ENERGY TECHNOLOGIES

Driving Product Development Through Modelling New and Historic Data in JMP

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2021-EU-30MP-780

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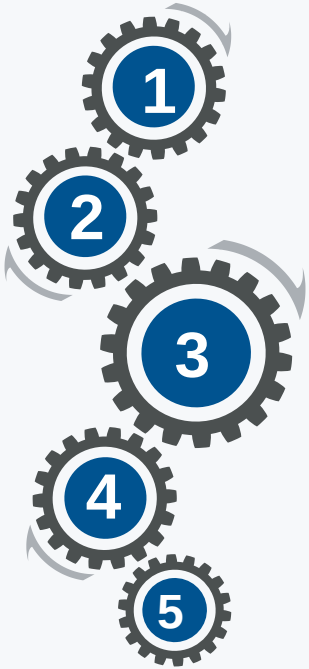
CONTENTS

Potential uses for dielectric fluids in hybrid and electric vehicles



WHO WE ARE

We are the name behind the high performance ingredients and technologies in some of the biggest, most successful brands in the world: developing, making and supplying specialty chemicals that are relied on by industries and consumers everywhere.

Our Business Model

Engage

We work in close partnership with customers and develop emerging technologies around the world

Create

We design innovative ingredients that enhance everyday products

Make

We manufacture to consistently high standards across the world

Sell

We generate revenue by selling our ingredients directly to customers

MARKETS WE SERVE

Personal Care

- Personal Care

Life Sciences

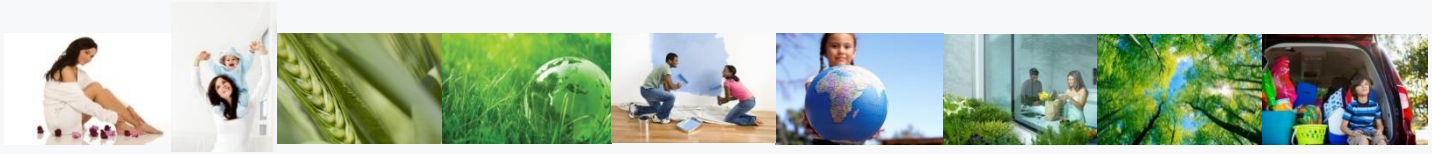
- Health Care
- Crop Care

Industrial Chemicals

- Industrial Chemicals

Performance Technologies

- Coatings and Polymers
- Geo Technologies
- Home Care
- Energy Technologies
- Polymer Additives



PROBLEM DEFINITION

- How do we improve the efficiency of electrical cooling systems?
  - Primary driver for this project is the electrification of transport
  - Primary focus on battery technology and automotive fluids
- What are the current cooling methods?
  - How can these be improved?
- Can build understanding of cooling fluids through data exploration and modelling?

CURRENT COOLING METHODS

What?		Why?	How?	Alternatives
Batteries		To prevent degradation	Air cooling Cold plate cooling	

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Power electronics		To prevent overheating	Heatsinks	

CURRENT COOLING METHODS

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Electric motors		To minimise current resistance	Cooling jackets	

CURRENT COOLING METHODS

What?		Why?	How?	Alternatives
Batteries		Prevent degradation	Air cooling Cold plate cooling	Direct immersion cooling
Power electronics		Prevent overheating	Heatsinks	Direct immersion cooling
Electric motors		Minimise current resistance	Cooling jackets	Spray cooling Drip cooling

EFFICIENT LIQUID COOLING OF ELECTRICAL EQUIPMENT

Dielectric Fluids

- Must be non-electrically conductive
- Should have high thermal conductivity for cooling
- Should be low viscosity to aid pumping efficiency

DIELECTRIC FLUID PROPERTIES

- The ability of a fluid to transfer heat is based on the equation below

$$Q = kA(T_2 - T_1)$$

Q	Heat transfer (W)
k	Heat transfer coefficient (W m^{-2} K^{-1})
A	Area (m^2)
T_2, T_1	Temperature of object surface and cooling liquid, respectively

- For efficient heat transfer a high heat transfer coefficient is required

DIELECTRIC FLUID PROPERTIES

- The heat transfer coefficient is defined in the equation below

$$k = \frac{\rho \lambda C_p}{\nu}$$

ρ	Density (kg m^{-3})
λ	Thermal conductivity (W m^{-1} K^{-1})
C_p	Specific heat capacity (kJ kg^{-1} K^{-1})
v	Kinematic viscosity (mm^2 s^{-1})

DIELECTRIC FLUID PROPERTIES

- In order to optimise this coefficient we want
  - High ↑ density
  - High ↑ thermal conductivity
  - High ↑ specific heat capacity
  - Low ↓ viscosity

$$k = \frac{\rho \lambda C_p}{\nu}$$

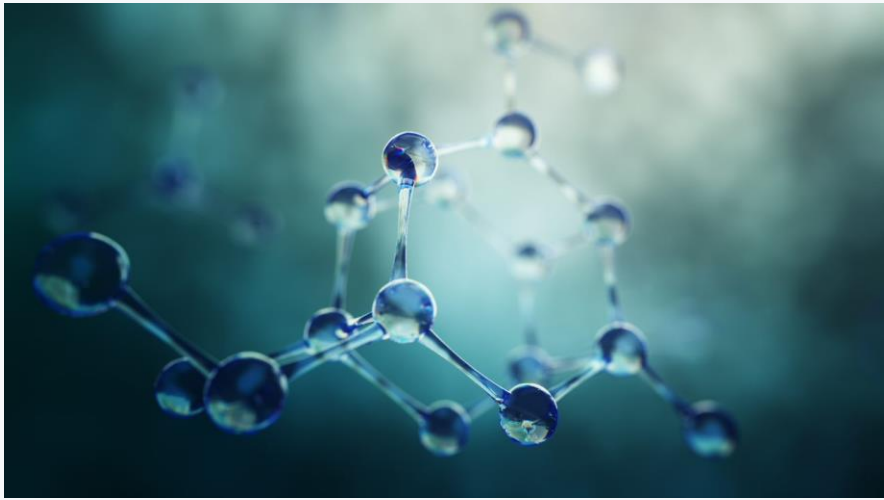
DIELECTRIC FLUID PROPERTIES

- We wanted to understand relationship between structure and performance
- Large scale study to measure physical properties of esters
- Modelling work carried out the relate physical properties to structure

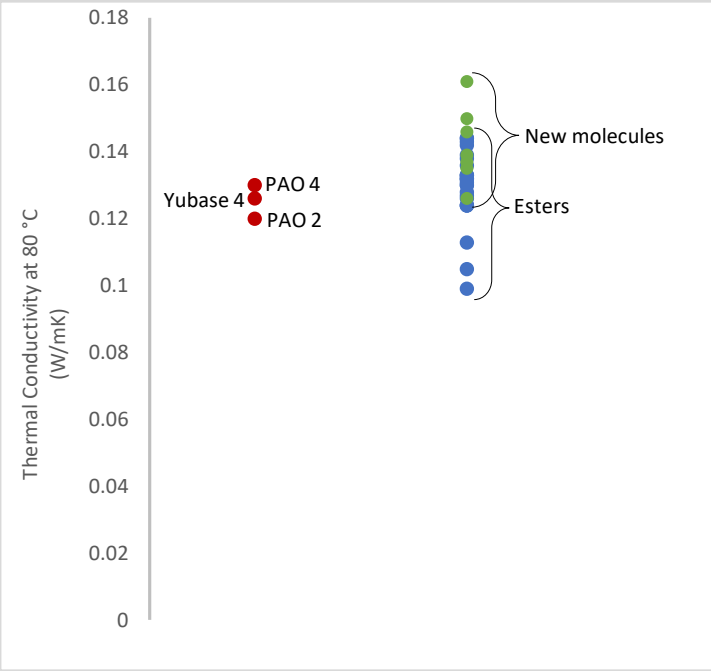
JMP

DIELECTRIC FLUIDS

- Structure performance model created through linear regression in JMP
- Model used to direct the synthesis of new materials
- Acceptable correlation seen between model and new molecules



NEW MOLECULES



- Directed synthesis of molecules with higher thermal conductivity
- Targeted improvement in thermal conductivity is possible
- Model aims to balance thermal conductivity with other factors
  - Must not negatively impact other properties
- Further development ongoing to refine model and widen scope

CONCLUSIONS

- Data obtained from applications testing has been used to successfully model product performance
- Model demonstrates the structure performance relationship of esters
- Model was used to predict materials with high thermal conductivity
- Predictions from the model verified through synthesis of new materials
- Demonstrated the possibility of tailoring the properties of dielectric fluids
- Success of this work has built momentum for the use of data and JMP to drive NPD

Thank you! Any questions?

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