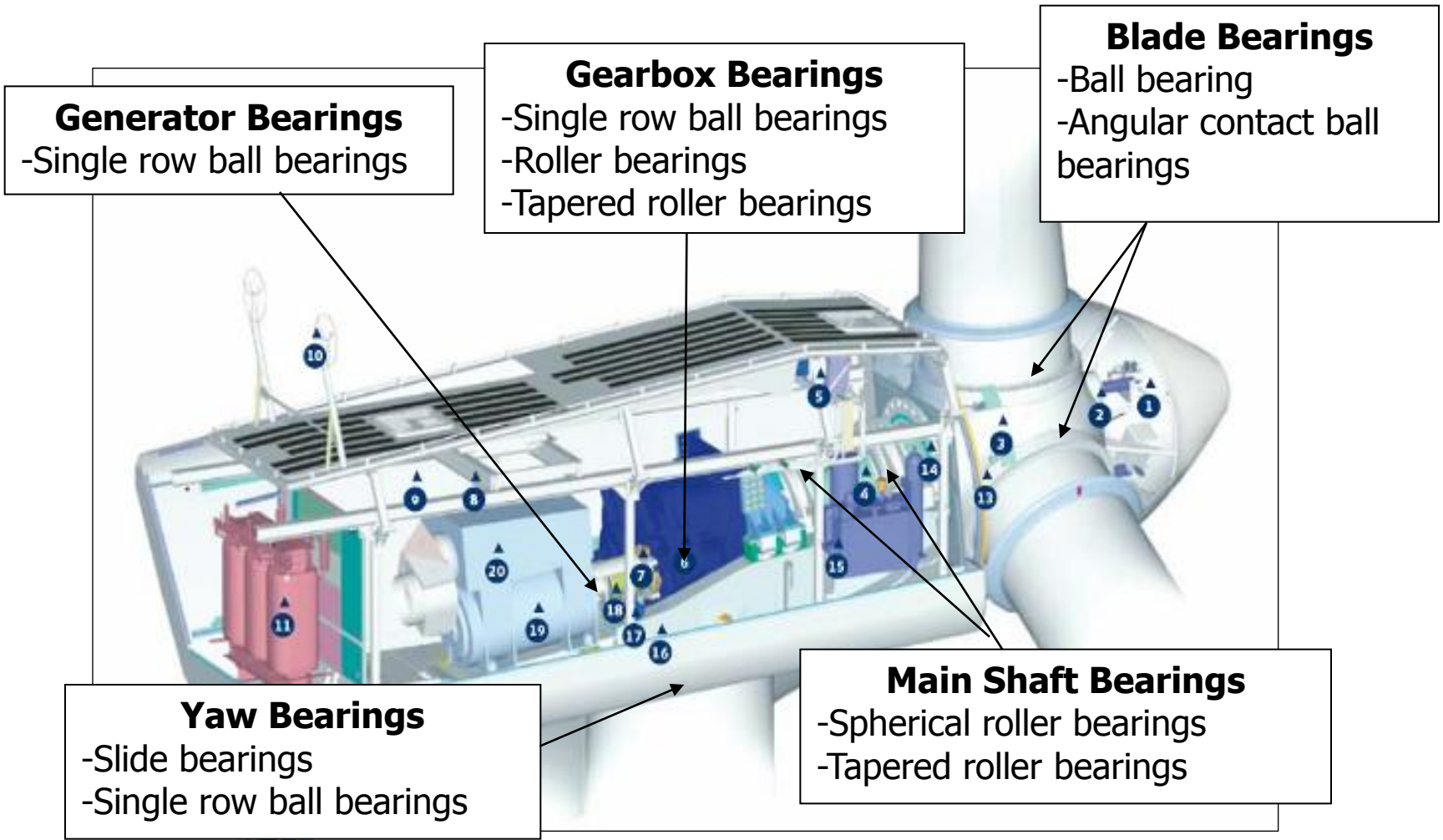
Blades are the primary energy capture component and experience a demanding range of load cases…

- Main materials are:
  - Glass fibre
  - Carbon fibre (*mainly for large >40m? blades*)
  - Resins and adhesives (epoxy, polyester, polyurethane)
  - Polymer foams
- Thick section materials e.g. 50mm at root end
- Complex 3-D stress states
- Lack of full material characterisation
- Blade designs either conservative or with unknown failure mechanisms

Blade & Turbine Testing at Narec

- Static certification and development test
- Specialist fatigue testing 50m+ blades
- Prototype development for:
  - New turbine concepts
  - Lightning strike testing & development
  - Power take-off
  - Drive train
  - Industrial research

Wind turbine bearings



Wind turbine bearings

- Main challenge is on main shaft and gearboxes
  - high axial loads
  - variable loads due to wind
  - lubrication cleanliness
  - lightning strike current
- Less frequent issues due to quality and tolerances
- Durable and lightweight bearings are the goal

Materials Inspection and Examination

- Cheap and large area inspection of composite materials is needed
  - High material attenuation makes ultrasonics and acoustic emission either slow or requires large number of sensors
  - Infra-red has large area capability, but requires that effects are visible at the surface
- Inspection and remote condition monitoring of the whole drive train are active areas of research
  - Main problem is the huge quantity of data generated by fleets of wind turbines and therefore “smart” monitoring systems are needed
- Cost of NDI and NDE compared with capital cost and revenue from electricity sales is a key issue

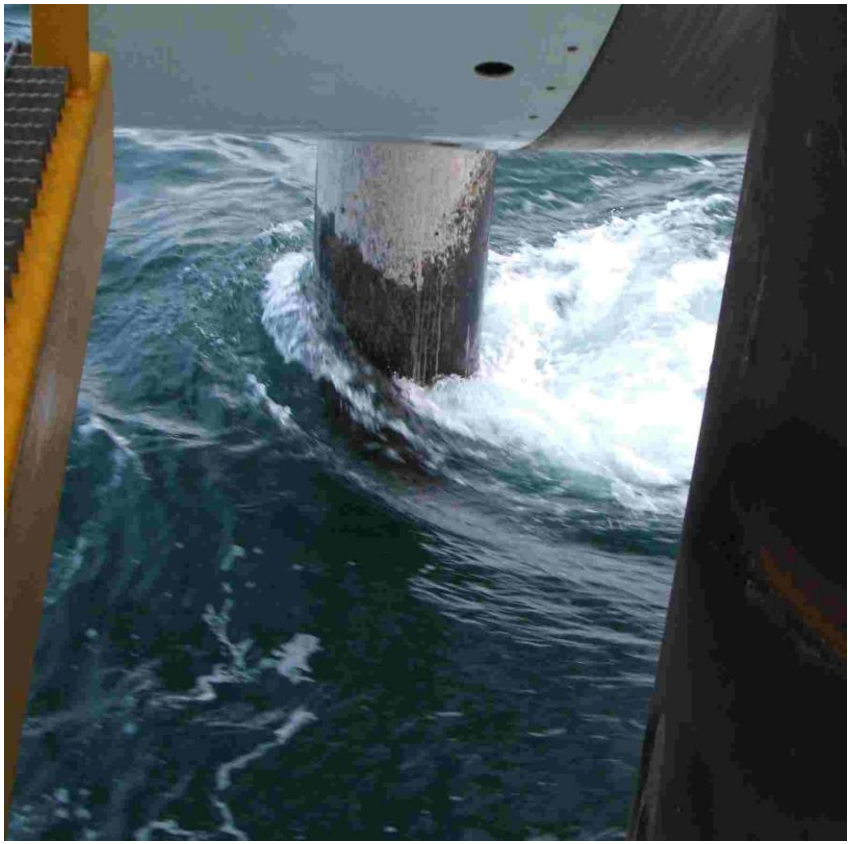
Offshore Wind - Risks and Problems

- Difficulties in installing and operating turbines:
  - Variable weather
  - Extreme load cases
  - Marine air / salt water
- Access for maintenance and repair – not guaranteed.
- With large turbines financial losses from not generating become significant.
- What new materials are realistically going to be used?

Marine Renewables

- Tidal
  - barrage – large scale
  - tidal stream (current) – several types
- Wave
  - hydraulic rams
  - oscillating water column (OWC)
  - overtopping

Marine Renewables – Environment and Extreme Load Cases



Tidal Barrage – Mainstream Technology

- La Rance
- Largest in World
- 40 year old (1967 completed)
- 7 years to build
- 22KM^2 basin upstream
- 240MW
- Operated by EDF
- Head of 8m
- 330m long

Tidal Stream Technologies

- Horizontal Axis
- Vertical Axis
  - Wells, Darrious, Savonius
- Reciprocating Foil
- Other

www.tidalgeneration.co.uk, www.marineturbines.co.uk

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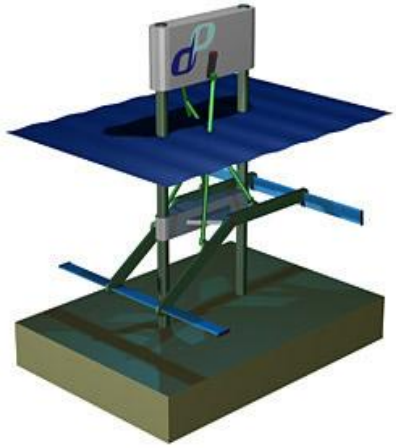
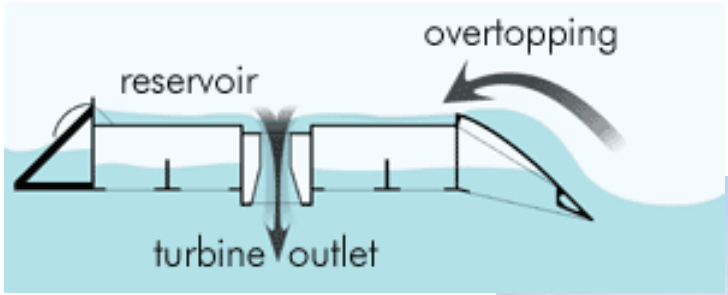


Humber Prototype Design

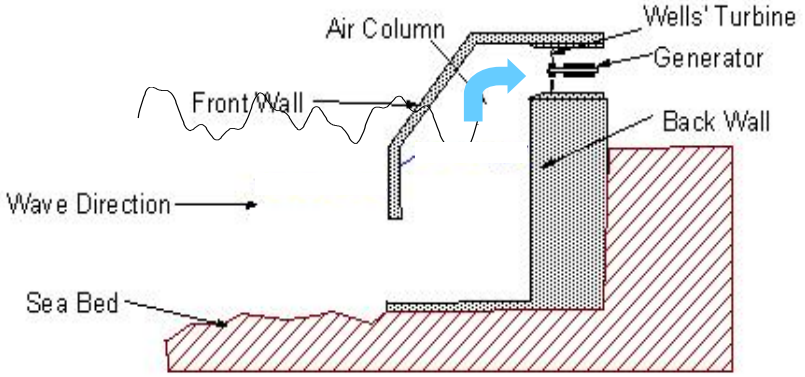
www.pulsegeneration.co.uk,
www.openhydro.com

Wave - Over Topping & Oscillating Water Column

- Wave Dragon Ltd
  - 237 tonnes prototype
  - Deployed 2003
  - Danish Wave Energy Test Station
  - Operational 18,000+ hours

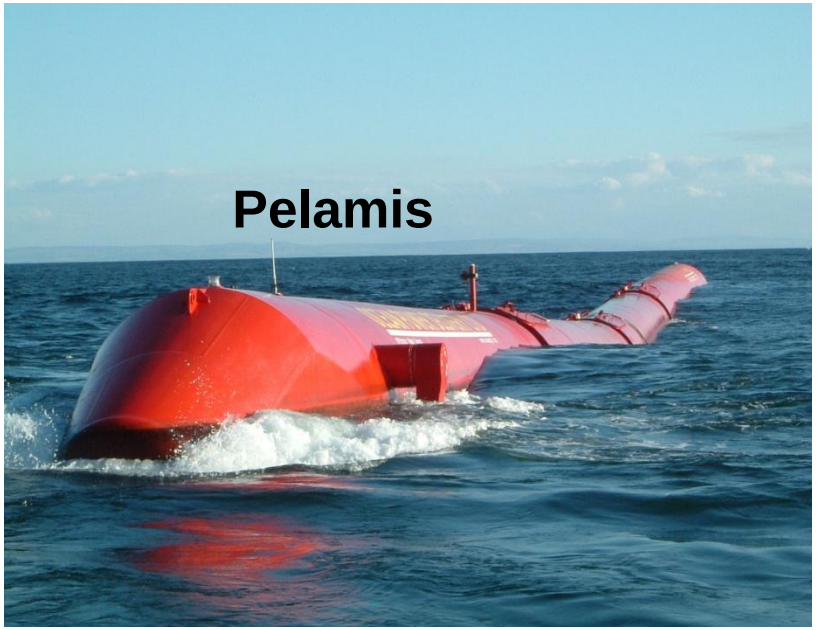


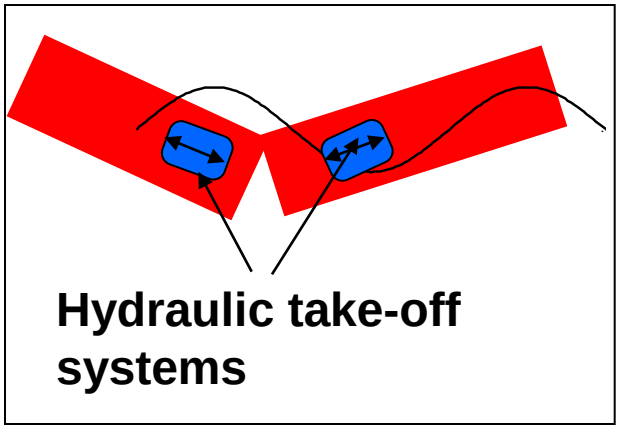
- Limpet, Pico, Sewave – breakwater use
- Floating – point absorber



Wave Power - Market Leader

- Ocean Power Delivery Ltd
- 750kW Hydraulic power take off
- Employees 70+
- 6 years development programme
- Projects
  - Orkney
  - Portugal
  - Wavehub





www.pelamiswave.com

Marine Renewables – Issues of Long-term Durability and Fouling

Observations – Materials in Marine Renewables

- Many different devices / technologies – non proven
- Large scale devices:
  - need lots of material for survivability
  - but for how much power generated?
- Typically use bulk engineering materials
  - steel & concrete
- Need to use composites, polymers, sealants, coatings
- Offshore Oil & Gas, plus marine industry know about material degradation (and its costs) but low priority at present in marine renewables
- Q. What material breakthroughs needed to make marine renewables affordable?