Designing robust electrical machines
FUTURE Vehicles WP2.2

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WP2.2 Aims

- Investigate operating machines closer to limits
- Requires better understanding of failure mechanisms
- Focus: thermal and electrical stressing
- Aim to develop approaches for diagnosis and prognosis

Deliverables: detailed database of models including ageing and degradation, and identified gaps in knowledge

Thermal modelling

• Generally well understood, but..
  – Convection is challenging
  – Thermal contact resistance may be unknown
• We are investigating these thought this and other similar projects (e.g. ADEPT http://www.addept-itn.eu)

CFD Simulation of Taylor vortices in an electrical machine airgap:

Thermal contact resistance

On a microscopic level, flat surfaces are not flat

There is direct contact...

...but also air pockets

We represent the combined effect with a thermal contact resistance (TCR)
Modelling contact resistance

• Classic model is Cooper, Mikic and Yovanovich (CMY):

• Gaussian distribution for heights of peaks

\[ \frac{h_c}{k} \frac{\sigma}{<|\tan \theta|>} = f \left( \frac{P_a}{H} \right) \]

conductance pressure

Relevance to electrical machines

- Stator-housing interface
- Copper-slot interface

Test setup for experiments

\[ R_{th} = \frac{T_i - T_o}{Q} \]

Machine geometry usually concentric therefore contact pressure not constant!

= experimental investigation

Camilleri R, Howey DA, McCulloch MD, “Experimental investigation of the thermal contact resistance in shrink fit assemblies with relevance to electrical machines”, IET PEMD, 18-20 April 2014, Manchester UK.
Relevance to electrical machines

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Lifetime modelling

- Initially we investigate impact of temperature on insulation, by measuring impedance, breakdown voltage, mass etc.
Ageing tests

• Long term ageing tests on insulation samples show loss of material, increase in roughness, decrease in breakdown strength, and impedance changes.


Coupled lifetime modelling

- Temperature and stress can both impact insulation lifetime.
- Zhurkov lifetime model similar to Arrenhnius, includes stress:
  \[
  \tau = \tau_0 \exp \frac{U_0 \gamma \delta}{kT}
  \]
- We constructed coupled thermal-mechanical simulations to predict likely failure point at slot exit:
• Many thanks to Dr Darren Kavanagh, Robert Camilleri, and to our industrial collaborators and sponsors
• I also work on batteries, see http://epg.eng.ox.ac.uk/content/energy-storage

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