Lubricant ageing in wet clutch applications

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Industry partners:
BorgWarner
Statoil Lubricants

Wet clutch - Engaged

Input shaft  Output shaft
Wet clutch lubricant

- Anti-wear
- Detergents
- Friction modifiers
- Antioxidants
- ...

Wet clutch - Engaged

Input shaft  Output shaft
Lubricant action in between surfaces (1vol%)
- Friction generates heat
- Wear of surfaces
- Friction modification
- Anti-wear films forming
- Additive interaction

Lubricant sump (99vol%)
- Oxidation
- Keeping contaminants soluble
- Hydrolysis
- Interaction between molecules
Wet clutch degradation

System parameters
- Temperature
- Contamination (e.g. Wear particles)
- Water

Wet clutch degradation mechanisms
- Adhesive/Tribochemical wear
- Abrasive wear
- Oxidation
- Thermal degradation
- Evaporation
- Hydrolysis

System parameters
- Temperature
- Contamination (e.g. Wear particles)
- Water
Wet clutch degradation

**Wet clutch failure modes**
- Loss of torque transfer
- Degradation of friction characteristics
- Surface failure
- Lubrication failure

**Wet clutch degradation mechanisms**
- Adhesive/Tribochemical wear
- Abrasive wear
- Oxidation
- Thermal degradation
- Evaporation
- Hydrolysis
- Temperature
- Contamination (e.g., Wear particles)
- Water

**Objectives**

- Predict lubricant degradation
- Define end of life
- Remaining useful life possible
Applications

- Short engagement times
- High power
- Continuous slip
- Low power

End of life lubricant

Friction coefficient vs. Speed at 70°C

Out of antioxidants

Decreasing Antioxidant Levels
End of life - friction characteristics

* Master thesis work of Henrik Lundh at Luleå university of technology in cooperation with BorgWarner (supervisor Pär Marklund, LTU)
Prediction of remaining life

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**Wet clutch degradation mechanisms**
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**System parameters**
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**ATF oxidation model**

*Calcut, B. D.; Sarkar, K. & Linden, J. L.
Estimating the Useful Life of an ATF Using an Integrated Bulk Oxidation and Friction Degradation Model
SAE Technical Papers, 2004*
Heat model

Heat generation $f(\mu,v,p)$ in friction interfaces

House and oil sump

Surroundings

Heat model output

Temperature [°C]

Time [min]

Engagement

Cooling

Friction interface temperature

Oil sump temperature
Heat model → Remaining life

**SUMP:**
Large part of the lubricant
~99%

**INTERFACE:**
Small part of the lubricant
~1%
Consumption of life model
[1 engagement]
Remaining life=1-Consumption of life

Significance of interface temperature
Remaining life=1-Consumption of life
In conclusion

- Defined end of life
- Cooling important
- Surface temperatures important
- Prediction model – Design process
Thank you for listening!

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  - Statoil Lubricants

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  - VINNOVA, FFI

Heat model

Heat generation $f(\mu, v, p)$ in friction interfaces

- $f(\text{rot speed, (Discs-House temp})$
- House and oil sump $f(\text{air vel, (House-Air temp})$
- Surroundings
\[ \ln(t) = A + \frac{B}{T} \]

Engagement power

Same energy of engagement
Engagement power

Energy alone is not sufficient

Wet clutch degradation pathways

Wet clutch failure
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- Lubrication failure

Lubricant degradation
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- Evaporation
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- Temperature
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- Water
Wet clutch frictional behavior

Torque transfer failure

Needed torque level

Failure!!!
Torque transfer failure

Large changes in frictional behavior?
Wet clutch - Disengaged

Wet clutch - Engaged