TriboDENS

Tribology, Dynamics and Energy Solutions

Unique test rig capabilities and case studies

TriboDENS

SWEEP

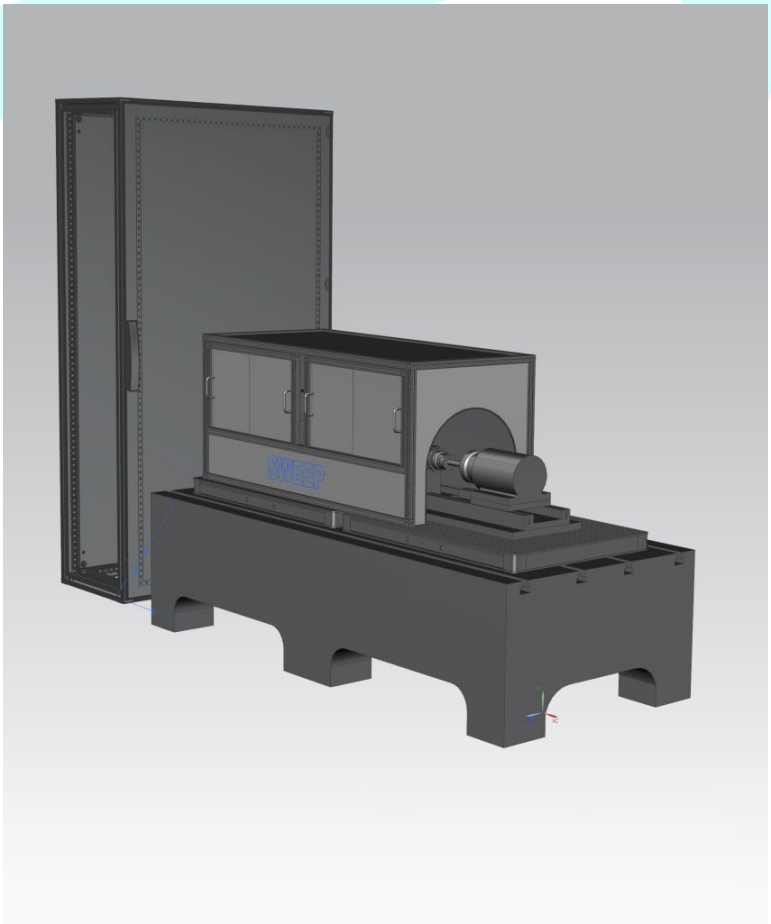
Unique high-speed and electrified bearing test rig

The new era of electrification and moving towards high-speed conditions has highlighted a long-standing lack of experimental characterisation techniques or design standards for dynamics, durability and friction of bearings.

SWEEP is our solution for the above characterisations for any high-speed applications including electric motors, light jet engines and turbochargers.

Test rig specification

- Testing different types of rolling element bearings, with additional module for journal bearing testing
- Rotational speed of up to 42krpm (can be extended upon request)
- Temperature control of the lubricant (-40 °C to 150 °C)
- Low ambient temperature control (up to -30 °C)
- Programmable control platform for duty cycles
- Dynamic excitations in the radial and axial directions with up to 10kHz frequency
- Dynamic bearing displacement measurement with up to 10nm resolution and 20kHz frequency
- Characterisation of stiffness and damping
- Characterisation of frictional torque and wear
- Implementing bearing current to replicate electric discharge erosion



TriboDENS

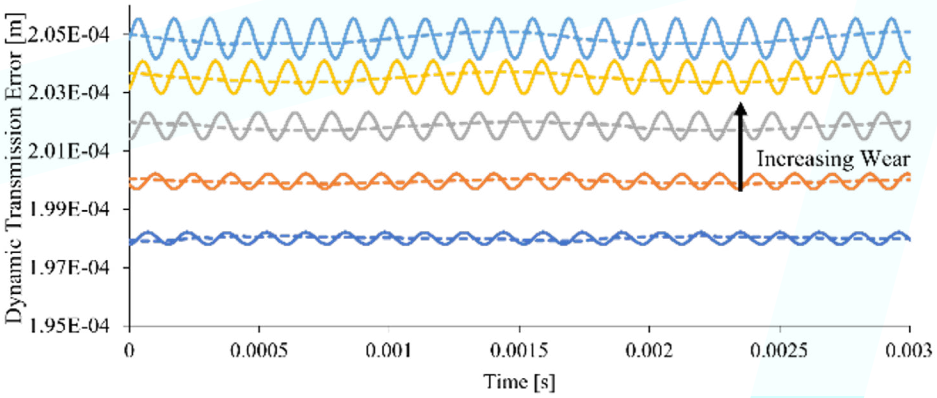
Case study

Helical gears combined wear, friction and NVH analysis

In a holistic modelling approach, we combine wear, friction and NVH analysis. Results below show why that matters. These are numerical results from validated models.

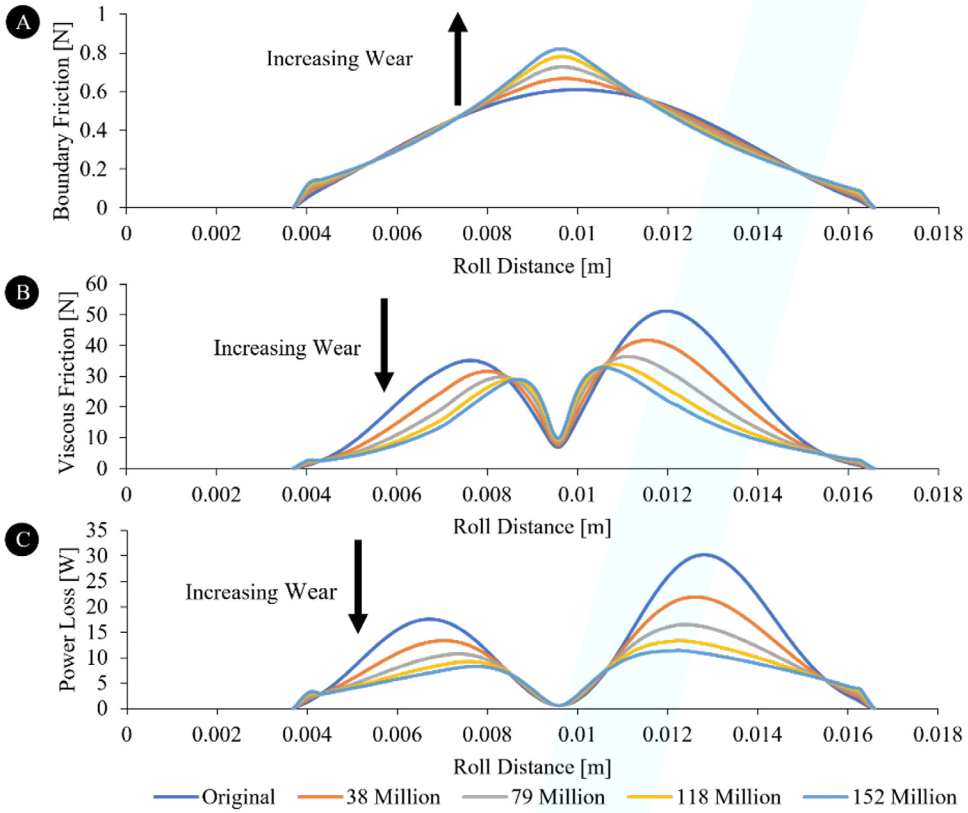
Transmission Error is measure of NVH refinement

Here we see that increasing wear degrades the NVH refinement



We can see by progressive wear, boundary friction increases, and viscous friction reduces

But overall, the frictional power loss in this example reduces by increased transient wear

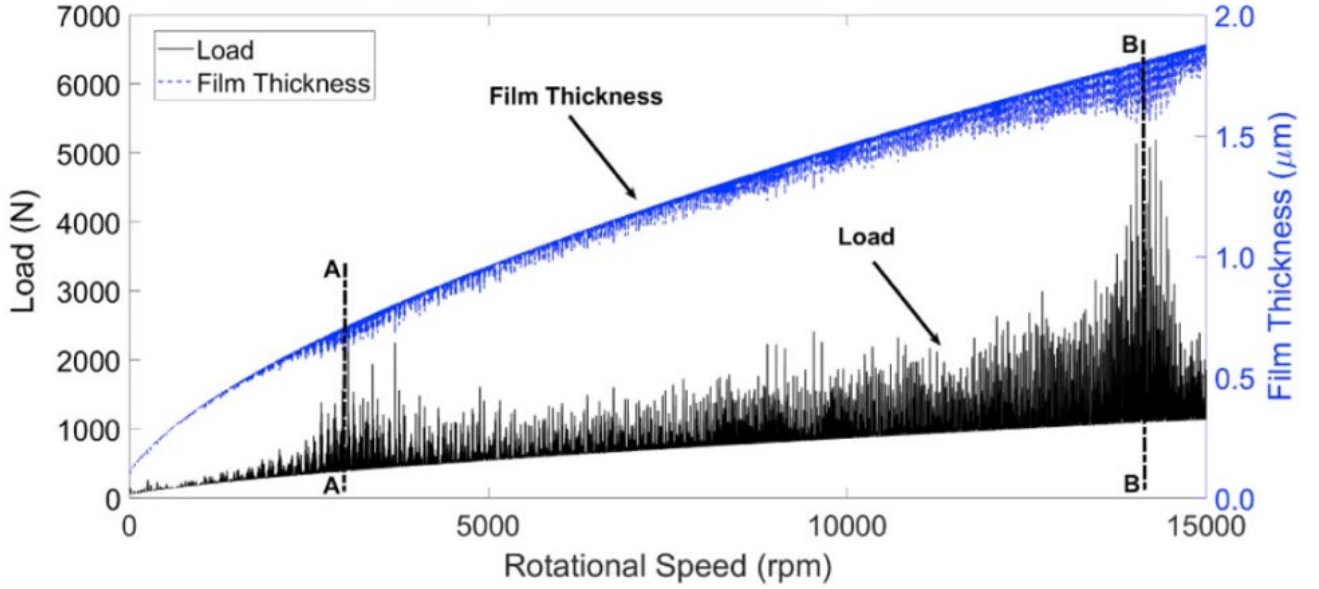


TriboDENS

Case study

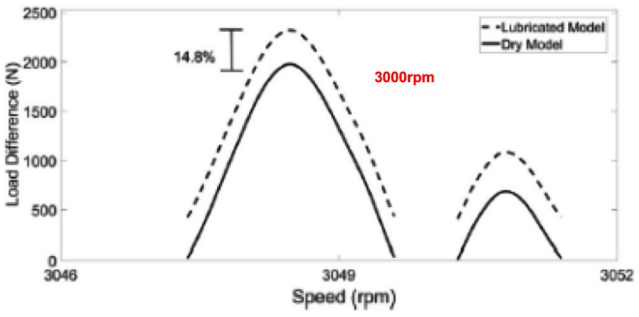
Helical gears combined wear, friction and NVH analysis

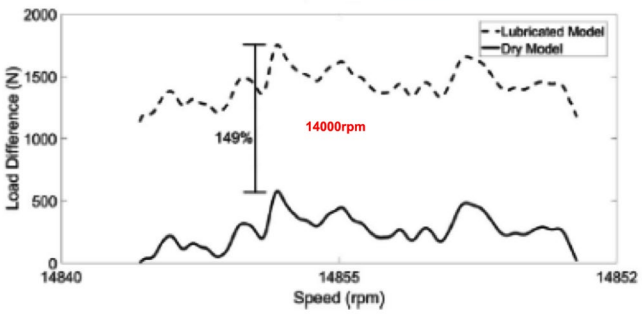
At high speed, the lubricant film thickness increases significantly and compromises the design clearance. An additional internal preload is induced, leading to speed dependant stiffness, damping and friction/wear. Below results are obtained from our SWEEP test rig, twinned by our unique software.



Results show the lubricant film thickness increases by nearly 10 times within 15krpm range. This adds significant internally induced load.

Any non-lubricated bearing model misses this detail, leading to inaccurate friction, wear and NVH predictions. This is covered in our models.





Above figures show the level of error between dry and lubricated models at different speeds. The higher the speed, the bigger the error.

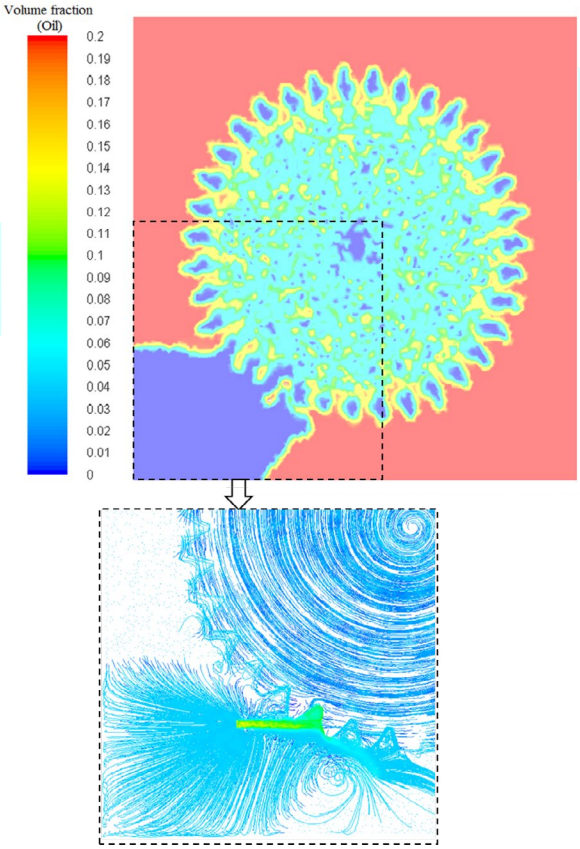
TriboDENS

Case study

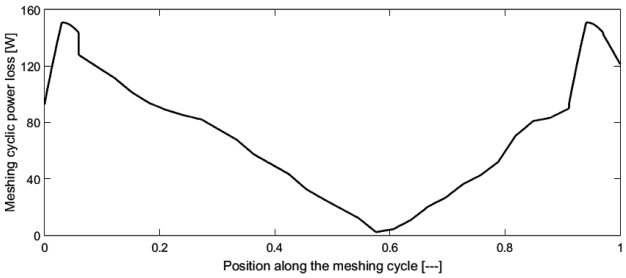
Design and optimisation of a jet-lubricated gear pair

Below results show how a combination of validated models comprising tribology, CFD and system-level analysis can yield the thermal behaviour of a high-speed and high performance gear pair. Without this unique combination, such prediction would not be possible. Therefore, no objective optimisation could be achieved.

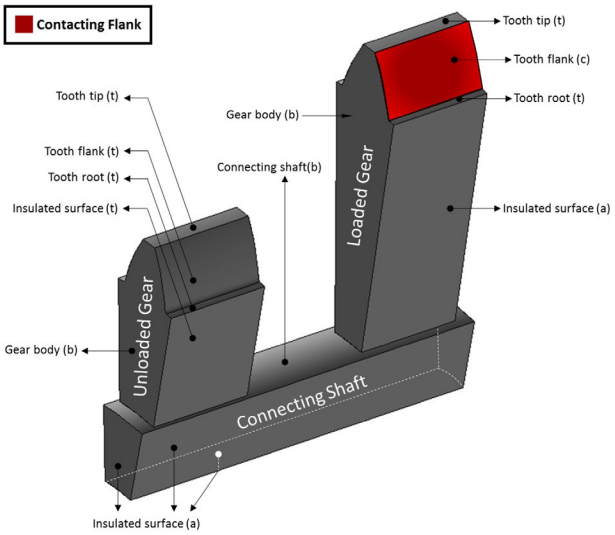
Heat dissipation model



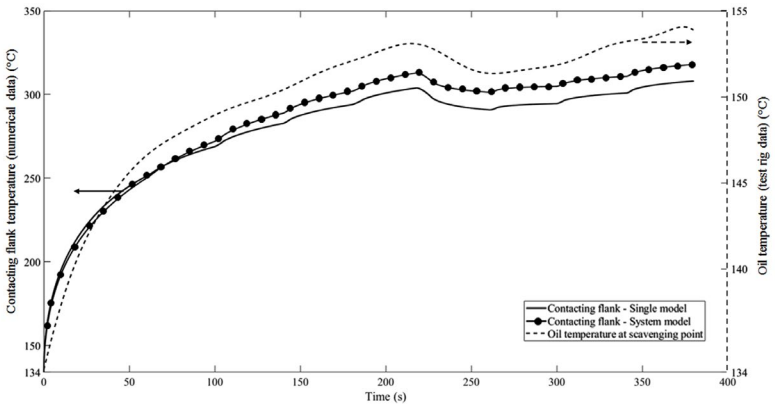
Heat generation model



Applied to a system-level model



Experimentally validated system results



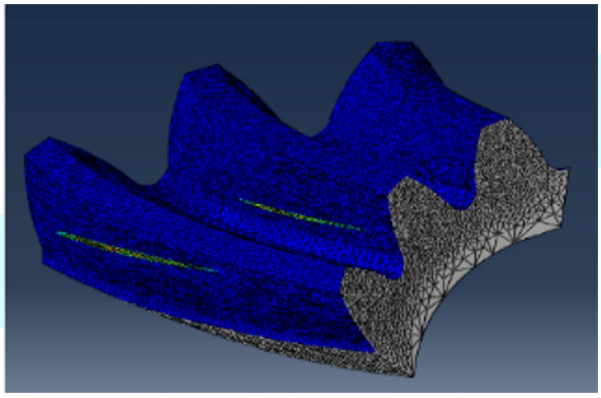
TriboDENS

Case study

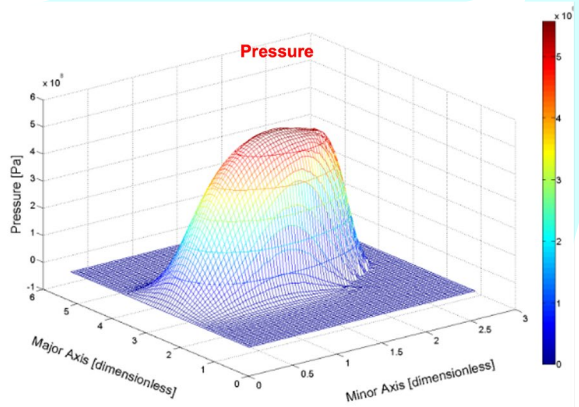
Friction and NVH of hypoid gears

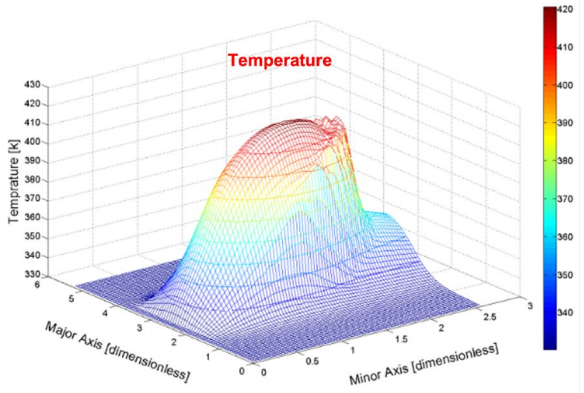
Hypoid gears are an excellent example of a challenging multidisciplinary problem. In the example below, Tooth Contact Analysis (TCA) is performed using measured data from a gear measuring machine, followed by a detailed tribology and dynamics analysis.

TCA from measured components

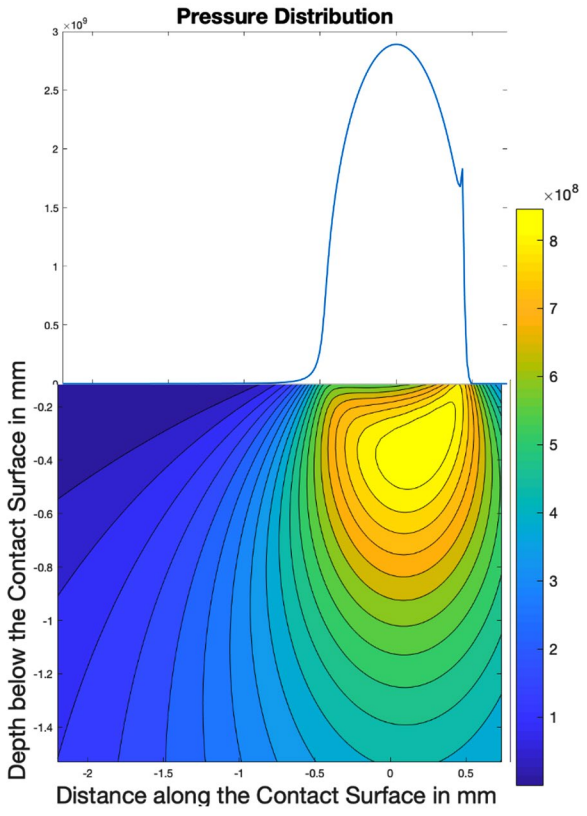


EHL contact simulation (numbers normalised)

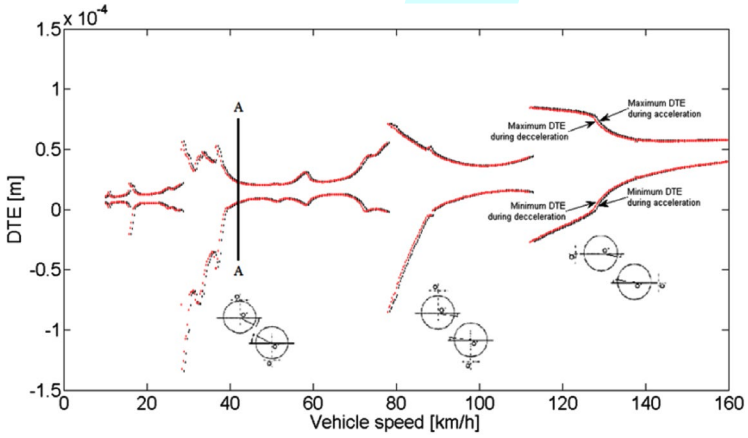




Stress and durability analysis



Transient NVH results (DTE)



TriboDENS

Case study

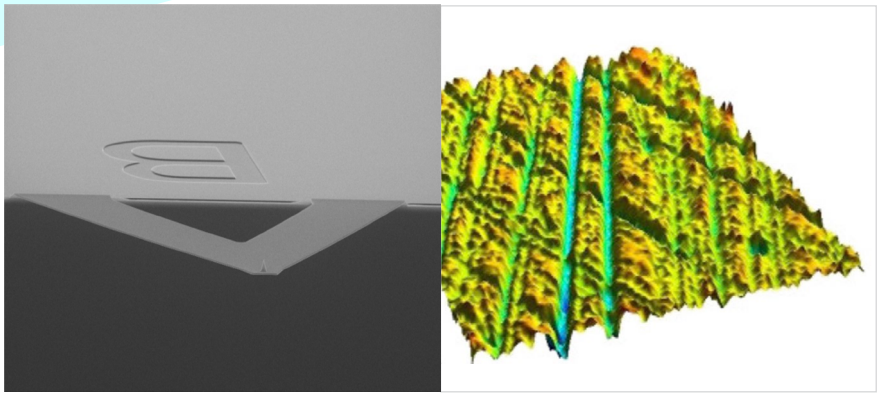
Development and optimisation of lubricants for applications

A fully formulated oil can significantly enhance wear and friction performance of components. To understand the behaviour of oil and optimise it for a specific application, a multi-scale analysis across all TRLs is needed.

The additive package should be tested on the surface from asperity level using an atomic force microscope, using tribometers at contact level and component/system level test rigs.

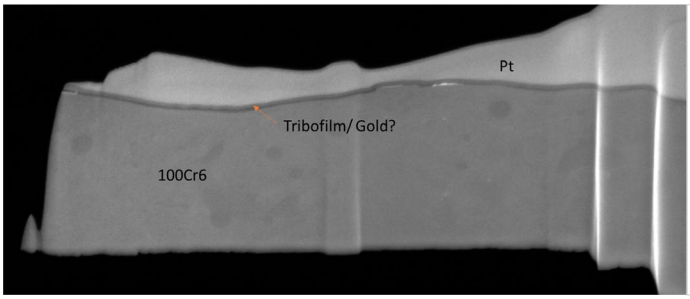
The achieved performance, for example the anti-wear tribo-film thickness and integrity can be characterised using XPS, scratch test, FTIR or FIB/TEM facilities.

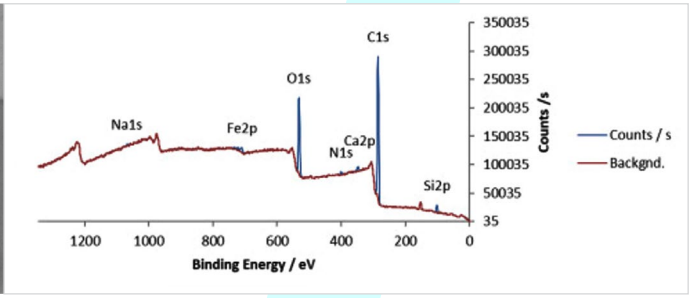
Tribo-film formation using Atomic Force Microscope (AFM)



Tribo-film formation using contact level tribometer

Tribo-film characterisation (XPS and FIB/TEM below)





TriboDENS

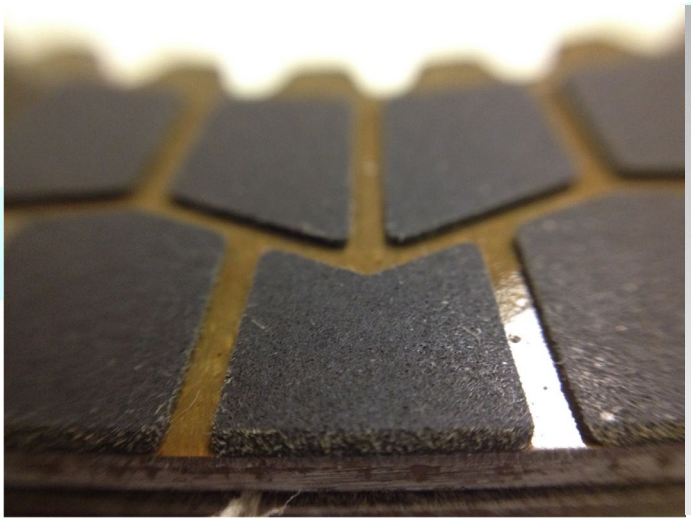
Case study

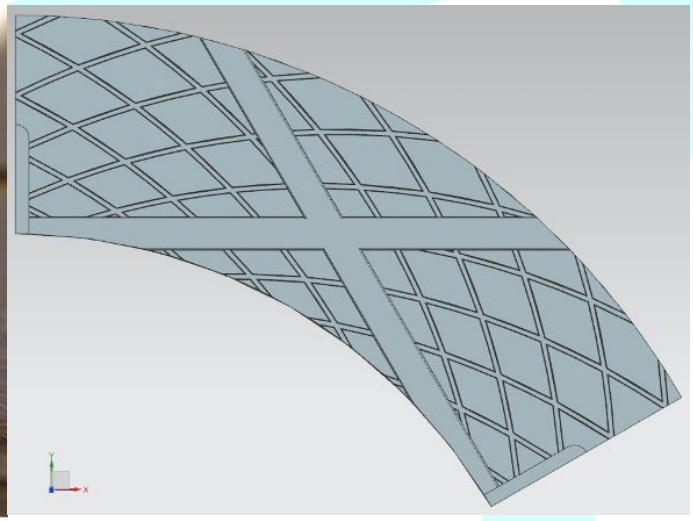
Wet clutch and brake optimisation

Wet brakes and clutches introduce significant frictional losses. Their design and optimisation may save considerable power in a drivetrain and powertrain system.

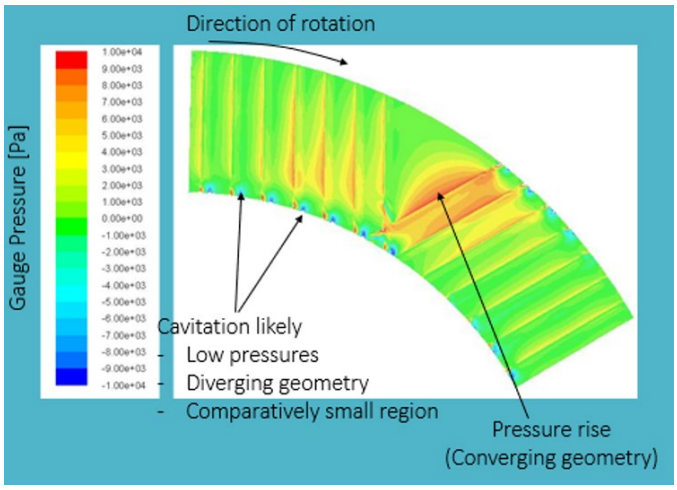
Our in-house models and dedicated test rig play a major role in the objective optimisation of these systems.

Different patterns of wet clutches and brakes

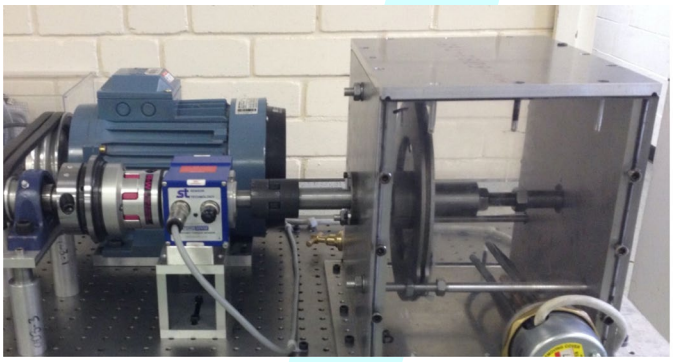




Simulation and optimisation



Test rig for validation



TriboDENS

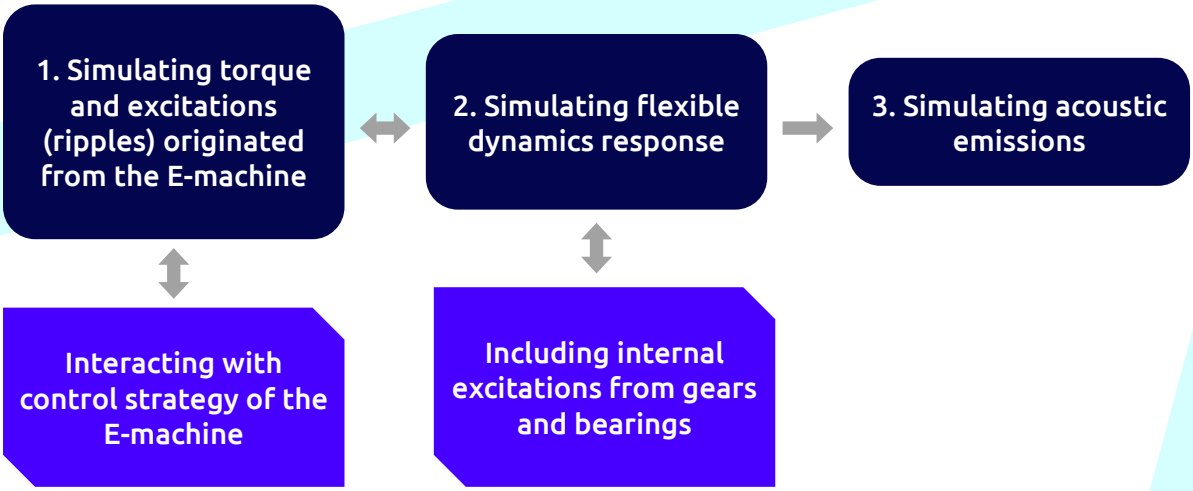
Case study

Electro-mechanical solutions

Rapid transition towards electrification has brought new engineering challenges. Simulation plays a key role in facilitating successful adoption of these technologies.

Our products and services, from unique software to the SWEEP bearing test rig are specifically designed for this purpose.

Below, our dedicated multi-physics approach for electro-mechanical systems is presented. This should be supplemented by our other methodologies.



Find out more information

Please feel free to contact
Dr Mahdi Mohammadpour for further information

Dr Mahdi Mohammadpour PhD CEng MIMechE FHEA
Associate Professor/Senior Lecturer in Dynamics

Loughborough University
Leicestershire LE11 3TU

T: +44 (0) 1509 227659
M: +44 (0) 7549 413791
E: m.mohammad-pour@tribodens.com

tribodens.com

85134/CPS/Oct23