Baseline Positron Source Target Experiment Update

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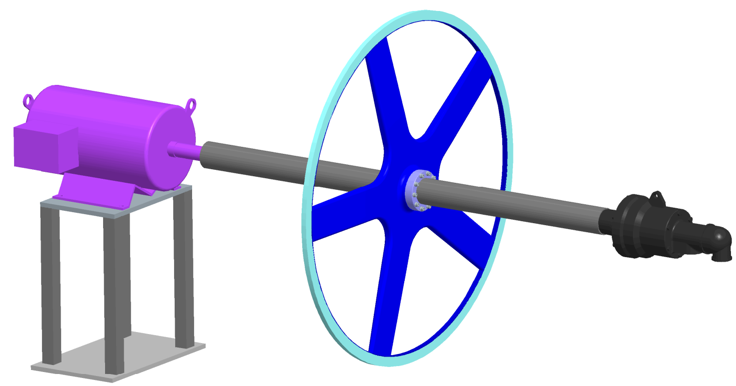
RDR Target Design

- 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.

Target documentation will be uploaded to http://www.ippp.dur.ac.uk/LCsources/Target/ and EDMS

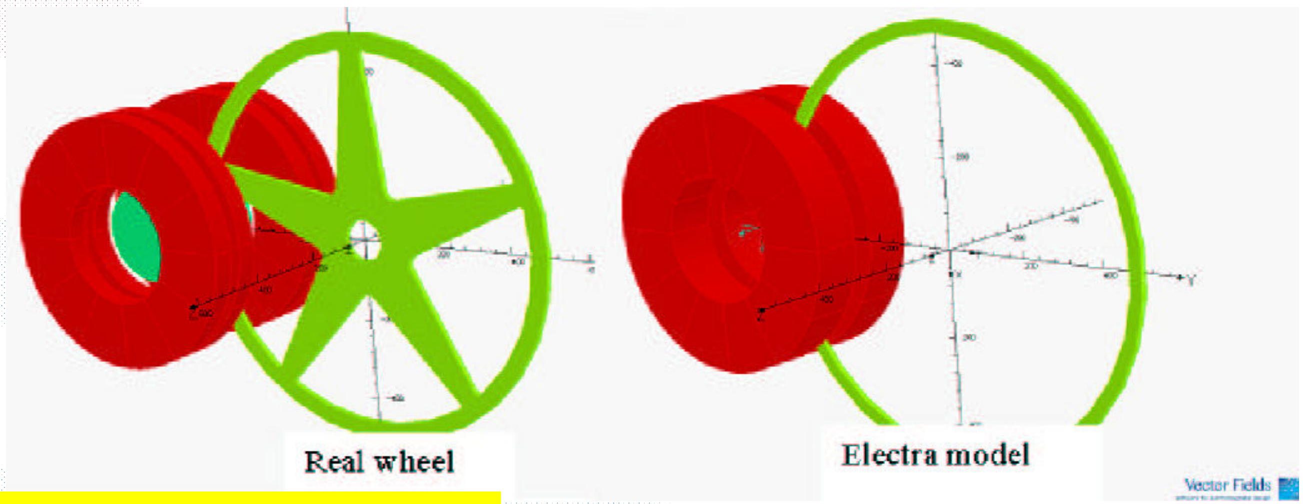


T. Piggott, LLNL

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

Target Wheel Eddy Current Simulations

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

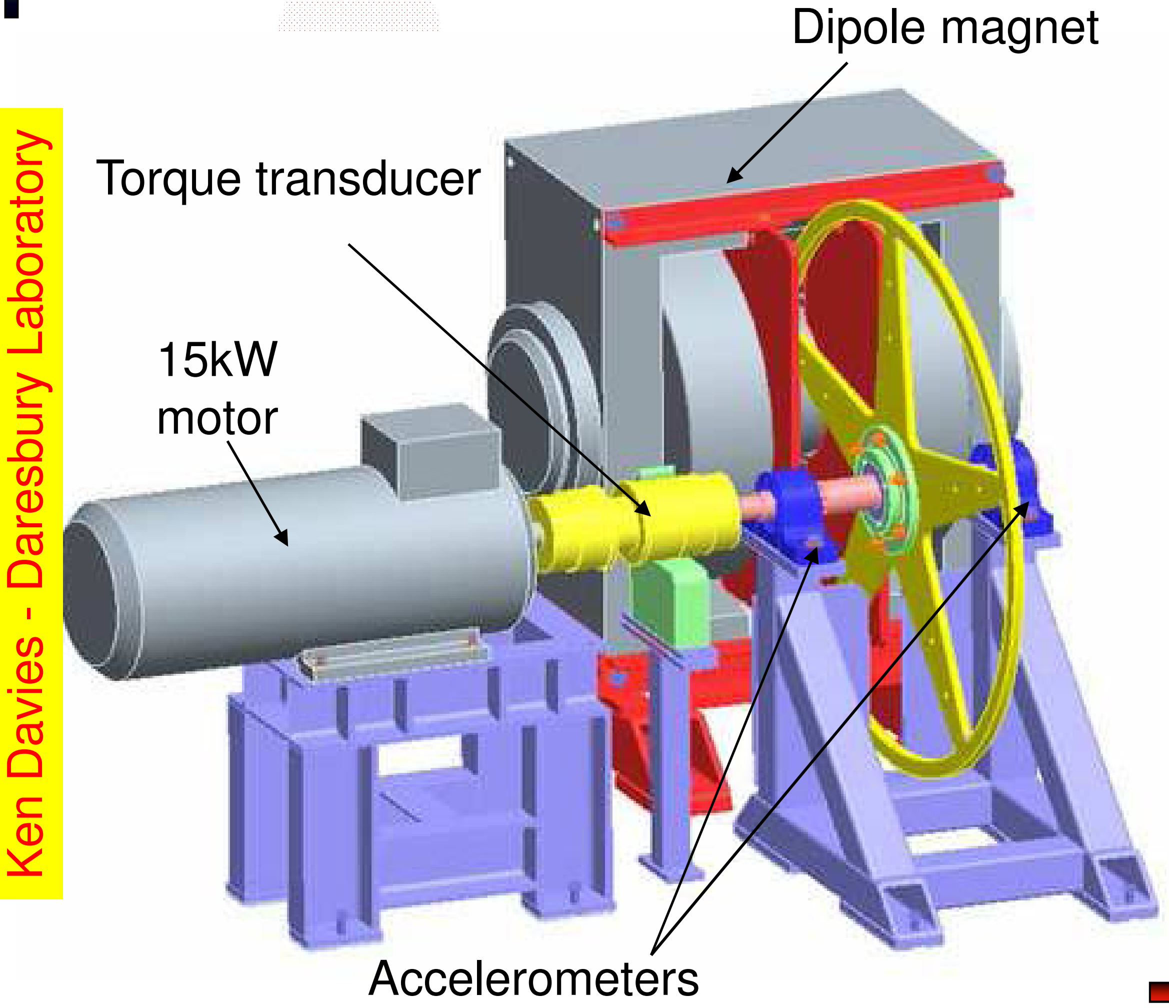


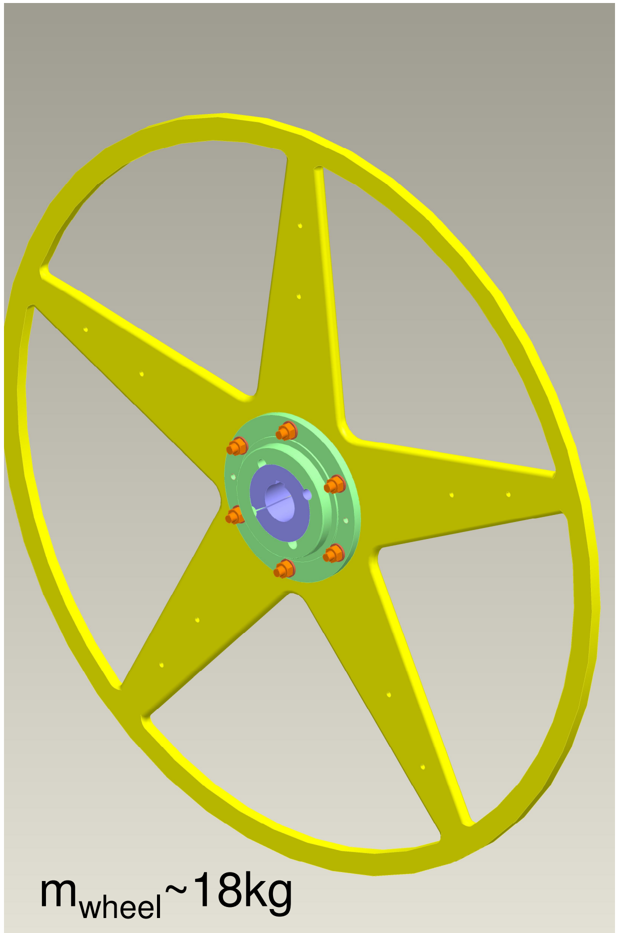
- **For 1T static field at ~2000rpm**
  - **RAL predicts ~6.6kW**
  - **ANL predicts ~9.5kW**
    - **S. Antipov PAC07 proceedings**
  - **LLNL predicts ~15kW**

⇒ Alternative capture optics, alternative materials, prototyping

Target Prototype Design

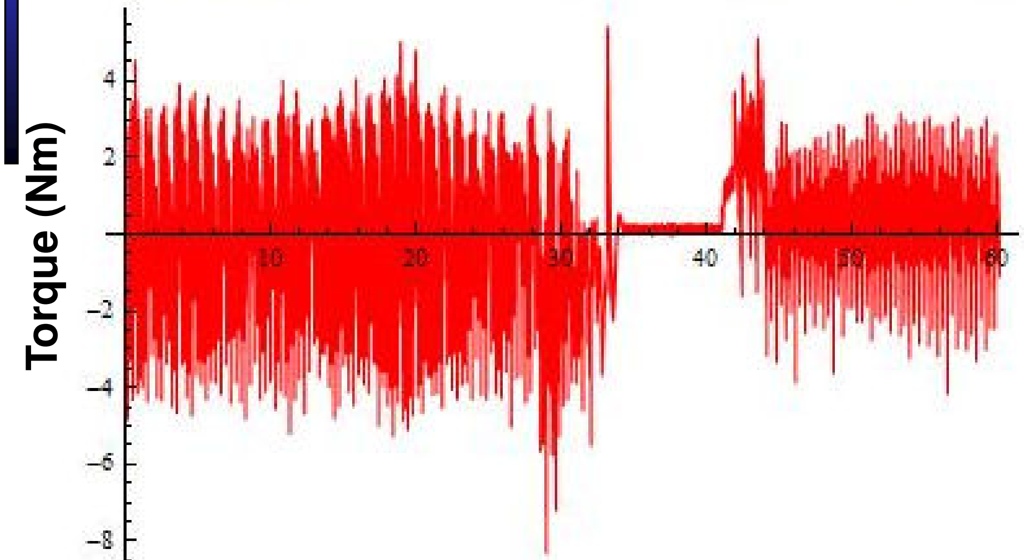
Prototype I - eddy current and mechanical stability

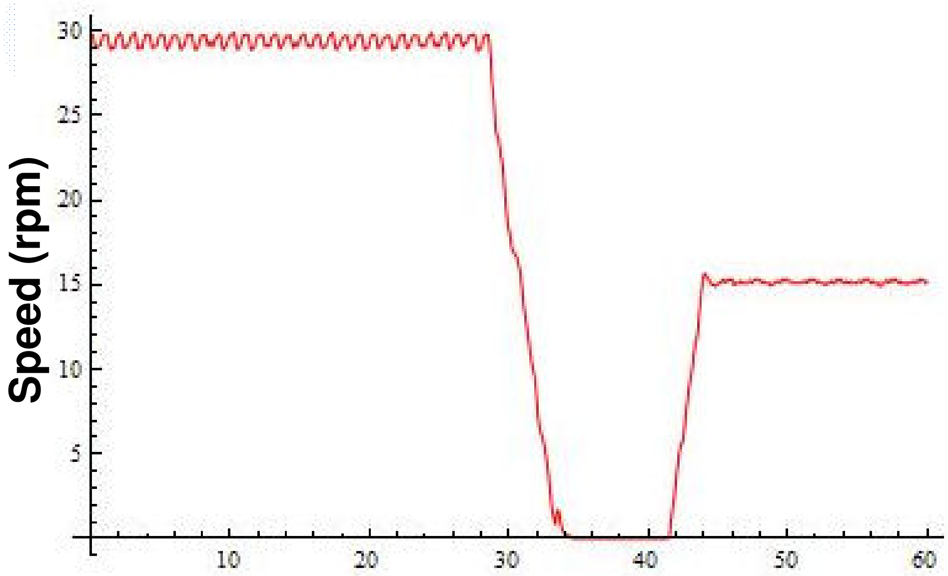




Ken Davies - Daresbury Laboratory

Initial Torque Data (no magnetic field)

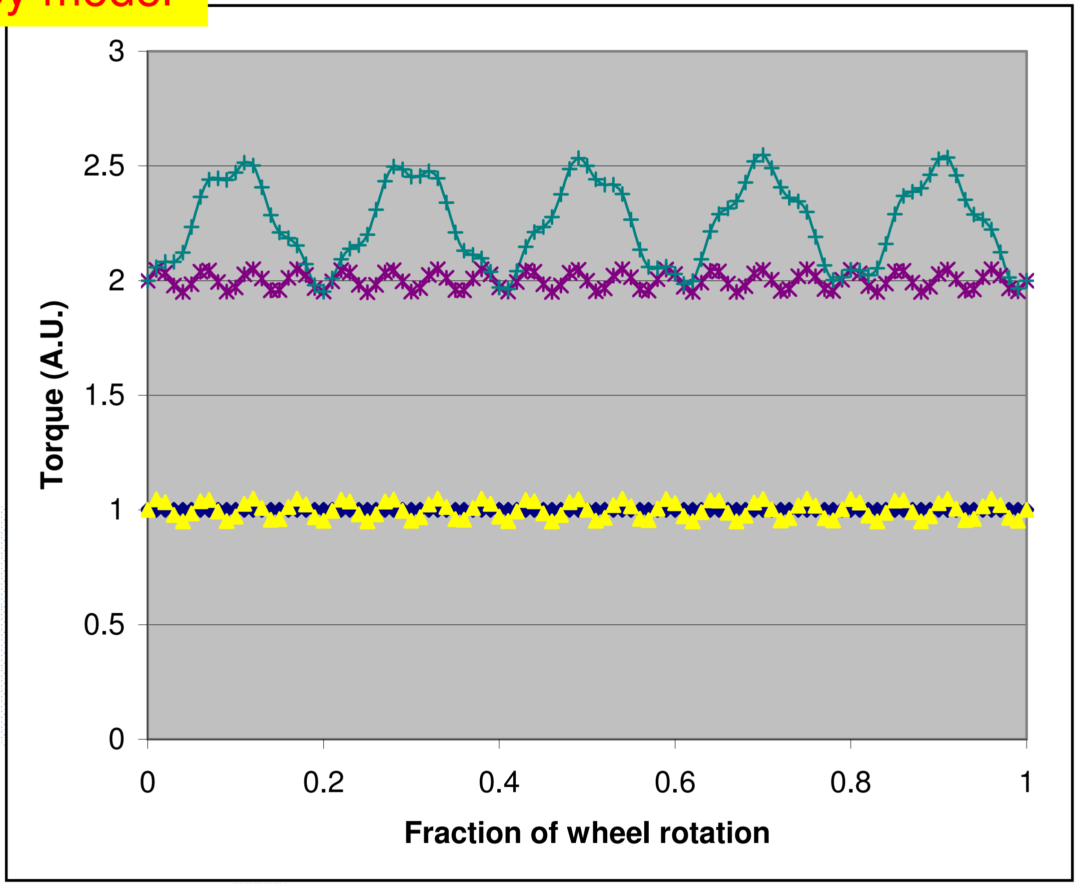




The upper figure shows the measured torque (Nm) as a function of time (s) . The lower figure shows the measured speed over the same period of time.

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

Understanding the Torque Data



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

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

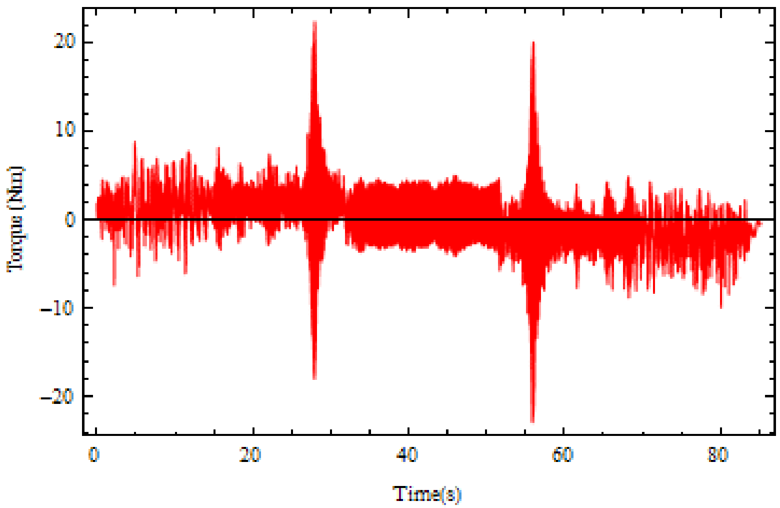
Magnetic field causes eddy currents to flow in rim (purple line)

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

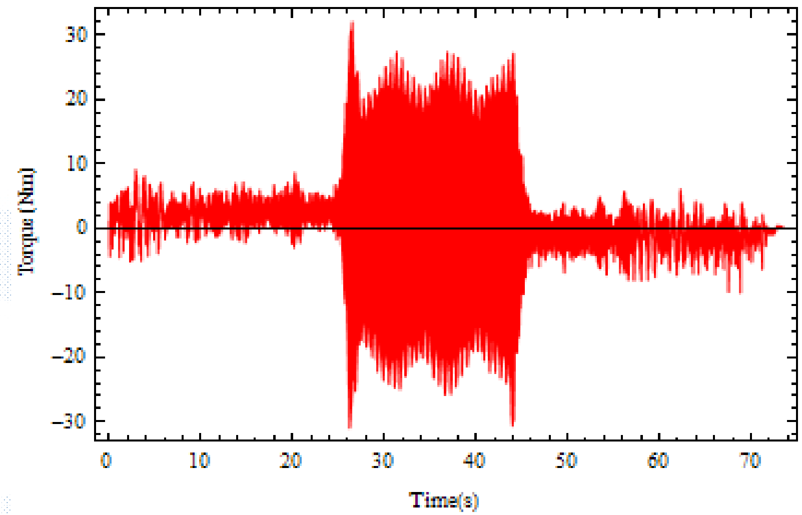
Resonances

L. Zang - Liverpool

198 rpm



174 rpm



Figures show Torque (Nm) as a function of time (s).
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.

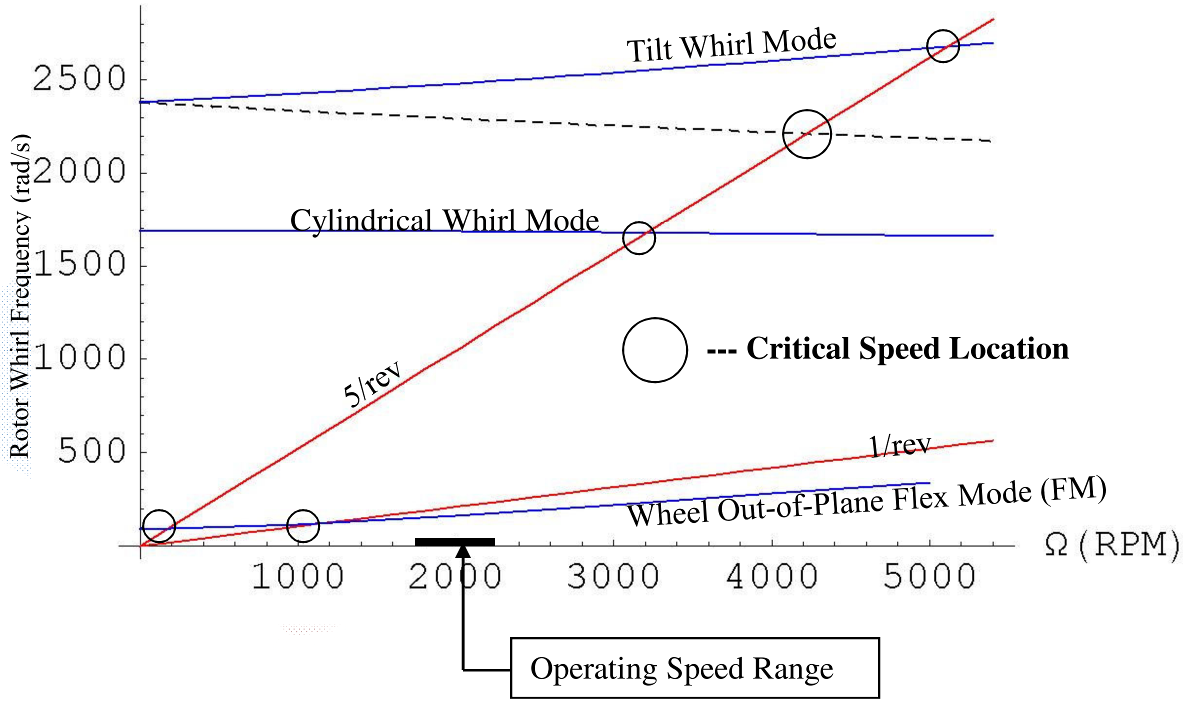
Predicted Critical Speeds

Lisle Hagler - LLNL

Nominal Design Basis Bearing + Mount Stiffnesses

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

Campbell Diagram



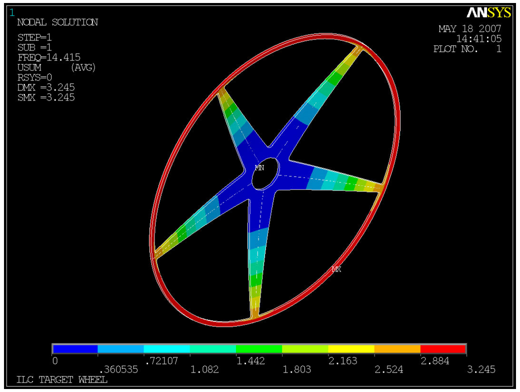
Sources of Rotor Excitation

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

Major Critical Speeds

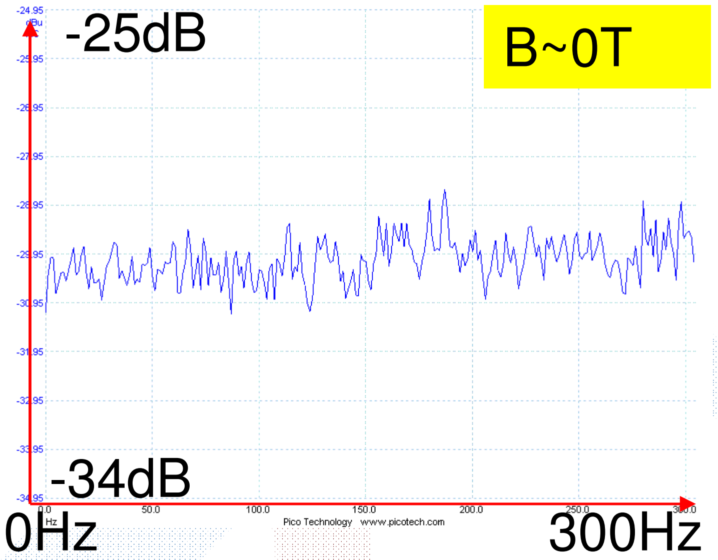
- 1st Wheel FM @ ~ 200 RPM
- 2nd Wheel FM @ ~ 1100 RPM
- Cylindrical Whirl @ ~ 3200 RPM
- Forward Tilt Whirl @ ~ 5000 RPM
- Reverse Tilt Whirl @ ~ 4200 RPM

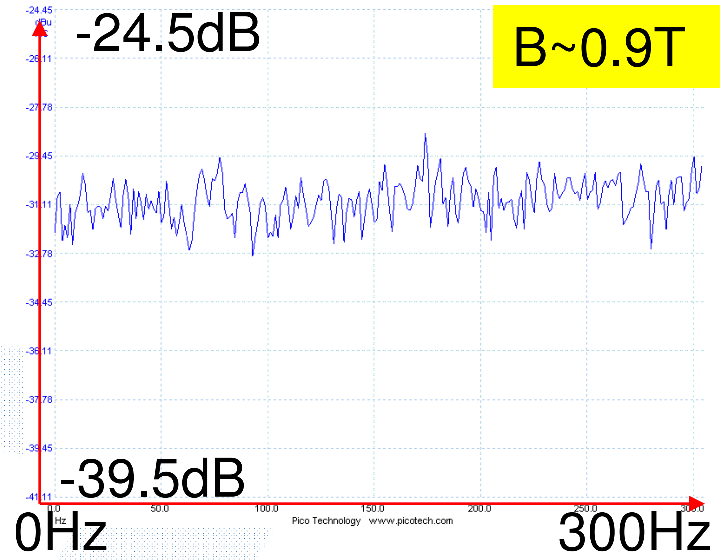
Wheel Out-of-Plane Flex Mode

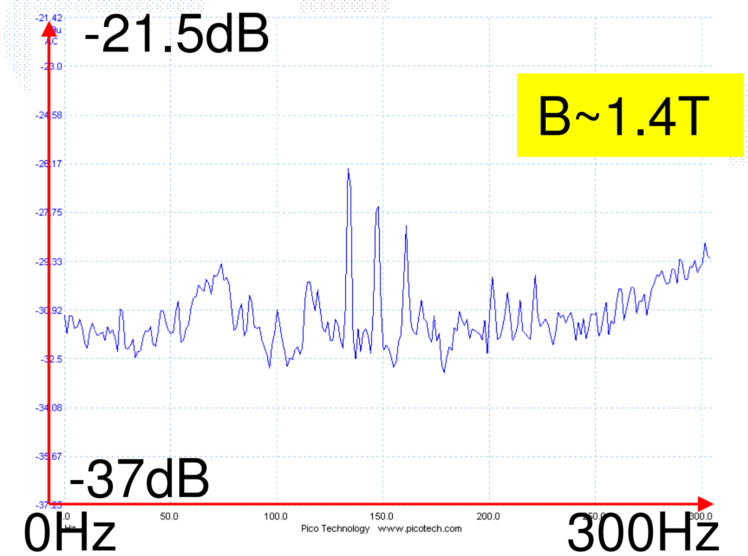


Critical speeds depend on bearing and coupling properties.

Accelerometer Data



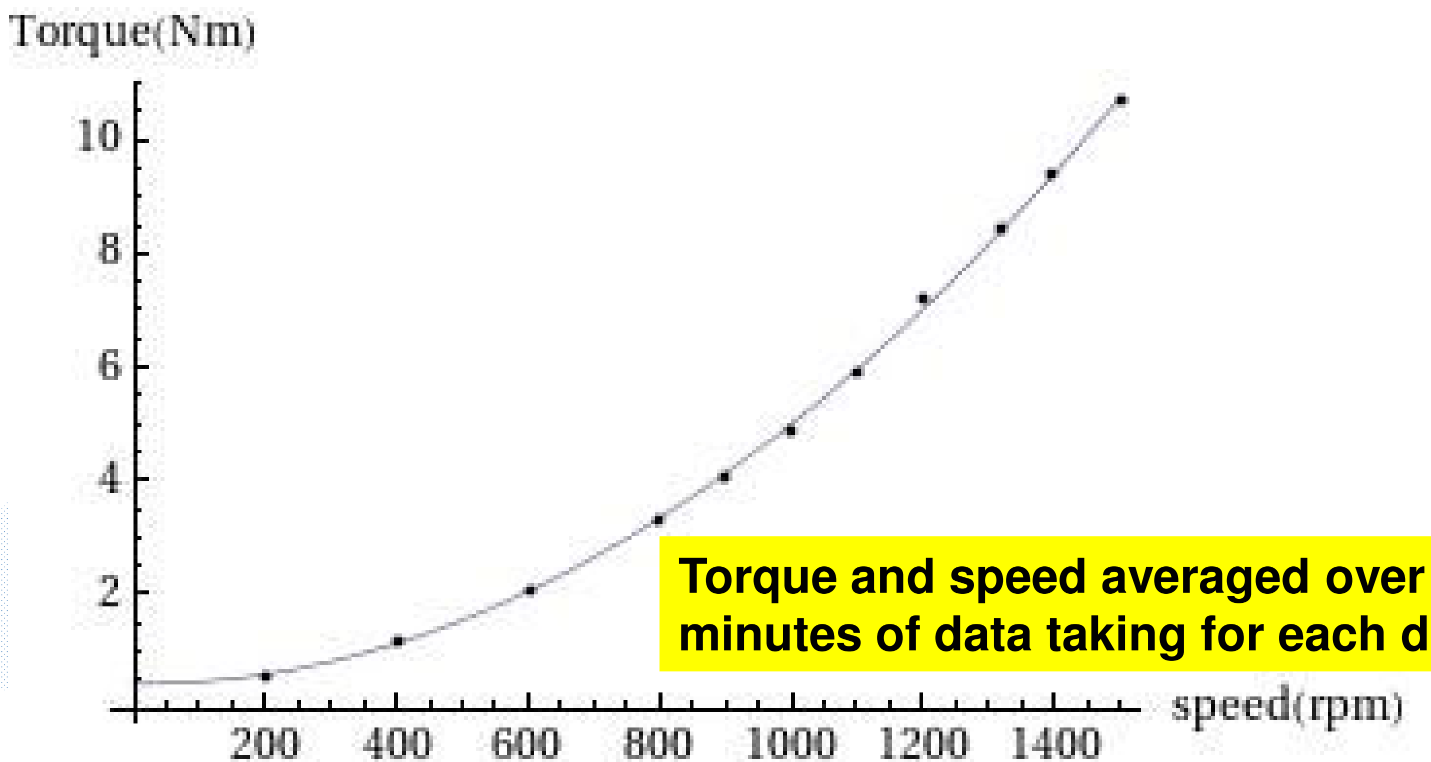




Data obtained from bearing-mounted accelerometer with wheel operating at 800rpm.

Despite auto-scaling of plots, the changes in the power spectrum are clearly visible.

Characterising Frictional Forces



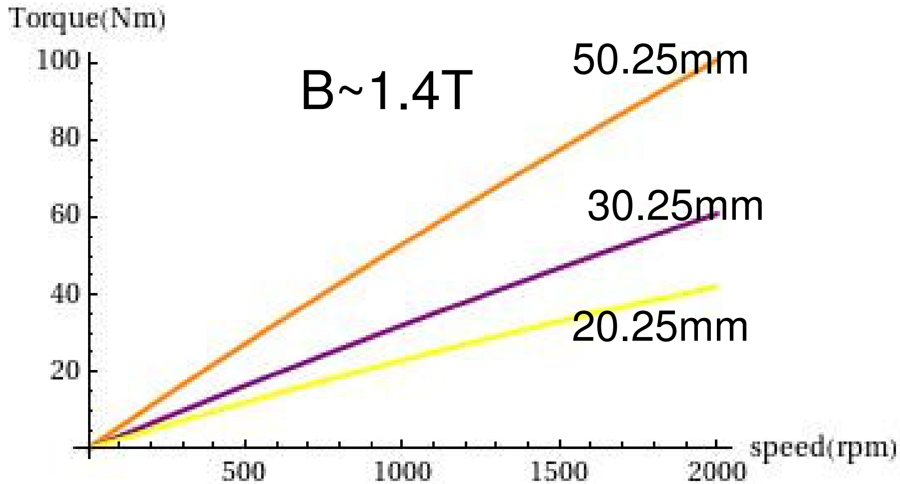
Torque and speed averaged over three minutes of data taking for each data point.

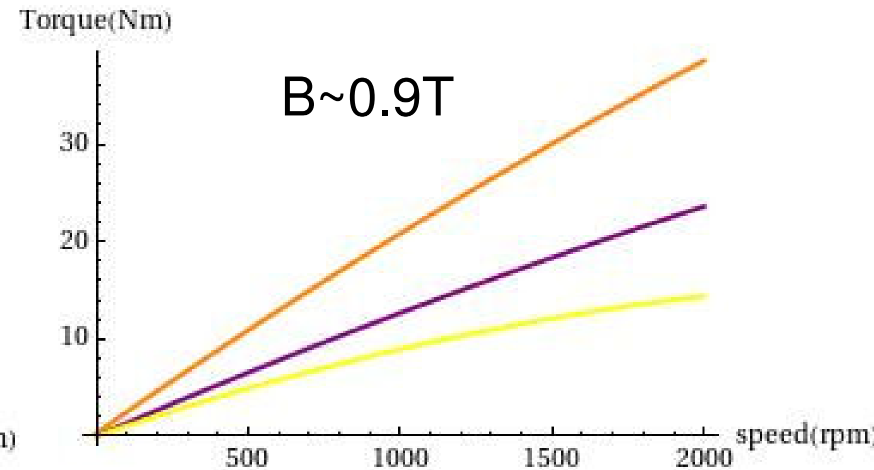
Data obtained with magnet off. Line shows quadratic fit to data points.

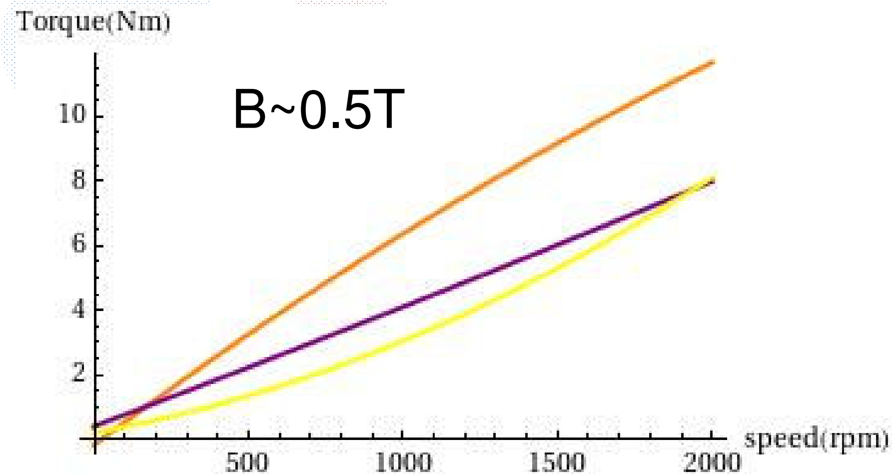
Wheel has not yet been operated above 1500 rpm.

Extrapolates to ~19Nm at 2000rpm, but behaviour may change at higher velocity as bearings heat up.

Effect of B Field on Average Torque

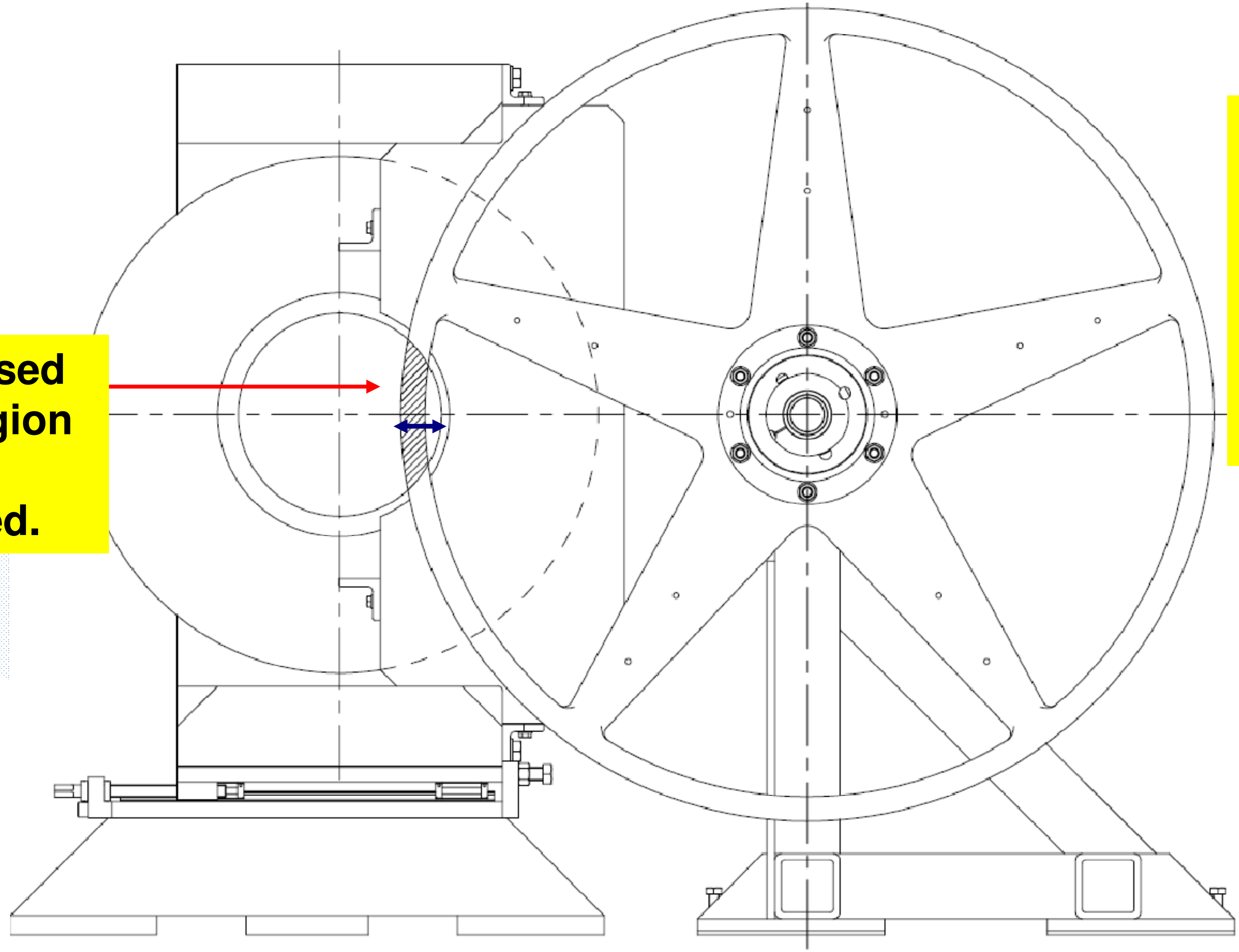






- The plots show a quadratic fit to the measured torques (≤ 1200rpm) where the effects due to bearing friction have been removed.
- The colours represent different immersion depths of the wheel in the field.

Immersion Geometry

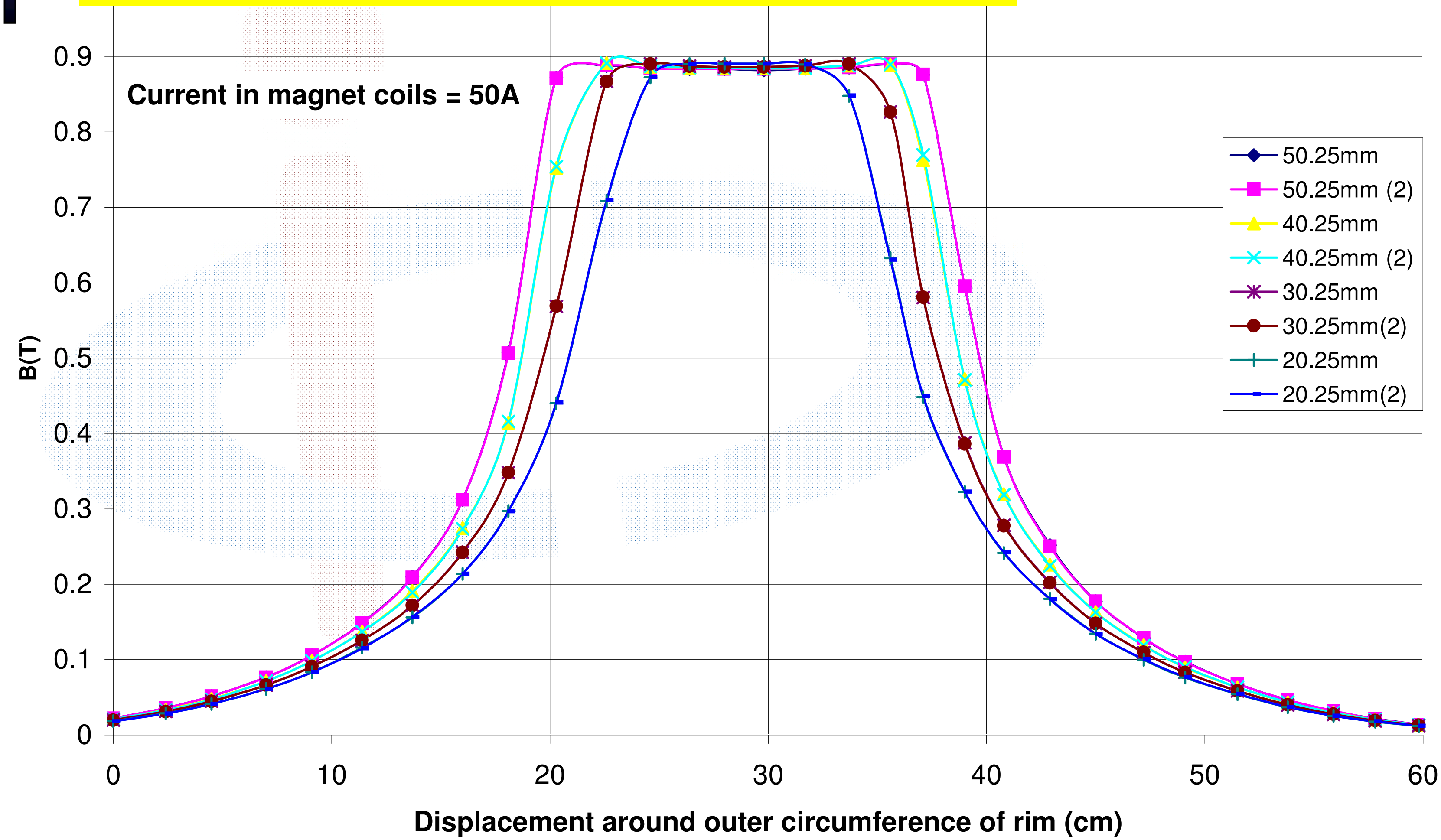


Immersed rim region shown hatched.

Cross-sectional view of target assembly at full immersion.

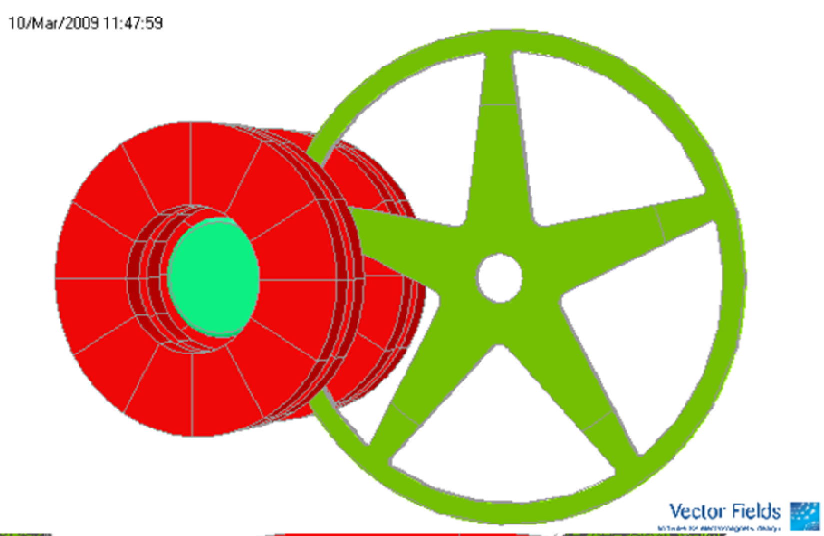
Magnetic Field Maps

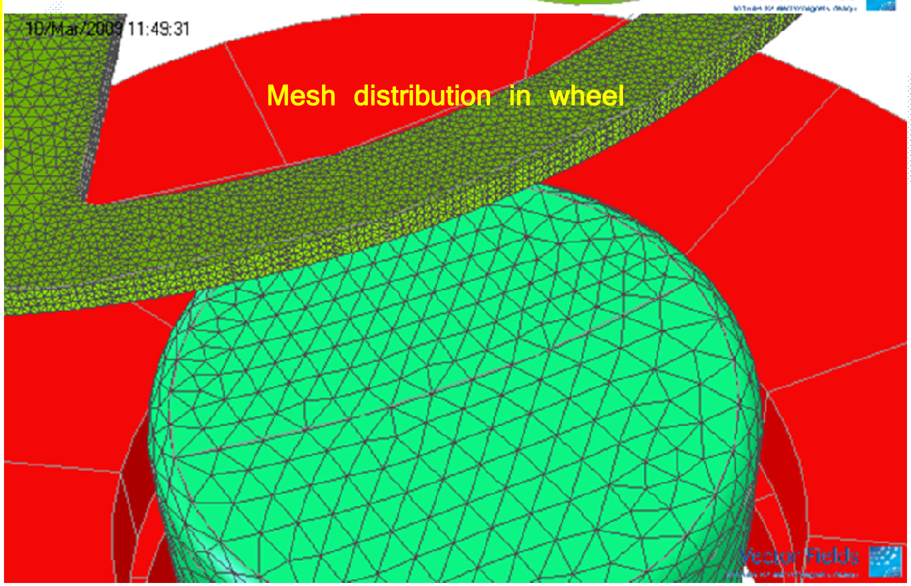
Example of field maps with peak field ~0.9T obtained with Hall probe attached to wheel rim.

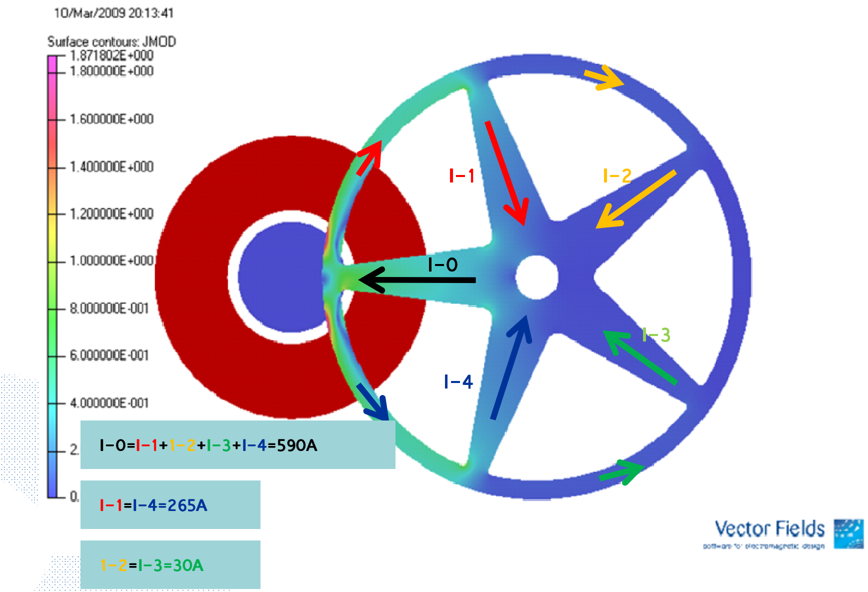


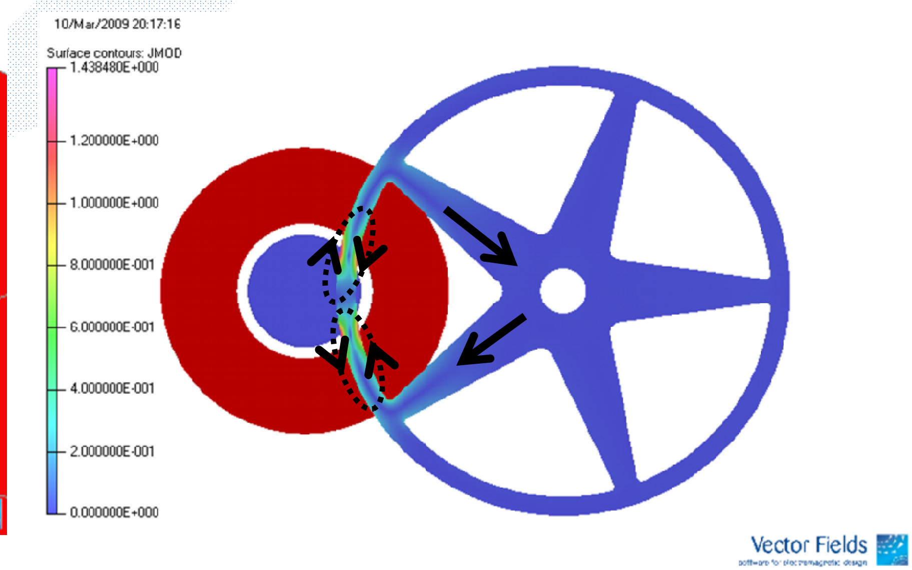
Carmen (spoke) Model Simulations

J. Rochford, RAL

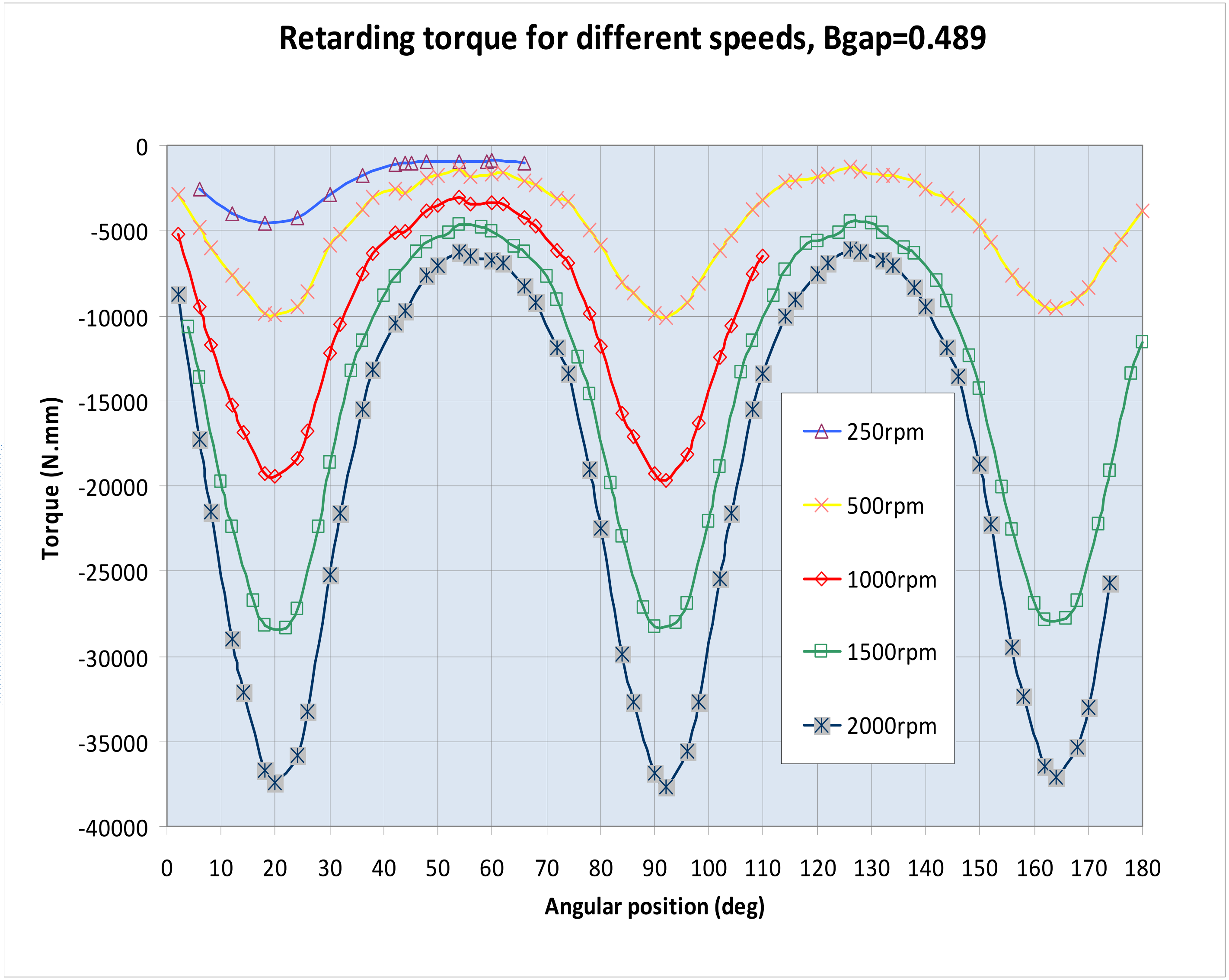






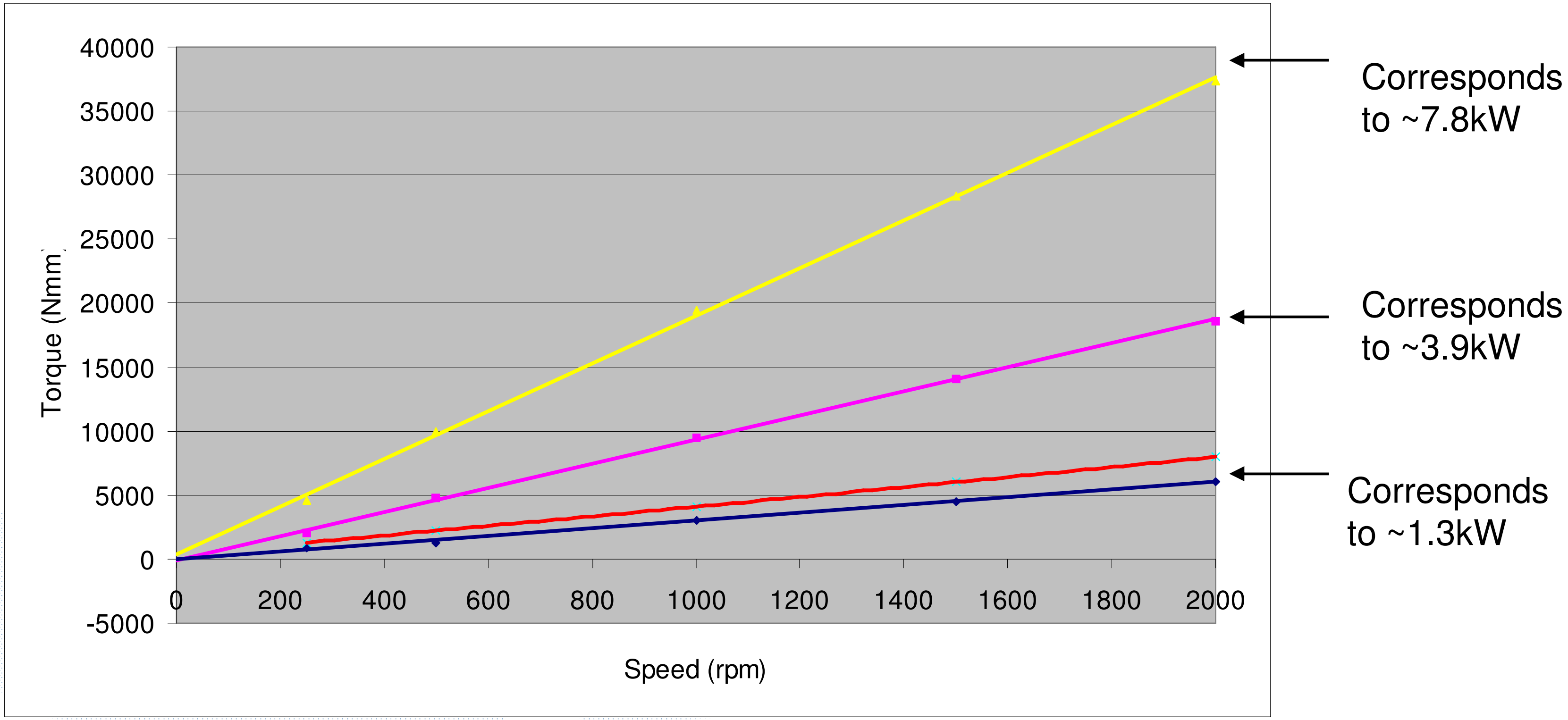


CARMEN Model Prediction



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 a field of peak strength 0.489T.

The red line shows the current best fit from the data. Spoke effects appear to be far smaller than indicated by the CARMEN model.

Summary

- Prototype complete.
  - Data-taking began Nov 08.
  - Measurements taken for speeds <1200rpm
  - Higher speeds $\Rightarrow$ vibration and noise (in air)
  - Extrapolating to 2000rpm suggests wheel will be able to operate in immersed fields ~1T without problems.
  - Detailed studies of torque Fourier spectra, etc ongoing
- CARMEN model developed at RAL.
  - Consistent with earlier (rim only) ELECTRA model
  - Predicts large effect from spokes
  - Spoke effects not currently seen in data
  - Further model under development at LLNL