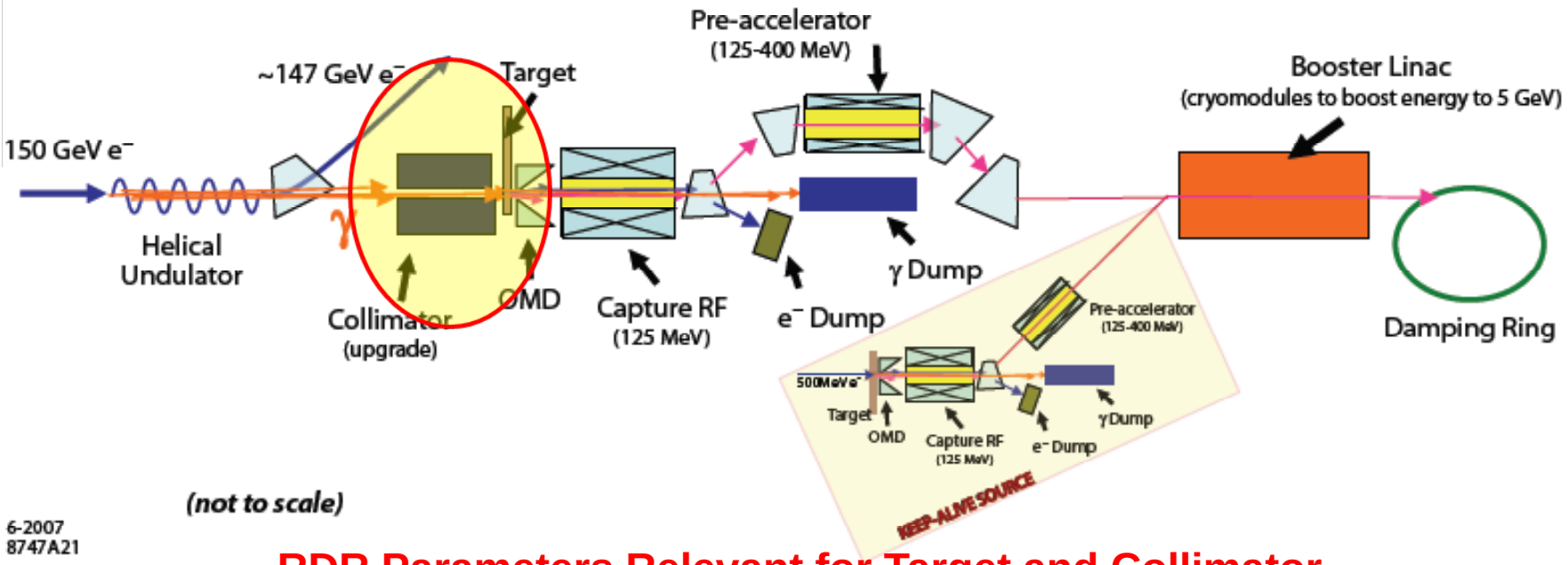
The Cockcroft Institute
of Accelerator Science and Technology

Baseline Target Prototype Status

Ian Bailey

Lancaster University / Cockcroft Institute

PPS Schematic - ILC RDR

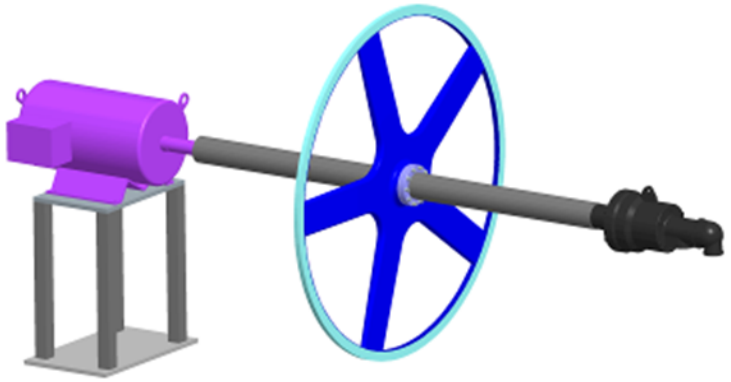


RDR Parameters Relevant for Target and Collimator

- Centre of undulator to target: 500m
- Active (K=0.92, period=1.21mm) undulator length: 147m
  - Photon beam power: 131kW (~doubled if QWT adopted)
  - First harmonic: 10MeV
  - Beam spot: >1.7 mm rms

RDR Target Design

- **Wheel rim speed (100m/s) fixed by thermal load (~8% of photon beam power)**
- **Rotation reduces pulse energy density (averaged over beam spot) from ~900 J/g to ~24 J/g**
- **Cooled by internal water-cooling channel**
- **Wheel diameter (~1m) fixed by radiation damage and capture optics**
- **Materials fixed by thermal and mechanical properties and pair-production cross-section (Ti6%Al4%V)**
- **Wheel geometry (~30mm radial width) constrained by eddy currents.**
- **20cm between target and rf cavity.**
- **Axial thickness ~0.4 radiation lengths.**



T. Piggott, LLNL

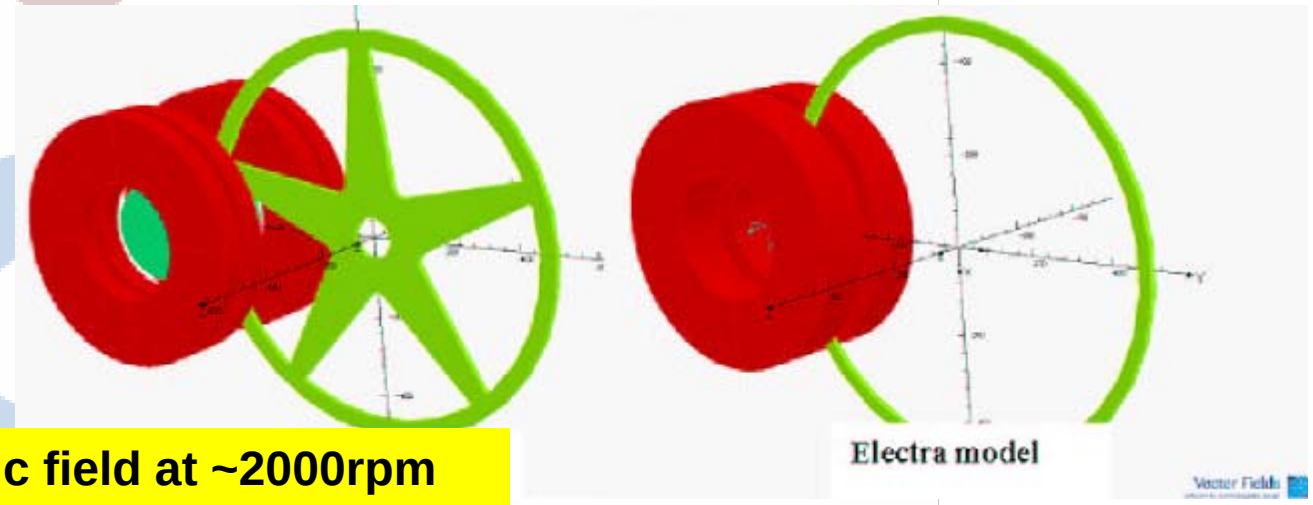
Drive motor and water union are mounted on opposite ends of through-shaft.

Target Actions from Zeuthen Meeting (2008)

- Complete Eddy current tests at Daresbury – Ian/Leo Nov 08 (store properly afterwards!) Data-taking ongoing (see this talk)
- Generate simulations to compare with experimental results – Jeff / RAL? Nov 08 Simulations started at both LLNL (C. Brown) and RAL (J. Rochford).
- Guarding thickness verification – Tom (now) Prototype guarding in place.
- Pressure shock wave analysis – Stefan (next meeting) and numerical modelling – Tom (later)
- Ensure consistency between ANL/DESY simulations – Wei/Andriy (next meeting)
  - Energy compression before DR
- Lifetime studies of target (LLNL)
- Engineered solution, including prototype tests – water, vacuum, …
- Alternative liquid metal (BINP/KEK tests) – Junji
- Where are ferrofluidic seals used – Ian (next meeting)

Target Wheel Eddy Current Simulations

Immersed target ⇒ up to a factor 2.5 increase in capture efficiency c.f. QWT

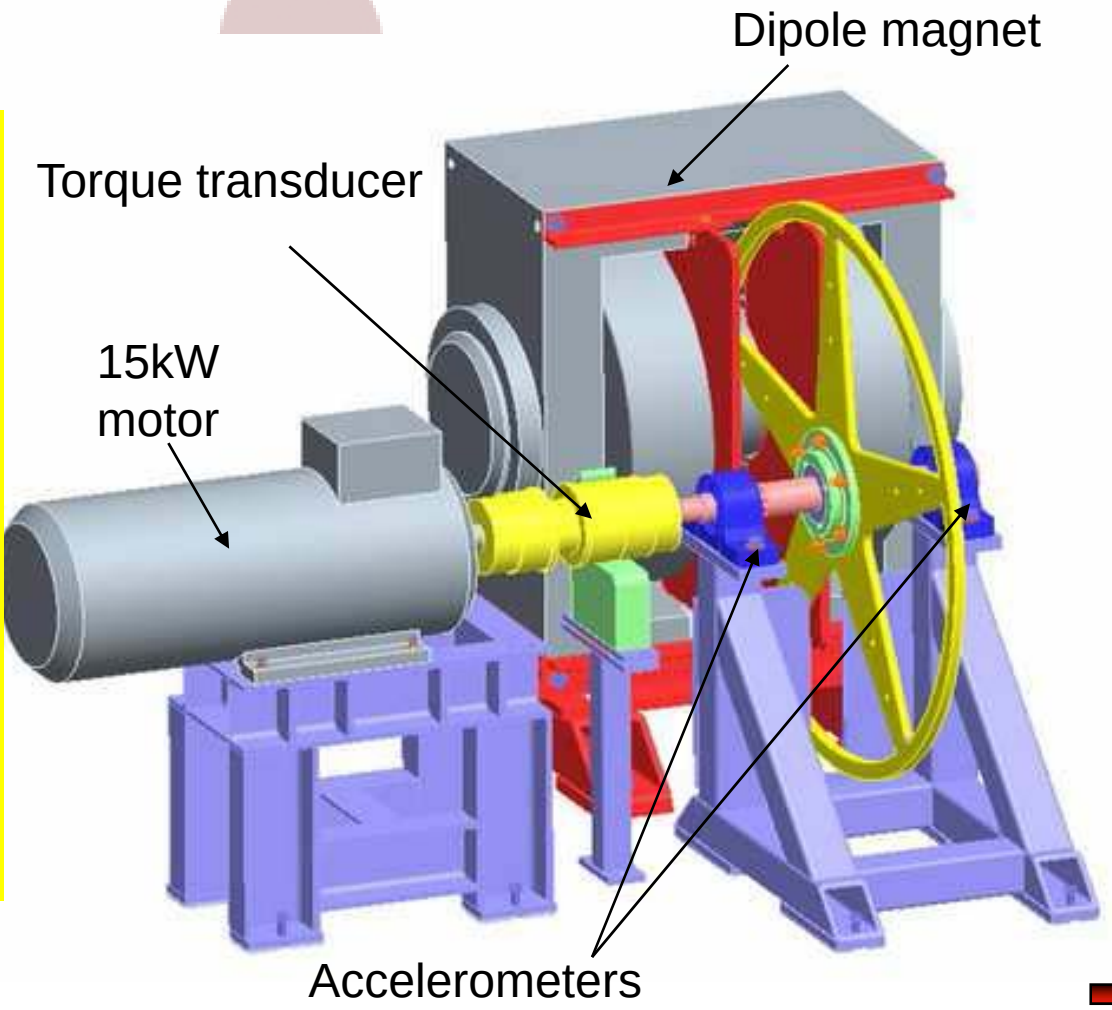


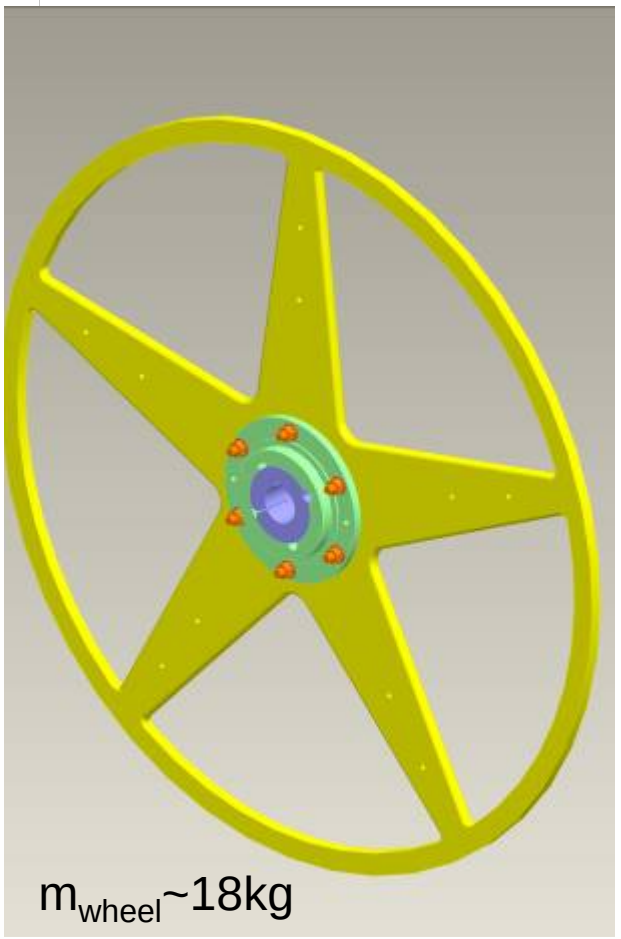
- **For 1T static field at ~2000rpm**
  - **RAL predicts ~6.6kW**
  - **ANL predicts ~9.5kW**
    - **S. Antipov PAC07 proceedings**
  - **LLNL predicts ~15kW?**

⇒ Alternative capture optics, alternative materials, prototyping

Target Prototype Design

Prototype I - eddy current and mechanical stability





Target Prototype with Local Guarding Support Structure

Ken Davies - Daresbury Laboratory

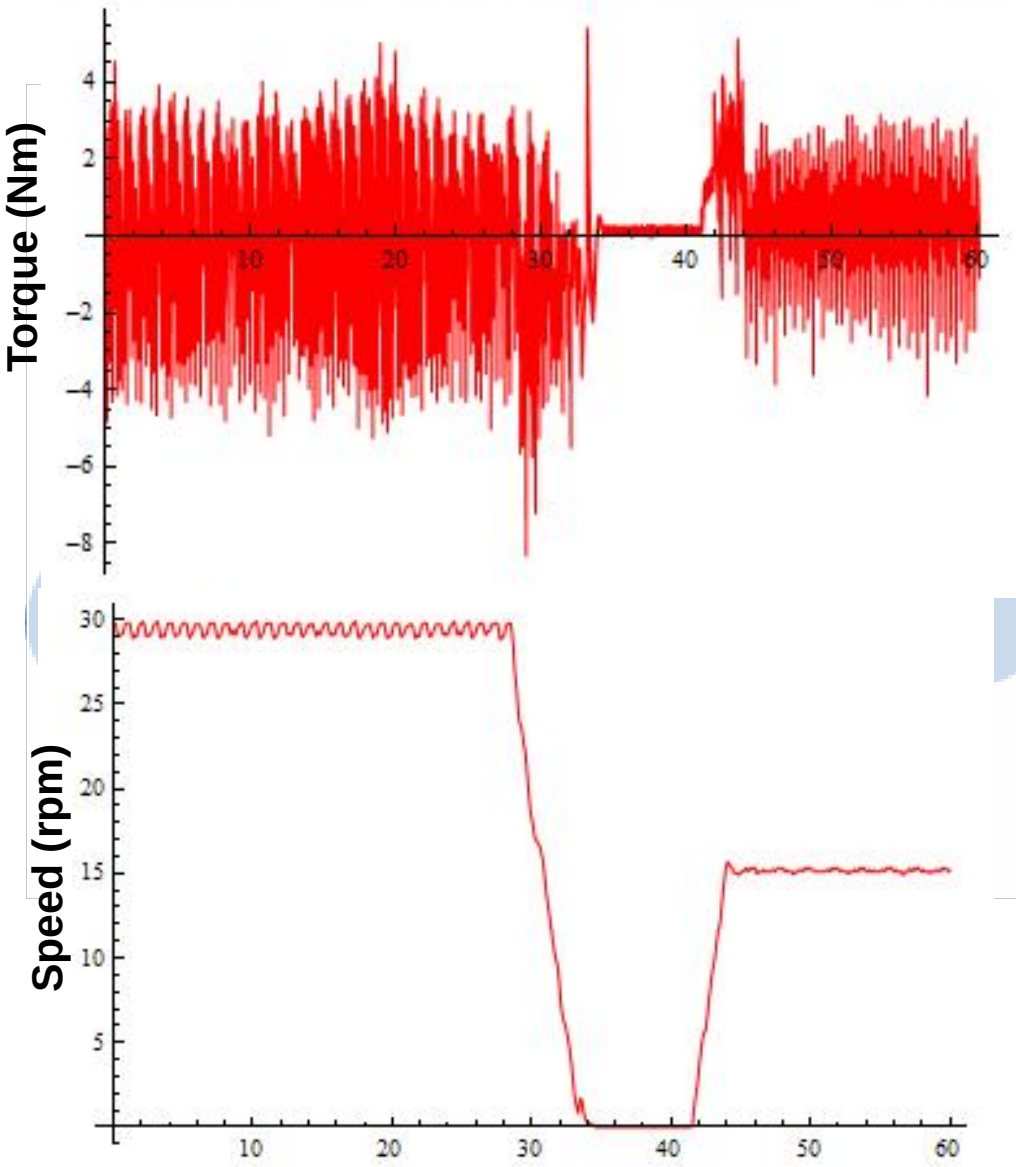
Wheel design supported by rotordynamic and fatigue calculations from LLNL. Cross-checks carried out at RAL.

Guarding design (5mm st steel) supported by FEA studies at LLNL and analytical studies at the CI.

Target Prototype Status

- Experimental area at DL allocated and caged (Summer 2007)
- Services rerouted (water and electricity)
- Magnet and support structure installed
  - model 3474-140 GMW water-cooled electromagnet
  - variable pole gap (0mm to 160mm)
  - variable target immersion (~70mm)
- Drive motor (15kW) installed
- Ti alloy wheel manufactured and installed
  - Also possible Al wheel (grade 5083).
- DAQ design finalised
  - Accelerometers installed and interlock fitted.
  - Torque transducer installed.
  - Thermal cameras awaiting installation
  - Hall probes available
- Cooling system implemented.
- Local guarding installed Sep 08.
- Data-taking underway.

Initial Torque Data (no magnetic field)

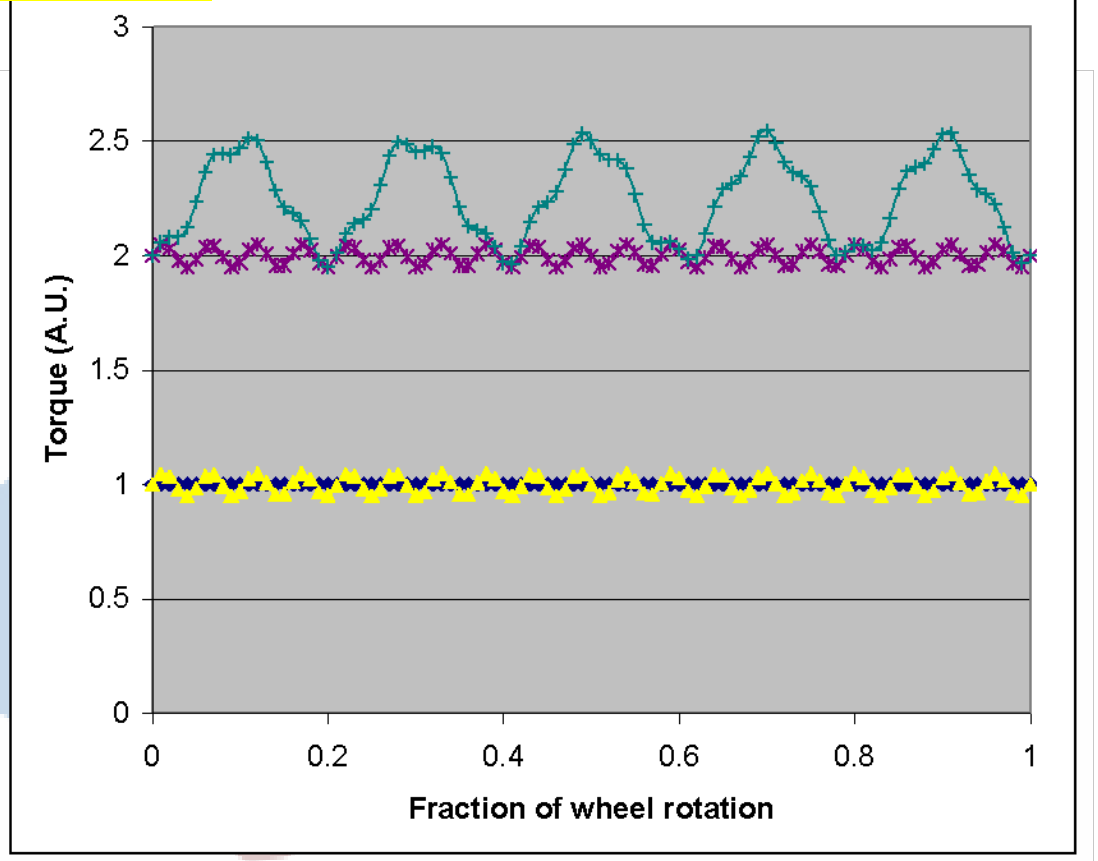


The upper figure shows the measured torque (Nm) as a function of time (s) . The lower figure shows the measured speed over the same period of time.

The torque is sampled at a rate of 2.4kHz. The speed is sampled at a rate of 0.6kHz.

Understanding the Torque Data

Toy model



Without magnetic field expect average torque given by dark blue line.

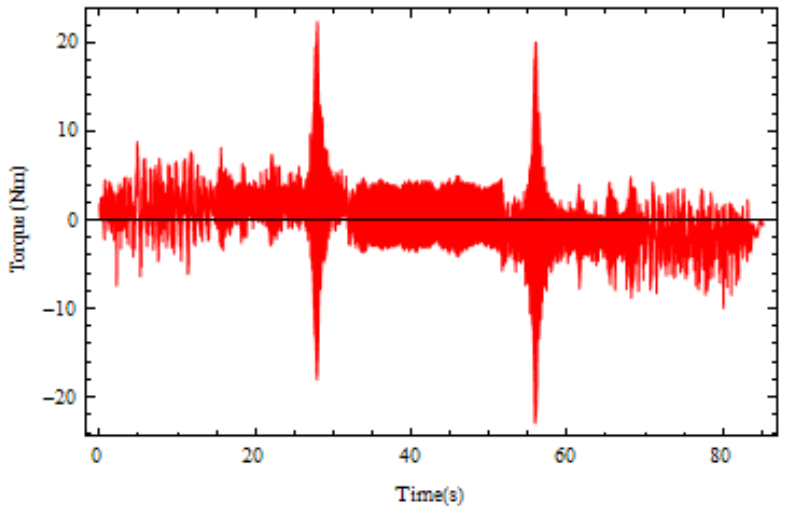
Motor controller and structure of motor coils, bearings, etc add oscillations (yellow line)

Magnetic field causes eddy currents to flow in rim (purple line)

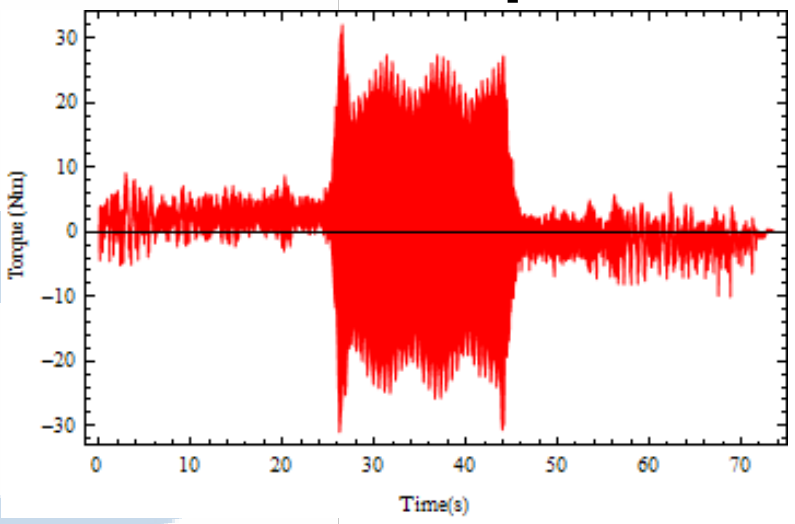
Additionally, eddy currents can flow in spokes when they are close to the magnet poles (light blue line).

Resonances

198 rpm



174 rpm



Left figure: wheel accelerated past 198 rpm and then decelerated.

Right figure: wheel accelerated to 174 rpm and then decelerated.

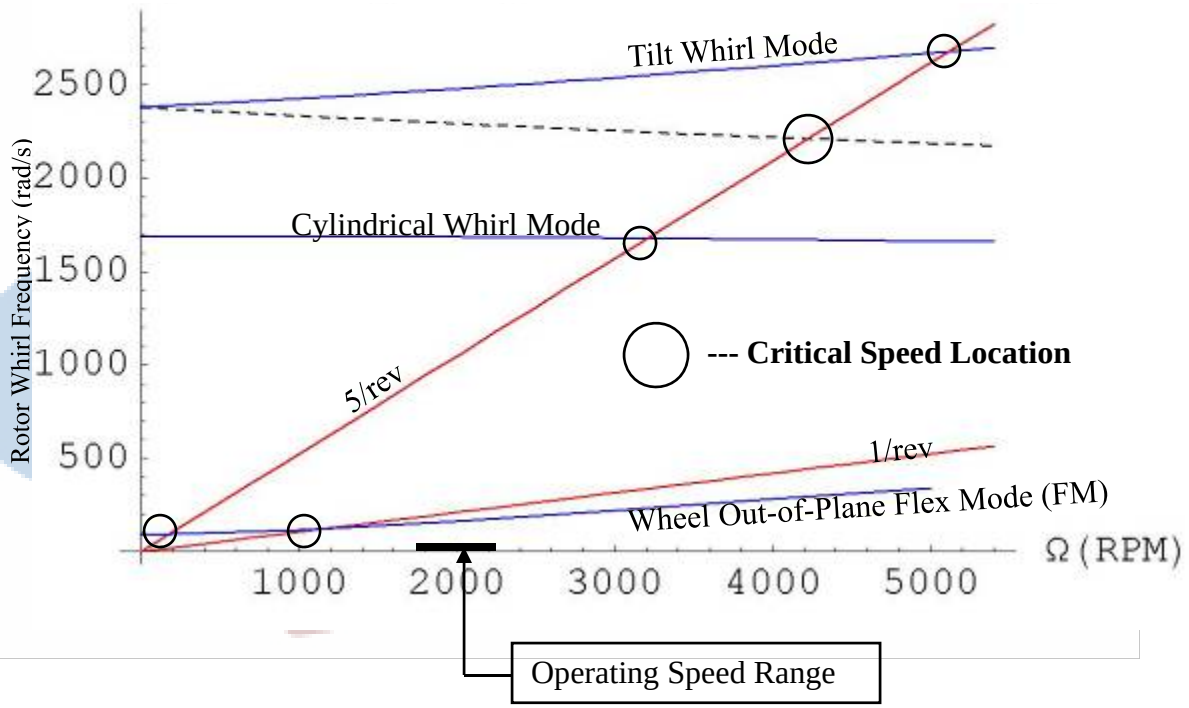
Resonances correspond to mechanical excitations of the wheel assembly.

Predicted Critical Speeds

Nominal Design Basis Bearing + Mount Stiffnesses

Support Translational Stiffness = 1,000,000 lbf/in Support Rotational Stiffness = 10,000 lbf*in/rad

Campbell Diagram



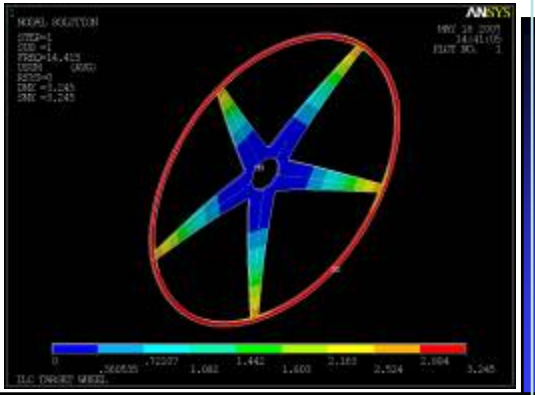
Sources of Rotor Excitation

- Lorentz Force @ 5/rev
- Unbalance @ 1/rev

Major Critical Speeds

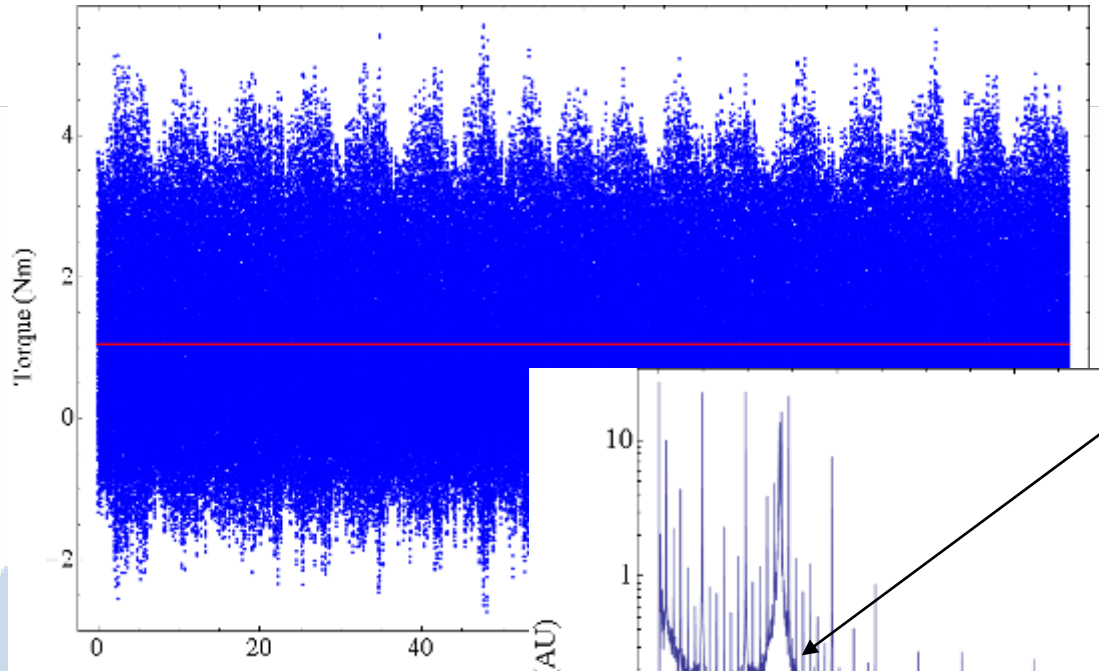
- 1st Wheel FM @ ~ 200 RPM
- 2nd Wheel FM @ ~ 1100 RPM
- Cylindrical Whirl @ ~ 3200 RPM
- Forward Tilt Whirl @ ~ 5000 RPM
- Reverse Tilt Whirl @ ~ 4200 RPM

Wheel Out-of-Plane Flex Mode

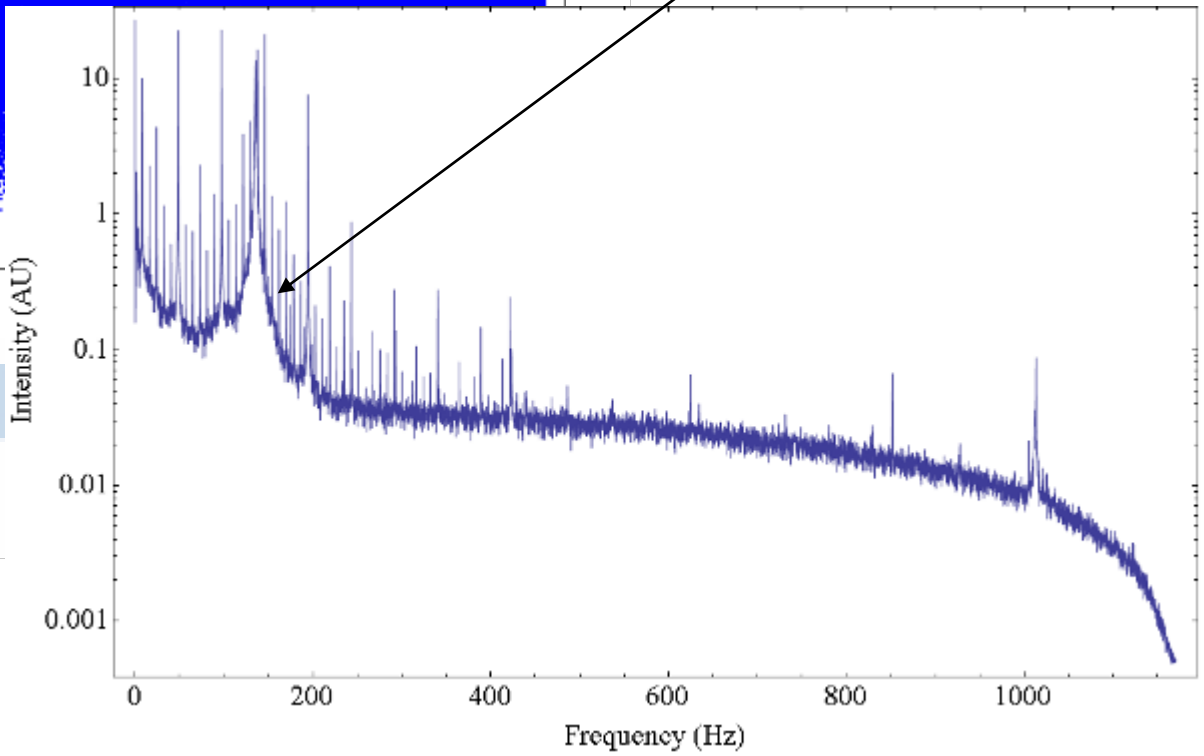


Lisle Hagler - LLNL

Torque Fourier Spectra

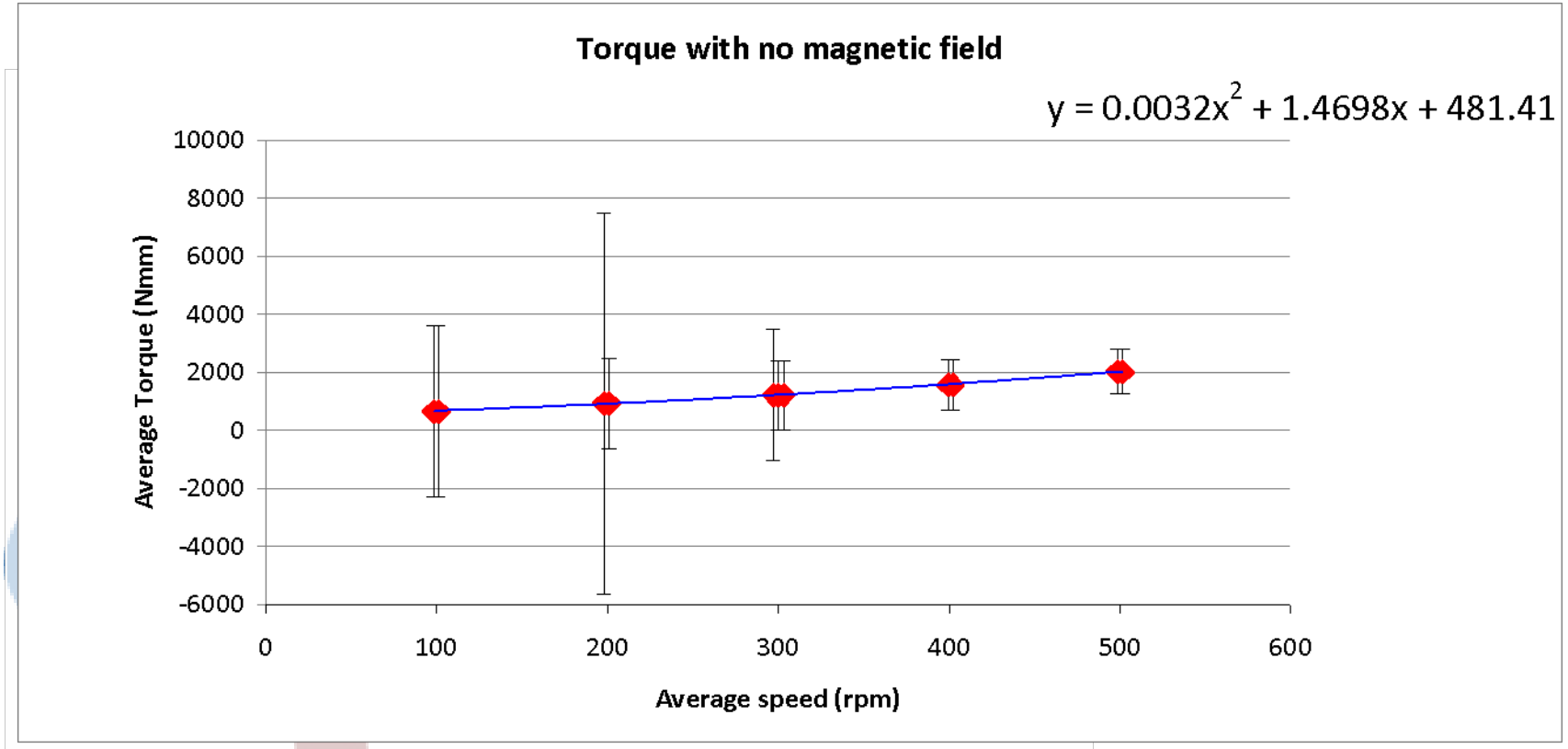


Origin of peak at ~135Hz not yet understood.



Duncan Scott - DL

Characterising Frictional Forces

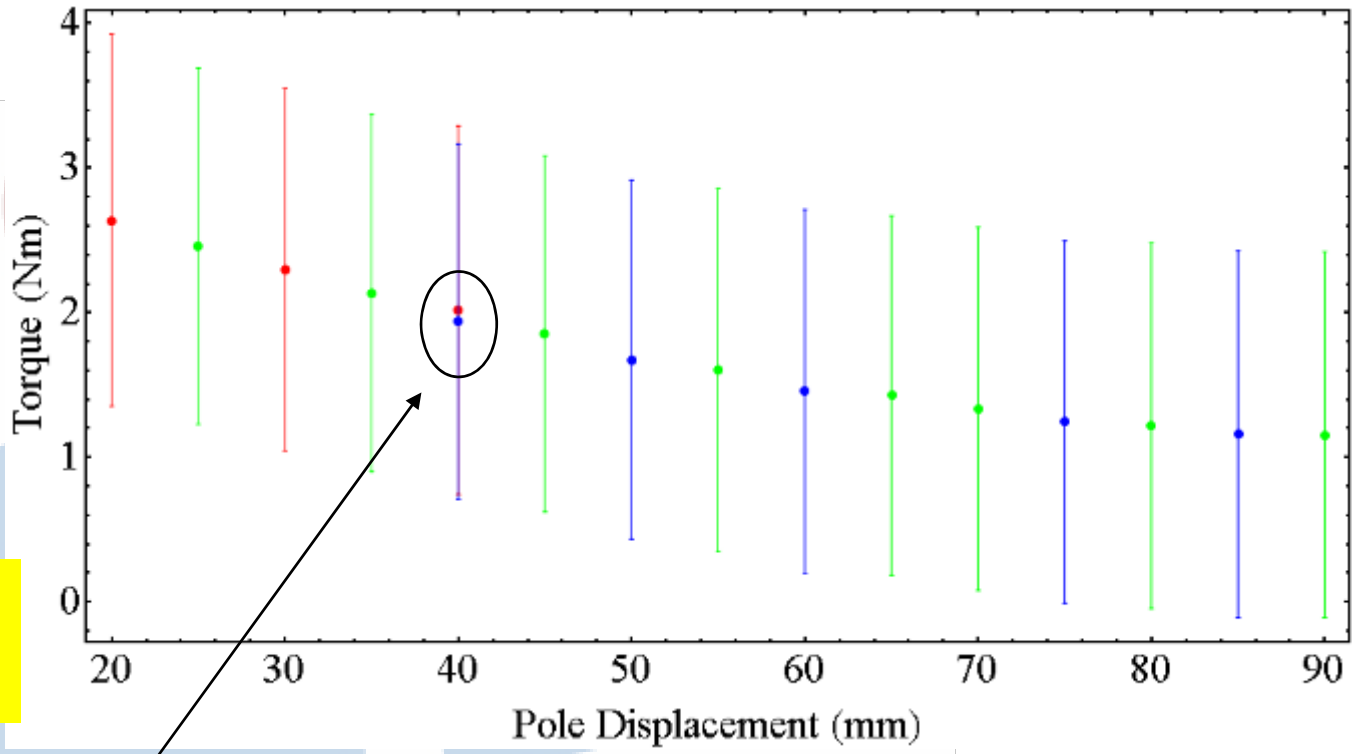


Wheel has not yet been operated above 500 rpm

In this regime friction shows approximately linear increase with velocity

Extrapolates to ~3Nm at 2000rpm, but behaviour may change at higher velocity.

Characterising Frictional Forces (2)



250 rpm

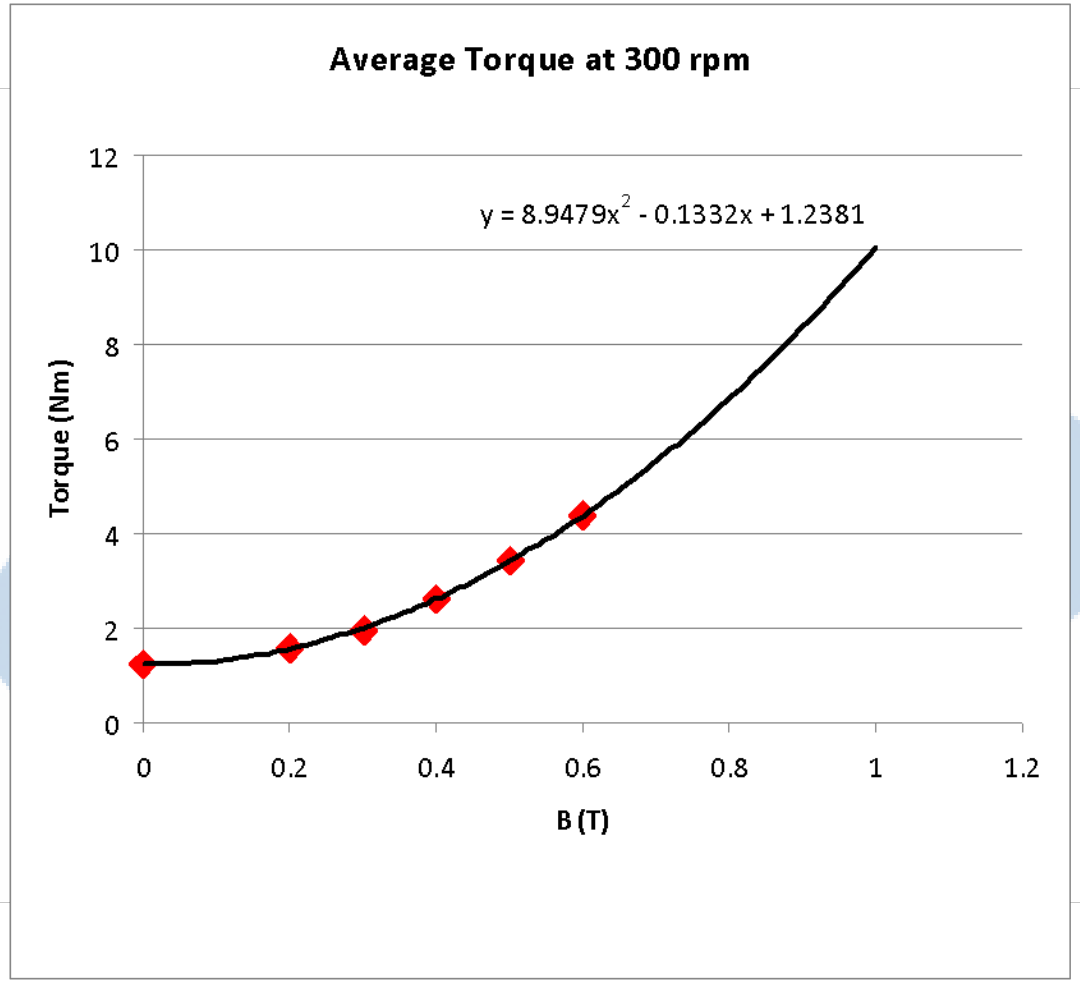
0.485T

Immersion depth of wheel in magnetic field is varied from 40mm to 20mm, 20mm to 90mm and 90mm to 40mm.

Data sets at 40mm immersion show disagreement.

Interpretation: heating effects in bearing cause friction to alter with time…

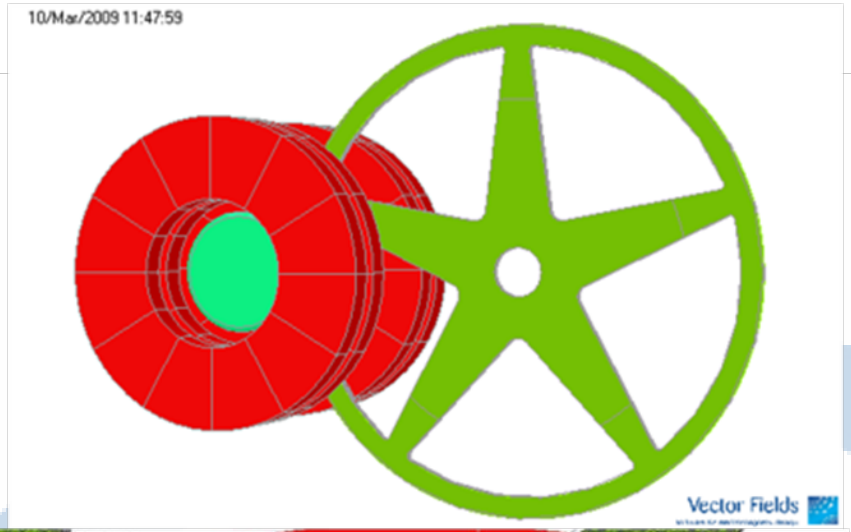
B Dependence of Torque

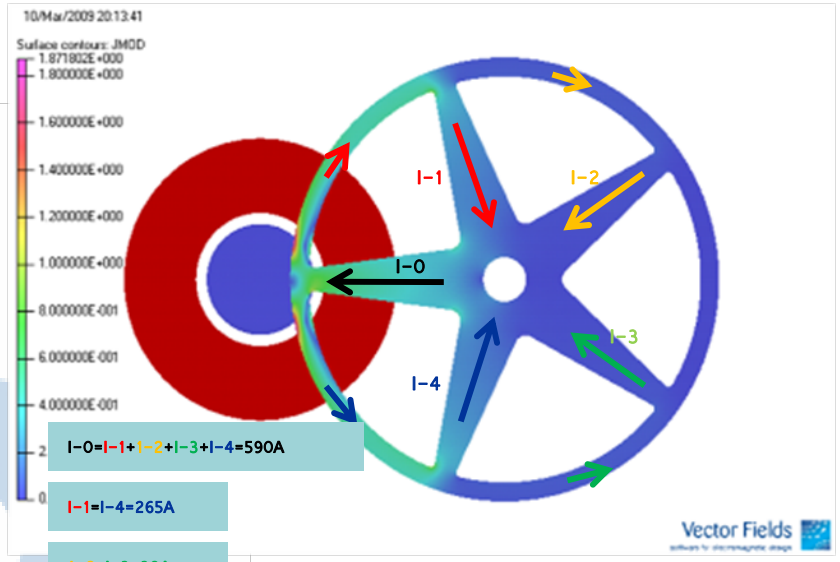


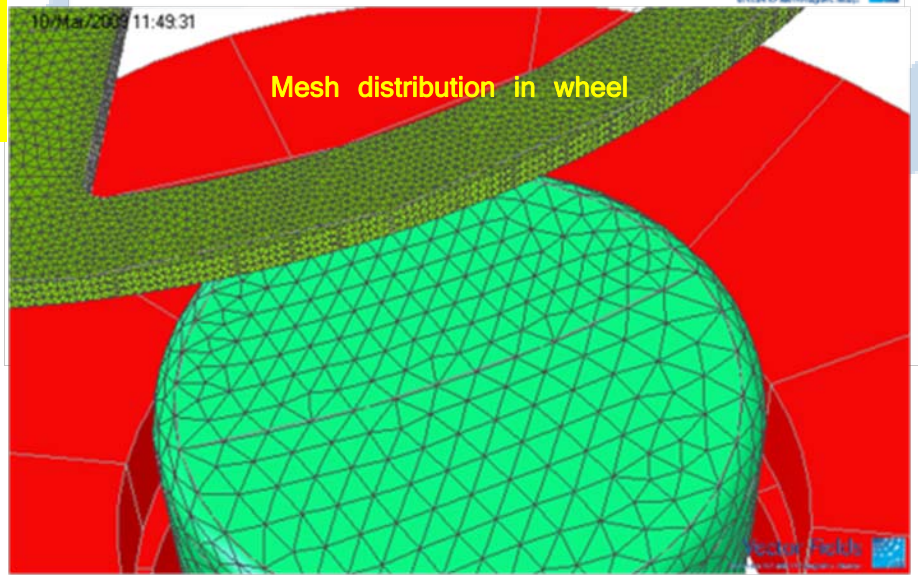
Black line shows extrapolation from data using quadratic fit.

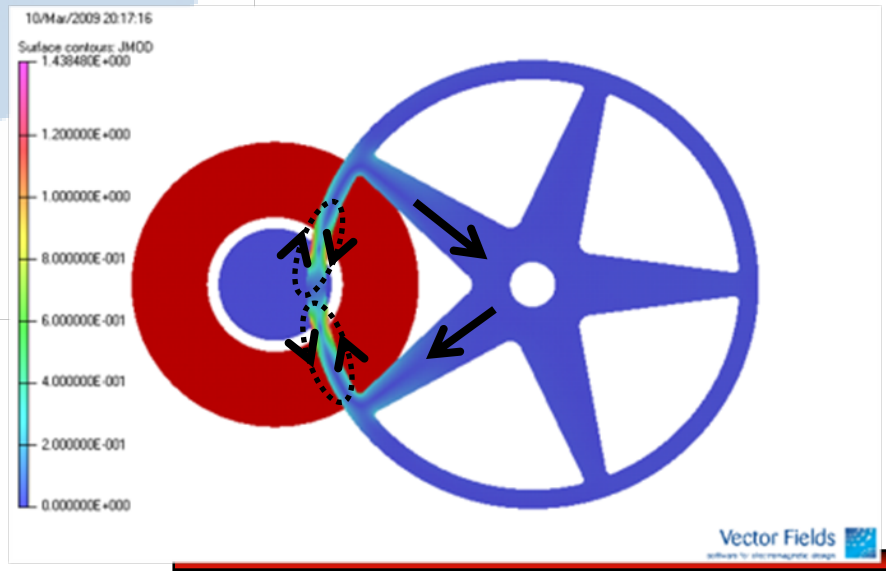
Carmen (spoke) Model

J. Rochford, RAL

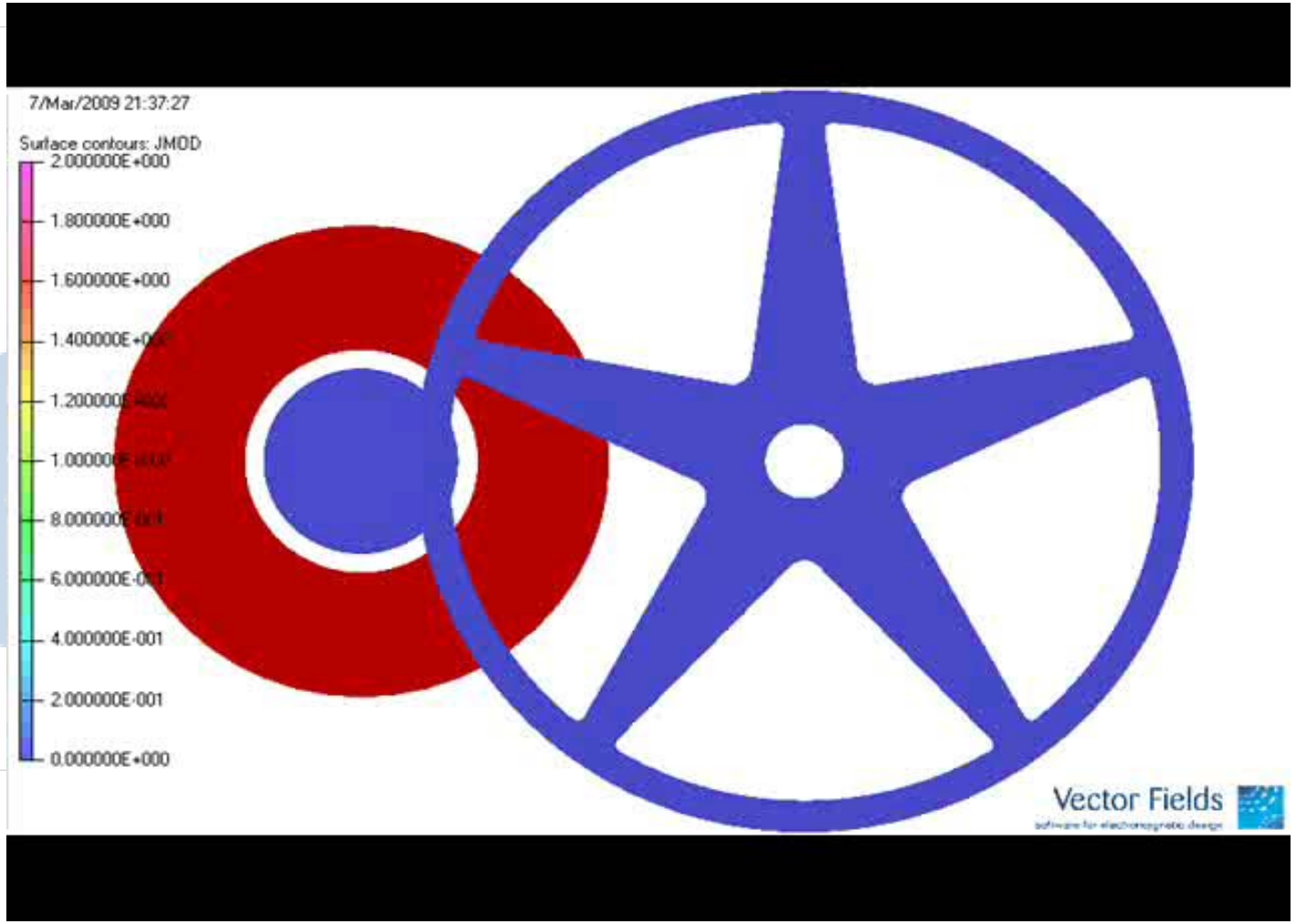






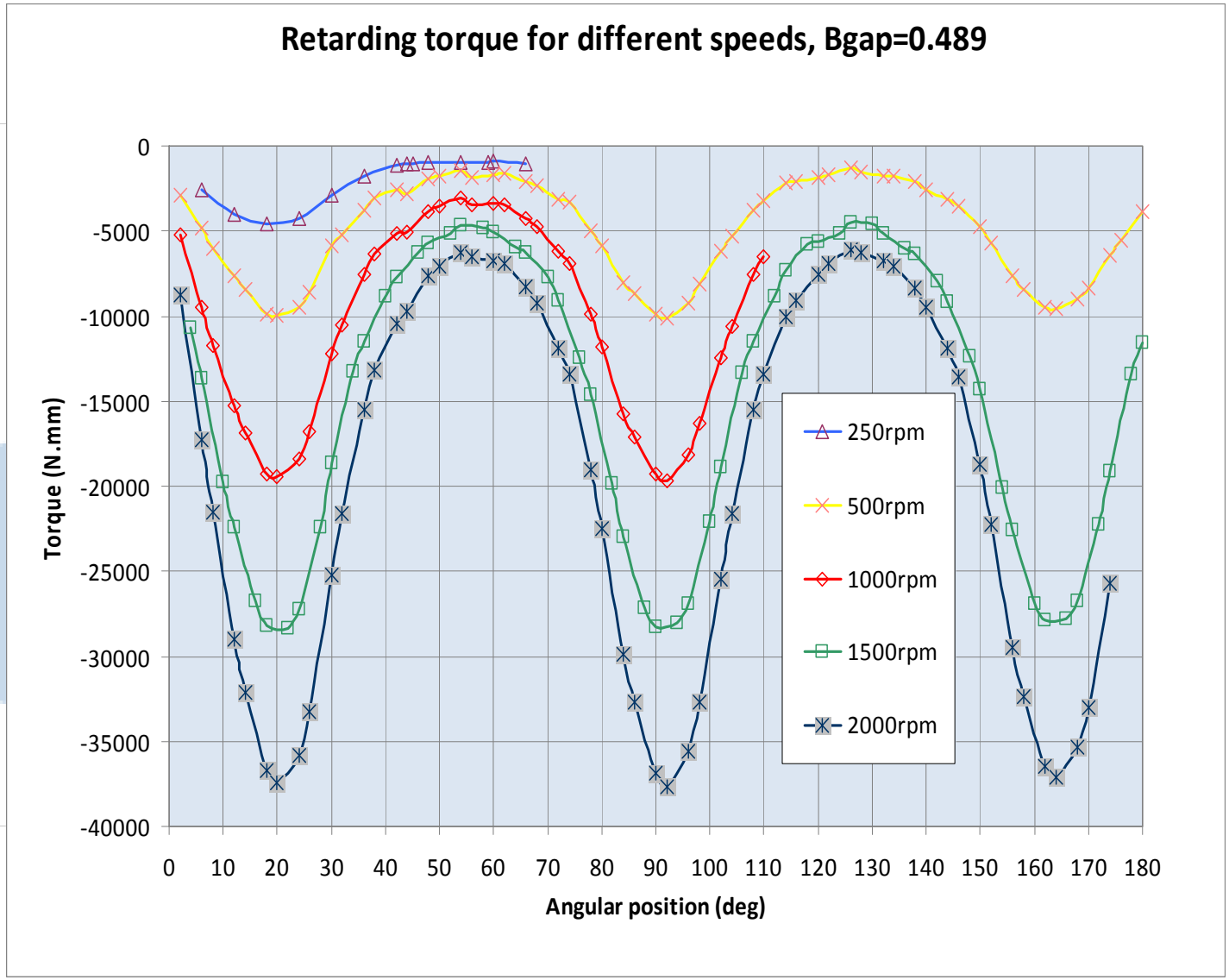


Carmen Model (2)



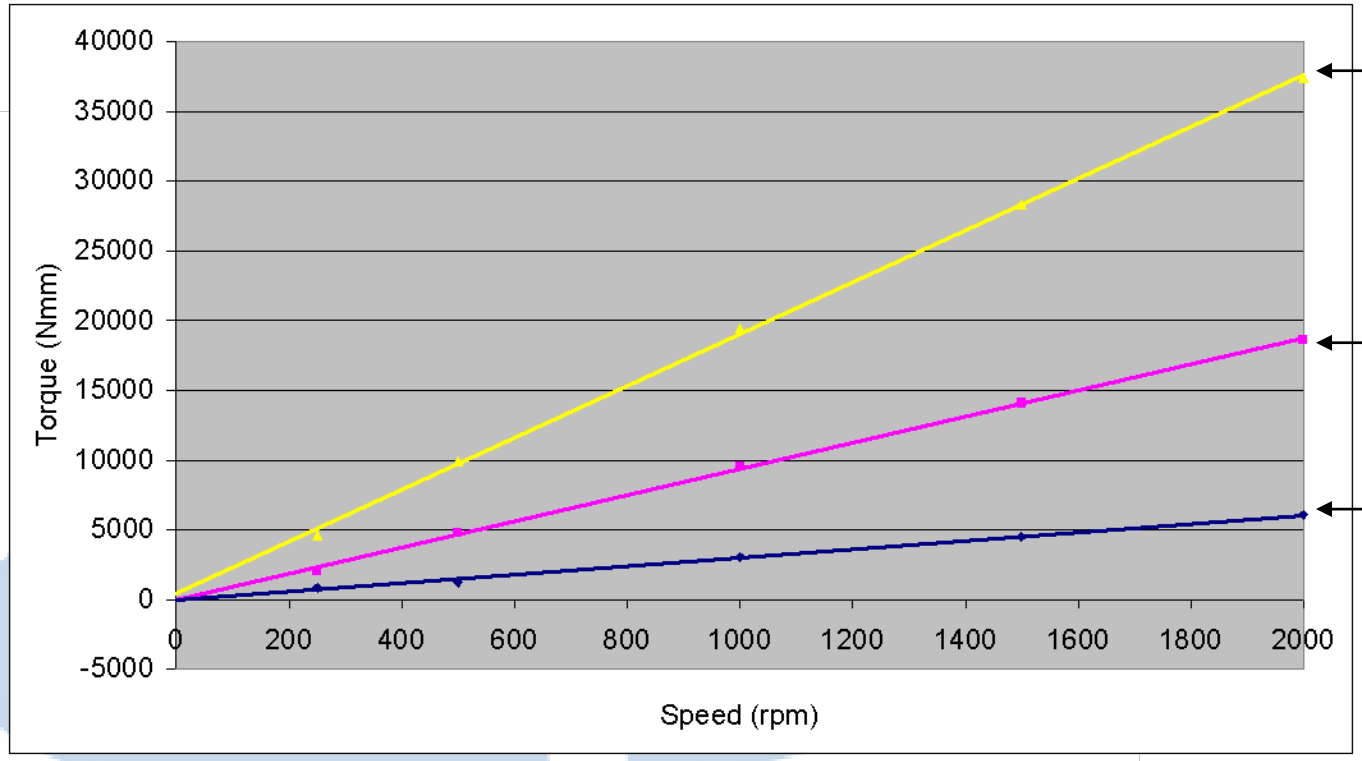
J. Rochford, RAL

CARMEN Model Prediction



J. Rochford, RAL

CARMEN Model Prediction (2)



Peak (yellow), average (magenta) and minimum (blue) torques as predicted by the CARMEN model for rim immersed in 0.489T field.

Data at 250rpm gives average torque due to field

= 2.07Nm - 1.13Nm friction = 0.94Nm c.f. CARMEN average 2.08Nm…

Summary

- Prototype complete.
  - Data-taking began Nov 08.
- CARMEN model developed at RAL.
  - Consistent with earlier ELECTRA (rim-only) model.
  - Effect of spokes expected to be large.
  - Preliminary analysis of data (<500 rpm) does not show spoke effect in either average torque or torque spectrum.

Further Work

- Complete characterisation of friction.
- Proceed to higher speeds.
- Eddy current model for cross-checking being developed at LLNL.
- Remove motor-controller from torque signal by allowing the wheel to coast down from high speeds with the motor electrically disconnected.
- Use Fourier spectrum to analyse spoke effects.
- Rotordynamic analysis.
- Thermal analysis.

Sufficient to measure average torque.