Model-led NVH Process for EV Drive Applications -

The next chapter of CAE-led Design

Presenter: Annabel Shahaj

Agenda

- Automotive industry challenges due to electrification
- Benefits of a CAE-led design process for NVH prediction
- Introduction to the EDISON project
- Romax Evolve in the Electric Machine Design Process

Challenges of Electrification for the EV powertrain

Industry Drivers

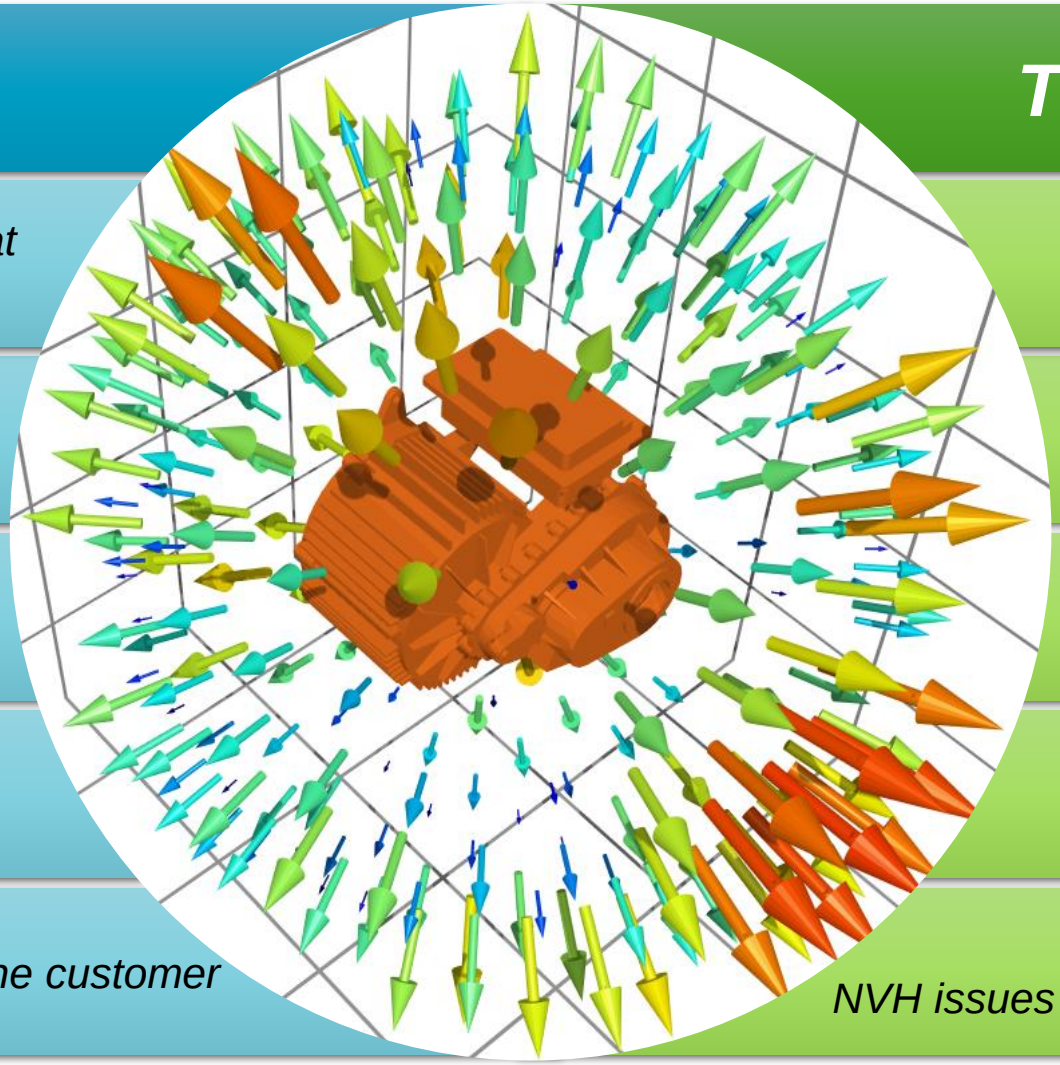
Increase innovation to find solutions that overcome new challenges

Reduce cost to consumer – bring into line with conventional powertrains

Reduce time-to-market, remain competitive

Accelerate design process to reduce development time and cost

Maintain quality at levels expected by the customer



Technical Challenges

New noise environment with reduced masking requires careful NVH design.

High rotation speeds leads to higher frequency noise.

New lightweight, stiff chassis designs make structure-borne noise more likely.

Greater need to balance NVH with other design targets requiring multi-attribute optimisation.

New powertrain layouts with unknown NVH issues requires a CAE-led approach to NVH.

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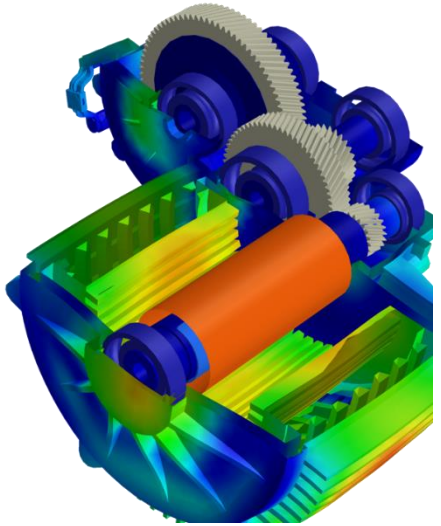
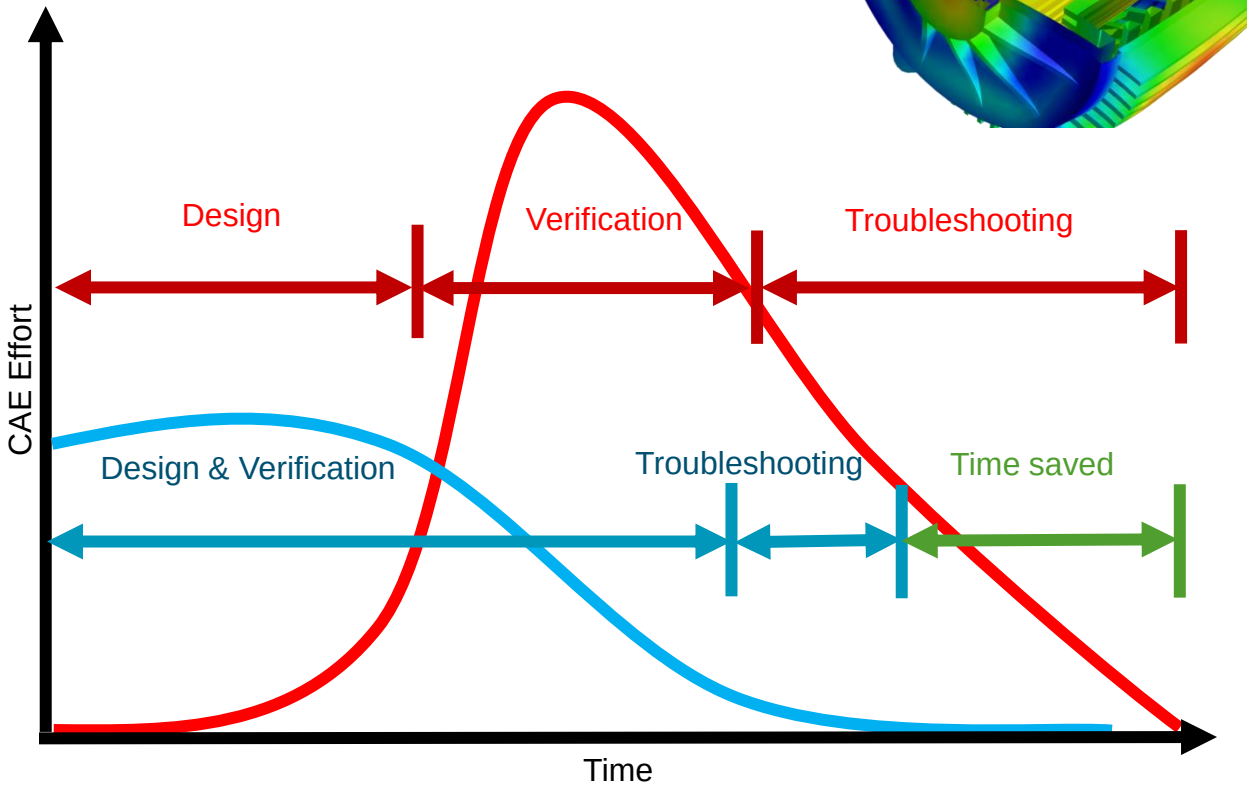
Classic vs. CAE-led design

- Classic design process
  - Experience based approach
- CAE-led design process
  - Simulate early; simulate often
  - Continuous validation against design targets – iron out problems before they are problems
- CAE-led design benefits
  - Enables innovation
  - Faster development
  - Less prototyping and testing
  - More competitive end product
- CAE-led Design for NVH
  - Due to its nature, NVH often isn't considered early in the design process.
  - NVH Often: Simulating performance repeatedly during development allows you to identify potential issues and iron out many problems early on

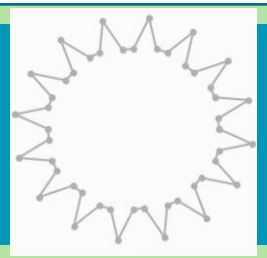


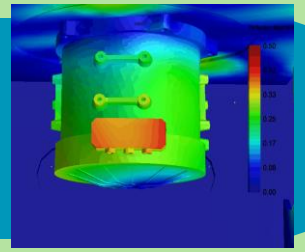


Tools for EV powertrain NVH analysis

eMotor development team

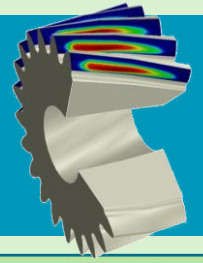
Romax evolve

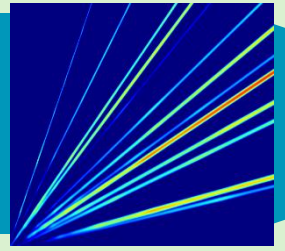




Gearbox development team

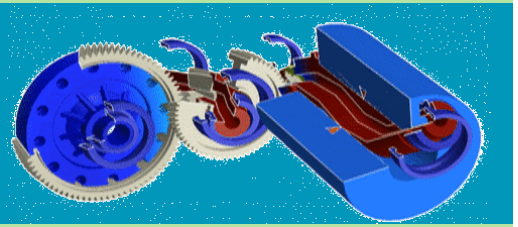
Romax spectrum

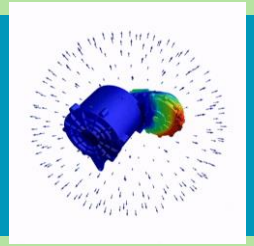




ePowertrain system team

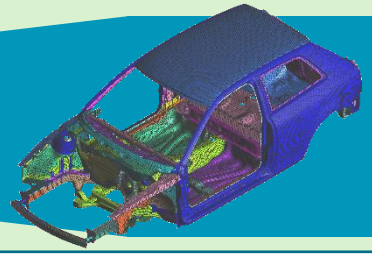
Romax spectrum



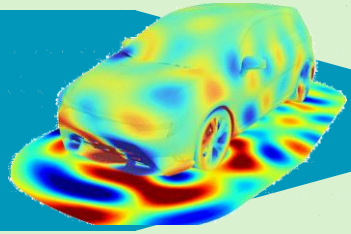


Vehicle NVH team

Na



Ac



Component & Subsystem

System

Vehicle

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Romax Evolve as Part of EM Design

Traditional electric machine design tools

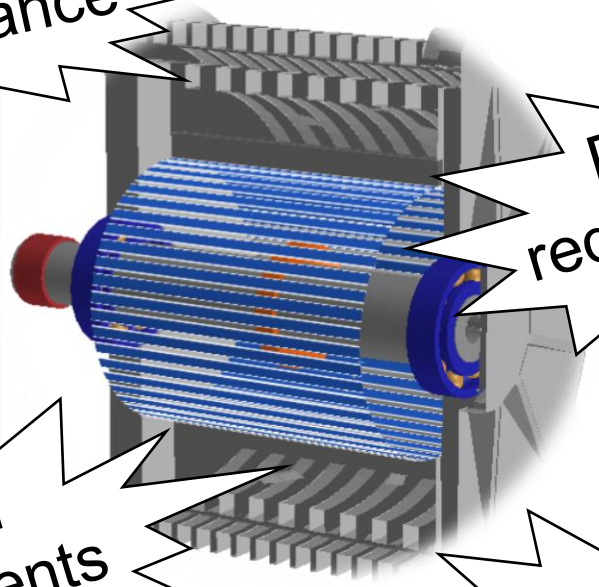
- Electromagnetic
- Operating point
- Efficiency
- Thermal

Performance

Design requirements

Design requirements

Refinement



- Bearing rating
- Bearing efficiency
- Housing design
- Rotor dynamics
- NVH
- Acoustic

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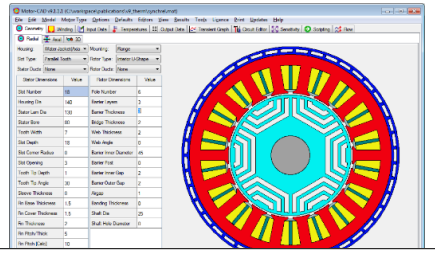
Romax Evolve: Feature Highlights

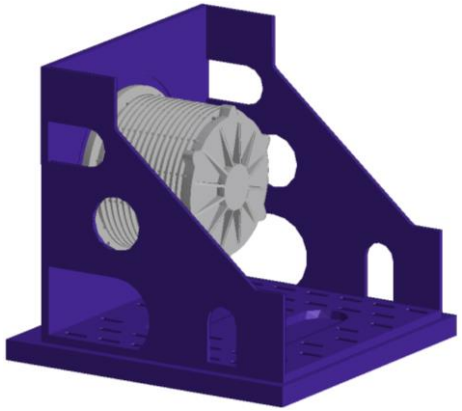


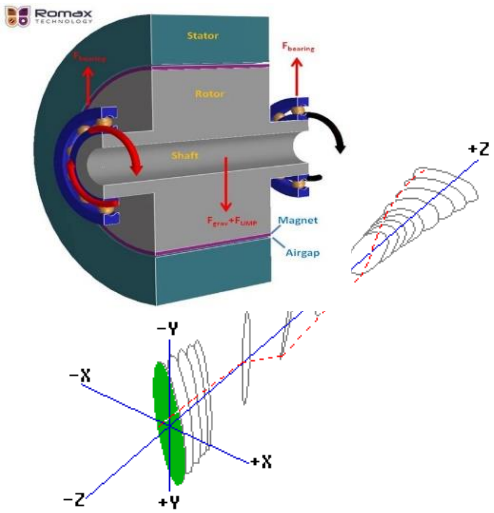
Motor Design Limited

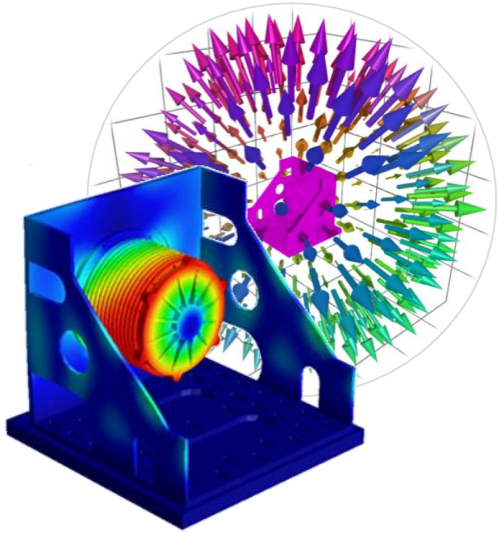
Ansys PREFERRED SOLUTION PARTNER

Altair Flux™ JMAG® Simulation Technology for Electromechanical Design

SIMULIA







Integration
Fully integrated with other Nexus products. Interfaces to major **electromagnetic simulation tools**

Modelling
Quickly build a **complete structural model** of an electric machine including bearings, housing, rotor, stator. Import **parametric motor geometry**

System Analysis
Analyse component behaviour in the context of the whole machine structure. Understand **bearing durability and efficiency**. Analyse structural performance

Rotor Dynamics
Predict **critical speeds and vibrations** caused by mechanical imbalance and unbalanced magnetic pull

NVH
Predict **vibration and radiated noise** caused by electromagnetic forces. Identify NVH problems and try out solutions

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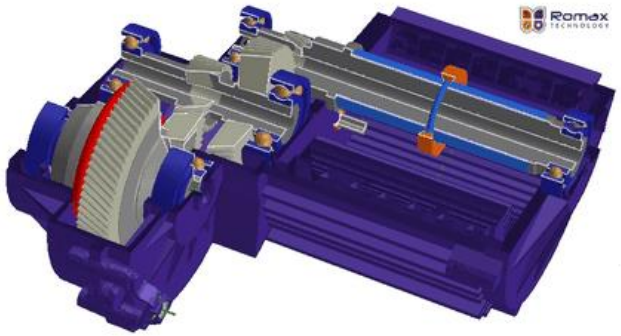
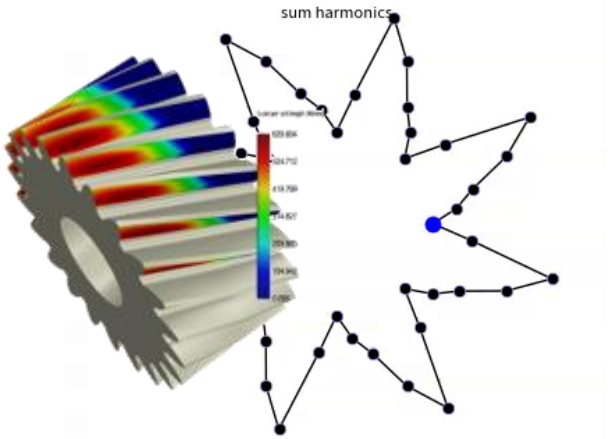
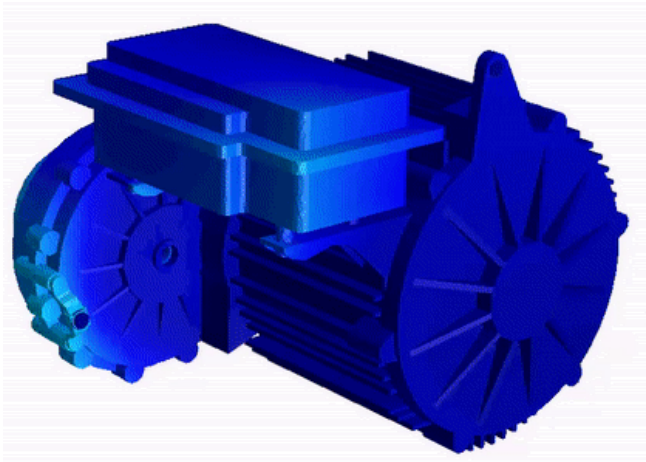
Romax Spectrum: Feature Highlights



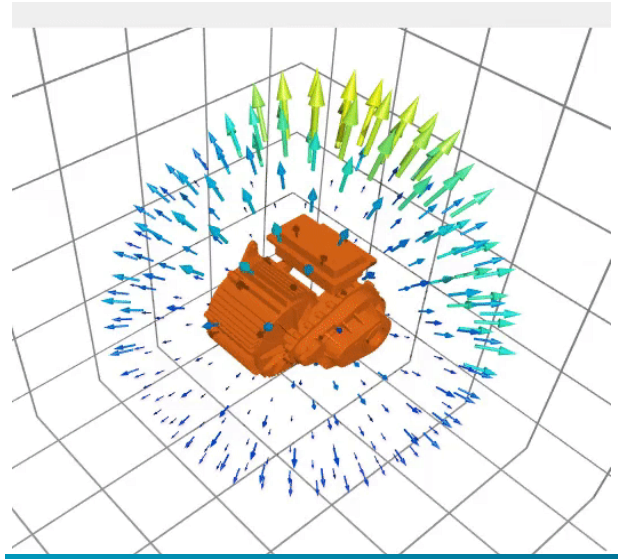
Modelling
Complete, parametric whole-system modelling of the powertrain incorporating world-class gear and bearing contact models to give the accuracy you need for sensitive NVH simulations.



Excitations
Validated analysis to predict dynamic gear excitations including unique planetary gear simulation and integrated links to partner electro-magnetic software for calculating electric machine forces.



System vibration
Frequency domain simulation of system vibration response giving you instant access to the answers you need along with the engineering insight into how to make your design better.



Radiated noise
Embedded acoustic solver brings complex simulation with automated calculations to see if your design meets its noise targets.

Romax Evolve in the EDISON Project

The EDISON Project

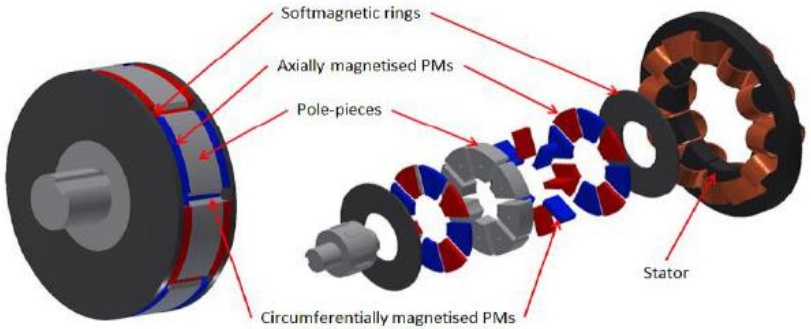
Co-funded by Innovate UK, the UK's innovation agency

Project partners

- Romax Technology (lead),
- Jaguar Land Rover,
- Dassault Systemes UK,
- GRM Consulting,
- National Physical Laboratory,
- University of Sheffield

Duration

- 3.25 years (April 2018 - June 2021)



Overview

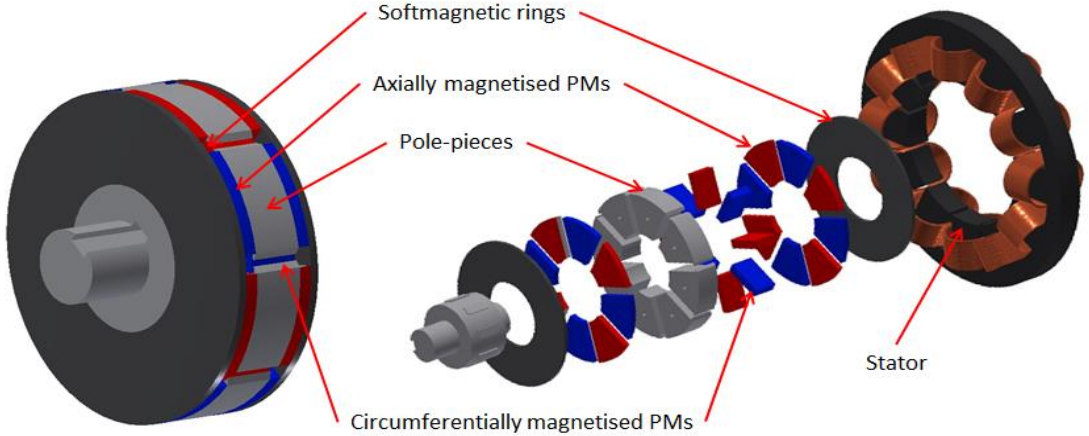
The project will develop:

Novel ferrite magnet motor technology for a passenger vehicle application

Electromechanical analysis toolset enabling effective system optimisation and integration

The Ferrite Magnet Motor

- A flux focusing rotor concept has been developed by The University of Sheffield. When used in conjunction with ferrite magnets, this construction enables a ferrite motor concept with:
  - ✓ Air gap flux density to match rare earth types
  - ✓ Lower material costs
  - ✓ Potentially no supply chain issues
  - ✓ High efficiency
  - ✓ High power density
  - ✓ No inherent NVH issues

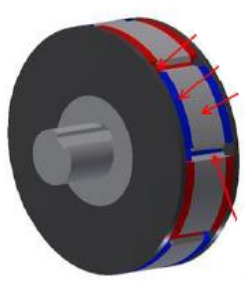


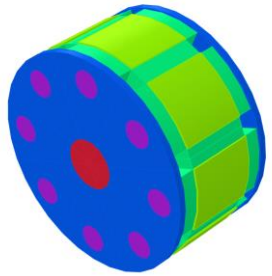
- The electromagnetic concept has been proven to work by the University of Sheffield

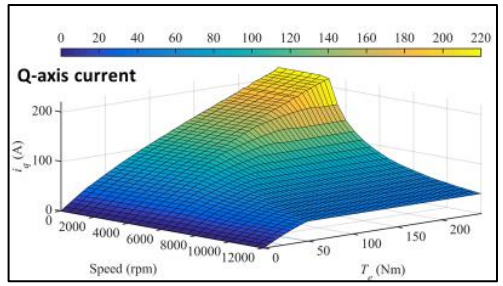
- The EDISON project aims to demonstrate a robust mechanical construction for an automotive application

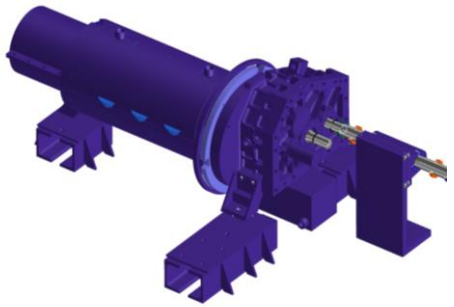
Project Aims – Next-generation Motor Technology

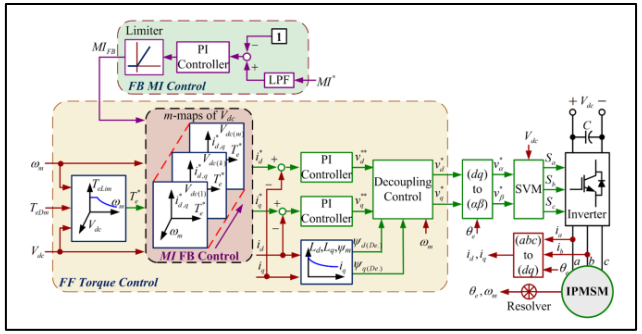
- To develop a novel ferrite magnet electric machine for a Jaguar Land Rover passenger vehicle specification
  - From concept selection to detailed design for prototyping
  - Build and test of the motor in isolation, *and* as part of an integrated electric drive unit
  - Demonstrating machine performance and NVH behaviour











Challenges in designing the prototype EDU

- Design trade-offs and objectives to achieve:
  - Packaging arrangement of the shafts and gears
  - Achieving the required ratio in the space available
  - Durability of the gears and bearings
  - Vibration response from the gears and motor
  - Avoiding rotor dynamics problems
  - Mount viability checks
  - NVH test planning

EDU Specification

Concept motor design and system design were carried out in parallel

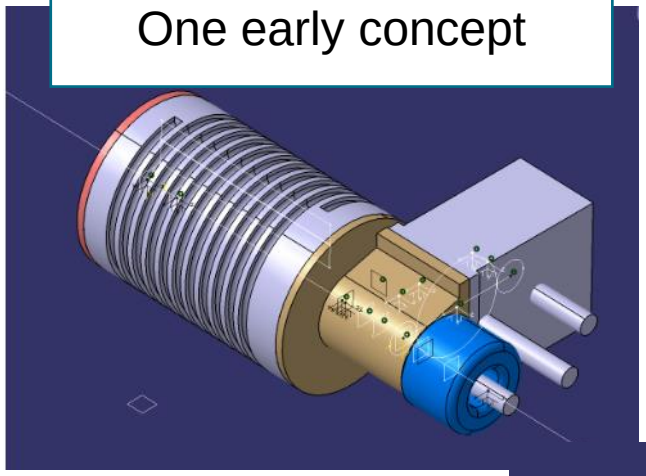
Motor designed for vehicle specification, including packaging space

- Motor packaging space provided by Jaguar Land Rover required a long, thin electric machine

Gearbox specification matches machine to dyno

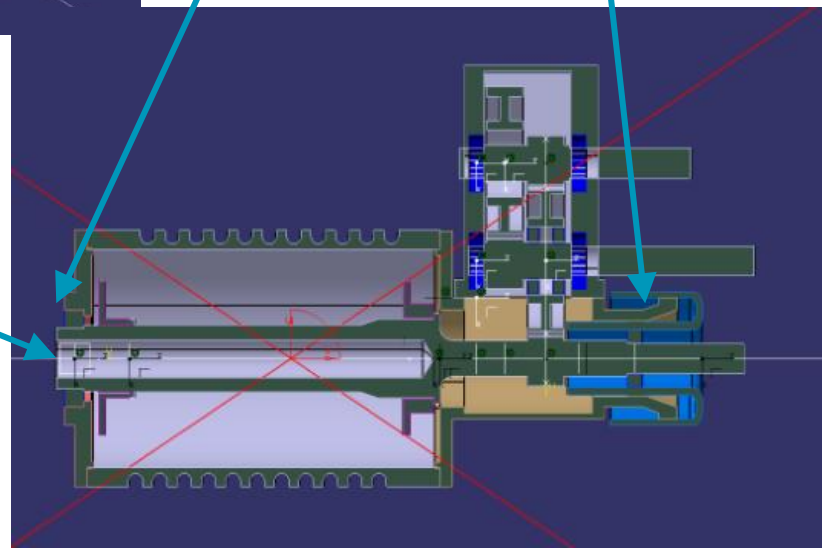
- Fitting the whole EDU to the dyno leads to a long rotor shaft

One early concept



Relatively large bearing span

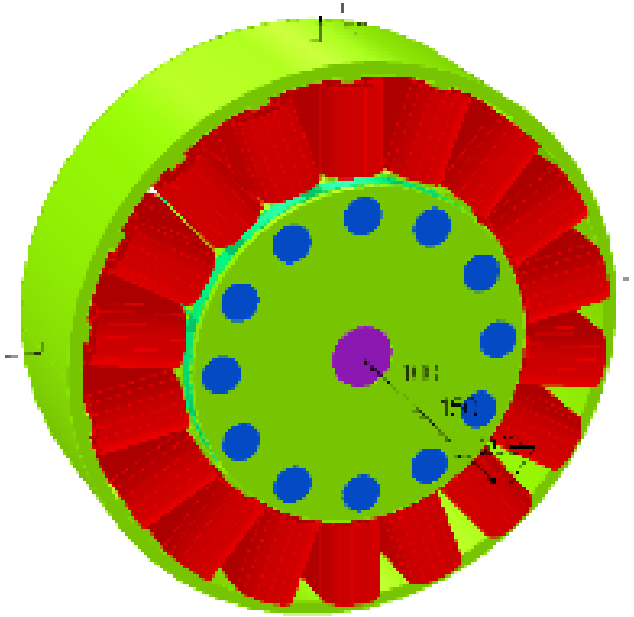
Long shaft

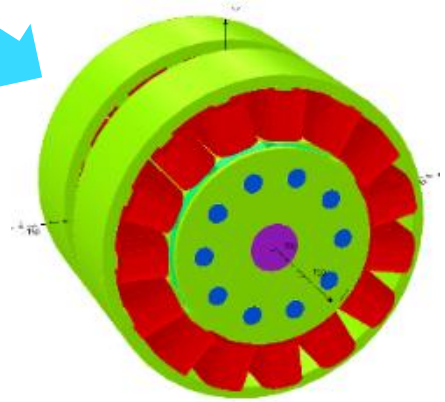


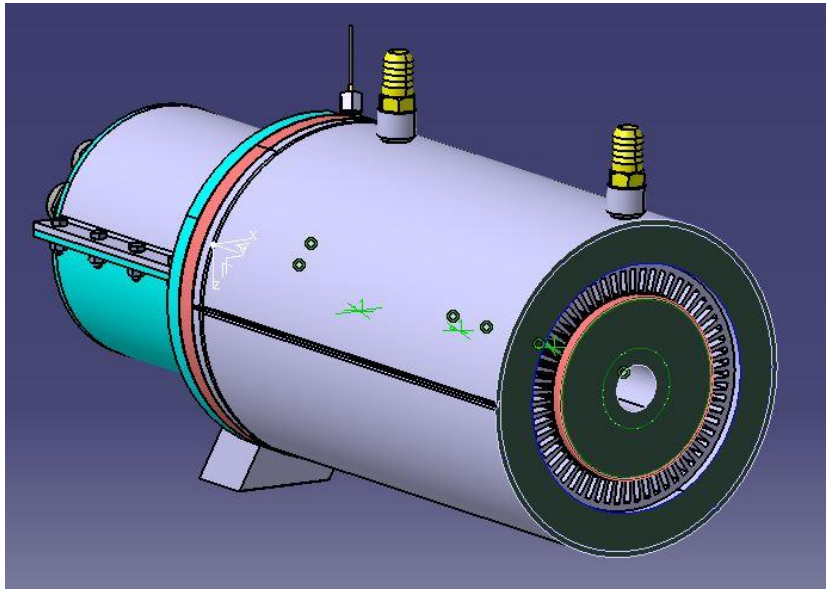
Modelling

Ferrite Machine Design

- The flux focusing concept requires a rotor with low aspect ratio (Length : Diameter)
- Axial stacking was investigated with a concept level model
- Packaging space constraints have been achieved by using three rotor stacks
- Detailed design work considering electromagnetic and mechanical aspects has been carried out in order to achieve a robust design solution

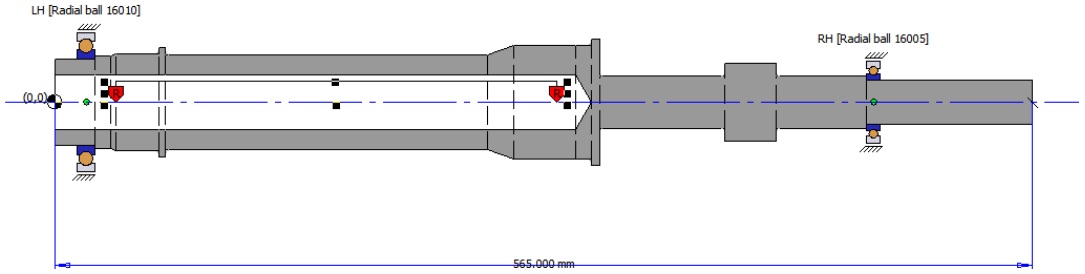


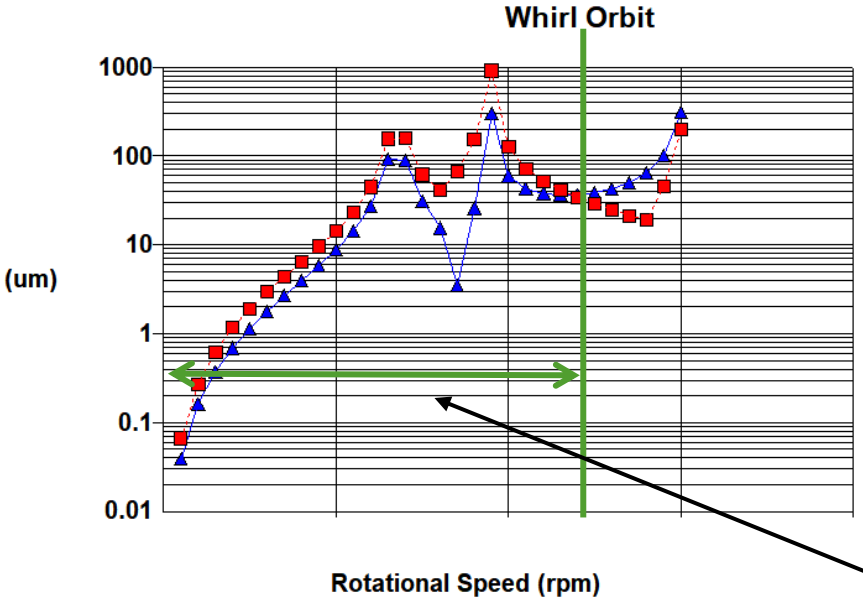




Assessing the concept for rotor dynamics issues

Large bearing span and long shaft make the setup potentially susceptible to rotor dynamics problems



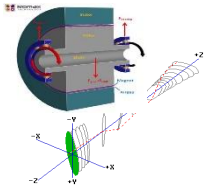


Speed range to test

Early concept of the rotor shaft and bearings

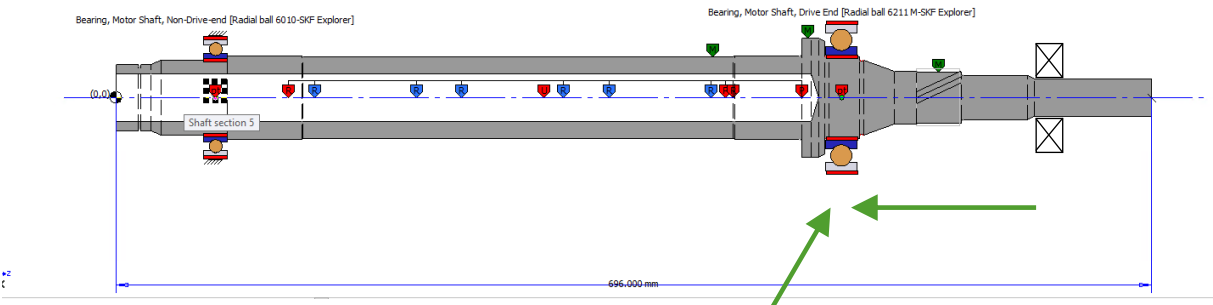
Dynamic analysis shows two whirl frequencies in speed range of interest for tests

What changes can we make to the concept to avoid shaft whirl during testing?



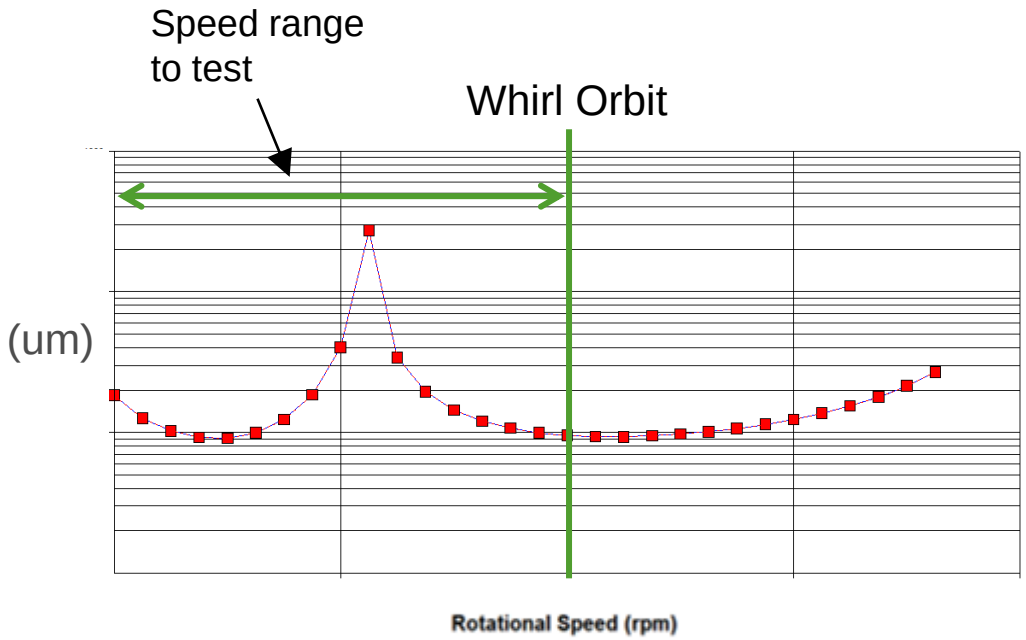
Shifting critical whirl speed – Bearing Position

Bearing and shaft changes can be made quickly in Evolve and system reanalysed



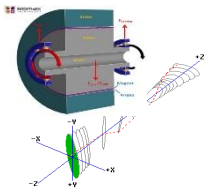
Shaft diameter increased
Larger bearing used

Bearing span shortened

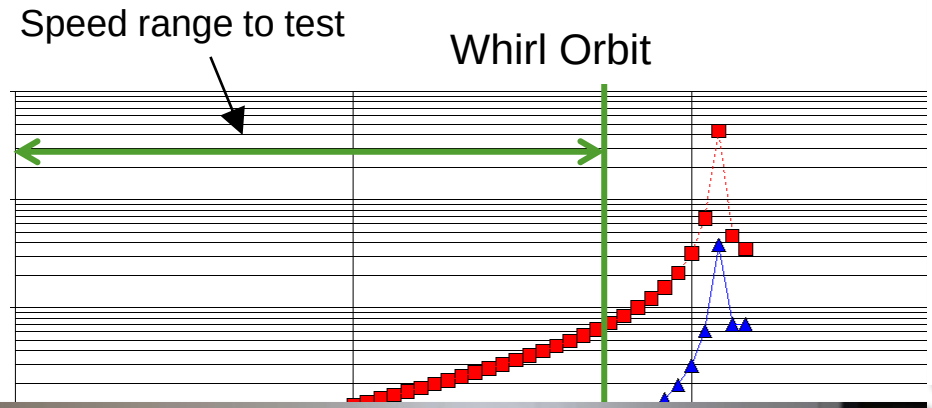


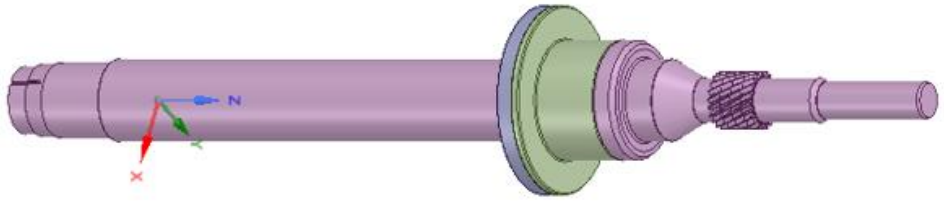
Changes have removed one of the whirl frequencies

However, a critical speed still exists within machine operating range



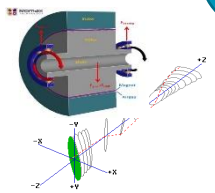
Shifting critical whirl speed – Bearing Preload





operating range

Identify potential rotor-dynamic issues easily, and validate design changes quickly



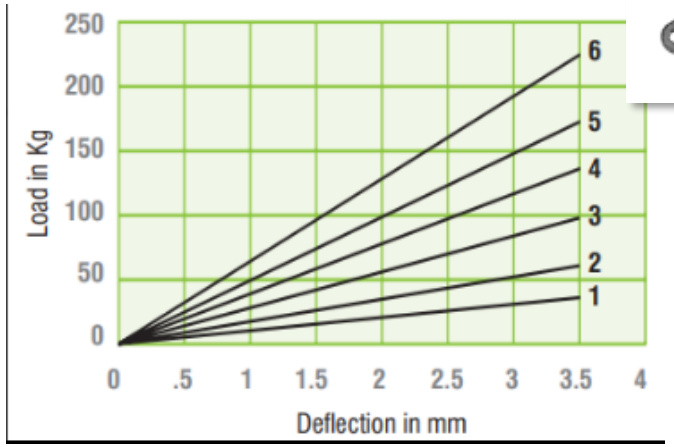
Test rig due diligence – mount isolation study

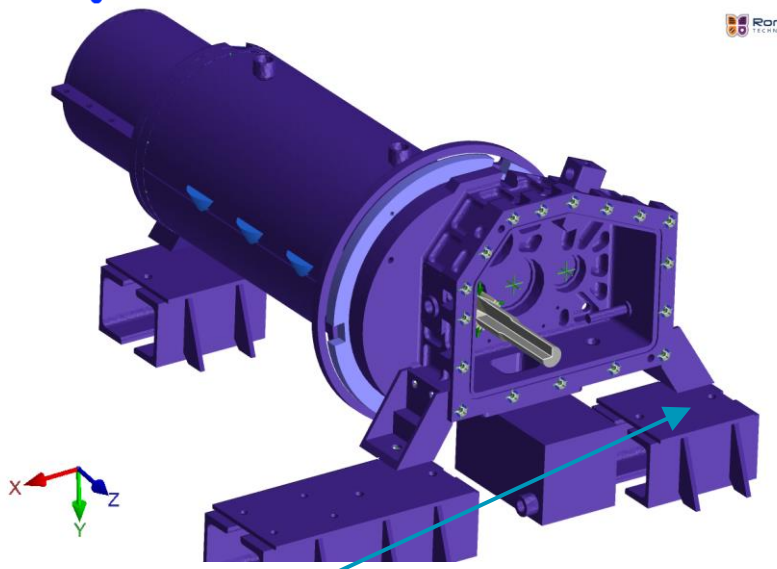
Test-rig mountings recommended by supplier based on static loads

Static analysis enables assessment of system deflection under own weight and torque

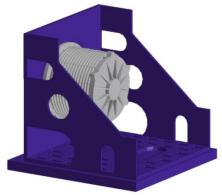
Test rig system design – validate suitability of mounting arrangements

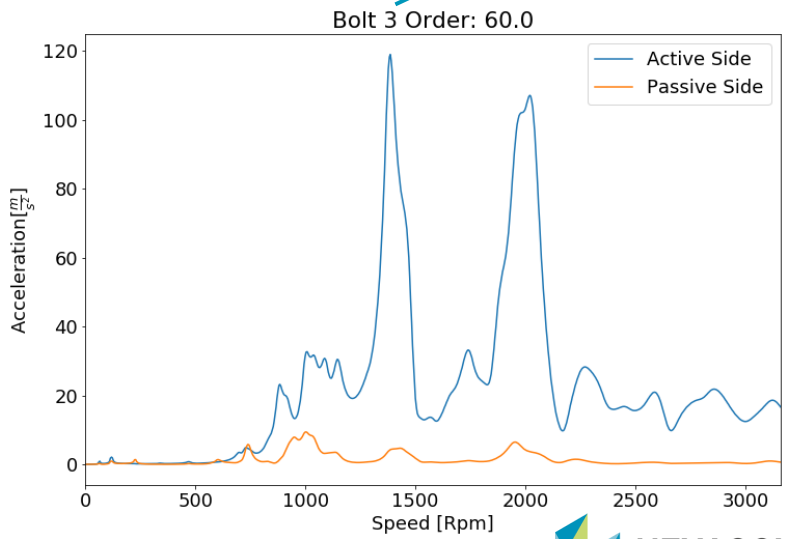
Mount Stiffness Characteristics





Dynamic analysis needed to validate satisfactory insolation from the rest of the test rig





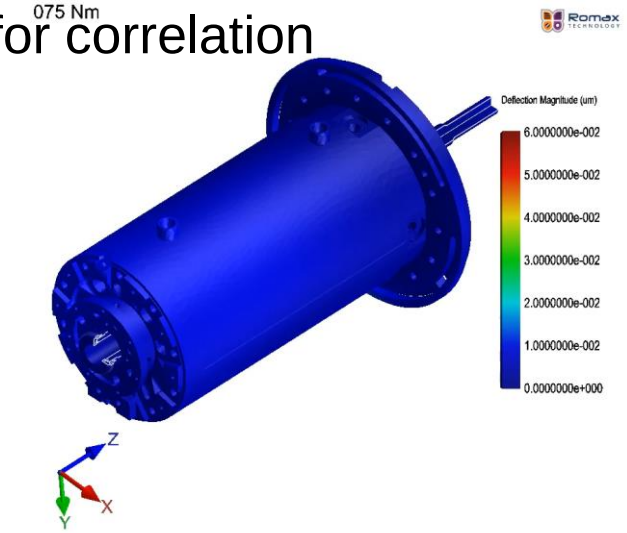
System Analysis

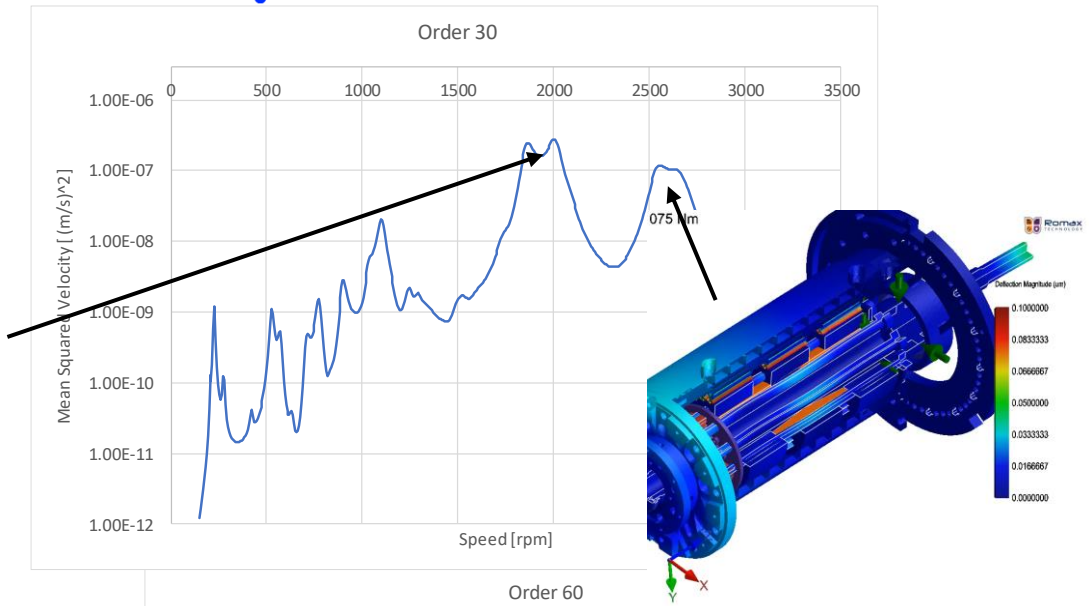
Test planning

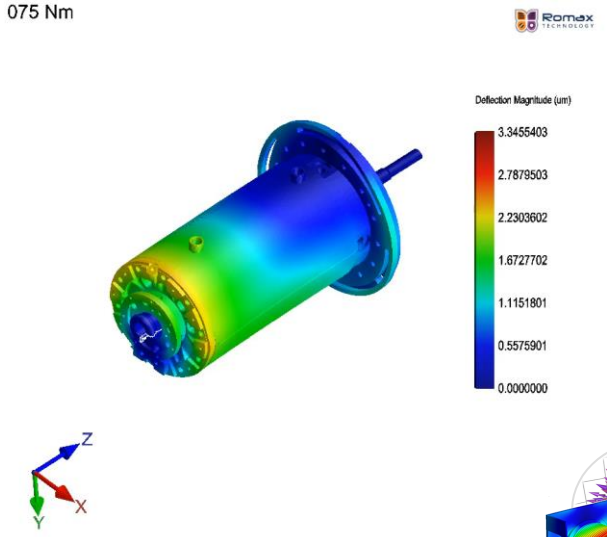
Locating accelerometers for correlation

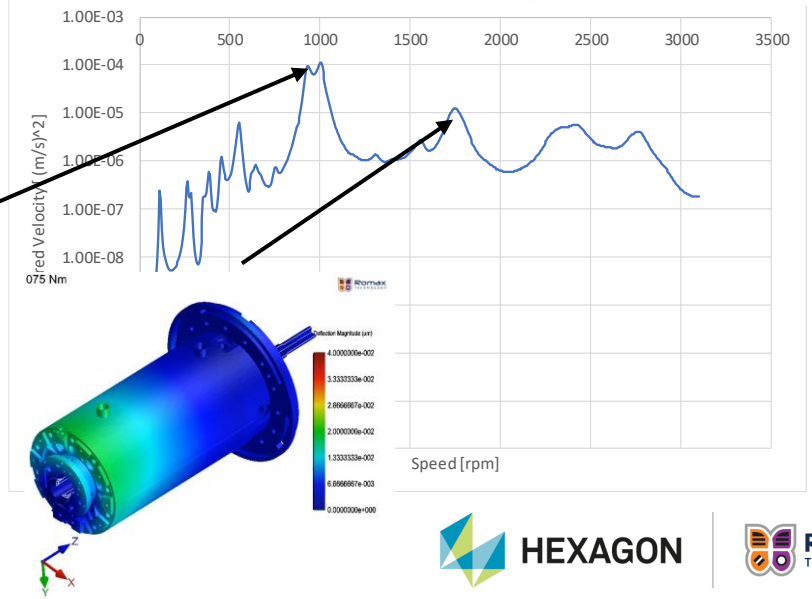
Make best use of lab availability – use CAE to predict where to locate a limited number of sensors on the test rig

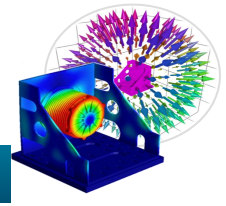
Test planning – how can we make the most of our testing?









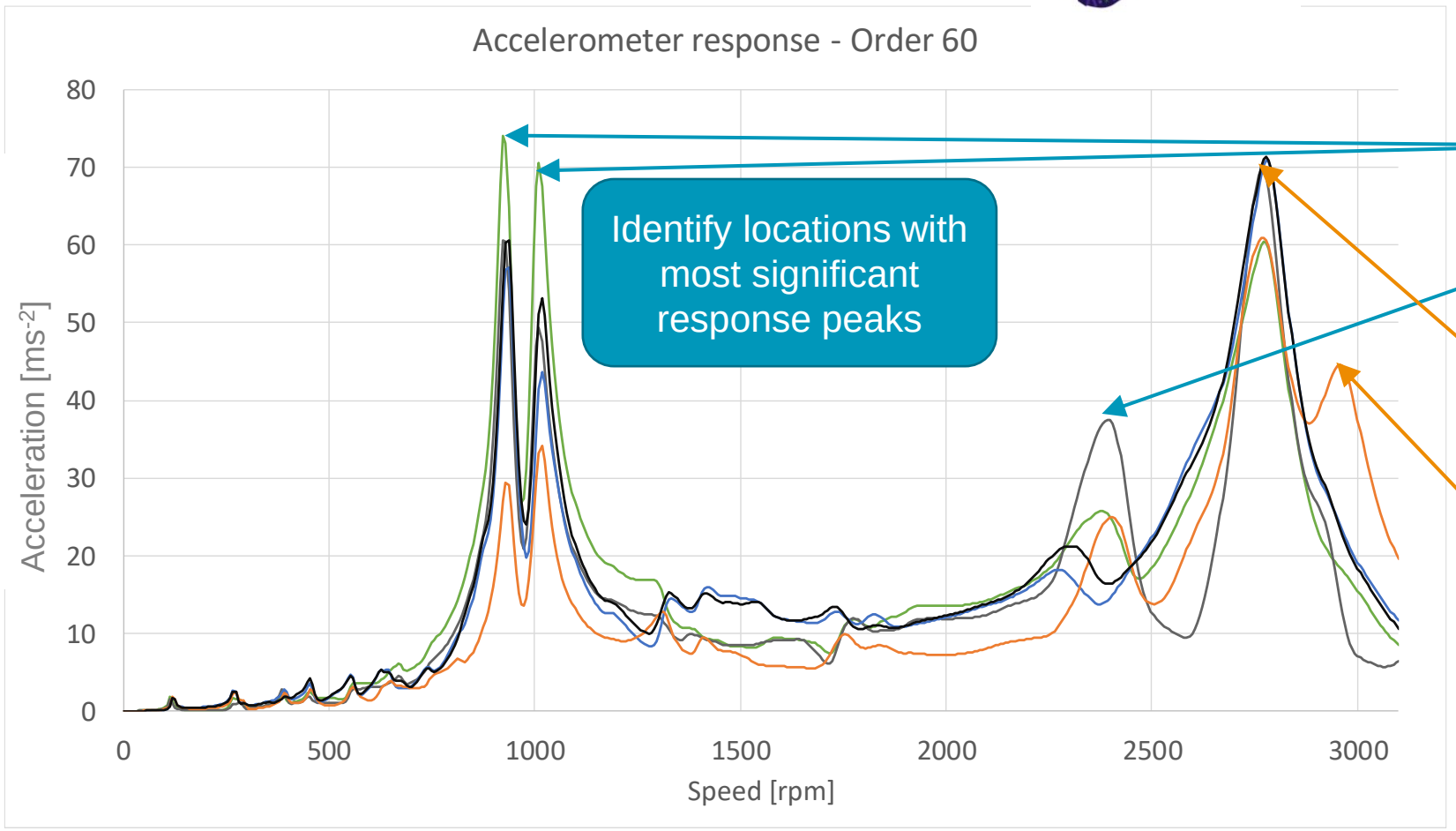


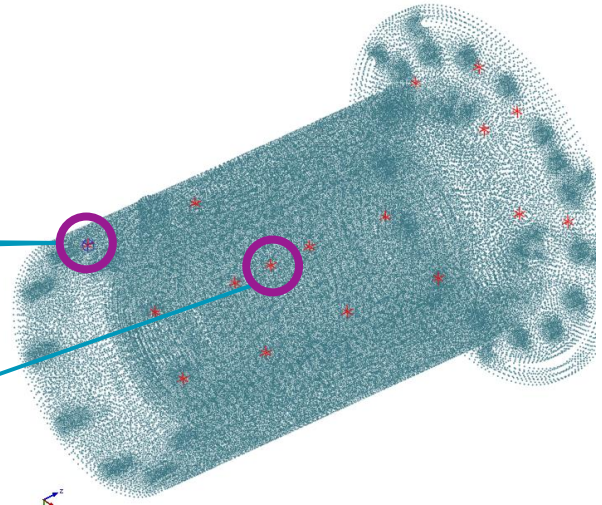
NVH

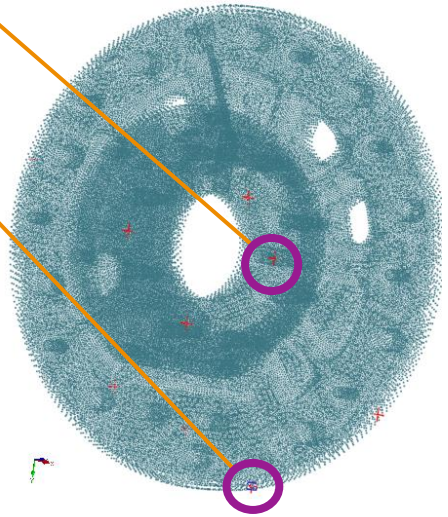
Accelerometer position selection

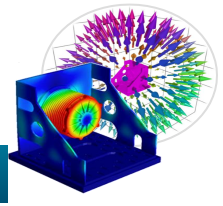
Romax evolve

EDISON



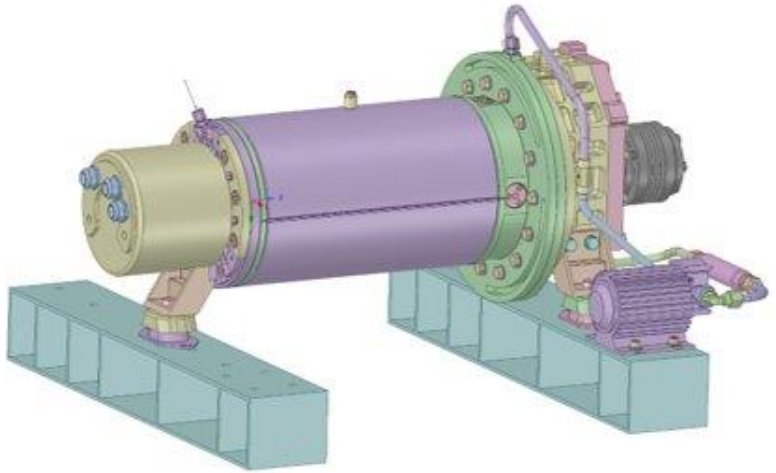






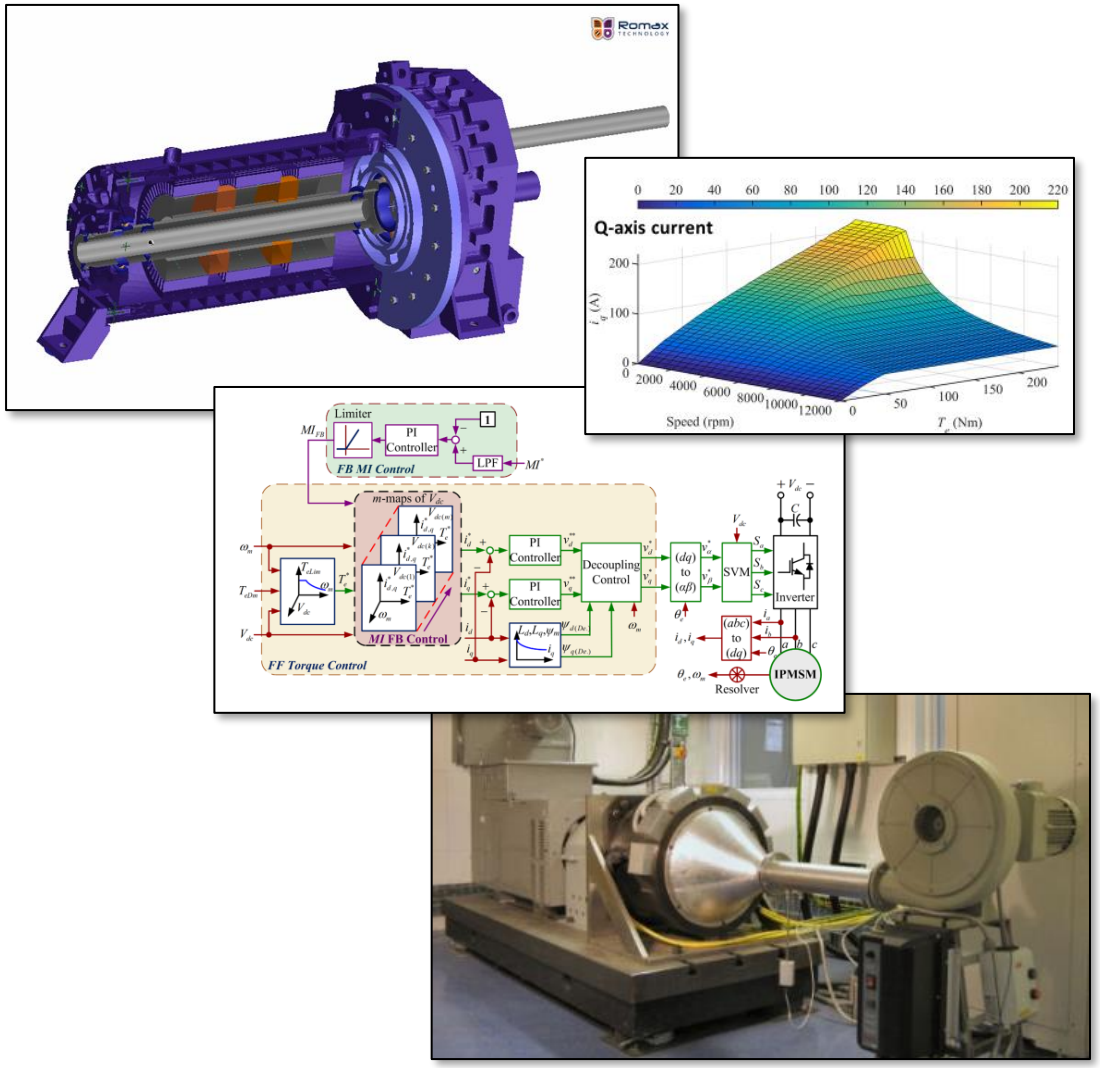
Design Evaluation Summary

- Romax Evolve was used to evaluate and guide design process
- Analysis used helped identify rotor dynamics issues and determine preload required to avoid critical speed from falling in the machine operating range
- Romax Evolve helped confirm that mounts will sufficiently provide sufficient support and vibration isolation
- NVH analysis helped guide the positioning of accelerometers for correlation study



EDISON next steps

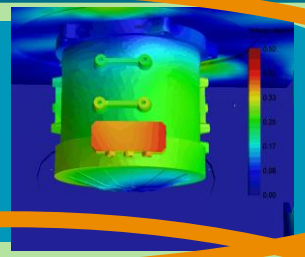
- Demonstrate performance of ferrite motor
- Measure NVH from the integrated electric drive unit
- Correlation of NVH test with analysis



Tools for EV powertrain NVH analysis

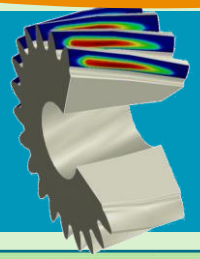
eMotor development team

Romax evolve



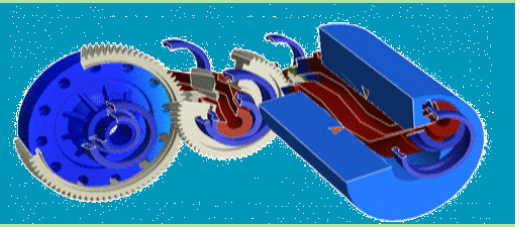
Gearbox development team

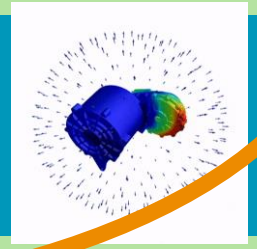
Romax spectrum



ePowertrain system team

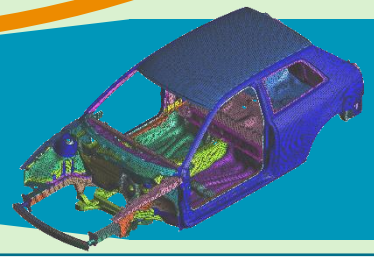
Romax spectrum





Vehicle NVH team

Na



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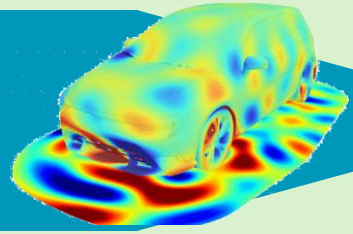

Component & Subsystem

System

Vehicle

EDISON

Any Questions?

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