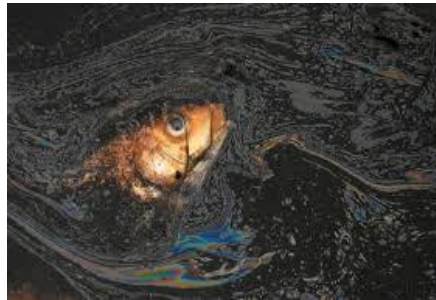


Glycerol-based green lubricant for an Oil-free, Fossil-free and PFAS-free hydropower

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- *CTO at Sustainalube AB*

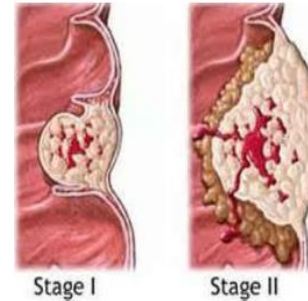
Traditional lubricating oils create problems for humans, animals, and plants



Water pollution



Skin damage



Stage I Stage II

Cancer risks



**A suffering
Swedish person**

[1] "Towards Sustainable and Eco-. Friendly Cutting Oils". Satish V. Kailas. Department of Mechanical Engineering. Indian Institute of Science

[2] https://urldefense.proofpoint.com/v2/url?u=https-3A_da.se_2016_09_sju

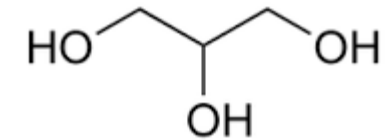
Available technology in the market

- **So-called green solutions:**
 - (1) Vegetable oils (**oxidation**);
 - (2) Synthetic esters (**fossil, expensive**);
 - (3) Polyalkylene glycol (**fossil, unstable**);
 - (4) Water (**poor lubrication, toxic**).

- **Our idea:**
 - **Glycerol + green additives.**

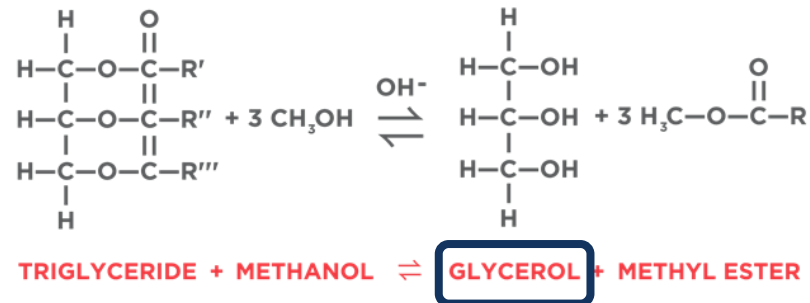
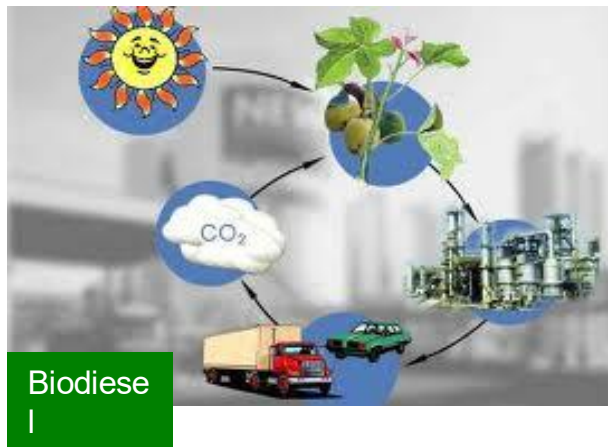


Glycerol (E422) is close to our daily lives



Oversupply of glycerol

- **1 kg of Glycerol** is generated for each 10 kg of bio-diesel (RME) produced.
- The top 7 countries produced **~36.5 million tons of bio-diesel** in 2022.¹



Is it possible to use glycerol as lubricant?

1. <https://www.statista.com/statistics/271472/biodiesel-production-in-selected-countries/>

Glycerol basic properties

[Source: Wikipedia]

Properties	Glycerol	H ₂ O	Oil
Flash point (°C, close cup)	160	-	~ 100
Viscosity (Pa·s @ 20 °C)	1.412	< 0.005	~ 0.05
Solubility	Miscible with H ₂ O	-	Organic solvent
Pressure-viscosity ^[1]	4.7	< 4	18
Compressibility (×10 ⁻¹⁰ Pa ⁻¹) ^[2]	2.1	4.6	9
Heat capacity (J/kg/K)	~ 2400	4186	~ 1800
Thermal conductivity (W/m/K)	0.28	0.6	0.15
Vapor pressure (mmHg (50°C))	0.003	0.1218	~ 8.5 (at 40°C) ^[3]

[1] http://www.tribology-abc.com/calculators/barus_roelands.htm

[2] <http://lab.fs.uni-lj.si/lft/Documents/40--4-Oil%20and%20Water-FT.pdf>

[3] https://www.petroskills.com/blog/entry/00_totm/nov-17-fac?page=5#.XdMe5lVKipo

Glycerol-based lubricants



Agriculture and Food



Electric Vehicles



Forest



Heavy Equipment



Hydropower



Industrial Manufacturing



Mining and Rock Drilling



Robotics

Products for hydropower:

1. Central Lubrication Grease

Egenskap	Testmetod	Resultat
Densitet	ASTM D 1298	1.12 g/mm ³
Utseende	Färg	Vit-gul
Konsistens NLGI	ASTM D 217	1*
Droppunkt	ASTM D2265	90 °C
Lätt biologiskt nedbrytbar	OECD 301F	Ovan 90%
Fryspunkt	ASTM D 97	Nedan -50 °C
Rostskyddstest	ASTM D665 A	Godkänd

*Har produkter tillgängliga från NLGI 000 till 2

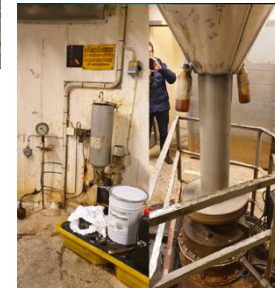
Advantages:

- **Excellent low-temperature performance**
- **Completely non-toxic, readily biodegradable**
- **No allergic reactions**
- **Easy to keep your machine clean**, simply by rinsing it with water.



Lubricating grease

Hydropower Guide Bearing



Lubricating grease

Saw Chain



Products for hydropower:

2. Hydraulic Standard

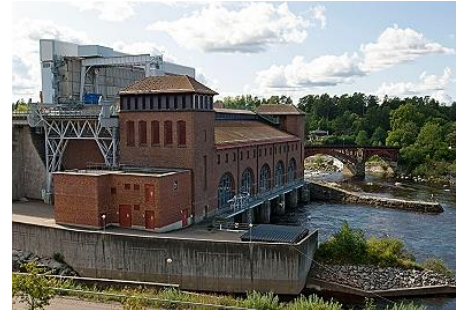
TEKNISK DATA

Egenskaper	Testmetod	Resultat
Densitet	ASTM D1298	1.15 g/mm ³
Viskositetsklass	ISO VG	VG 68
Flampunkt	ASTM D92	över 200 °C
Flytpunkt	ASTM D97	-50 °C
Lätt biologiskt nedbrytbar	OECD 301F	över 95%
Kopparkorrosion	ASTM D130	1b
Lastbärande kapacitet	DIN 51354	9-10
Nötningsmotstånd	ISO 20763	vinge: -0.3 mg ring: -48.3 mg
Luftavgivning vid 50°C	ASTM D 3427-12	5.5 minuter
Skumningssekvens I/II/III	ASTM D892	20 ml

Advantages:

- **Completely non-toxic, readily biodegradable**
- **No allergic reactions**
- **Oil-free.**

Hydraulic system: 60 °C, 250 bar, 24h/7, 3 years



Vattenfall, Älvkarleby, (1) 2020.09 till **now** (2) 2022.09 till **now**



Statkraft, Nyfors, 2023.05 till **now**

Products for hydropower:

3. Hydraulic Cold

TEKNISK DATA

Egenskap	Testmetod	Resultat
Densitet	ASTM D1298	1.10 g/mm ³
Viskositetsklass	ISO VG	VG 46
Flampunkt	ASTM D92	över 200 °C
Flytpunkt	ASTM D97	-50 °C
Lätt biologiskt nedbrytbar	OECD 301	Godkänd*
Copper corrosion	ASTM D130	1a

*Bedömt utifrån resultat av ingrediensers nedbrytbarhet

- It can be considered as a “HFC” hydraulic fluid.
- Can work well down to -30 °C to -40 °C .
- Good results after 200 bar and 50°C for 100 hours.



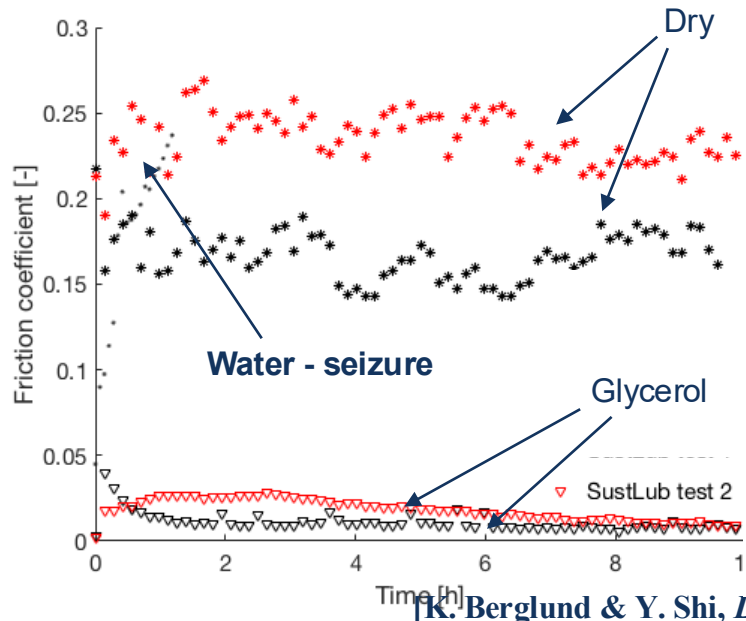
Statkraft, Skeen, 2023.09 till **now**



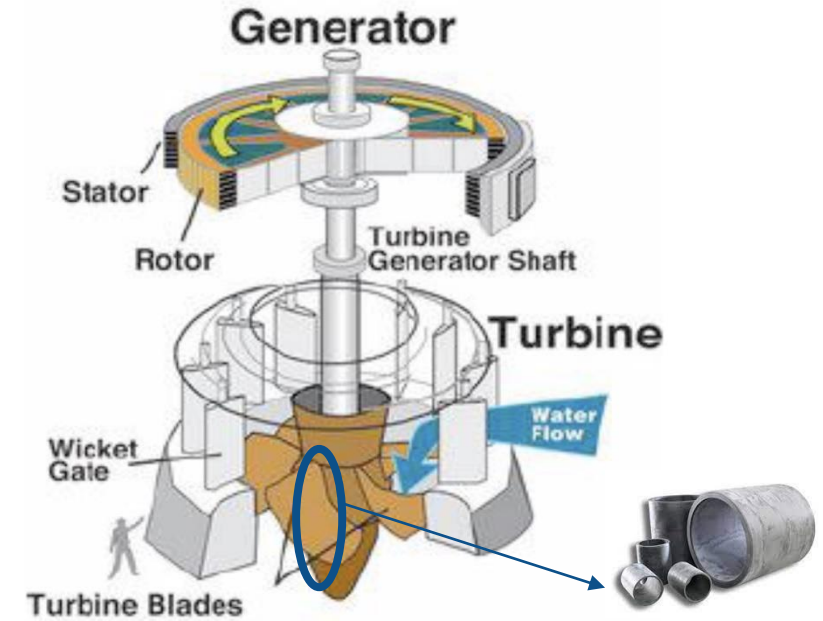
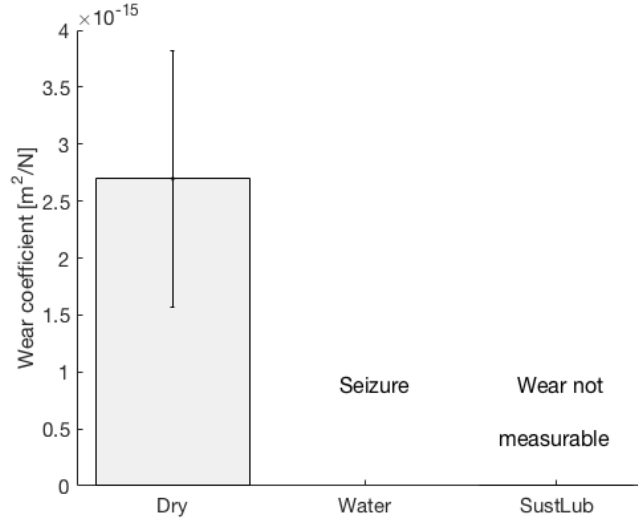
Uniper, Verperyd, Outside Ronnebyån, 2023.1012 till **now**

Products for hydropower:

4. Glycerol lubrication for Kaplan Runner Hub



[K. Berglund & Y. Shi, *Lubricants* 2017]



With around 40% friction reduction!

Current customers:

Uniper
Fortum
Andriz (Finland)

Ongoing partners:

LITOSTROJ POWER (slovenia)
Andriz (Austria)
Turab (Sweden)

Advantages:

- PFAS-free solution
- Fossil-free

History of Kaplan runners

Oil-filled Kaplan runners

Self-lubricated Kaplan runner bearings

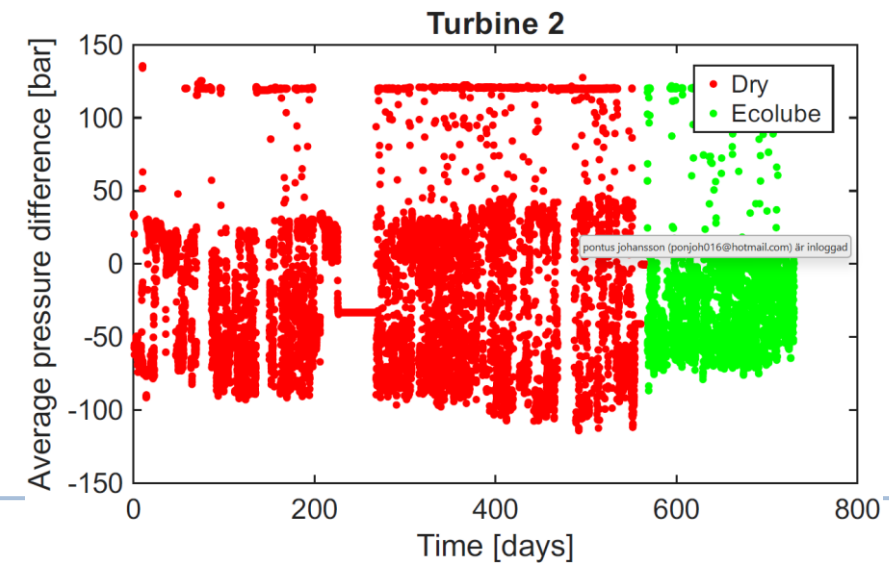
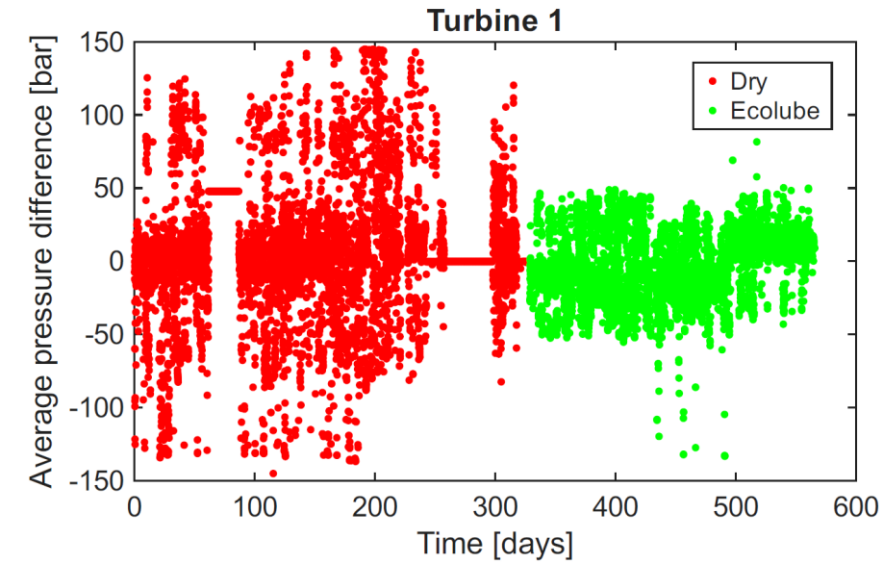
**From 1980/2000
(small/big runners):**

Transition to more
eco-friendly Kaplan
runners

Glycerol-filled runners

From 2022:
Solving problems
with high regulating
pressures. Can be
used with both
bronze and polymer
bearings

**Before (red) and after (green)
filling two runners with glycerol**



Challenges with Kaplan runners

Oil-filled Kaplan runners

- Often used sparsely to minimize risk of leakage.
- Kaplan runner often shares lubricant with the hydraulic system → Water-soluble lubricants needs to be fullfil requirement for both hydraulics and Kaplan runner.

Environmentally adapted runners (water-/air filled)

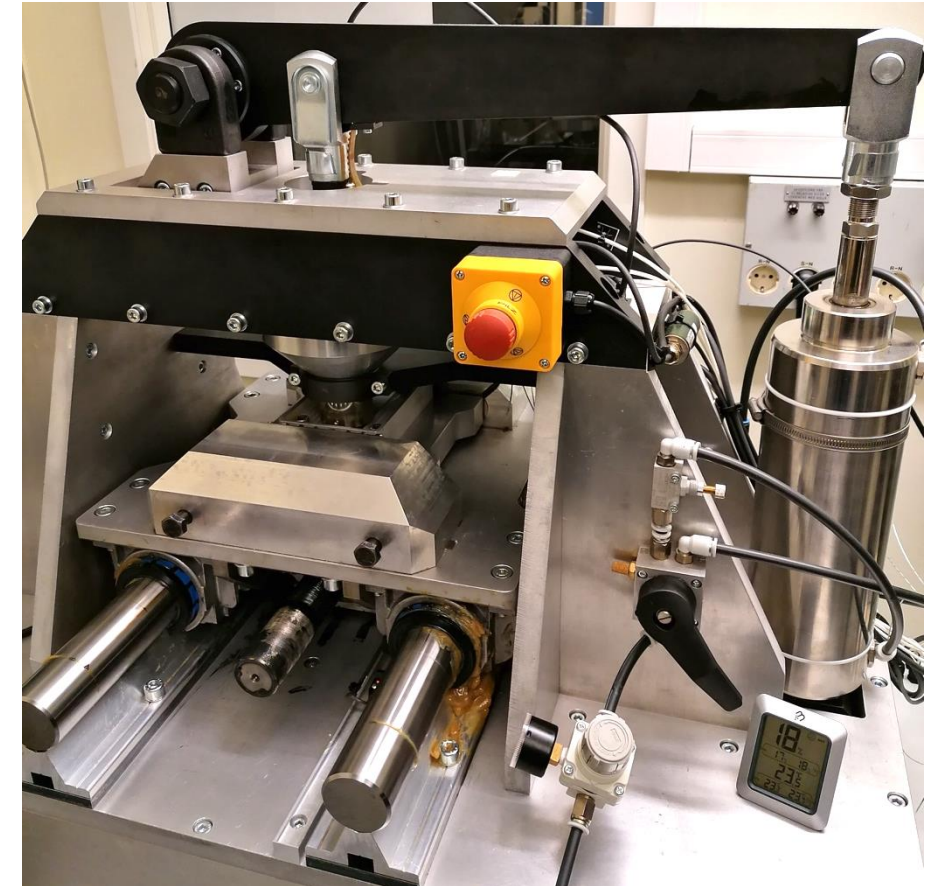
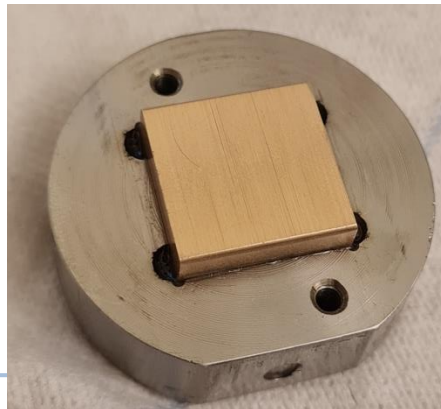
- Self-lubricated bearings often contain PTFE → risk of PFAS pollution
- Often regulated runner blades by hydraulic oil

Development of hybrid lubricant – Hydraulic fluid + Kaplan runner lubricant

For old oil-filled Kaplan turbines

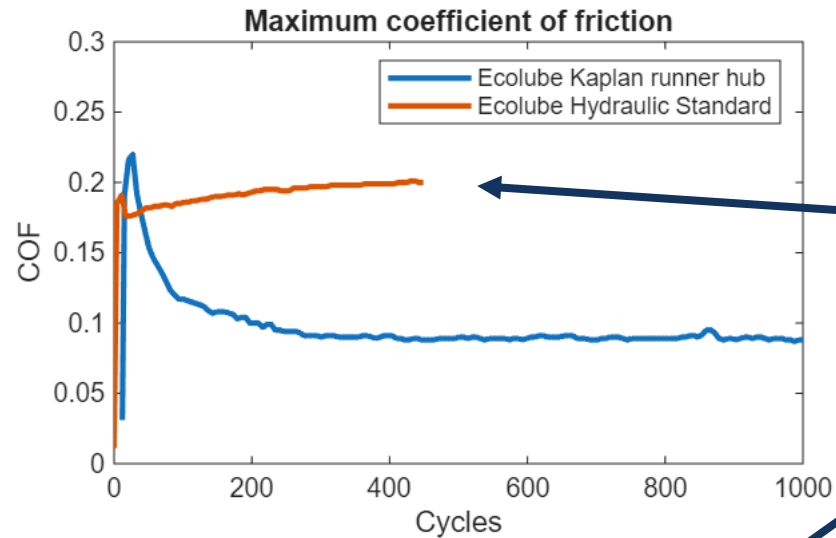
Requirements:

- Coefficient of friction < 0.1 for Kaplan runner hub
- Suitable viscosity and viscosity index for hydraulic systems
- High wear protection for hydraulic pumps

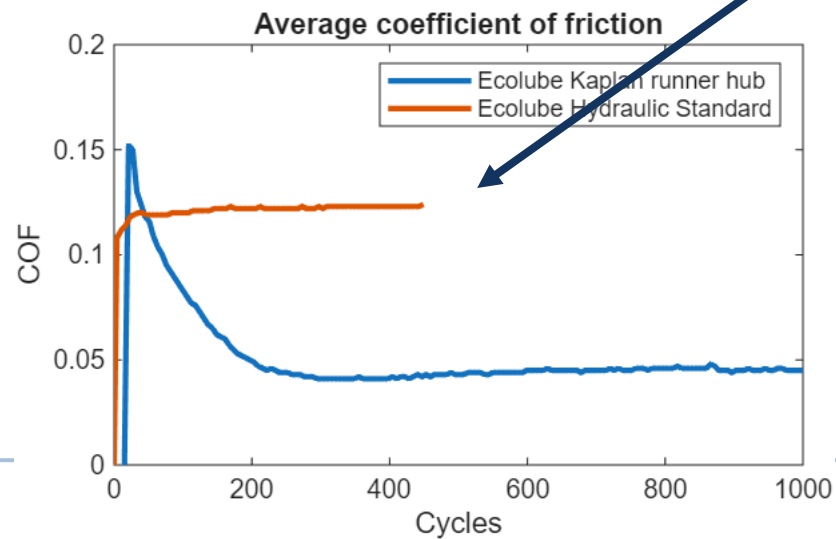


SVC tribometer

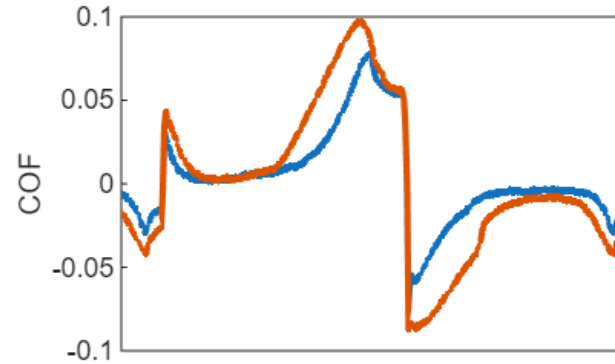
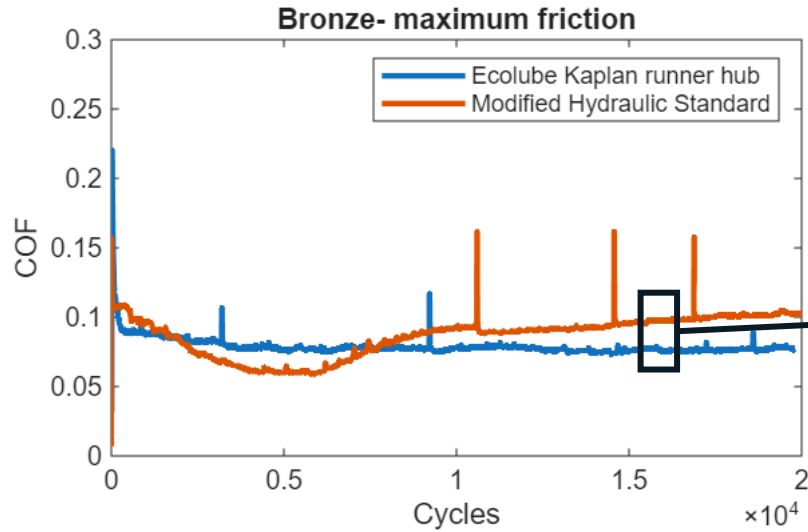
Preliminary results, hybrid lubricant in steel – bronze contact



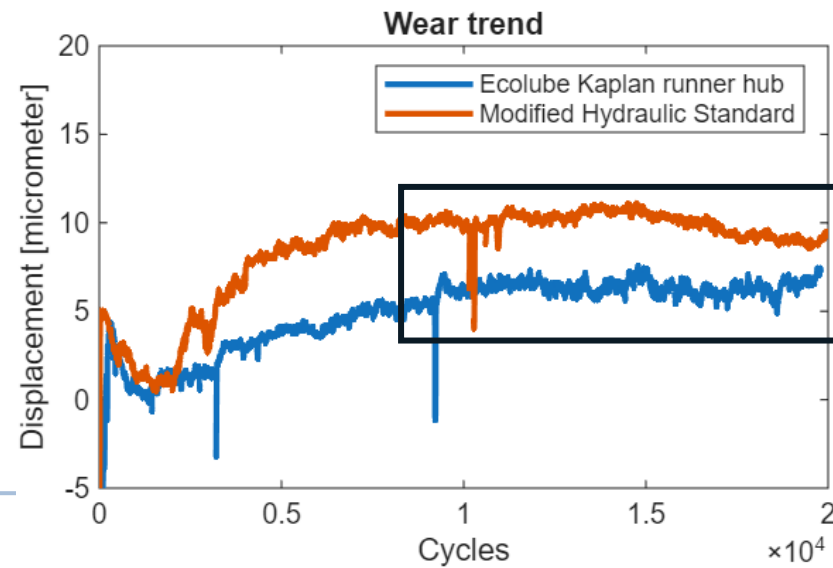
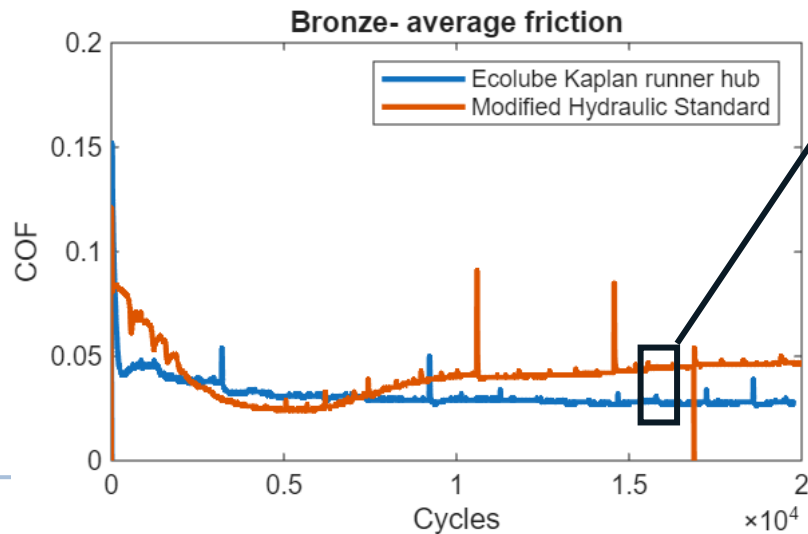
Too high coefficient of friction with Hydraulic Standard



Preliminary results, hybrid lubricant in steel – bronze contact



Additive package and glycerol concentration governs the coefficient of friction against bronze

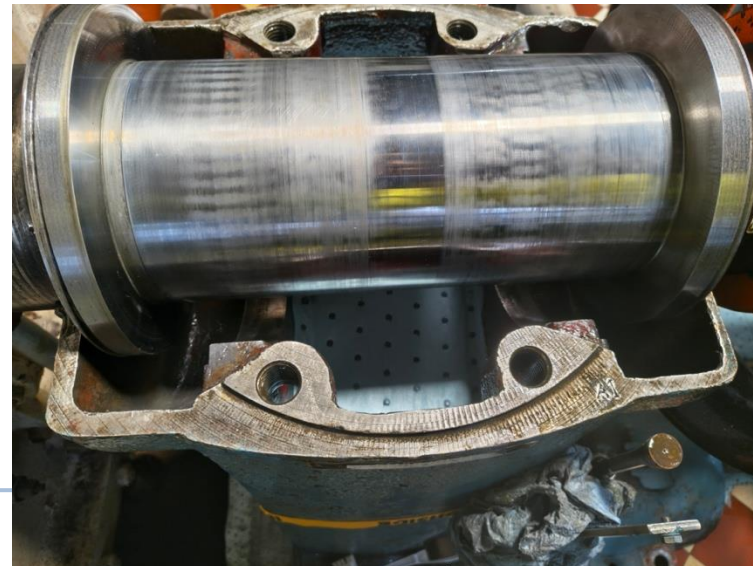


Zero wear!

Development of turbine bearing lubricant

Requirements:

- Thermally stable at 60°C
- Good wetting, even on oil
 - Supply by oil-ring
 - Impregnated materials with oil

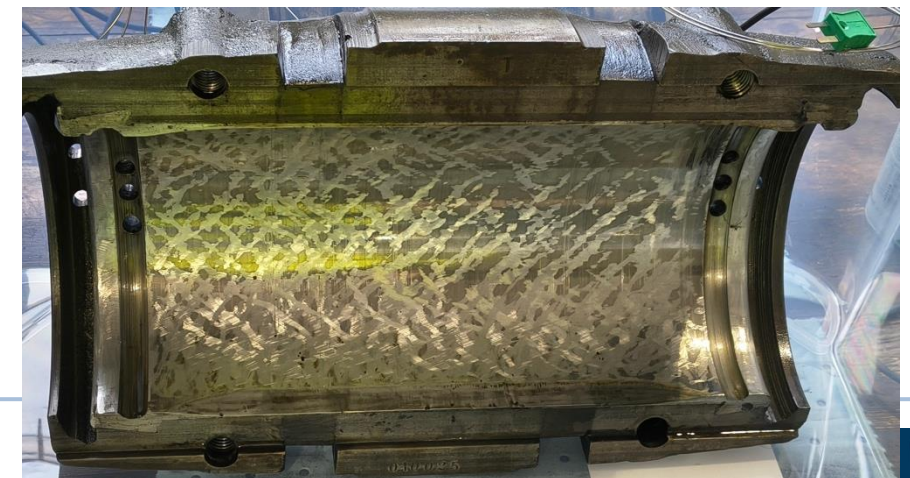
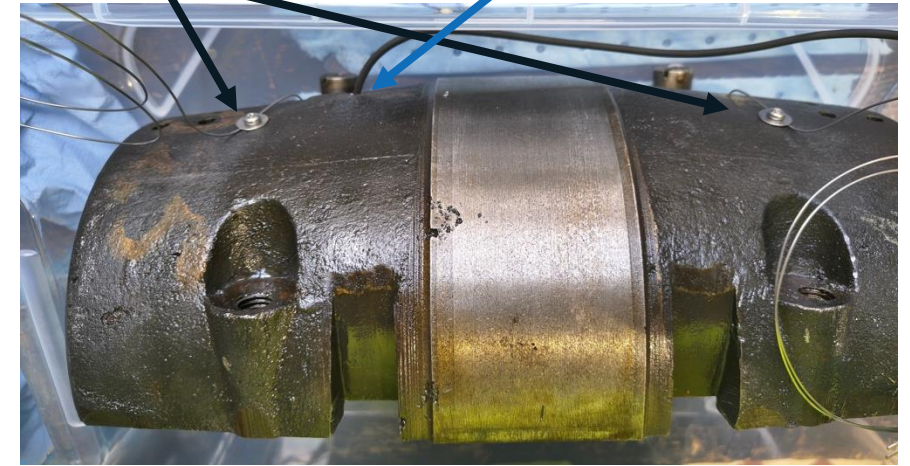


Preliminary results of bearing lubricant test

	Average temperature
Axial bearing temp (glycerol)	62 °C (Previous data indicate ~5-15 °C lower temp. with glycerol)
Radial bearing (glycerol)	34 °C
Radial bearings (oil reference)	39 °C

Two weeks of operation with stable temperature and significantly lower friction losses.

Thermocouples (for logging)
PT100 (for system alarms)



Thanks so much!

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