Journal of Zhejiang University-SCIENCE A
(Applied Physics & Engineering)

Loughborough University

# Heat generation and transfer in automotive dry clutch engagement

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**Key words:** Automotive clutch; Thermal network model; Clutch lining temperature; Friction; Tribometry; Lining material properties

**Cite this as:** Theofilos Gkinis, Ramin Rahmani, Homer Rahnejat, Martin O'Mahony, 2018. Heat generation and transfer in automotive dry clutch engagement. Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering), 19(3):175-188. https://doi.org/10.1631/jzus.A1700481

# Overview

This paper provides measurement of friction lining characteristics of dry clutches for new and worn state under representative operating conditions of applied contact pressures and temperatures pertaining to interfacial slipping during clutch engagement.

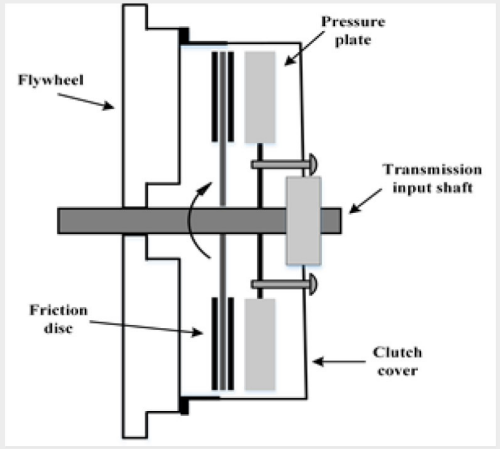
An analytical thermal partitioning network model of the clutch assembly, incorporating the flywheel, friction lining and the pressure plate is presented based upon the principle of conservation of energy.

The results of the analysis show a higher coefficient of friction for the new lining material, which reduces the extent of interfacial slipping during clutch engagement; thus, reducing the frictional power loss and generated interfacial temeptature..

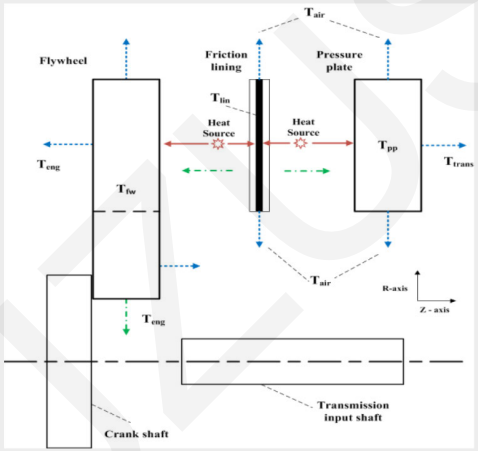
The study integrates frictional characteristics, microstructural composition, mechanisms of heat generation, effect of lining wear and heat transfer in a fundamental manner, an approach not hitherto reported in literature.

# Analytical Model

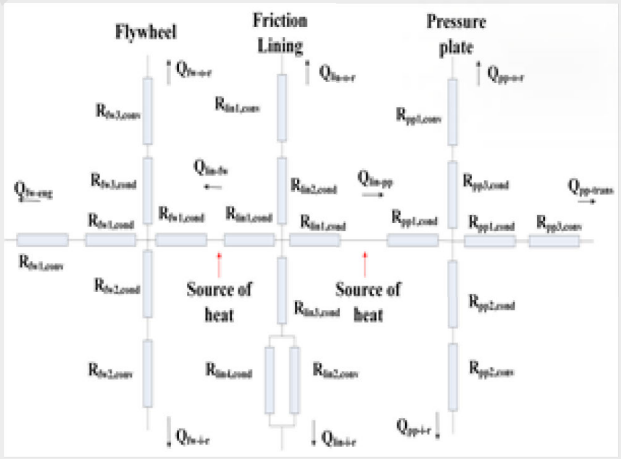
- A lumped model is developed based on the principle of the conservation of energy: $m_i c_i \frac{\partial T}{\partial t} = \sum \dot{q}$




Schematics of a dry clutch system



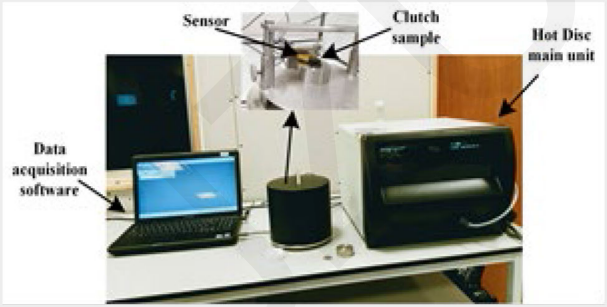

Analytical model



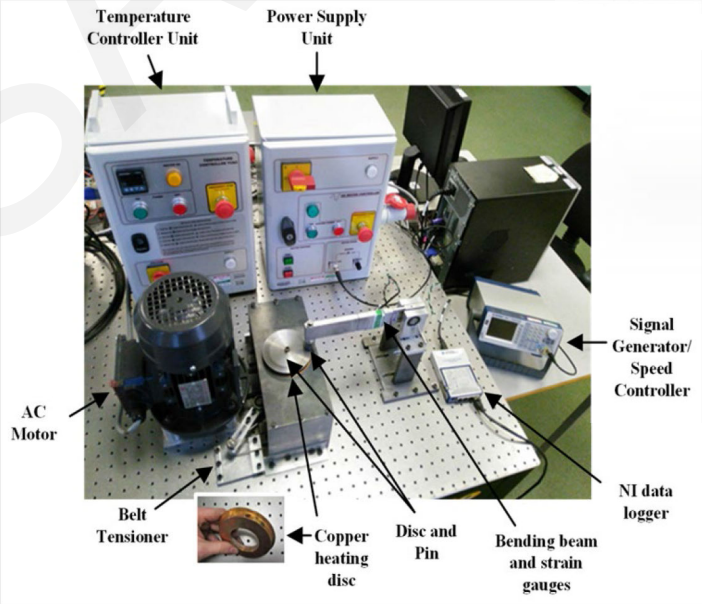

Computational thermal model

# Experimental approach

- Tribometry is used to obtain the interfacial frictional characteristics under realistic representative conditions.
- Full control over parameters such as sliding velocity, contact pressure and temperature.
- Material-specific thermal properties characterised using a thermal conductivity analyser




Thermal characterisation

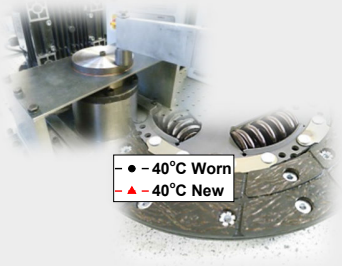


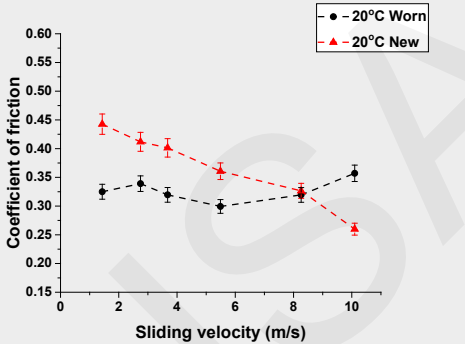

In-house pin-on-disc tribometer

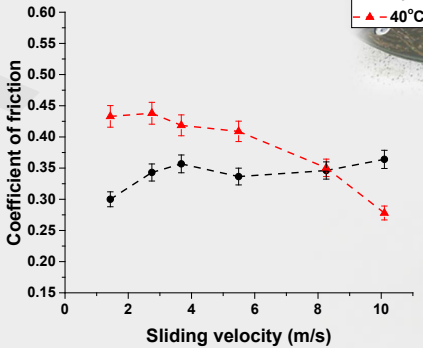
# Experimental results

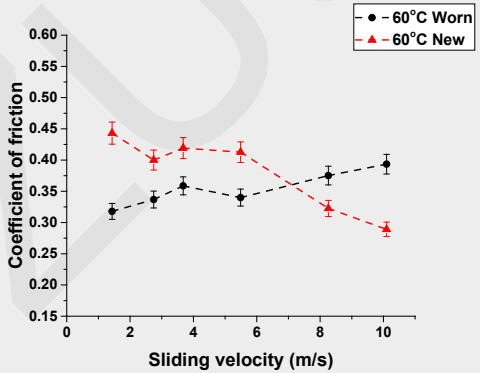
- Using tribometry, frictional characteristics are measured for new and worn clutch lining materials under various operating conditions.

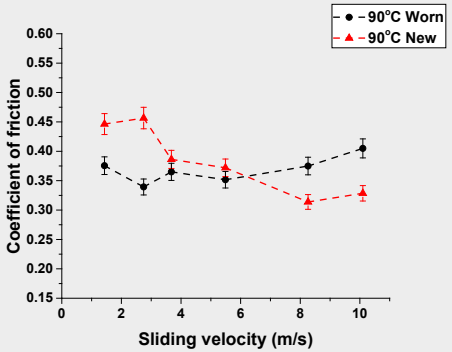
- The variations of interfacial coefficient of friction with contact sliding velocity at different disc bulk temperatures is presented.



# Numerical Predictions

For the numerical simulations two cases of clutch engagement are considered:

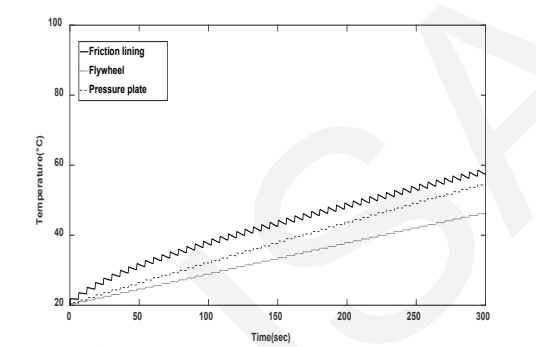
Case 1: This case corresponds to 0.5s engagement time, followed by a dwell time of 5s in the fully clamped state.

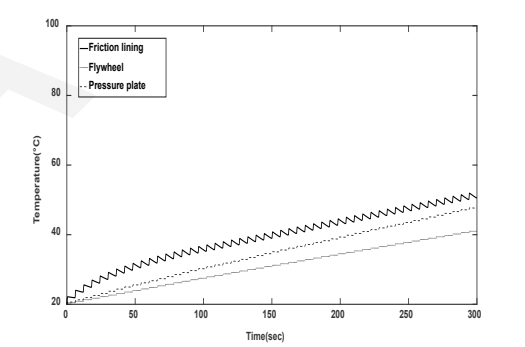
Case 2: In this case the engagement time is increased to 1s, representative of prolonged slipping during clutch actuation.

New

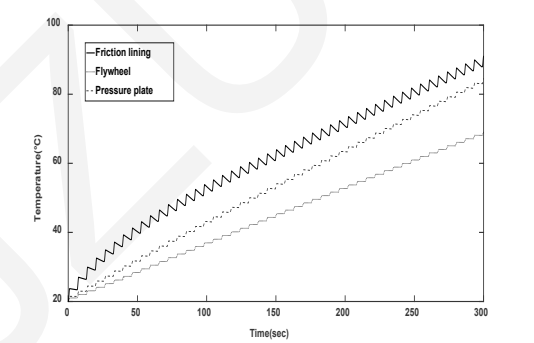
Worn

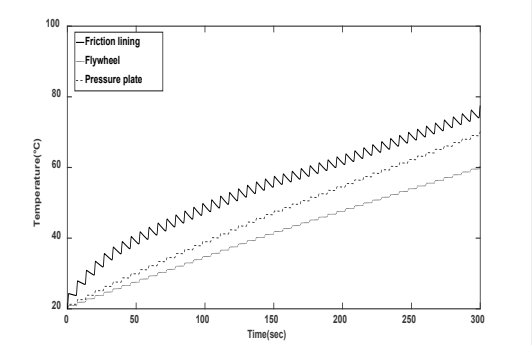
Case 1




Case 2



# Main conclusions

- Experimentally measured characteristics show the temperature-sensitive nature of the new friction lining material, whilst the same was not noted for the worn lining.

- A microstructural study of the worn lining indicates depletion of copper particles from the lattice structure, thus the reduced ability of the worn lining in conductive heat transfer. This is also established through measurement of thermal conductivity of the lining material variants used in this study.

- The results of measurements using the tribometer show a higher coefficient of friction for the new lining material than the worn variety.