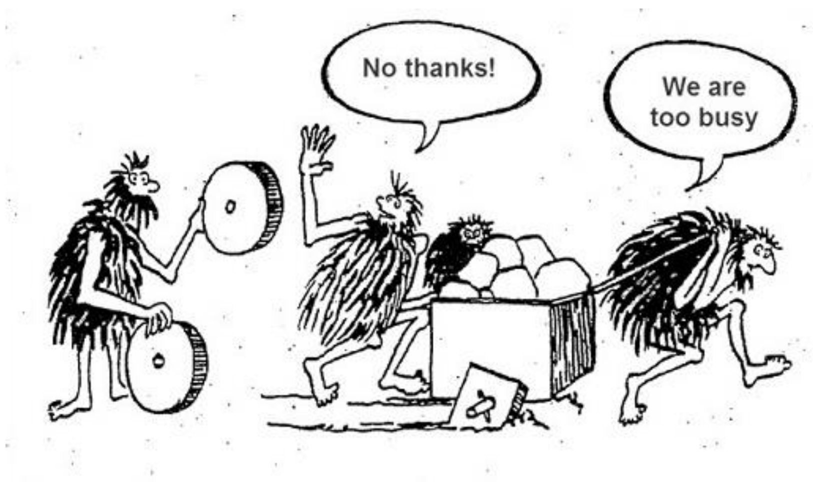
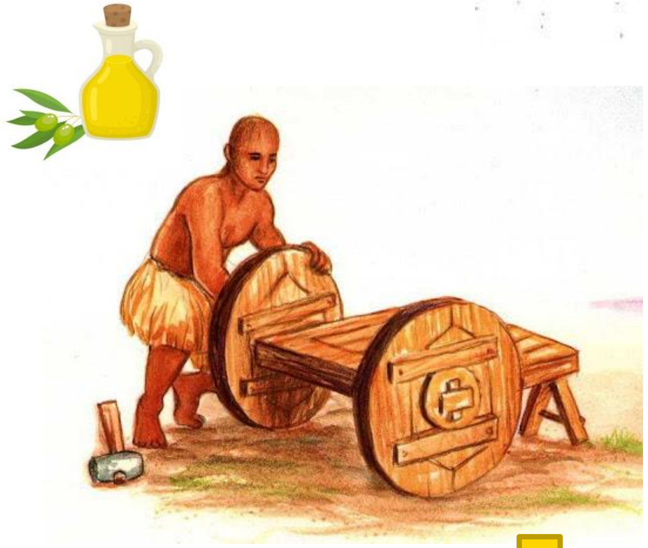
«New methodology for thermal properties evaluation of energy-saving lubricating oils»

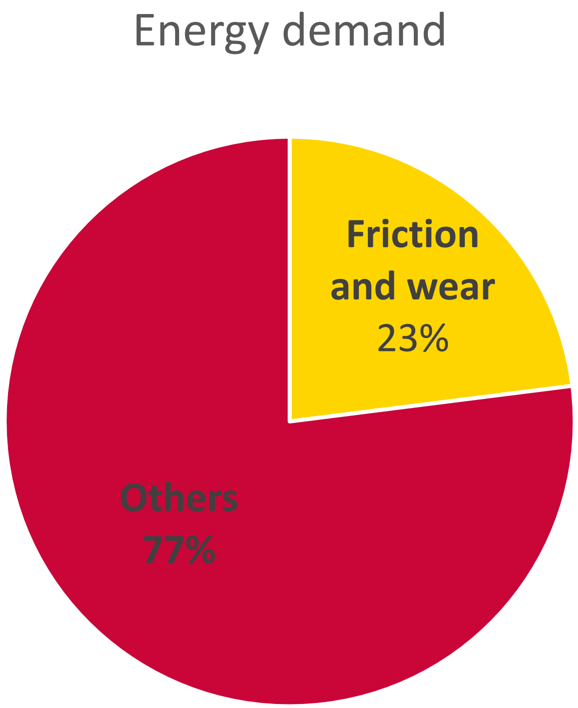
Evaluation of Lubricant Thermal Properties

Eleonora Colombo

Friction and lubrication role







Lubricant design

Lubricants can directly act on energy saving performances

LUBRICATE

- ✓ *Prevent **wear***
- ✓ *Reduce **friction***

CLEAN

- ✓ *Remove **contaminants***

COOL

- ✓ *Transfer **heat***
- ✓ *Enhance **durability***
- ✓ *Prevent **corrosion***

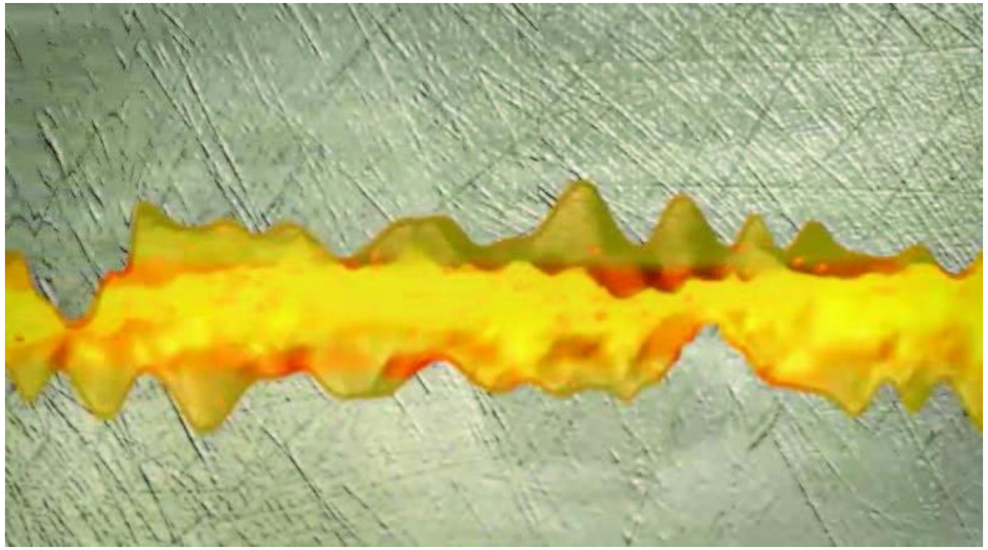
Thermal properties of lubricants

Relative motion between the mechanical parts

Friction phenomena

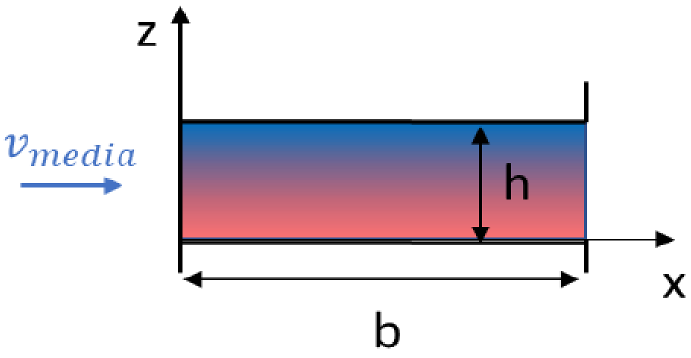
Heat dissipation

Lubricant thermal properties



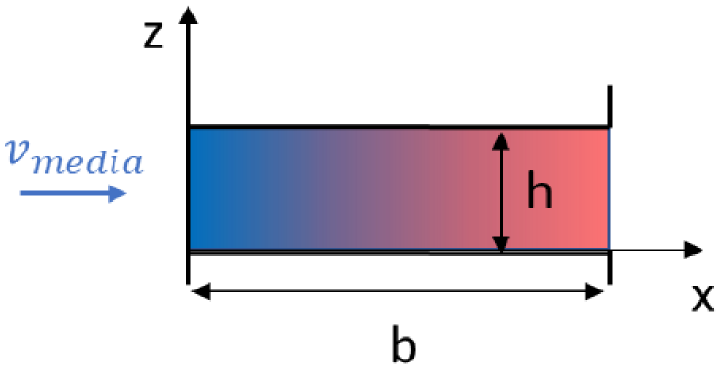
Heat transfer phenomena

Thermal conduction



Heat is transferred across the film thickness
in z direction

Advection



Heat is transferred along the film length and brought away by lubricant
in x direction

$$Pe = \frac{Advection}{Conduction}$$

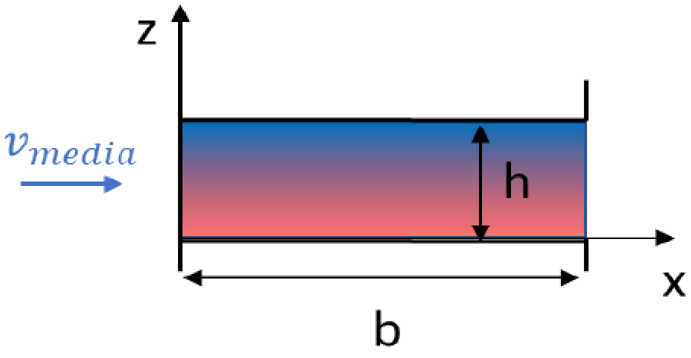
Heat transfer phenomena

$$Pe = \frac{Advection}{Conduction} = \frac{\rho\, c_p\, v_{mean}}{\lambda} \cdot \frac{h_{film}{}^{2}}{b}$$

$\rho\, c_p$ =product between density and specific heat
v_{mean} = mean velocity of lubricant
h_{film} = lubricant film thickness
λ = Thermal conductivity
b = Length of tribological coupling

$Pe \to 0$

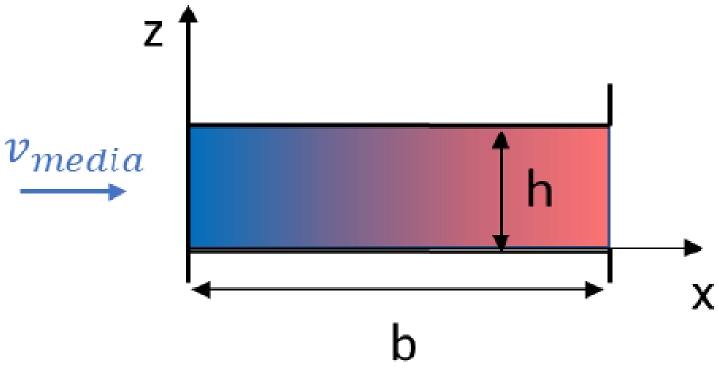
Thermal conduction



$v_{mean} \downarrow \quad h_{film} \downarrow$

$Pe \to \infty$

Advection

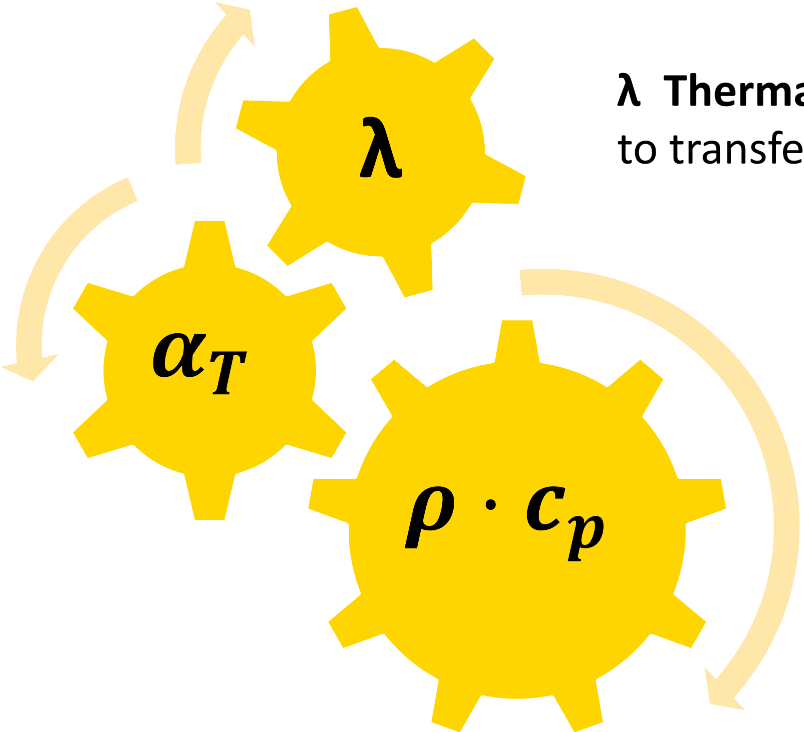


$v_{mean} \uparrow \quad h_{film} \uparrow$

Goal of the research activity

Estimate energy-saving potential of lubricating oils during lubricant design.

Analyse thermal properties of a wide range of base oils for lubricant design and of finite products



λ **Thermal conductivity** = ability of a material to transfer heat through conduction.

α_T **Thermal diffusivity** = rate of heat transfer in time.

$\rho \cdot c_p$ **Product of density and specific heat** = ability of a material to store heat and transfer it through advection.

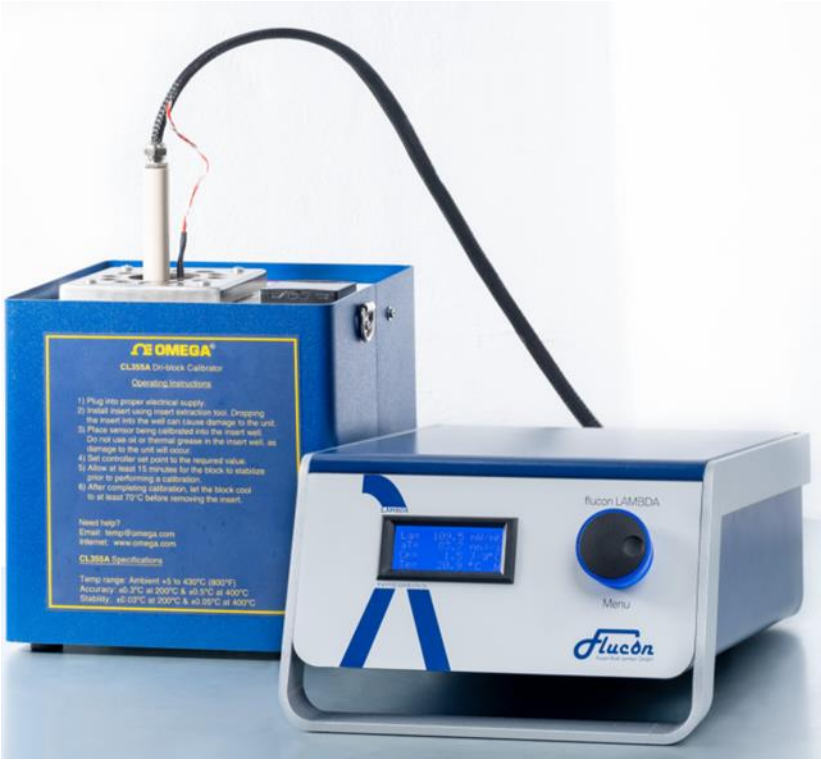
Tested samples

Thermal properties *are evaluated for different feedstocks*

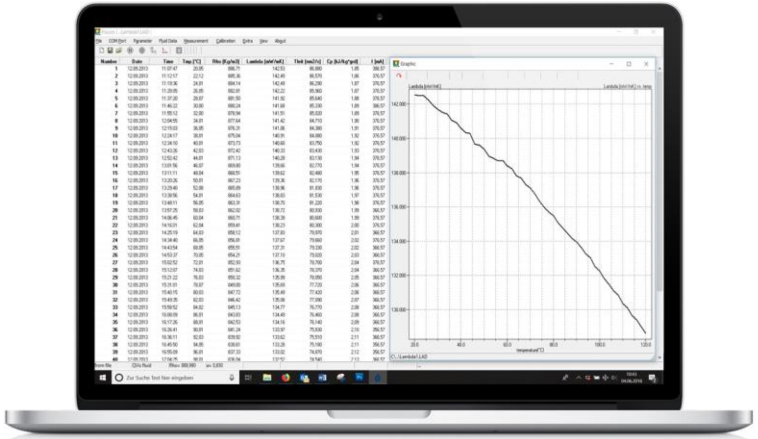
Base oil type	KV a 40°C [cSt]
PAG water insoluble	45
PAG water soluble 1	50-54
PAG water soluble 2	73-84
Renewable base oil GPIII	58
Mineral base oil GPIII	49
Re-refined base oil GPI+	58
MIX mineral base oil GPI	55.2
esters	46
MIX estolides	58.7
MIX polialphaolefins	57.8
MIX nafthenic base oil	56.7

Effects related to viscosity are minimized.

Instrumentation and principles of measurement



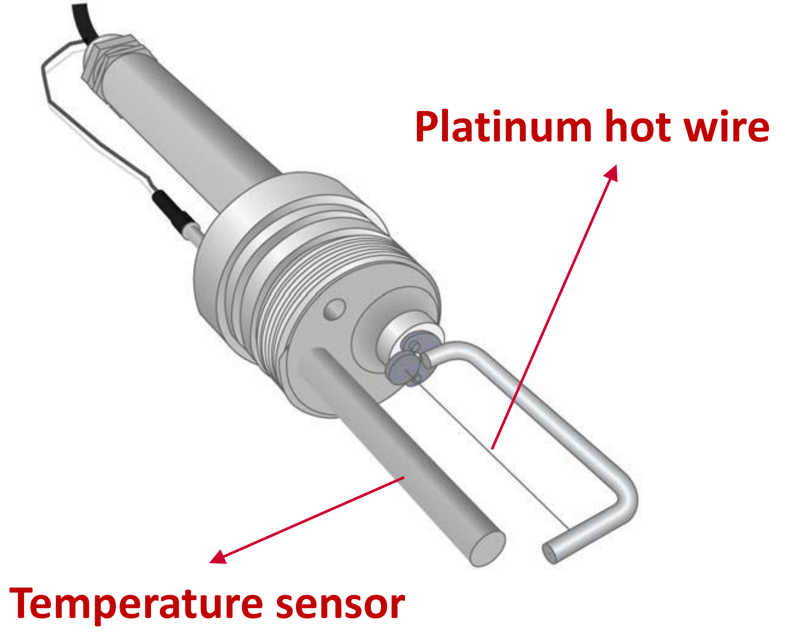
- *The experimental apparatus Flucon LAMBDA:*
  - *Electronic device,*
  - *Measuring probe and sample cup,*
  - *Thermostat Omega,*
  - *Laptop,*
  - *FluconLAM PC Software.*

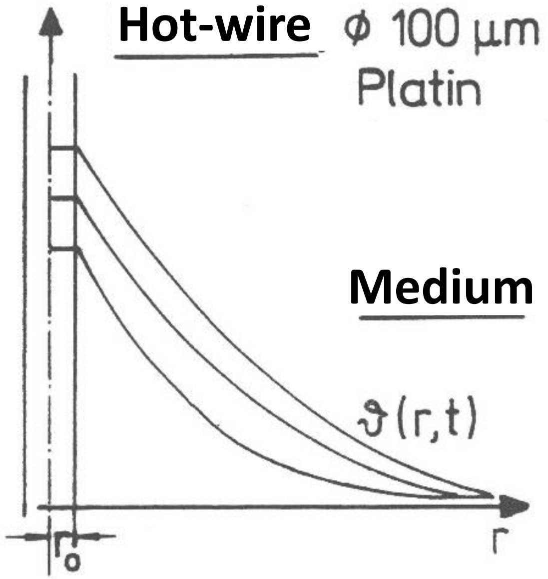


Instrumentation and principles of measurement

- *Measuring principle:*

Instationary hot-wire method → Thermal conductivity $\boldsymbol{\lambda}$ → Thermal diffusivity $\boldsymbol{\alpha_T}$





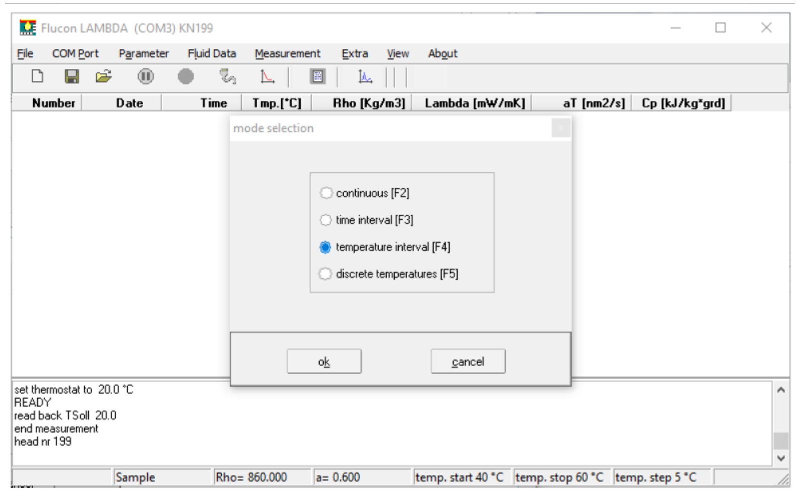
I° Fourier's law

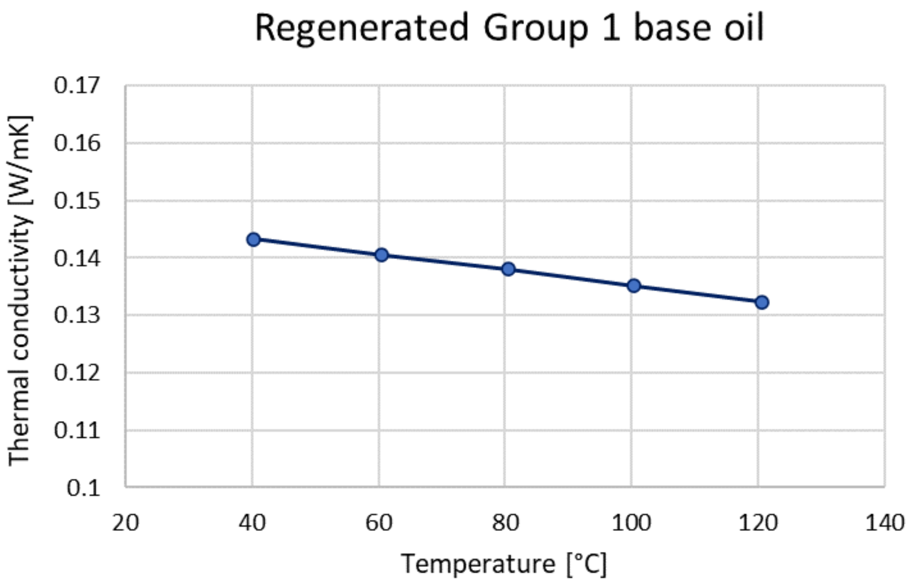
$$q = \lambda \nabla T$$

II° Fourier's law

$$\frac{\partial \vartheta}{\partial t} = \alpha_T \nabla^2 \vartheta$$

Development of a new procedure





In one single experiment

- *Thermal properties are measured at 40, 60, 80, 100 and 120°C.*
- *5 repetitive measurement at each temperature*
- *~3 hours*

Estimation of $\boldsymbol{\lambda}$, $\boldsymbol{\alpha_T}$ *and* $\boldsymbol{\rho * c_p}$

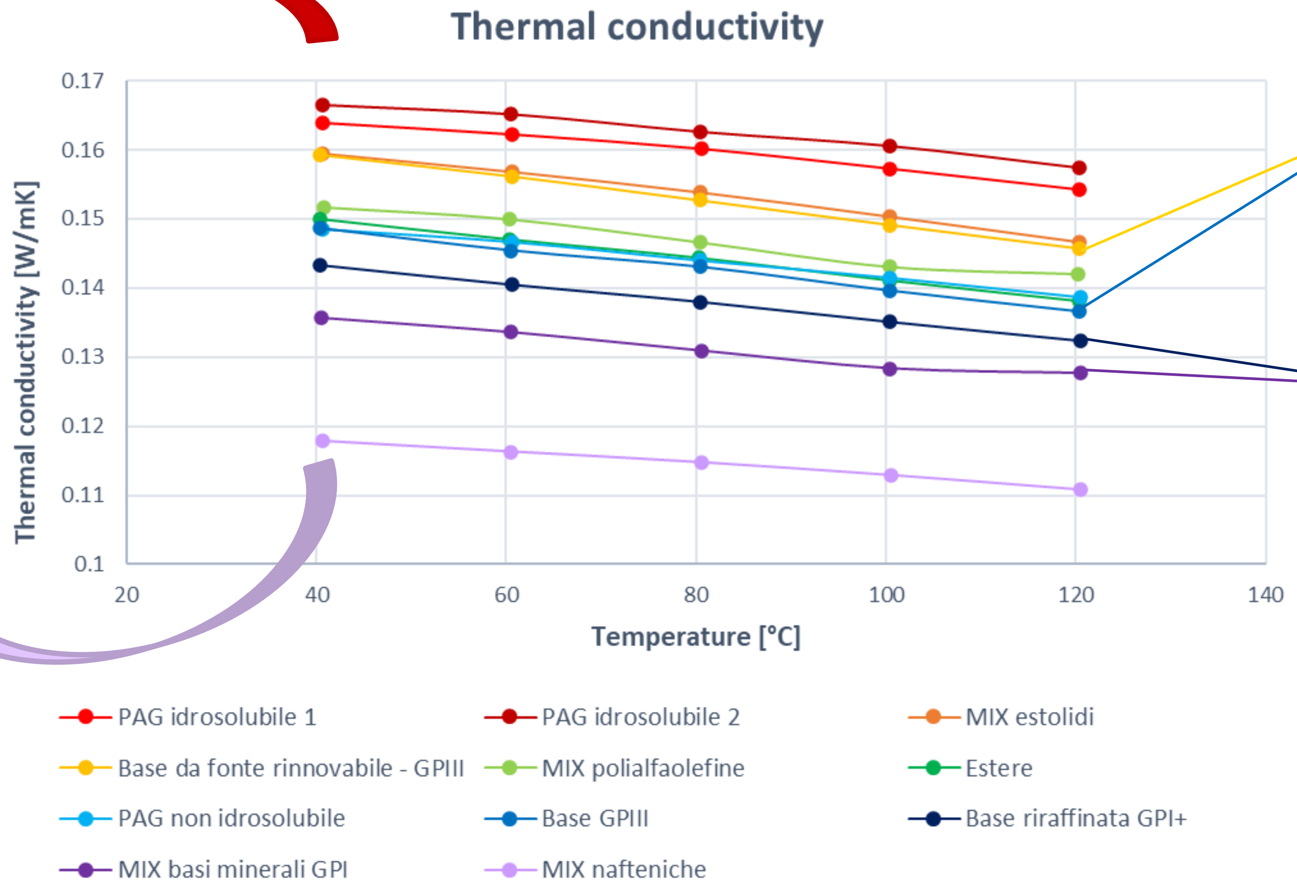
$$\rho \cdot c_p = \frac{\lambda}{\alpha_T}$$

Thermal conductivity

Water-soluble PAG

$$0{,}17\,\frac{W}{mK} > \lambda > 0{,}11\,\frac{W}{mK}$$

Mixture of naphthenic bases

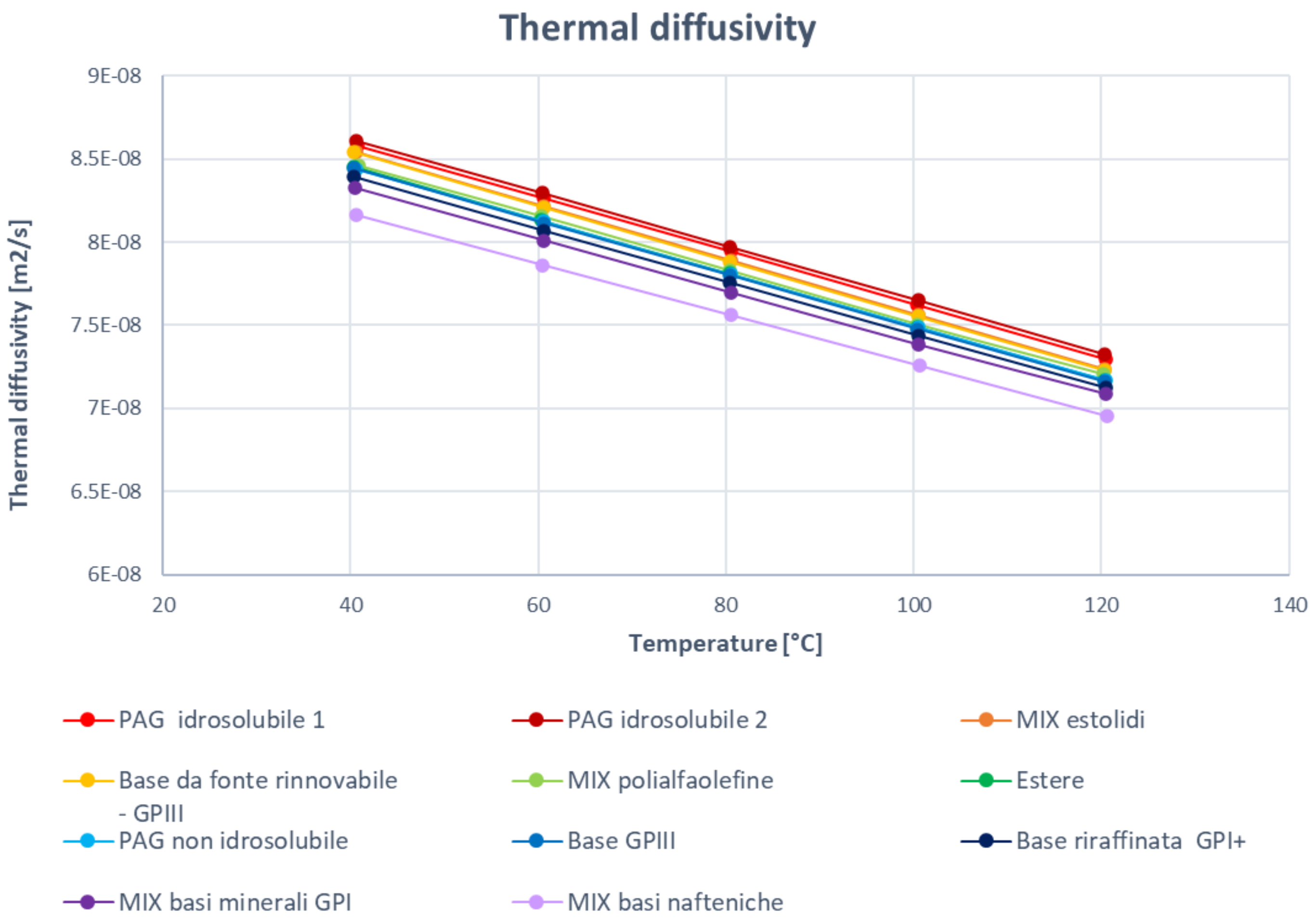


Renewable GPIII *presents a bit greater thermal conductivity than* ***mineral base oil GPIII***

Regenerated Base oil GPI *shows a slightly higher thermal conductivity than* ***mixture of mineral base oil GPI***

Thermal conductivity decreases at increasing temperatures *for all the analysed base oils.*

Thermal diffusivity

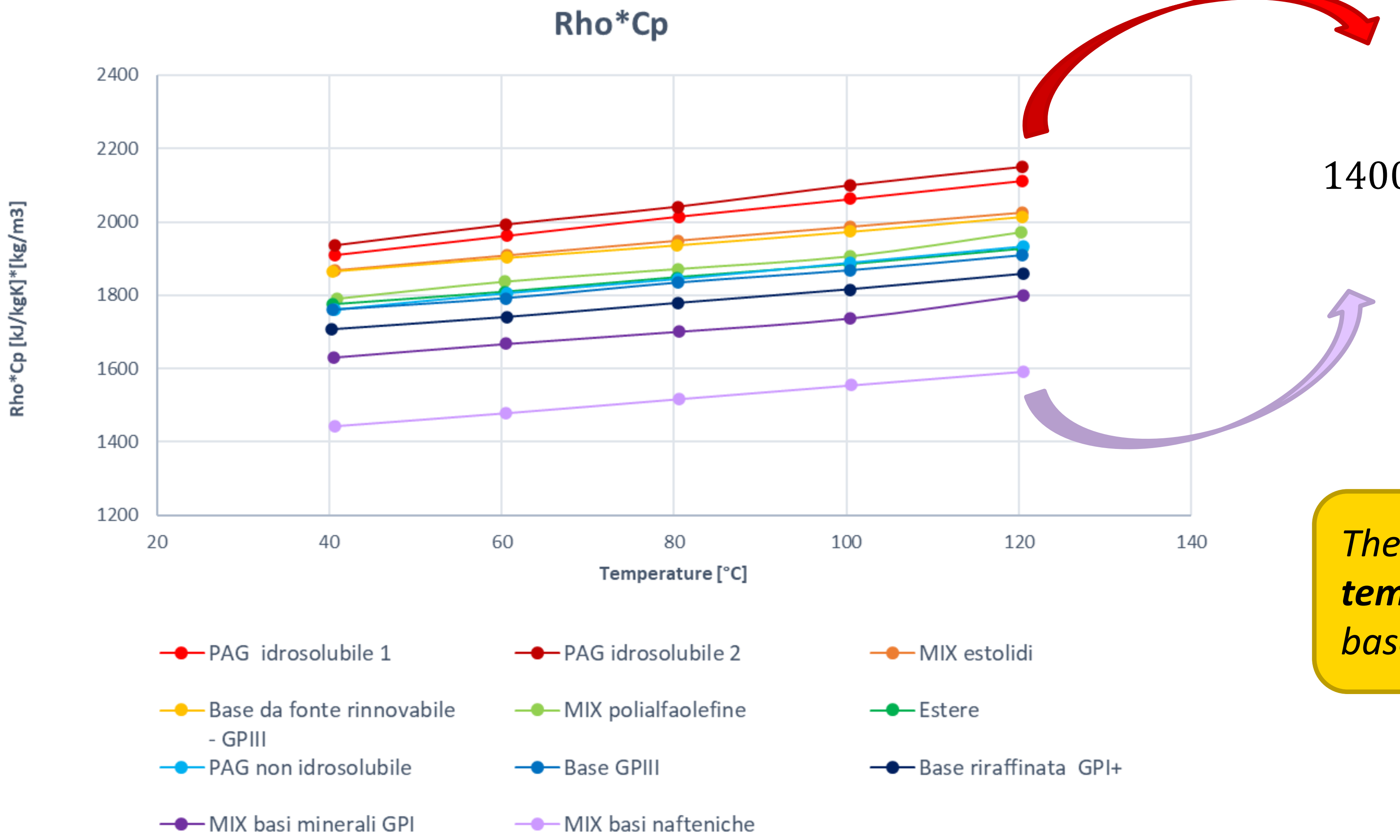


$$9 \cdot 10^{-8} \frac{m^2}{s} > \alpha > 7 \cdot 10^{-8} \frac{m^2}{s}$$

Thermal diffusivity decreases at increasing temperatures *for all the analysed base oils:*

The ***thermal inertia*** *of lubricants grows when temperature grows.*

Product of density and specific heat



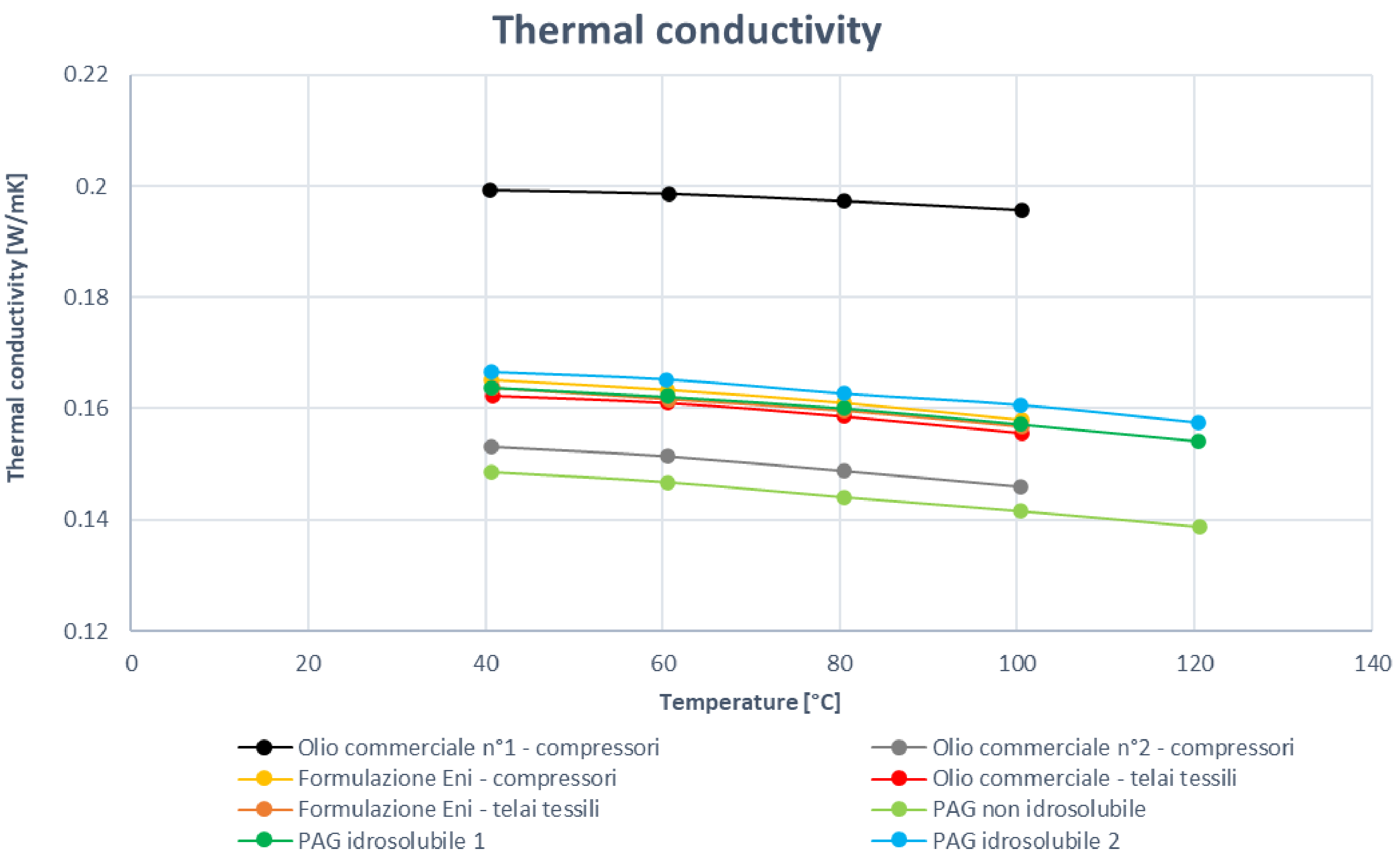
Water-soluble PAG

$$1400\,\frac{kJ}{m^3K} > \rho \cdot c_p > 2200\,\frac{kJ}{m^3K}$$

Mixture of naphthenic bases

The ***product increases at increasing temperatures*** *for all the selected base oils.*

Comparison of thermal conductivities between base oils and finite products - PAG



The behaviour of finite lubricant is closely related to base oil behaviour

Conclusions

The developed methodology enables:

- *The evaluation of all thermal properties of lubricating oil at variable temperatures in one single experiment*
- *Provide with additional data the in-house developed products with respect to other competition companies.*
- *Gain additional information for the estimation of energy-saving performance of lubricating oils*

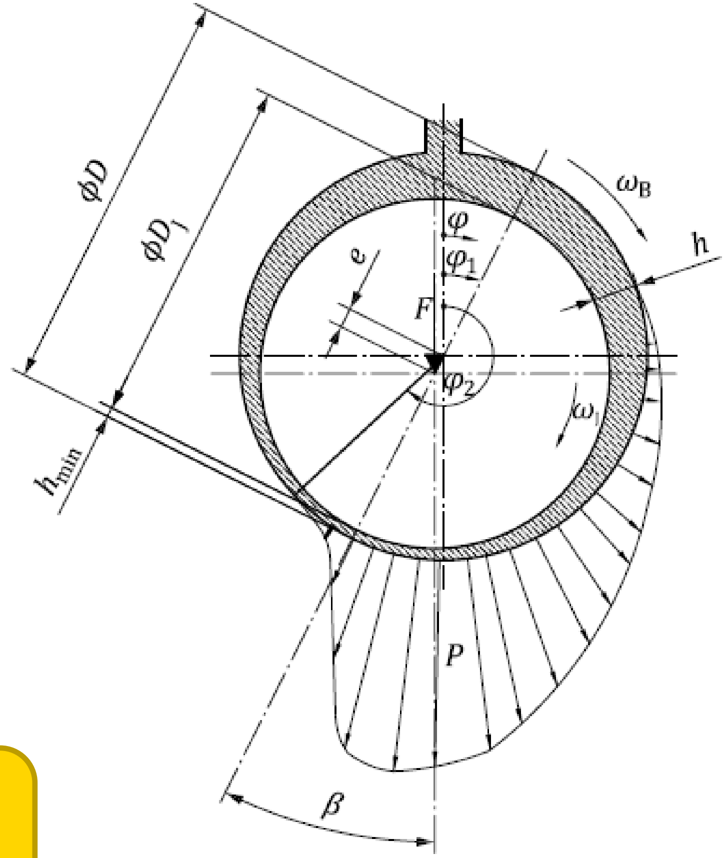
$$P_{diss} = \dot{V}\,\rho\,c_p * (T_{in} - T_{out})$$

Future development

Additional experimental activity on new samples

Simple theoretical model to simulate power dissipation as a function of lubricant properties

Lubricant Design



Q&A

Thank you

Q&A

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