Thermal Modelling of a Small Wind Turbine Gearbox for Condition Monitoring

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Motivation

- Wind turbine gearboxes operate in a broad spectrum of load and speed variations
- Difficulties in predicting reliability, and preventing failures [1].
- Lengthy lead time and repair time typically causes an increase in the cost of energy [2].

Various measurement techniques have been used to diagnose gearbox failures such as; vibration, oil quality and temperature. State of the art remaining useful life methodologies predominately use data driven machine learning techniques to predict failure; approaches that rely on large amounts of operational data and failure histories.

Objectives

- Use a detailed understanding of the physics inside a gearbox, so that when a fault occurs, the failure can be diagnosed, located and a prognosis can be developed to predict and even prevent failure.
- Exploit temperature measurements to understand a 'healthy' gearbox and then use it to detect and locate abnormal gearbox operating conditions.

Method

An 11kW two stage, parallel gearbox with splash lubrication, used for small wind turbine applications was used as the case study for this research.

Thermal modelling based on the principles of heat transfer theory

- Conduction
- Convection
- Radiation

A 'healthy' gearbox model was created, based on analytical modelling of power loss and lumped parameter thermal modelling of heat propagation through the gearbox system. Components are split into a number of lumped mass isothermal nodes, and the heat generated applied at the respective nodes [5]. The heat transfer between nodes are represented by 'thermal resistances', analogous to electrical resistances [6]. This can be demonstrated by figure 1.

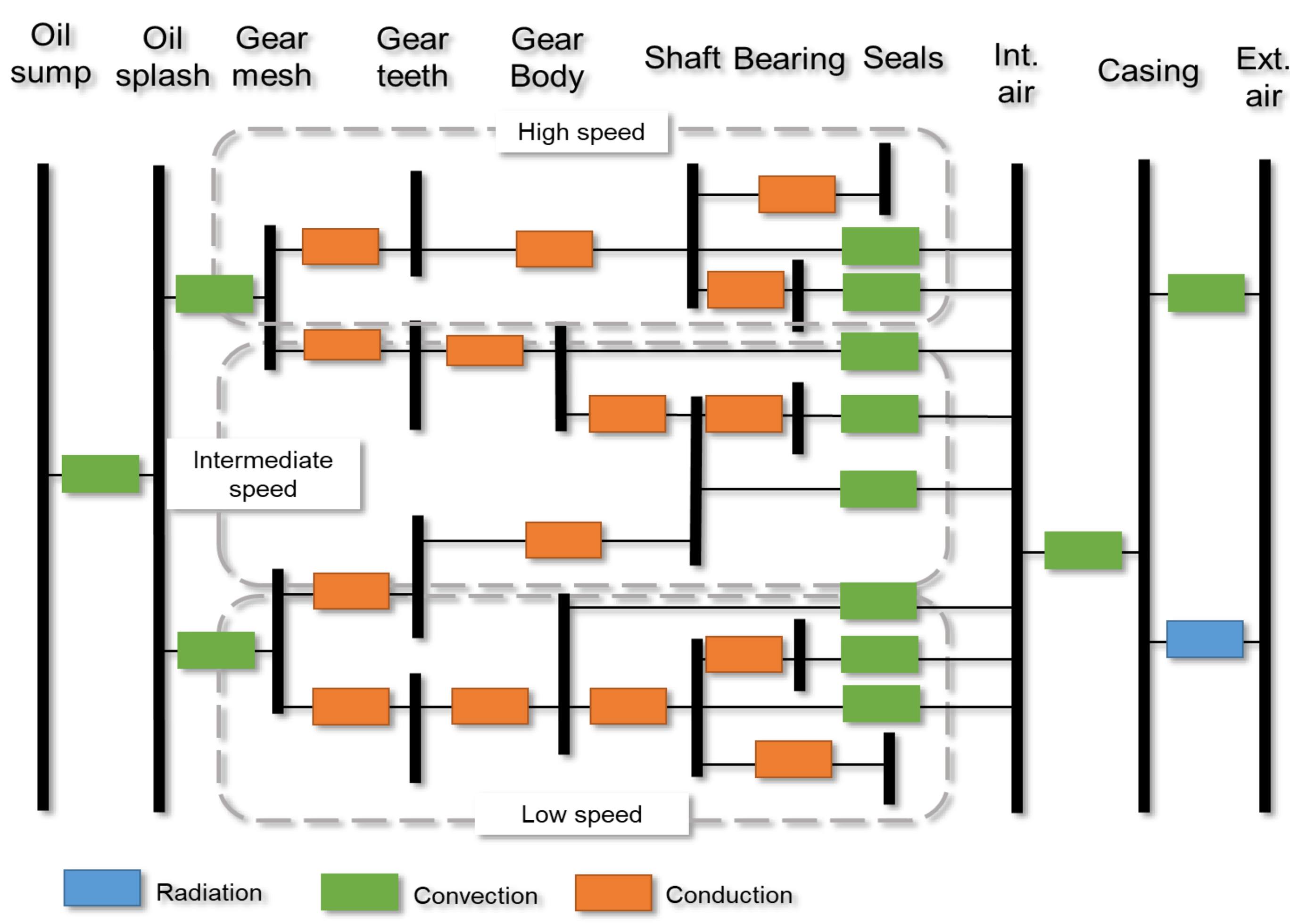


Figure 1

Results

It is assumed that the heat generation in the system is equal to the power losses at different locations, caused by the interaction of components. The total loss P_T is represented by (1) [3] [4], the sum of losses at particular components.

$$\sum P_{\mathrm{T}} = \sum P_{\mathrm{GD}} + \sum P_{\mathrm{GI}} + \sum P_{\mathrm{BD}} + \sum P_{\mathrm{BI}} + \sum P_{\mathrm{S}} \qquad (1)$$

P_{GD} Load dependant gear losses, friction from gear meshing

P_{GI} Load independent gear losses, churning and windage

P_{BD} Load dependent bearing losses, friction

P_{BI} Load independent bearing losses, viscous friction

P_S Seal losses

Losses in at respective components were calculated and fed into the model, the results of which can be seen in Figure 2.

Heat Propagation through Gearbox components

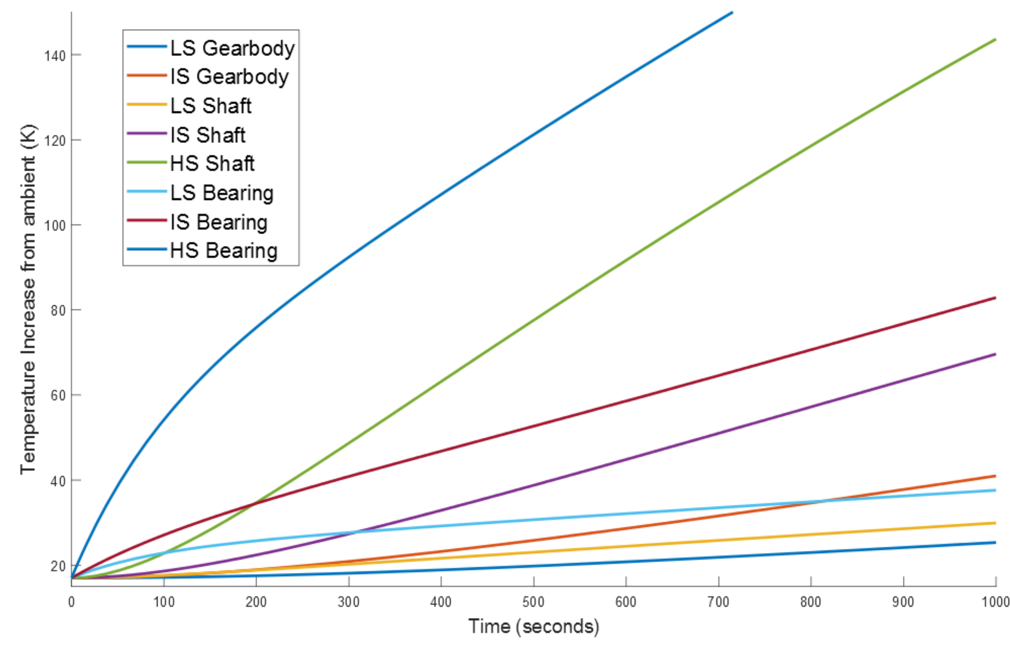


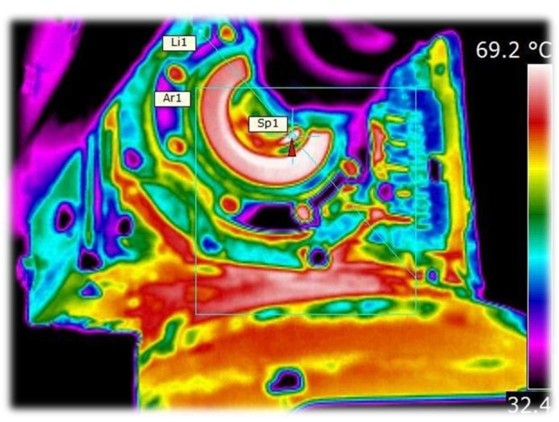
Figure 2

This shows the high speed components generate and retain the greatest amount of heat. This is logical as it is commonly the high speed components which fail most frequently. Modelling the lubrication system has proved difficult and will be an area to refine in future work.

This thermal model was partially validated by experimental data taken from a test rig. It is predicted that the model can be used to monitor a fault at component level, based on the assumption that if a system presents degradation on a contact surface, it will generate more power losses and a different thermal behaviour [7].

Conclusions & Future Work

- A validated thermal model demonstrates the level of fault and associated heat generation that can be detected.
- The next step will be to induce failures into the model and see how the heat propagation changes, validate this experimentally.
- The outcomes of this have the potential to be upscaled for larger, more turbine gearbox applications to make condition monitoring more accurate, potentially reducing the cost of energy from wind.



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