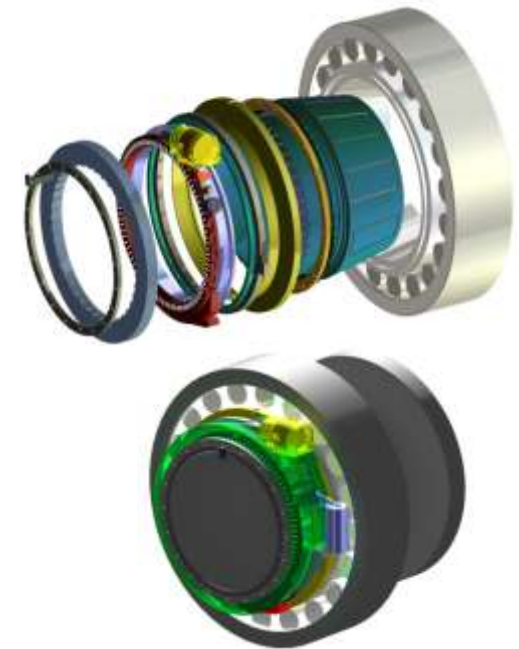


# MultiLife™ Bearing for Offshore Turbines



Jon Wheals, Chief Engineer  
Innovation/Technology, Ricardo

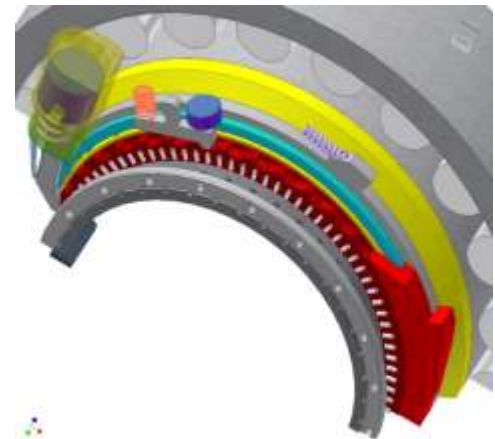
RenewableUK  
Offshore Wind, Liverpool  
30 June 2010, 10:30-10:50



Bearing  
Manufacturer



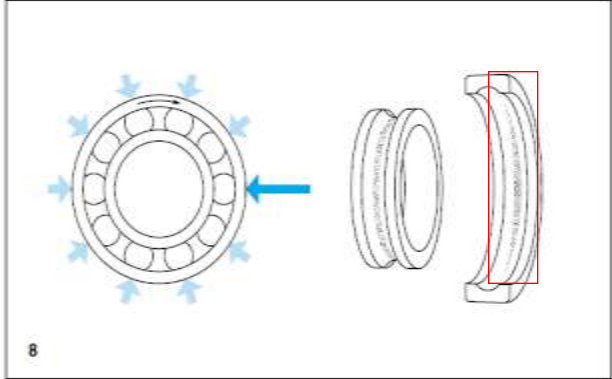
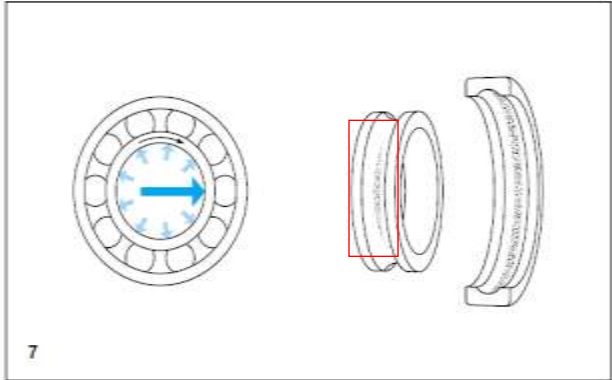
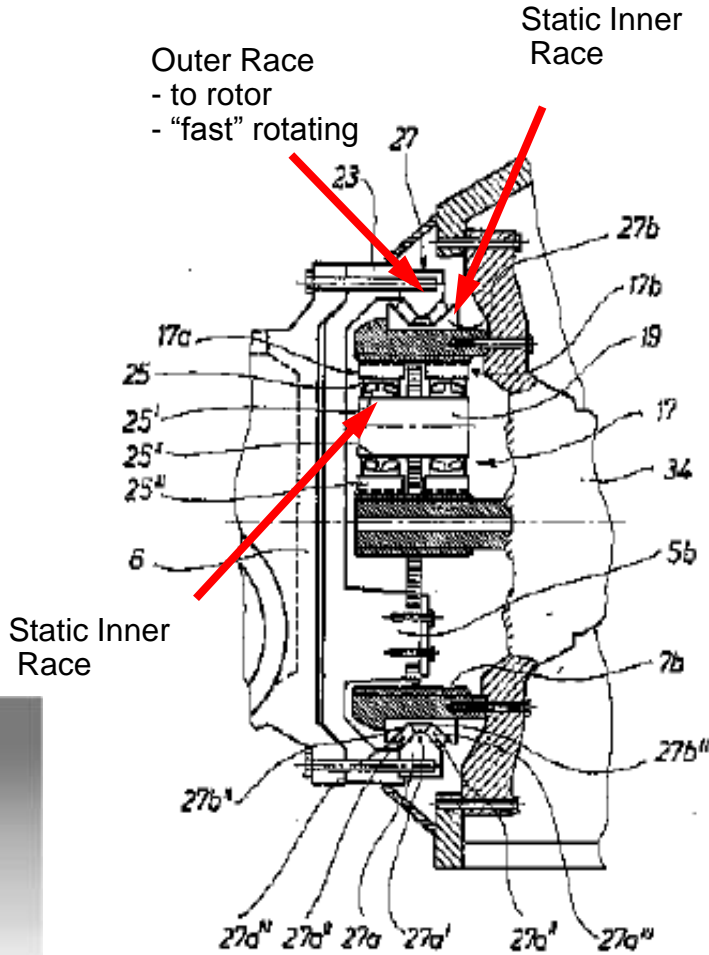
- Project background - new offshore turbines and retrofit
- Credentials
- Solution Principle
- Requirements
- Potential Solutions
- Technical Approach
- Control System
- Development Program
  - Test Plan
  - Test Rig
  - Test Schedule
  - Instrumentation
- Conclusions
- Acknowledgements



# Localised wear of "fixed" Inner Race – often a problem ...

- Main Shafts – some designs
- Planet bearing

Example of double-taper hub arrangement





# Alternative Bearing Solutions

## Alternative Known Solutions

- **Oil Additives** – easiest to apply, but no claims backed by warranty for significant improvements
- **Coatings** – low cost/simple, but failure propagation rapid and uncertain
- **Ceramic Race** – discounted due to cost, catastrophic failure under shock, debris damage
- **Plain Bush** (slow speeds imply hydrostatic versions with feed pumps)
  - Pro (robust, compact, low cost, slow fault development)
  - Cons (aspect ratio – larger heavier gearbox, efficiency [device + pump] )
  - Question : what penalties can be tolerated:+20% gearbox mass, 2-5% efficiency loss?
- **Tilt Pad Bearing** (Kingsbury, Mitchell)
  - Pro (As Plain Bush, but near infinite life if applied correctly )
  - Cons (aspect ratio [long/thin] – larger heavier gearbox, efficiency [device + pump] )



Source: SKF



Source: MIT, USA



Source: Kingsbury, USA

Pivoted shoe thrust and journal bearing



**Pragmatic New Solution:** an alternative approach involves varying the position of the race that is normally fixed to a shaft or housing such that wear is equally shared around the full circumference of the race, rather than being concentrated on an arc. Such an approach is anticipated to yield a **5-fold increase in bearing life.**



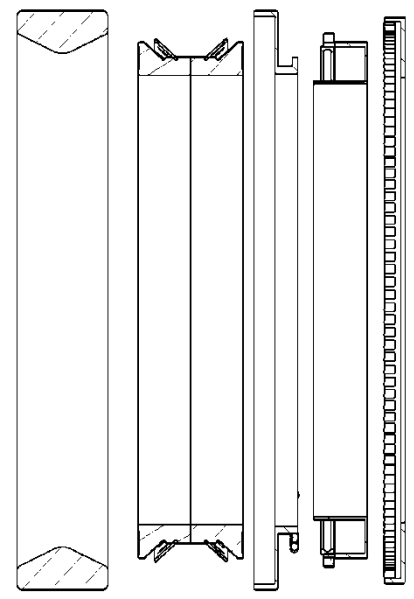
## Discussion of Requirements

- Functions of Rotation Mechanism
  - Support/release race on shaft (radial, axial, wobble) - even a slide fit between the inner race and the shaft allows “ovalling” = fatigue
  - Rotate race to target position relative to shaft
- Objectives/Challenges
  - Failsafe if indexing system fails - the bearing must revert to an “as standard” installation
  - No reduction in driveline efficiency & no shutdown during rotation
  - Applicable to shaft-mounted (inner) and casing-mounted (outer) races
  - Applicable to a nominally standard bearing in a standard gearbox
  - No radical technology – sympathetic to supply chain
  - Absolute position estimation required
  - No electronics or additional sensors !
  - Re-usable
- Fundamental motion of inner race: slow continuous or intermittent ?
- Device is provided as a standalone solution for certain locations within the gearbox, but also as a complimentary solution alongside proven innovations such as flexpin planet mounts.

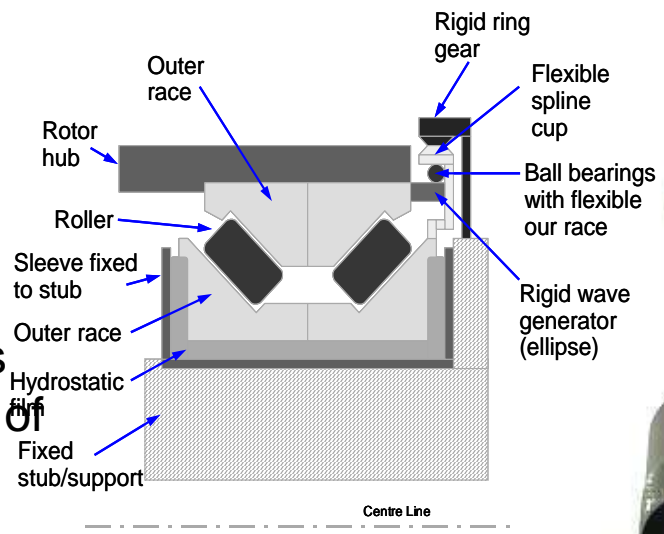


# Driven "Fixed" Race – high ratio geared drive

- Commercial examples of flex-spline drives available to 0.3m diameter, but solution is readily scaled to WTG hub bearing sizes (2m dia.)



Ricardo Concept design



- Conclusion : solution appears viable for continuous rotation of the "fixed race"

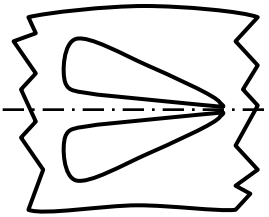
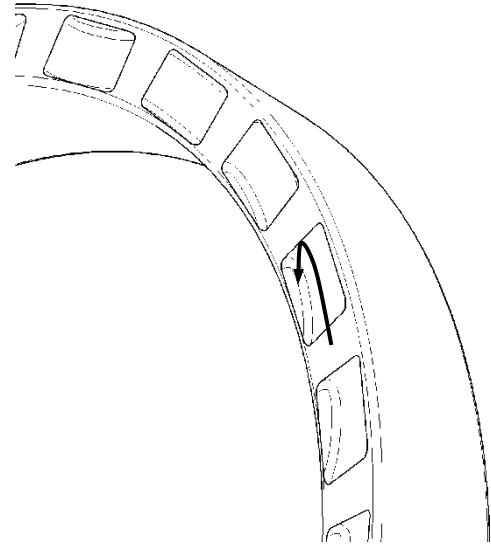
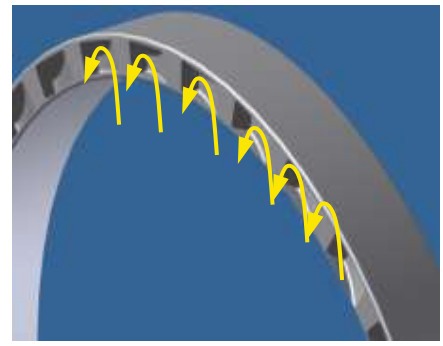
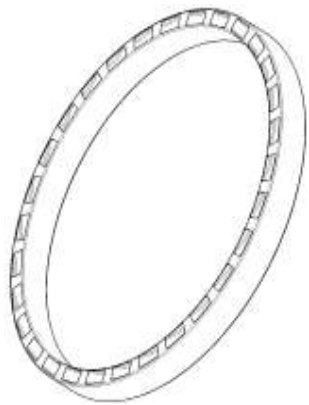
Concept included in Ricardo patent application 2008

Video

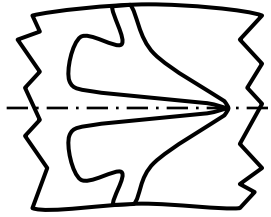


# Pelton-wheel on race

- Principle - jets of lubricant impinge upon scalloped recesses, to generate rotating forces. Distinguished by ground-fixed location of jets.
- Location of features
  - in the flank and/or outer diameter of the race
- Shapes of features to receive fluid
  - known recess designs applied to Pelton-wheels including multi-chamber recesses
- Spacing of recesses and jets
  - located on flanks and or outer diameter of race
  - spaced circumferentially to provide overlap and hence continuous torque for specific or all angular displacements of the race.
- Connection
  - May be a separate part that cooperates with the race preferably a sleeve



Side View of double chamber recess



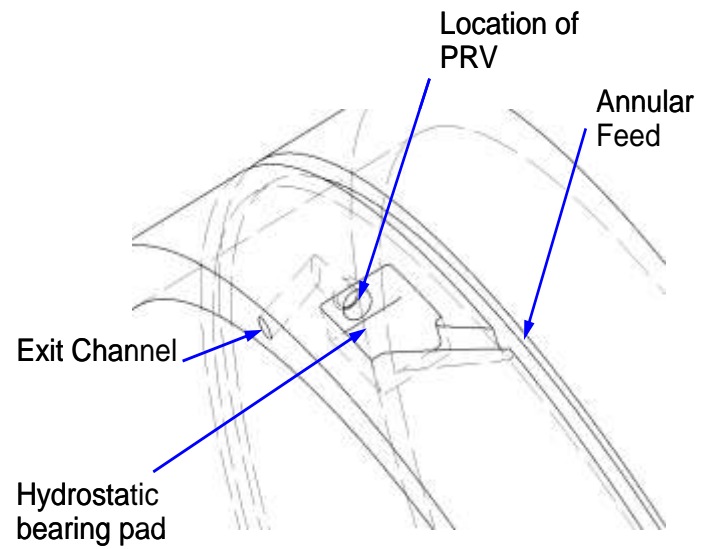
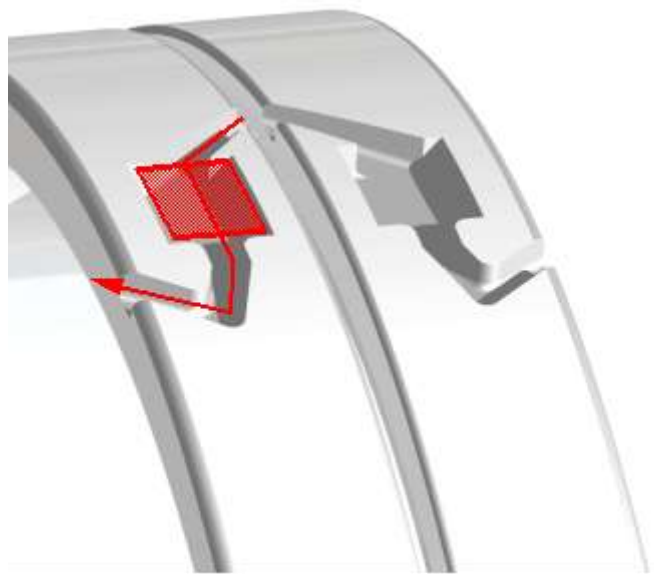
Side View of double chamber recess with radial exhaust ducts/channels

Concept included in Ricardo patent application 2008



# Thrust from Lube Flow

- Principle - lube flow is fed into channels in an element attached to the bearing to generate a rotating torque. Two versions are anticipated:
  - The geometry of the channels may include a reversal of direction causing a momentum change leading a force which urges the race to rotate.
  - The flow out of the device acts as a jet.



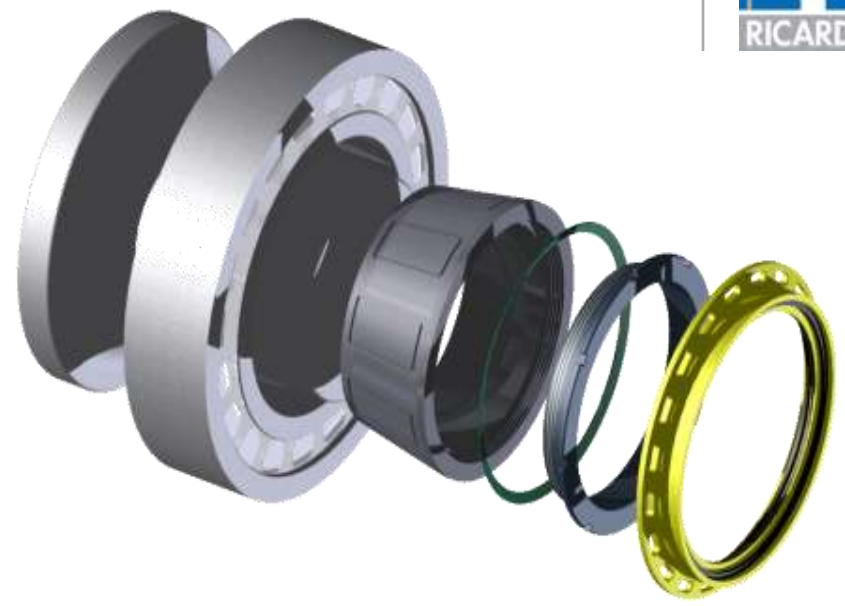
Video

Video

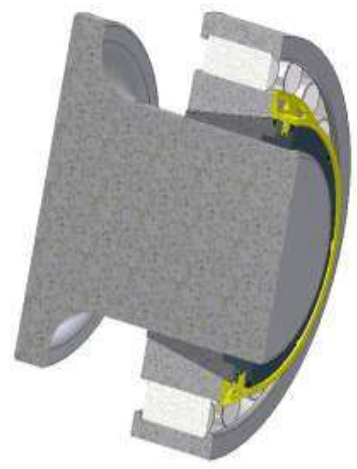
Concept included in Ricardo patent application 2008

# Cone support/release of inner race with hydraulic piston

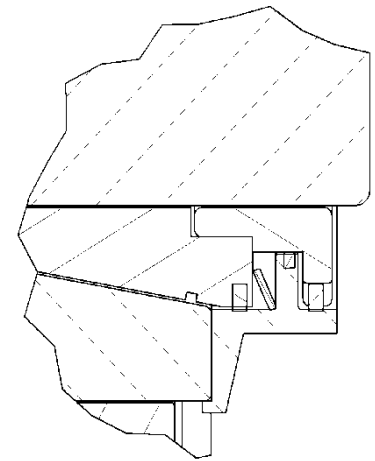
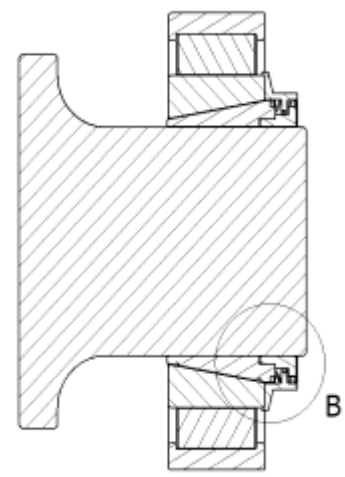
- Principle - hydraulic pressure drives a cone between a special inner race with a conical bore and the shaft
- Failsafe – if oil pressure is lost then the action of the Belville spring (green) re-engages the cone
- Hydrostatic channels on the cone ensure separation after a long period of engagement.



Yellow retaining ring is attached to the side of the inner race. In this example, holes located for lazer welding



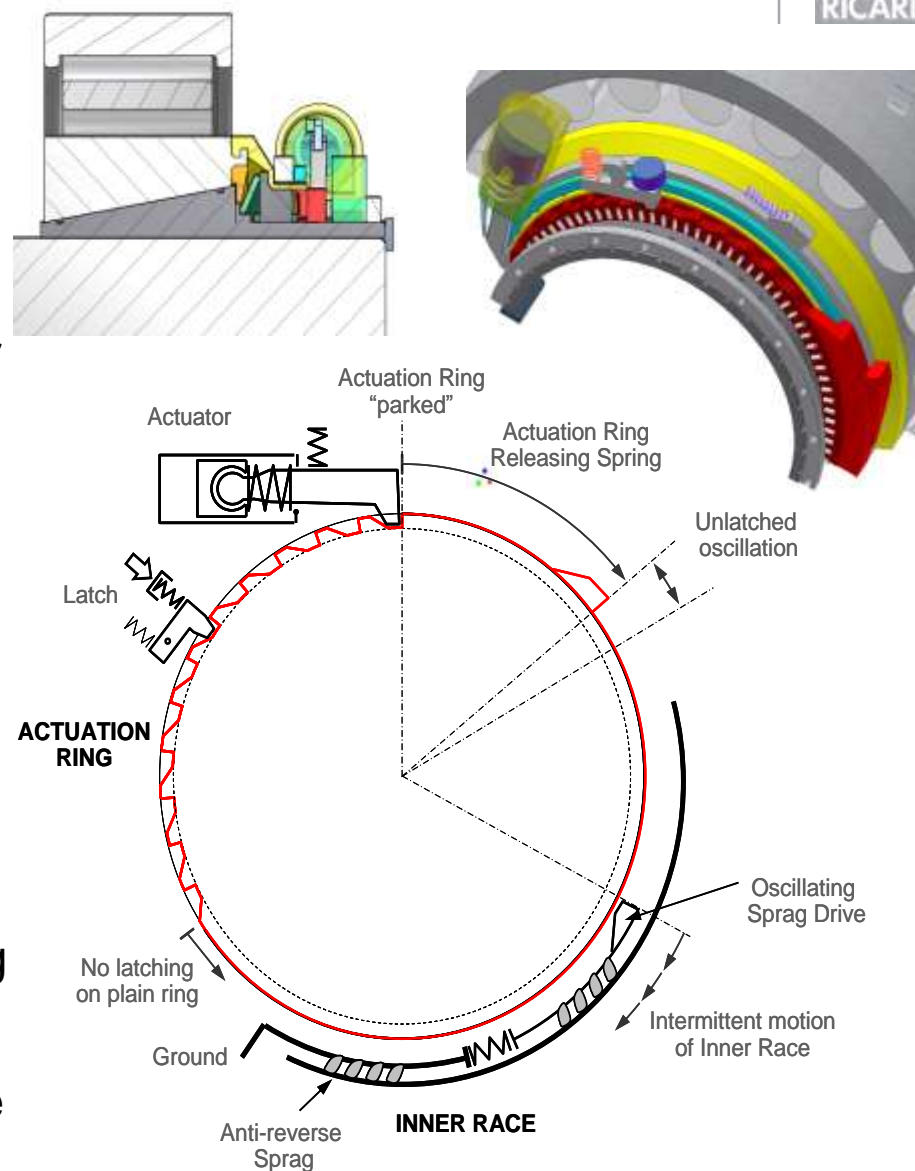
More details in accompanying paper



B : detail of piston and spring

## Positive Hydraulic Indexing Controlling Cone Support and Rotation

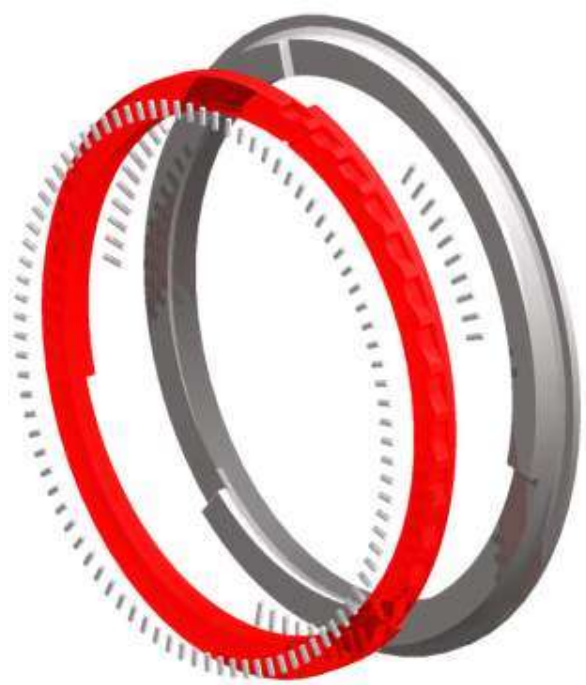
- Principle - Instead of hydraulic pressure ( $>50\text{bar}$ ), a roller-ramp acts to release the load from the cone spring. The ramp ring is driven by an oscillating hydraulic ratchet. This will operate at  $<10\text{ bar}$  with conventional gearbox oil.
- The ramp ring is held in place by a pawl that engage only when hydraulic pressure is present.
- Failsafe – if oil pressure is lost then the action of the Belville spring (green) re-engages the cone
- As before, hydrostatic channels on cone ensure separation after a long period of engagement.
- The assembly is rotated by a single oscillating hydraulic ratchet.



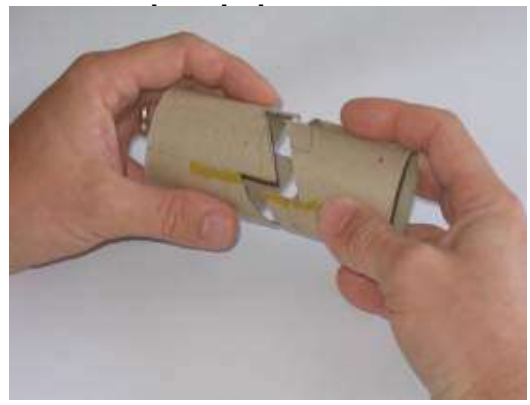
More details in related papers/patents



# Detail of Roller Ramp and Full Assembly

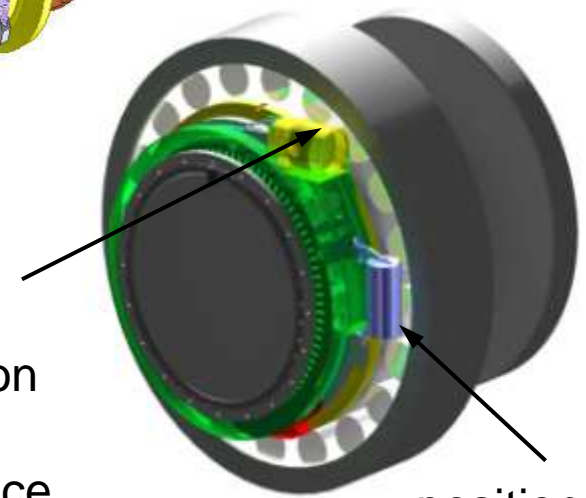


- Confirmation of concept detail using traditional



Compact assembly with radial dimension less than OD of outer race

More details in accompanying paper



position bell

# Superlife Bearings – sub-system functions

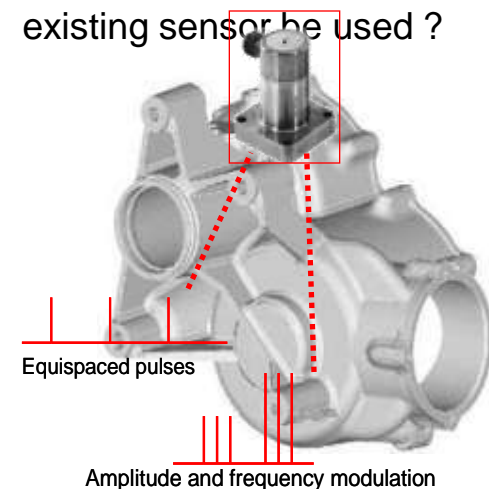
- Operational Sequence
  - Release race (parting of static joints/interfaces)
  - Stable bearing support of race during rotation
  - Torque to brake (in case bearing drag > shaft friction)
  - Torque to turn race (in case bearing drag < shaft friction)
  - Position Control
    - Open loop with positive indexing (position feedback not required)
    - Closed loop – uncertain relationship between driving device and position – requires means of monitoring race-shaft position. Occurs with friction drives that slip.
  - Park race
- Solutions – depends on the “accessibility” of the race
  - Mechanisms applied where possible
  - Hydraulic solutions applied where geared mechanisms not practical

- The indexing mechanism could generate:
  - a signal that could be counted
  - a code to indicate absolute position



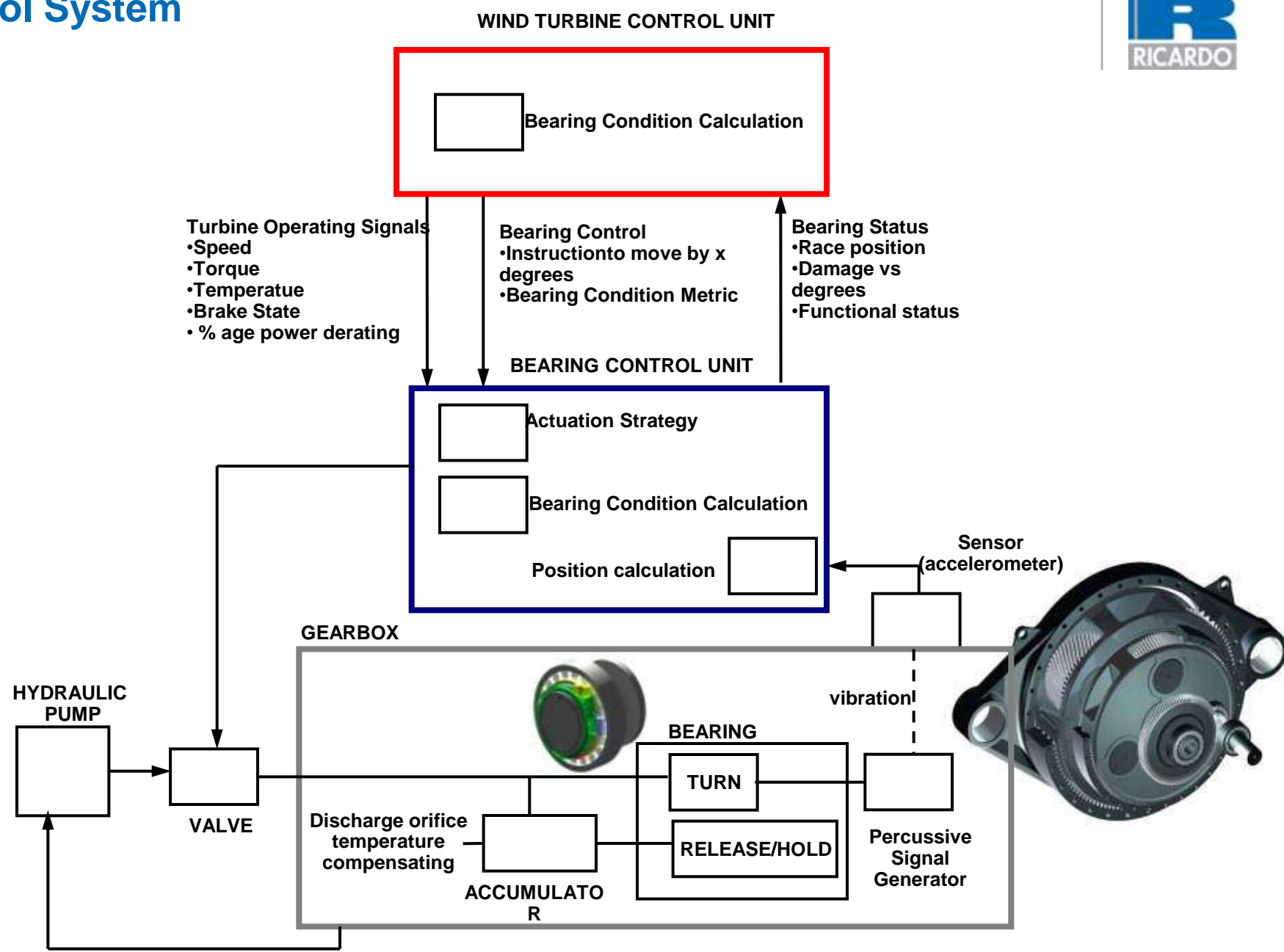
Source: www.redferret.net

- Bearing condition is measured by accelerometers. Could the existing sensor be used ?



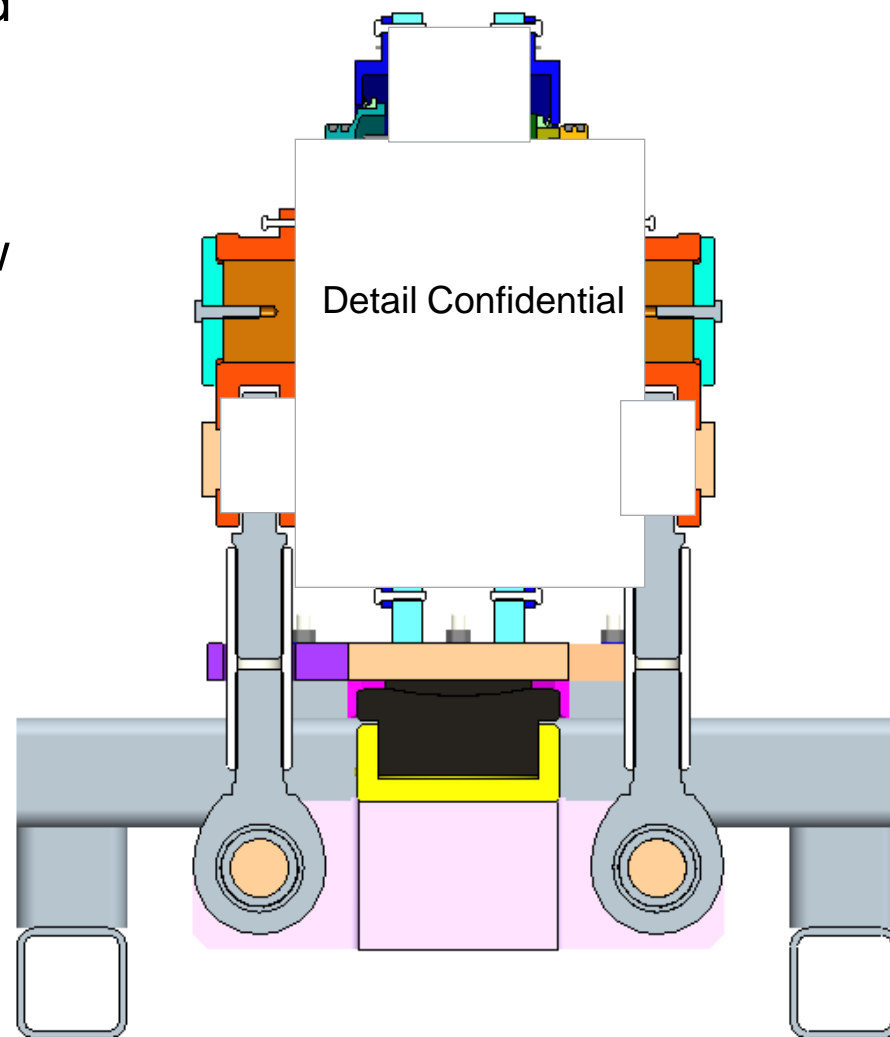
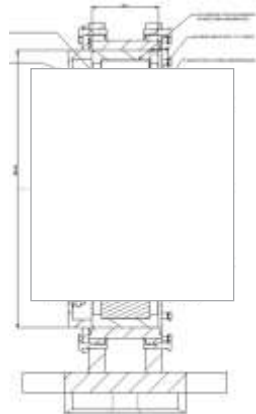
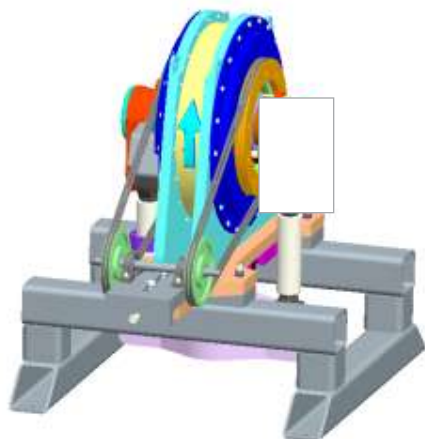


# Control System

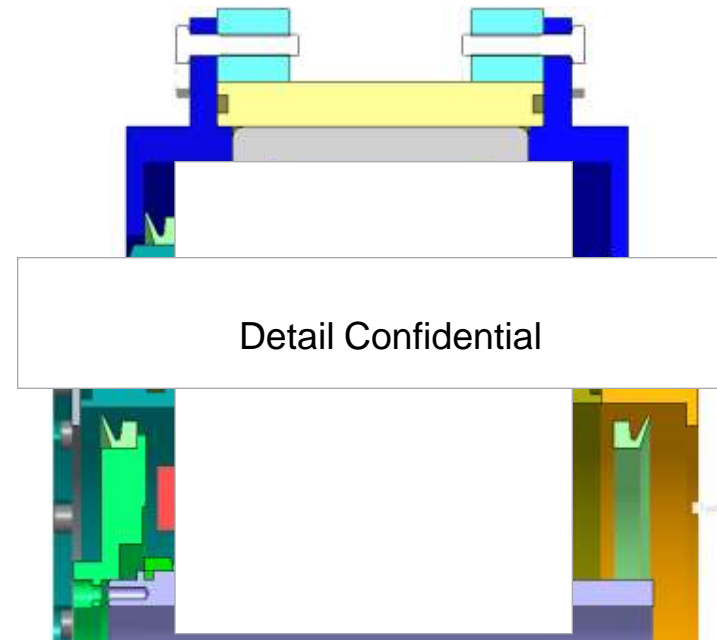


## Test rig to establish bearing life sensitivity to op. parameters

- Rig to test bearings under controlled experimental conditions
  - Radial load only to 90% of dynamic rating of bearing
  - Controlled lube temperatures/flow rate
- Acceleration through change to viscosity

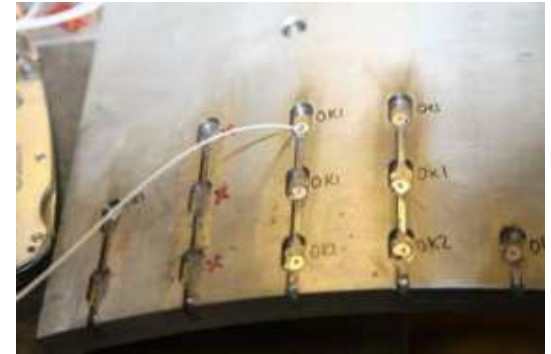


- Test1 – Parameter Setting/Calibration (Standard bearings) confirmation of acceleration factors
  - Setting of accelerometer threshold to define “failed”
- Test2 – Life distribution
- Test 3 – manual Indexing 60 degrees
- Test 4 – automatic indexing , various steps
- Test 5 – Intelligent Indexing [5W, 2 rigs]



# Instrumentation

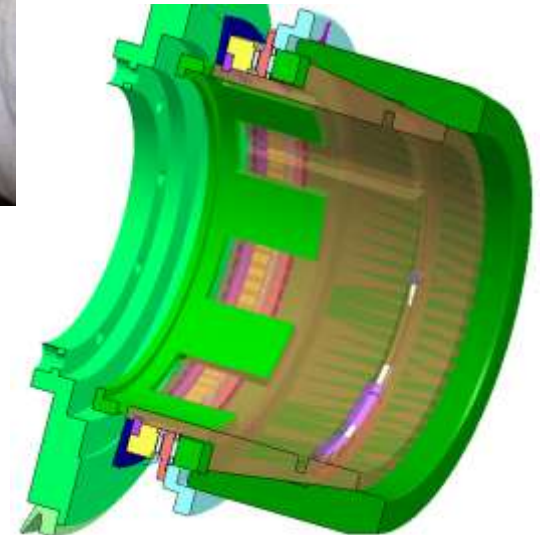
- Support from Sheffield University (Leonardo Centre for Tribology/Dept Mech Eng.)



- Oil film thickness using ultrasonic technique (array of 7 sensors in loaded region).



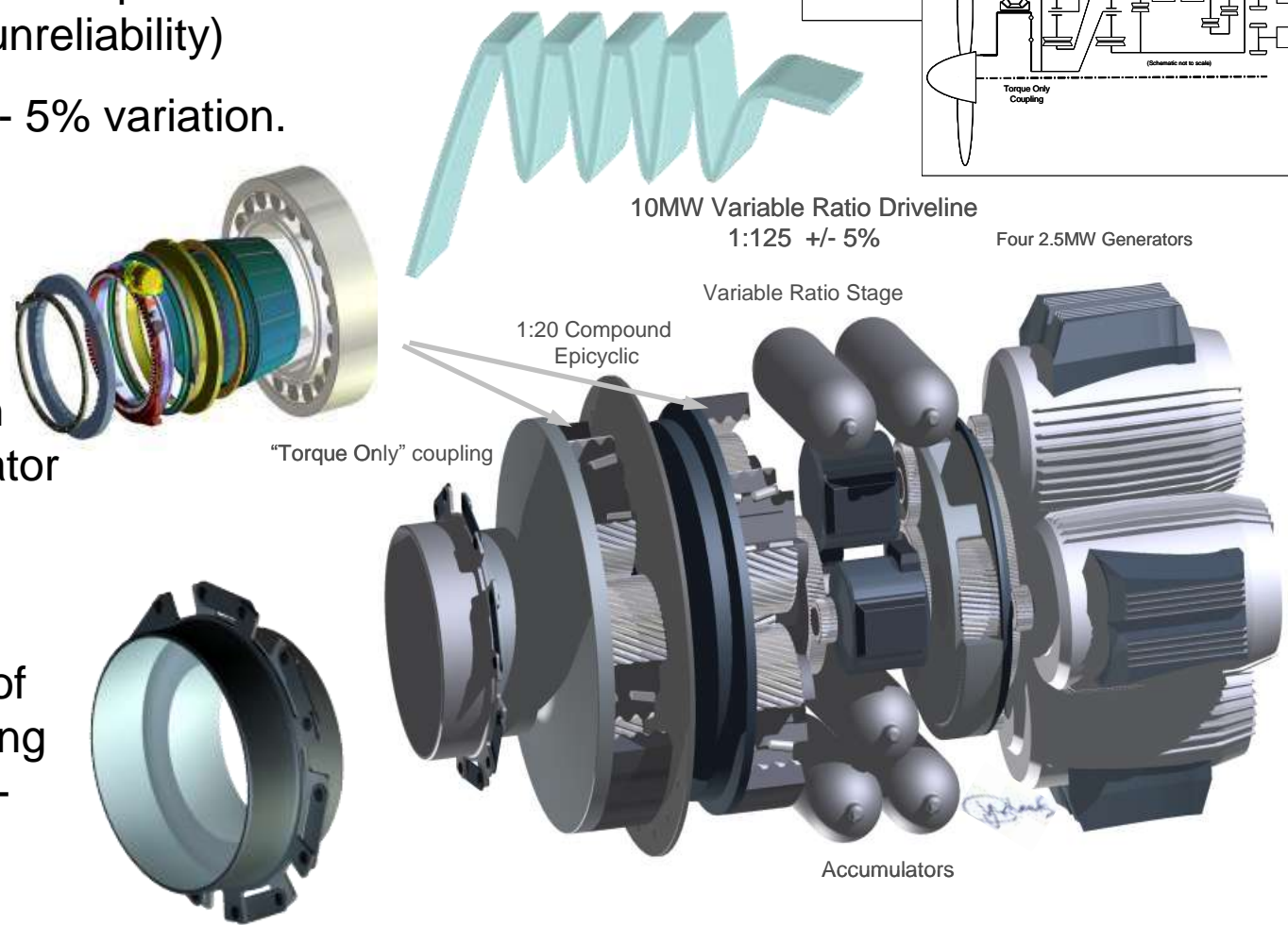
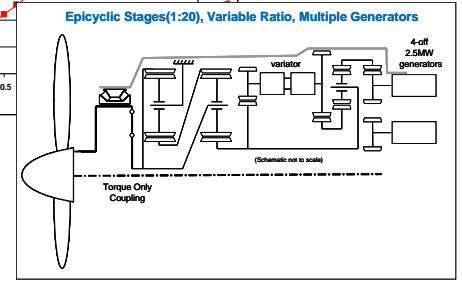
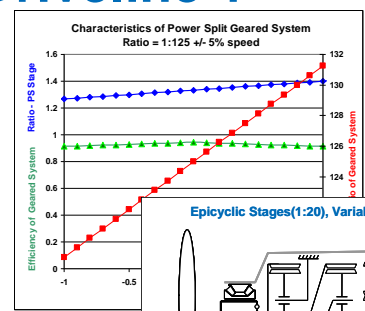
- Acoustic emissions for sub-surface crack propagation. 3-off for triangulation to locate crack source





# MultiLife – part of 30 year 10MW Variable Ratio Driveline ?

- Ricardo concept design for 7+ MW variable ratio driveline
- Fixed speed generators – single or multiple - eliminate power conversion stages (cost, unreliability)
- Ratio 1:125 +/- 5% variation.



- Truncation of Input torque in hydraulic variator
- Low mass potential
- Potential use of MultiLife bearing to achieve 30+ year life

## Summary & Conclusions

- A range of practical “race indexing” solutions applicable to existing bearing designs have been presented referred to as “Multilife<sup>©</sup> bearings”
- The concepts were developed without commercial bias – effectiveness and practicality being the sole criteria (Ricardo manufacture gearboxes, but not bearings)
- Applicable to all driveline configurations: gearbox and direct drive
- A mechanical solution was preferred, rather than an oil additive or coating so re-validation of existing lubricants is not required. It is anticipated that the existing warranty structure would maintained
- Design parameters to be determined during testing
  - Is continuous rotation or indexing most effective ?
  - What should the index increment be and how often moved ?
- Development plan described to include overload and torsional vibration – realworld events not adequately applied in current test standards
- What benefit in providing an extended gearbox warranty(>> 5 years) or making the bearings last longer than 20 years ? truly a Multilife<sup>©</sup> bearing
- Test data Q3/2010 onwards



## Acknowledgements & Notices

- Acknowledgements
  - NWIP for part funding
  - Prof. Robert Dwyer-Joyce  
(Tribology Specialist, Head Dept., Mechanical Engineering, Sheffield Univ, UK)
- Caveats - Ricardo is an independent provider of engineering services. Strict terms of confidentiality and independence of advice have been applied for over 100 years. Where mentioned, 3<sup>rd</sup> are not endorsed by Ricardo and readers are advised to consider alternatives.
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**Thanks for your attention**

Further details/related papers upon request

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