PO.161

Controlling loads in a wind turbine drivetrain

James Packer & Jonathan Wheals
Ricardo

1: Abstract

Wind turbine drivetrains are subjected to large dynamic loads, coupling two high inertia components with rapidly changing aerodynamic and generator loads. Events including emergency stop, gust, and grid changes cause torque overload, torque reversal and non-torque gearbox loads.

Driveline reliability continues as an issue, with evidence from insurers showing that claims remain high for gearbox failures in offshore wind turbines [1].

Ricardo proposes controller and mechanical solutions to control loads into wind turbine gearboxes, and therefore attain controlled reliability.

2: Objectives

- Show the importance of understanding the true failure mechanisms
- Show the importance of understanding transient effects
- **To show a means of reducing or avoiding damaging transient overloads**

3: Understanding the true failure mechanisms

Bearing fatigue life can be assessed to ISO standards 281 & 16281. However these only consider conventional high cycle fatigue damage.

These standards have not adequately predicted failure of bearings in wind turbine applications [2].

Particularly important is the effect of short term overloads in initiating localized damage, including factors such local damage around material inclusions, inevitable in large bearings, as studied in [3], a Ricardo sponsored PhD thesis.

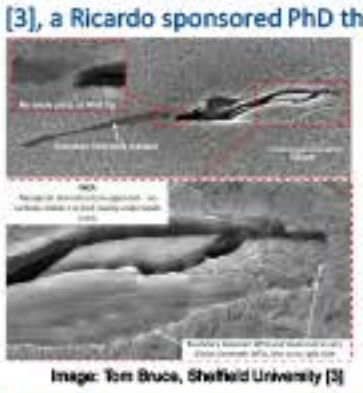
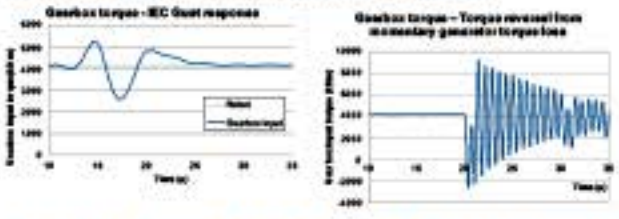


Image: Tom Bruce, Sheffield University [3]

4: Causes of transient overloads

Wind turbine drivetrains couple two high inertia components, the rotor and generator. With a variable speed generator, the resistance from the mechanical inertia of the generator still causes large transient torque spikes through the drivetrain.

Aeroelastic simulations using NREL's FAST [4] show this behaviour in a reference 5MW turbine [5].



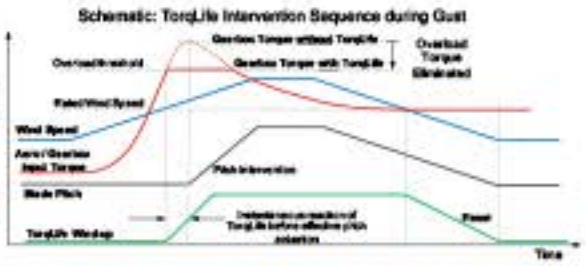
Impact loads during torque reversal also cause intense transient load spikes, for example during emergency stop or generator events.

6: Avoiding overload: **TorqLife™ eliminates transient overload and off-axis force and moment**

Industrial gearboxes with well controlled loads do not suffer the failure issues that continue to be seen in the wind industry.

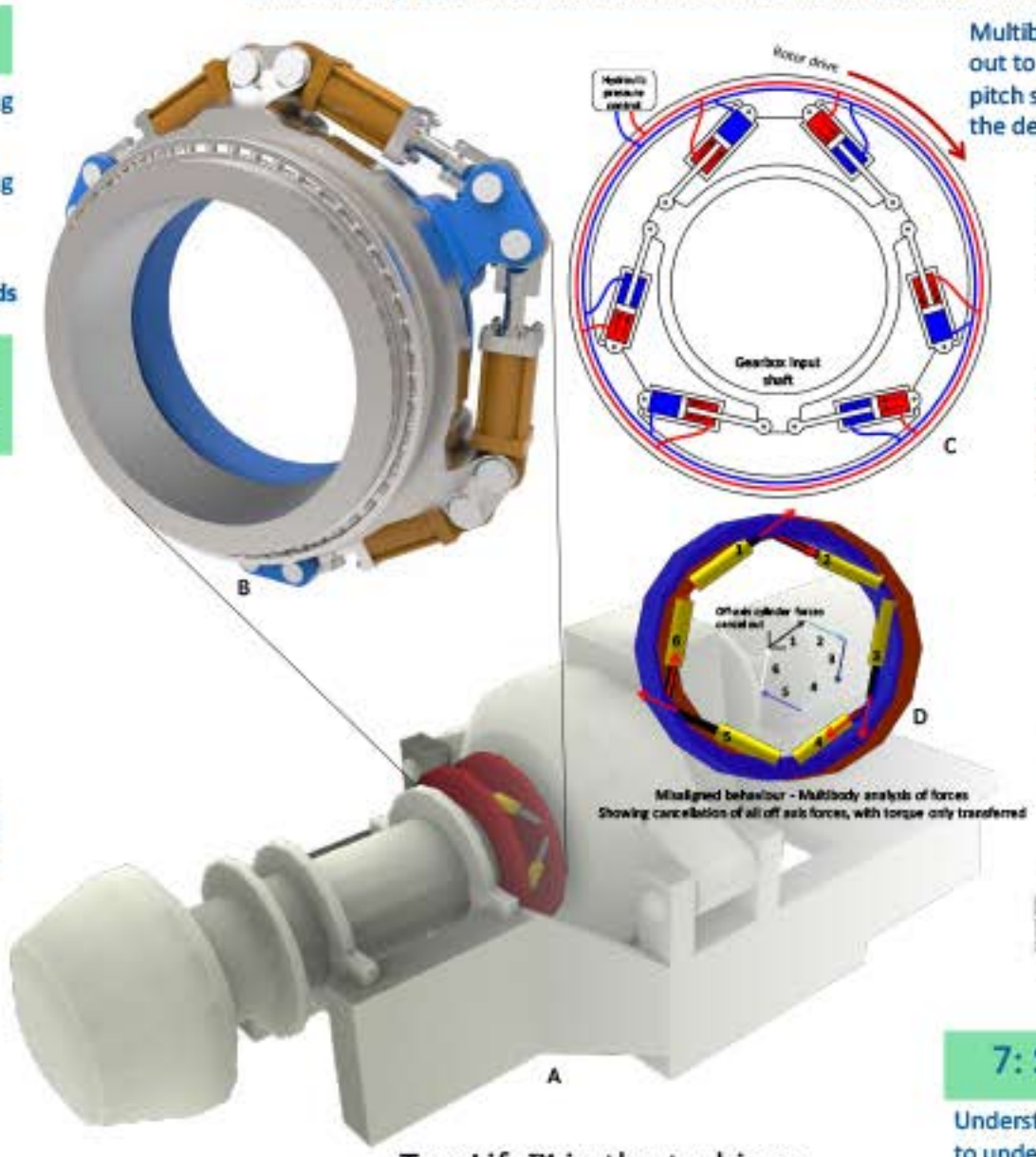
Therefore if we can control torque and off-axis loads to avoid overloads during gusts, grid events and torque reversal impacts, we can attain this level of durability for wind turbine drivetrains.

Ricardo has developed the TorqLife design to do this, and has shown its functionality through simulation and testing.



TorqLife operates between the rotor shaft and gearbox input shaft, transmitting torque through 6 hydraulic cylinders, with articulation to avoid off-axis torques and forces on the gearbox.

Short-term slip in TorqLife controls torque before the pitch system is able to respond, so torque overloads are eliminated.



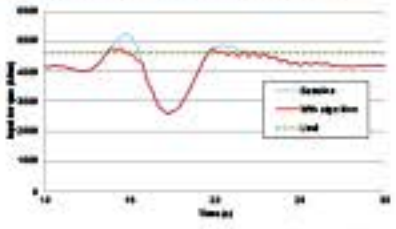
Misaligned behaviour - Multibody analysis of forces
Showing cancellation of all off axis forces, with torque only transferred

TorqLife™ in the turbine:

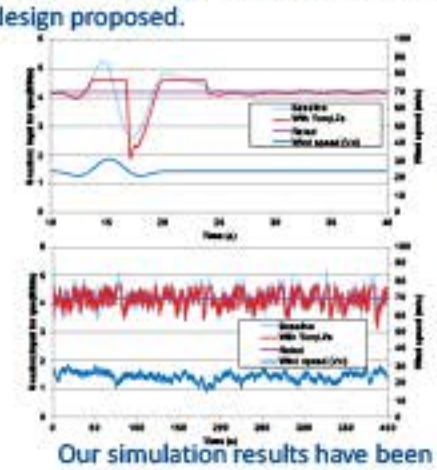
A: Position in driveline B: Example fill scale design C: Schematic showing torque transfer
D: Multibody simulation results – Misalignment compatibility for torque transfer only

5: Controller approaches to reducing transient drivetrain overload

One approach is to reduce overload by compensating for the generator's mechanical inertia during the short transients when overload would otherwise occur. This is done by transiently reducing the generator electro-magnetic torque [6]. This can reduce damage from overload in normal running, but is unable to reduce loads when the generator is not in a normal control mode, such as emergency stop.



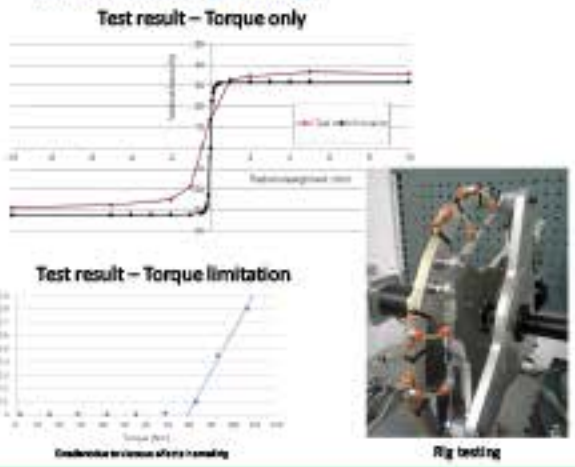
Multibody and aeroelastic simulation has been carried out to show the combined operation of TorqLife with the pitch system, showing the ability to avoid overload with the design proposed.



FAST [4] Simulation of response: IEC Gust

FAST [4] Simulation of response: Random wind profile

Our simulation results have been confirmed by instrumented rig testing:



7: Summary

Understanding loads and metallurgical response allows us to understand issues in wind turbine gearboxes, but we need a means of avoiding conditions that initiate failure.

A way to limit damaging loads has been devised, analysed and validated on a scale rig.

Fast hydraulic response works with the pitch system for short and long term torque control. With controlled torque and no off-axis loads, a 5-8MW design has been identified and is an enabler for a long-term drivetrain warranty.

This work has been part-funded by the UK Department of Energy & Climate Change, who have audited our calculations for a LCOE reduction of 5-13% [7]

For further information, please contact James Packer (james.packer@ricardo.com)

8: References & Patent application

TorqLife™ is covered by patent application GB1521113.0

1. Milford, S. & Dalsgaard, J., Reducing the cost of offshore wind by closing risk improvement measures on insurer's approach, Cable Varkling A/S, Poster presentation, EWEA Offshore, 2015
2. A. Grecia, S. Wang, J. Seitz, A. Eichwald, Material wear and fatigue in wind turbine systems, Wear 332 (1–2) (2015) 1083–1091.
3. Bruce, T., Analysis of the Premature Failure of Wind Turbine Gearbox Bearings. PhD Thesis – University of Sheffield 2015
4. NWTC Information Portal (FAST). https://nwtc.nrel.gov/FAST. Last modified 19-March-2015 ; Accessed 16-July-2015
5. Jonkman J, Butterfield S, Musial W, and Scott G. Definition of a 5-MW Reference Wind Turbine for Offshore System Development. NREL Technical report NREL/TP-500-38060, February 2009
6. Packer, J., Reducing mechanical torque overload in wind turbine drivetrains through controller control strategy. Proceedings of EWEA Offshore Conference, Copenhagen, 2015
7. Ricardo Report 5015-001780-3 to the Department of Energy & Climate Change, 10 February 2016

WindEurope SUMMIT 2016
27-29 SEPTEMBER HAMBURG
windeurope.org/summit2016
#windeuropesummit2016
Download the poster