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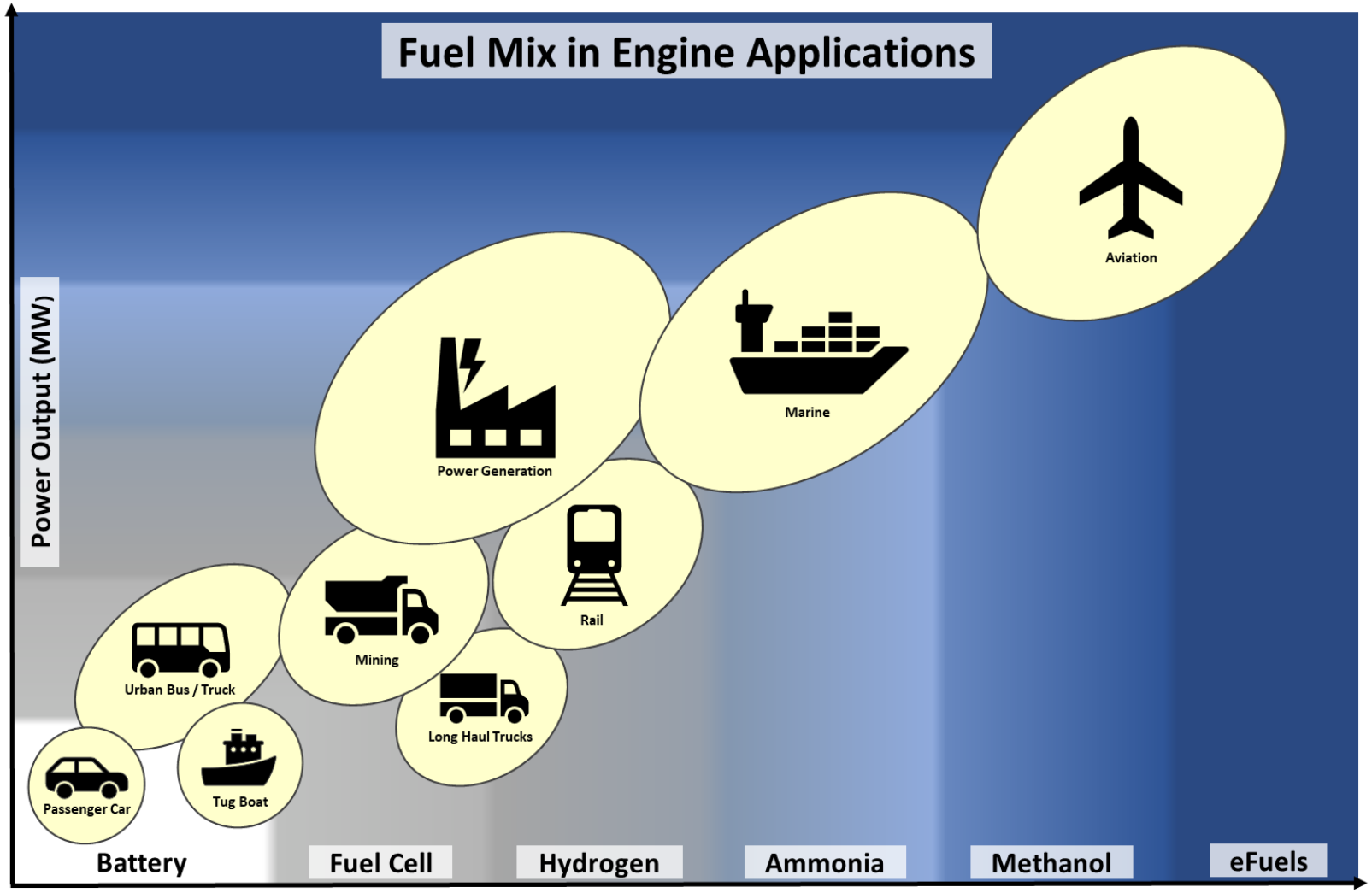
Innovation in Motion Miba

A3PS Eco-Mobility 2025

Evaluating plain bearing performance in alternative fuel engine applications

14th November 2025, Sebastian Kirchhamer

Future fuel in engine applications



Sources: Miba Internal, Revision 09/2024

Infrastructure availability and bunkering capacities will drive fuel diversification in the ICE market portfolio.

Future fuel in engine applications

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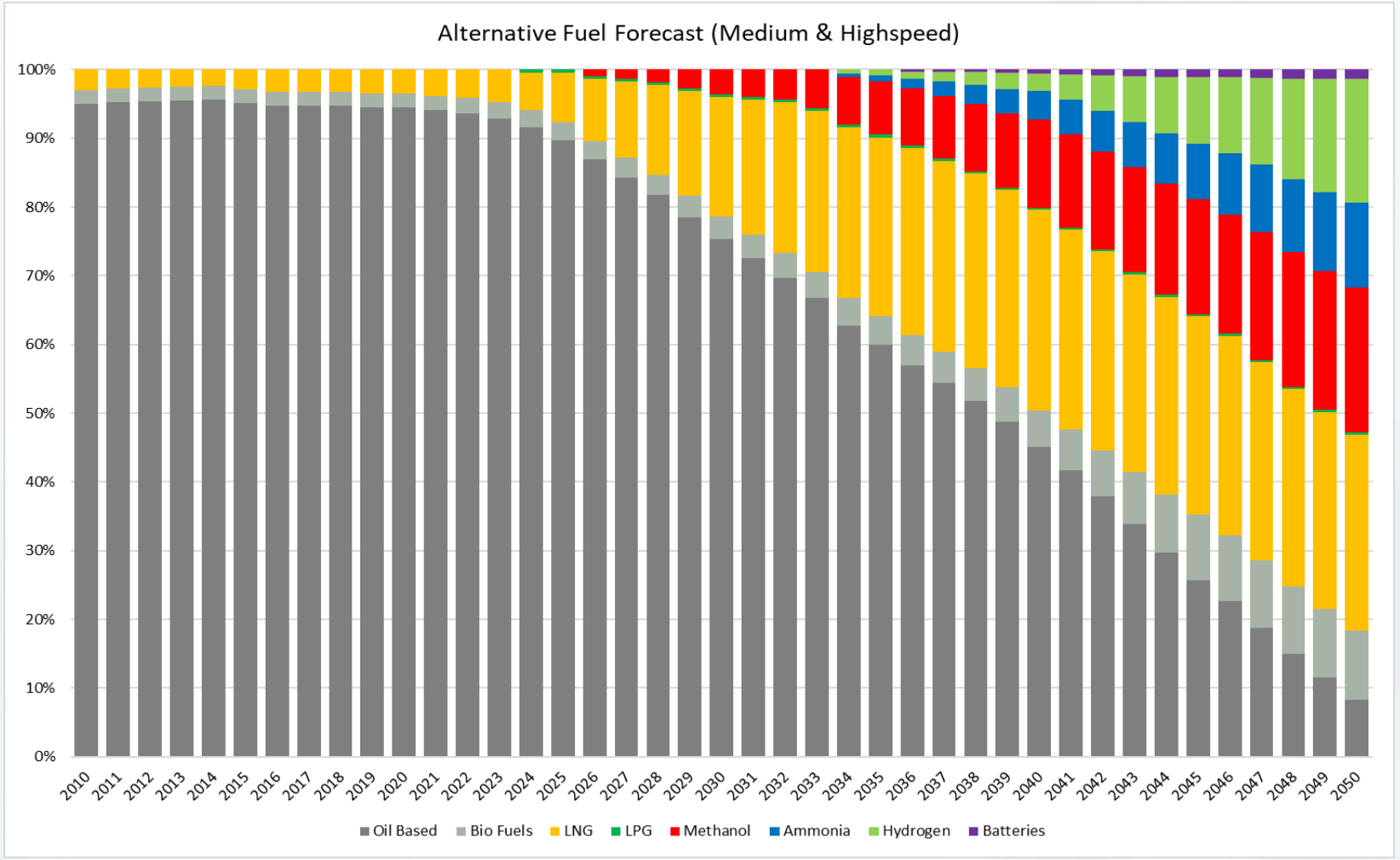

Upcoming regulations and fuel availability will drive alternative fuel applications to capture 50% of the market.

Motivation for Alternative Fuel Research

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Alternative Fuels

- New alternative fuels in the ICE (NH_3, H_2, MeOH...)
- Interaction of combustion products and fuel residues with bearing materials.
- Reactions of combustion products and fuel residues with oils (additives).

New Oil Formulations

- Changes in the engine oil formulations can influence the chemical interactions.
- Longer oil lifetime and oil change intervals.
- Use of new, fully synthetic base stock oils (Polyesters, Polyglycols…)

Bearing Challenges

- Chemical interactions with the bearing material.
- Chemical reactions with important oil additives.
- Water content in the engine oil from the combustion.
- Mechanical stress like pre-combustion (Hydrogen)

New fuels drive new tribological functional systems. We must understand these systems to be able to support engines with the right bearing solution.

Miba AF Testing Approach

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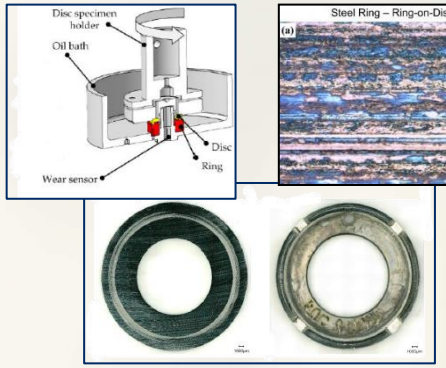
Oil Sample

Oil-Material Compatibility Testing

- Chemical interaction.
- Variability for different materials & oils
- Broad & fast screening methodology.
- Interaction of additives and contaminations with bearing materials.

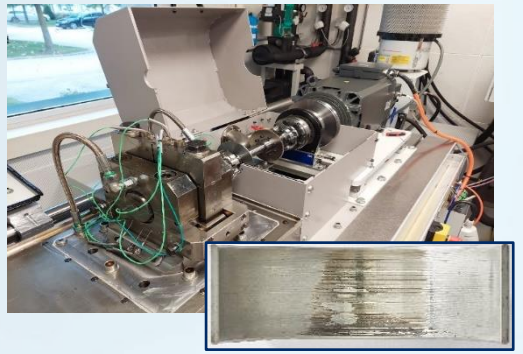
Tribometer Tests (Ring-on-disc)

- Tribological contact.
- Influence of additives on tribo-film formation.
- Screening wear behavior with different oil cond. (e.g. NH_3)



Test Rig Run

- Hydrodynamic test.
- Wear & Fatigue Testing
- Influence of different oils (new & aged) on the engine system.



Oil Material Compatibility Testing

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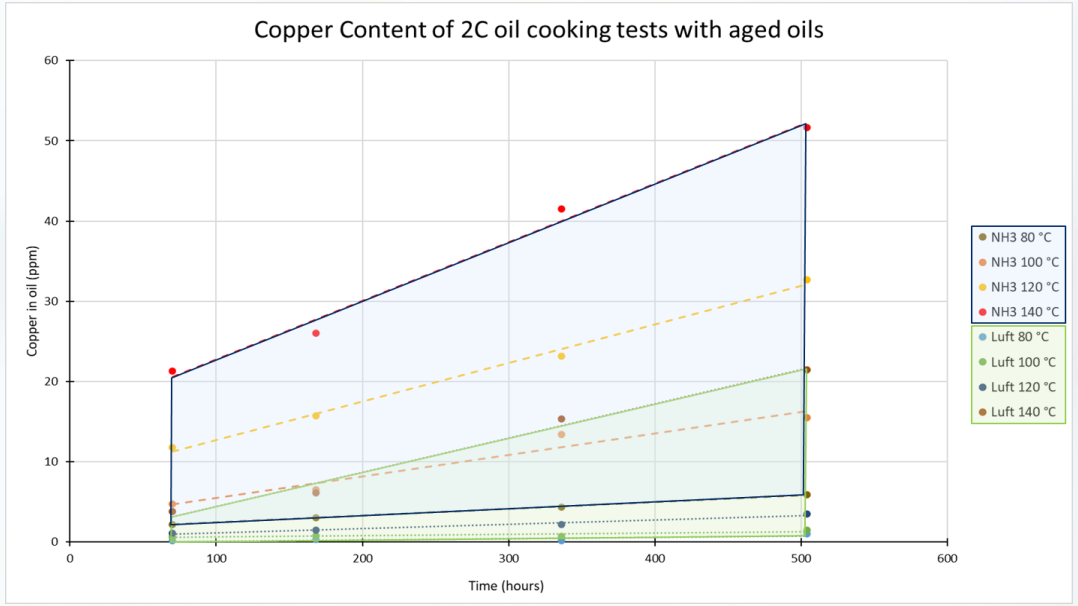
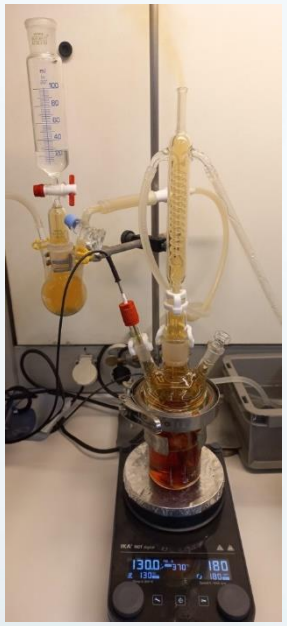
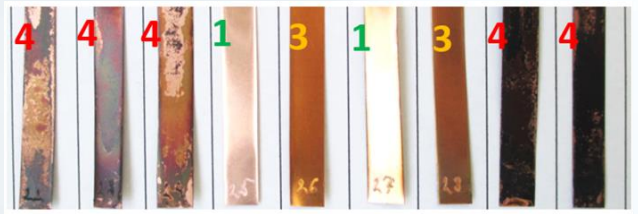
- Oil Material Compatibility Testing Strategy:
  - Standard procedure for evaluating static oil material compatibility.
  - Laboratory approach for research on corrosion phenomena.
  - Identify the optimal lubricant and bearing material combinations, leading to improved engine performance.





Miba Oil Laboratory

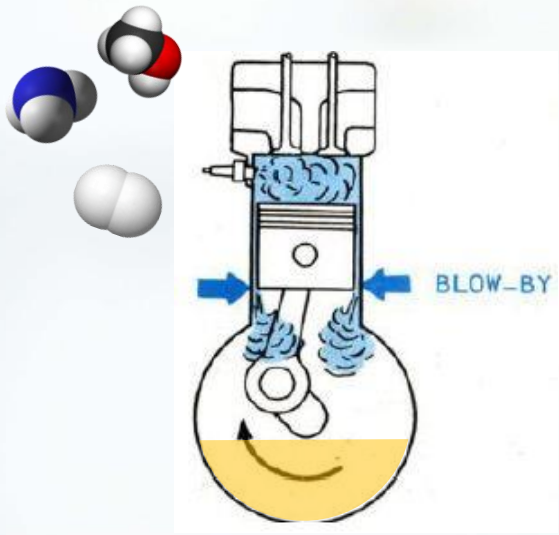
Miba Artificial Oil Ageing Technology



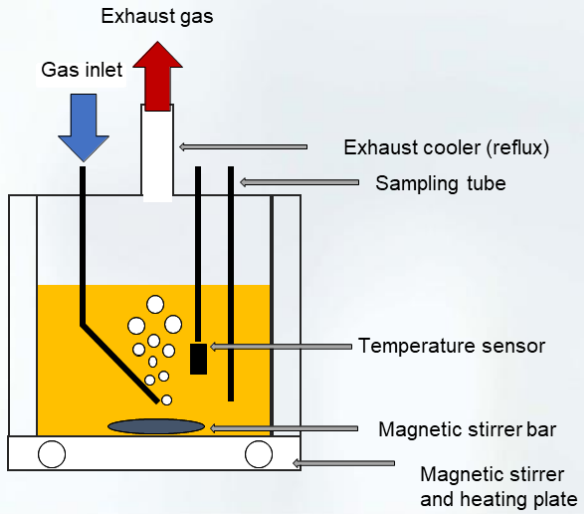
Standardized Oil-Material-Interaction Tests

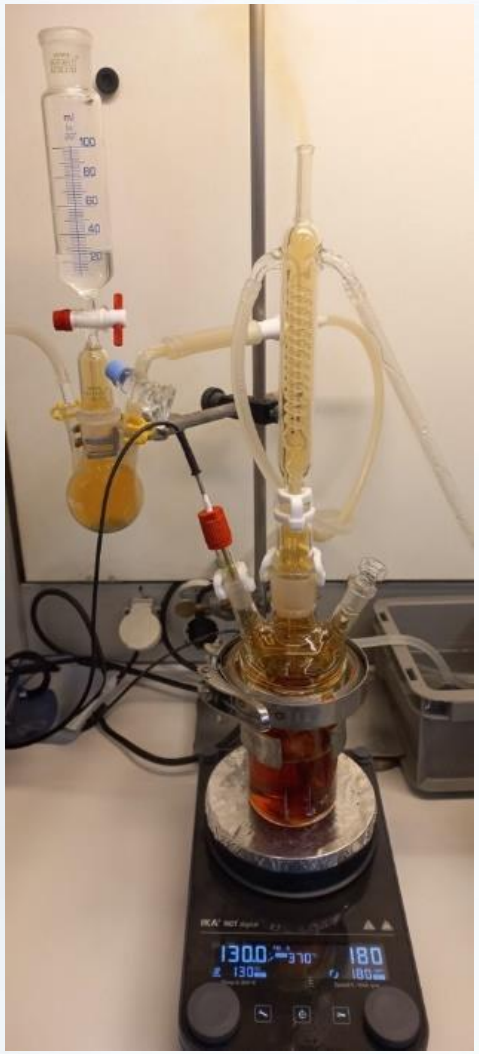
Miba Artificial Oil Ageing

- Lab scale simulation of engine oil ageing.
  - Influence of alternative fuels and combustion products.
  - Base for oil material compatibility tests.
- Comparison with in-field engine oils.
  - Oil condition parameters & reaction behaviour.

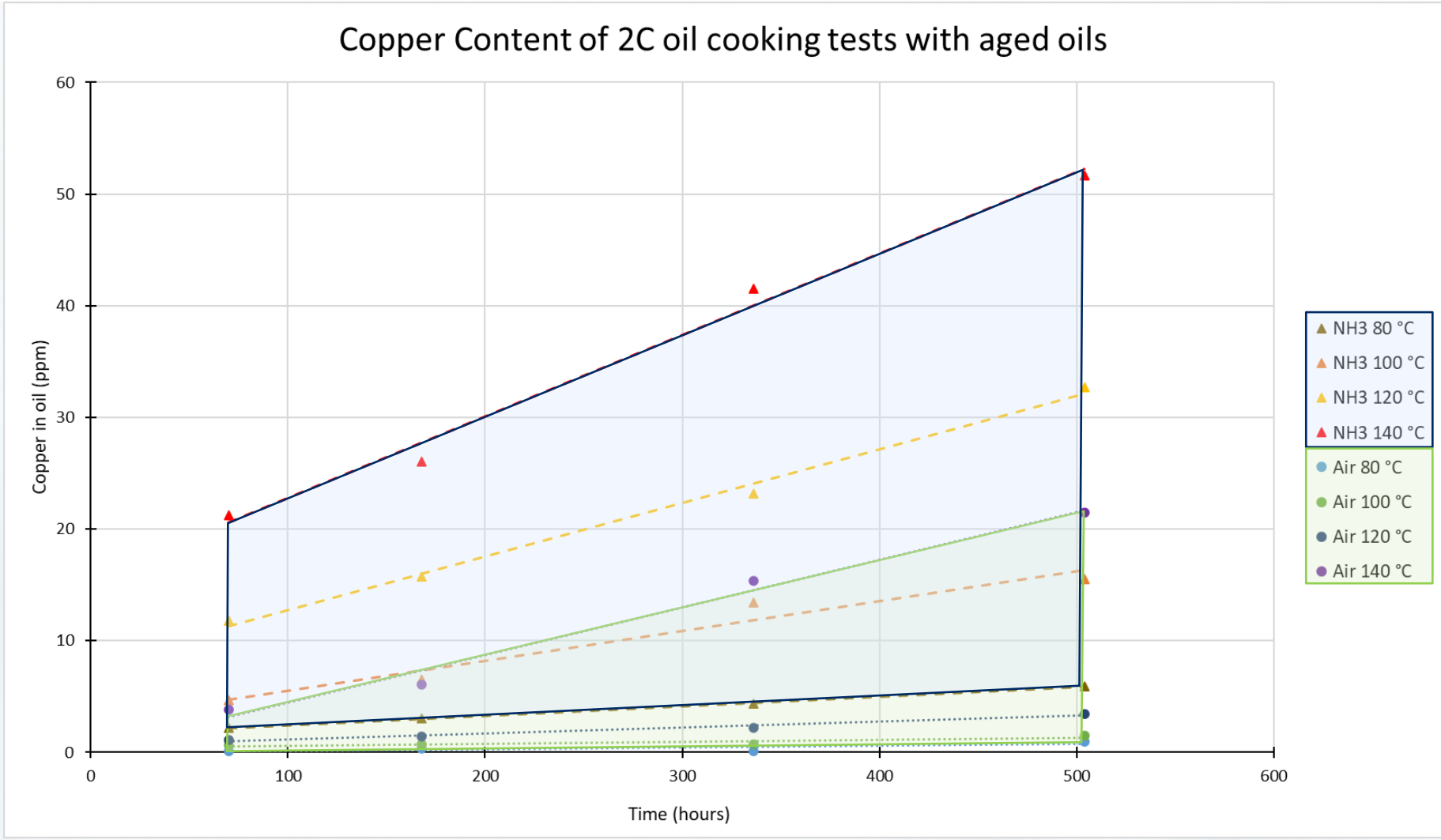


Downscaling to lab scale



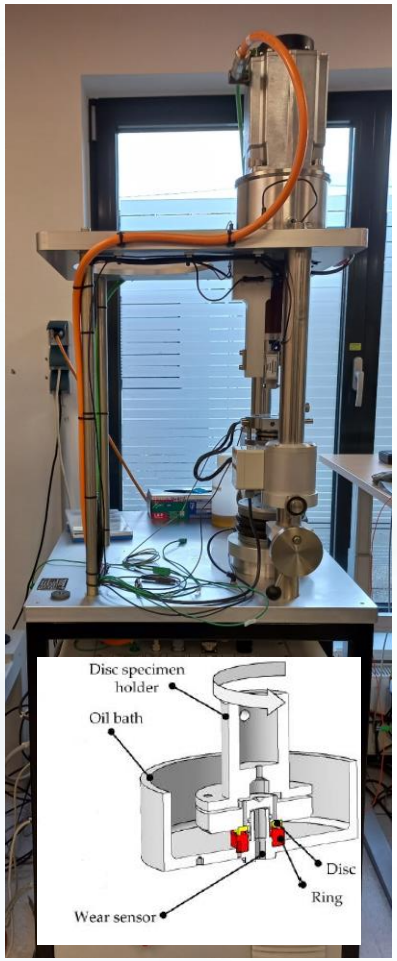


Oil Material Compatibility Testing

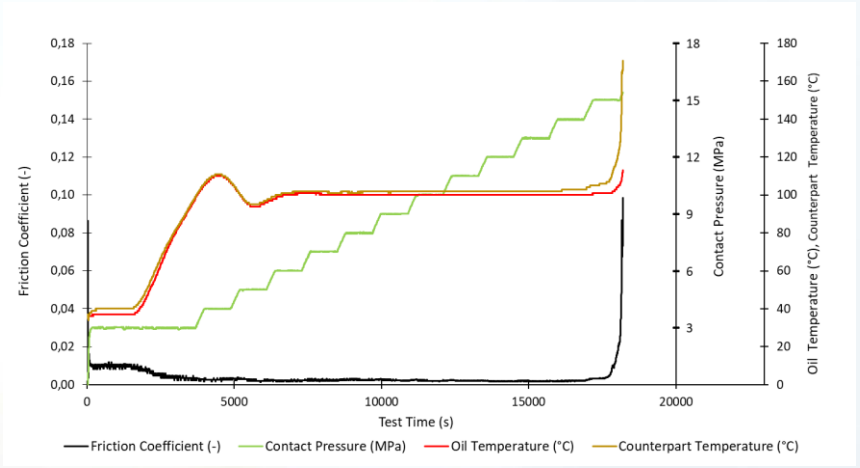


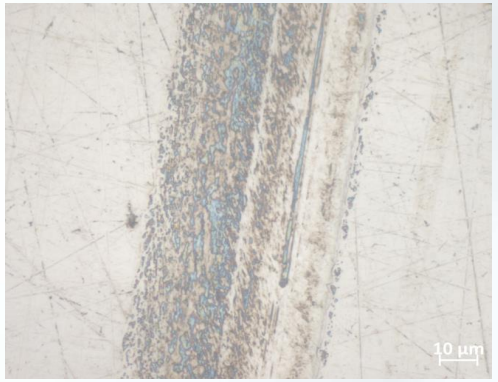
Higher corrosivity with ammonia aged engine oil.

Rotatory tribometer (Tribocorrosion)



Rotatory tribometer TE92 from Phoenix Tribology



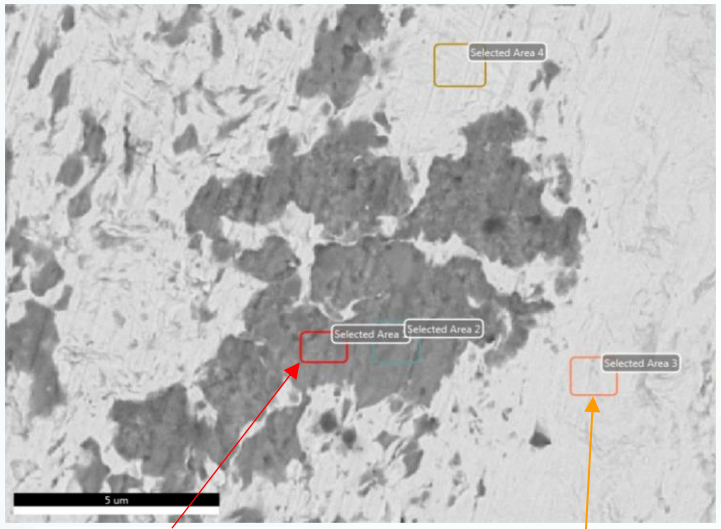


Tribofilm formation on steel ring

Beneficial output:

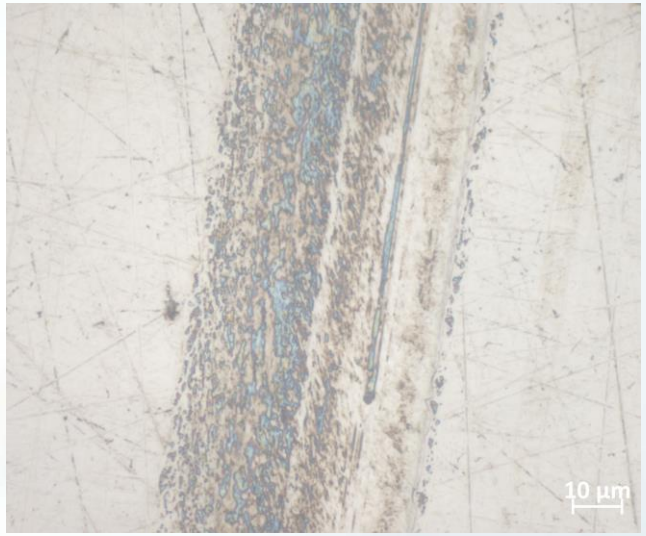
- Tribological properties of different material-oil-combinations
- Tribofilm formation with different oils
- Influence of aged oils (especially regarding alternative fuels)
- Tribocorrosion phenomena
- Changed load capability

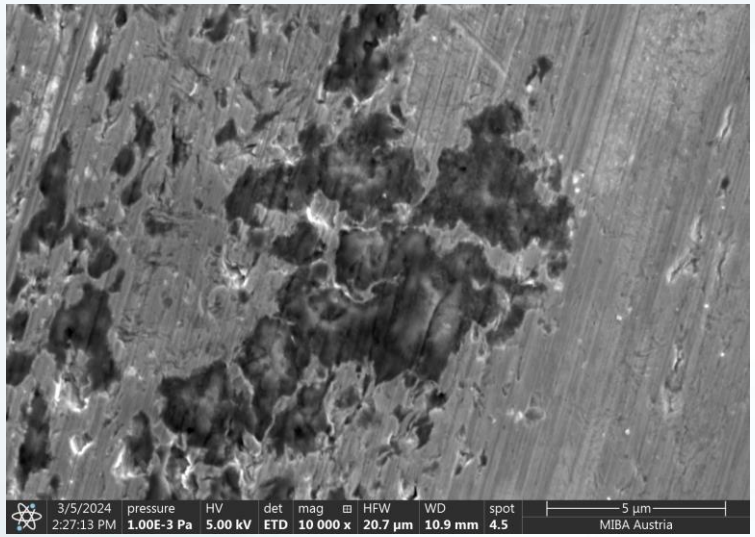
Tribo-Layer Formation (SEM Analysis)



Element	Weight %
C K	2.4
CaL	6.9
O K	31.7
FeL	2.2
ZnL	23.4
MgK	0.3
AlK	10.0
P K	12.1
S K	10.9

Element	Weight %
C K	7.7
O K	8.2
FeL	84.0



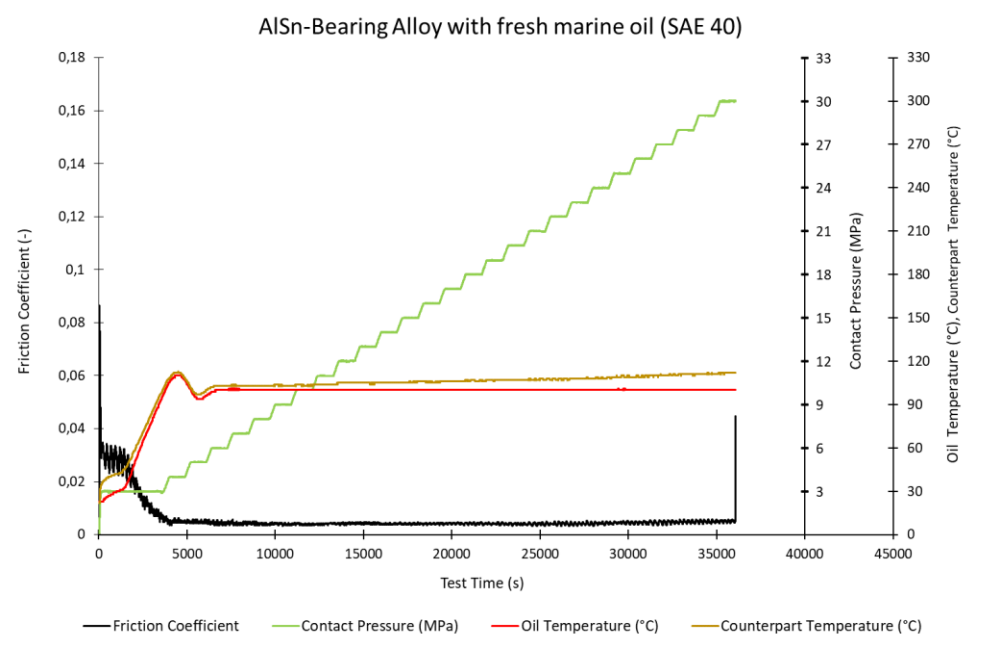


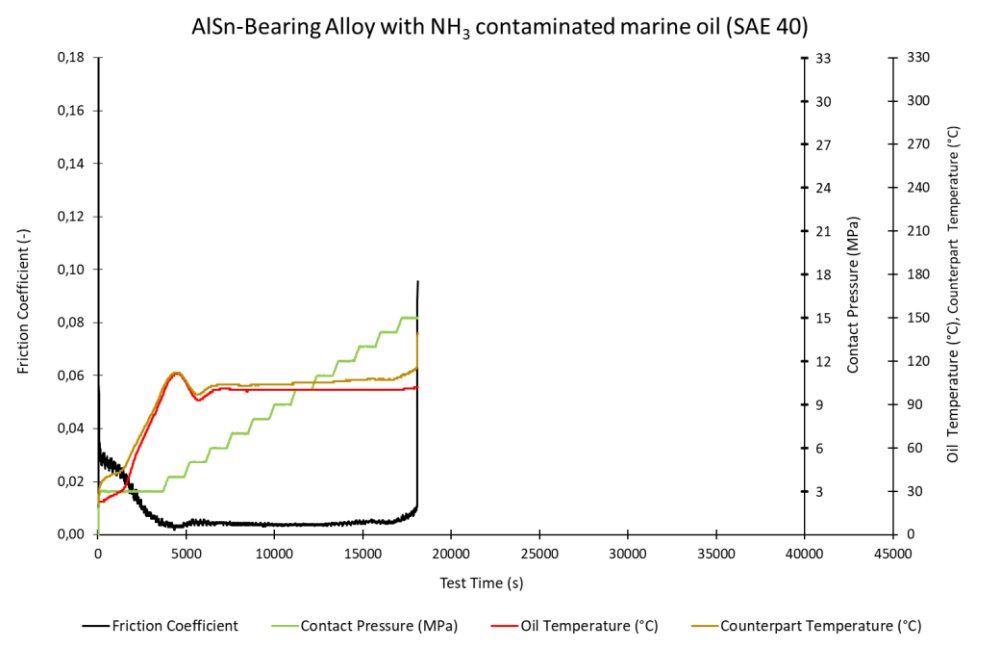
Purpose & Facts

- Testing of standard materials and new material combinations
- Lubricant and additive screening
- Investigation of tribofilm formation

Tribometer Tests NH_3-Oil

- Tribometer tests with Miba 15 (AlSn-Alloy) and NH_3-contaminated marine oil.
  - Ammonia engine test rig with ~300 rh under NH_3-operation.
  - No significant change in the critical oil parameters detected.
- Test with const. increasing load steps until 30 MPa contact pressure.





Alternative Fuel Application – Performance Testing

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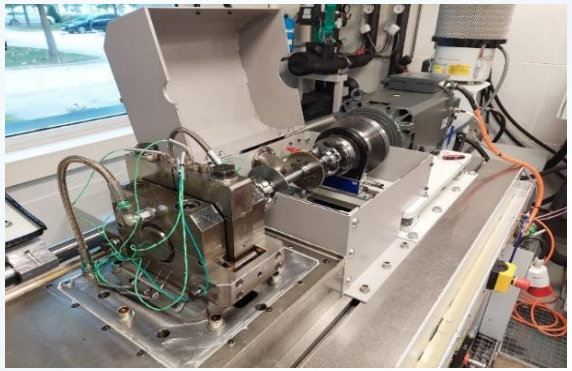
- Testing of aged oils:
  - Aged oils from field applications or artificial aged oils.
  - Testing of MeOH field engine, Hydrogen & NH_3 engine test rig oils.
  - More different oils from engine test rigs & field applications expected.
- Test of new oil formulations:
  - Behavior of class V engine oils in different applications. (Pb-corrosion)
  - New oil additive formulations for AF applications. (e.g. H_2-engines)
- Expected results:
  - Oil-Material-Compatibility (Copper corrosion, Synthec stability…)
  - Bearing performance (Wear resistance, Tribolayer formation…)



Test Criterion Engine Type and test condition, time (h)	Purpose	Interpretation
Load / Wear Medium speed 75 MPa, 12 m/sec, 15 h	Wear robustness	Wall thickness cracking
Wear / Fatigue Medium Speed 75 MPa, 12 m/sec , 70h	Long term wear rate	Wall thickness crack propagation
Load / Wear High Speed 75 MPa, 20 m/sec, 15h	Wear robustness	Wall thickness cracking
Seizure Test Step Load, 12m/sec	Tribological robustness	Failure load
Misalignment Medium & High Speed 75 MPa, 12 m/sec, 15 h	Conform- ability	Load distribution Seizure inclination
Continuous dirt Medium & High Speed 75 MPa / 16 m/sec	Dirt sensitivity	Number of shocks
Corrosion Medium & High speed Oil cooking test	Sensitivity Environment oil additives	Layer formation Thickness of reaction layer
Cavitation Medium and High Speed Hardness / Ultrasonic	Material robustness cavitation	Hardness Weight loss

Miba Test Rigs NH_3-Oil

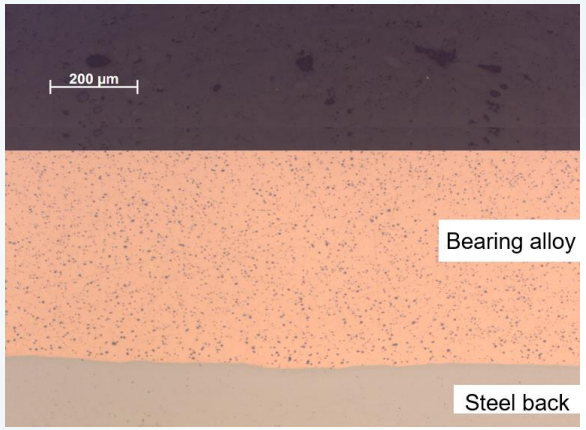
- SCE Test (gas engine application) with Ammonia
  - 500 rh of testing under full ammonia operation.
  - Approx. 300 ppm free Ammonia in the oil.
  - 600 ppm water in the oil detected.
- No change in critical oil parameters (TBN/TAN, Oxidation…)
- Wear/Fatigue test for med. speed (75 MPa, 12 m/s, 70 h)
- Miba 15 bearing material (AlSn-Alloy)
  - Test stopped after 20 h with the NH_3-oil.
  - Significant increased wear of the AlSn-Material.
  - Drag-out of AlSn-Material.

Miba 15 (Gas Engine Oil)

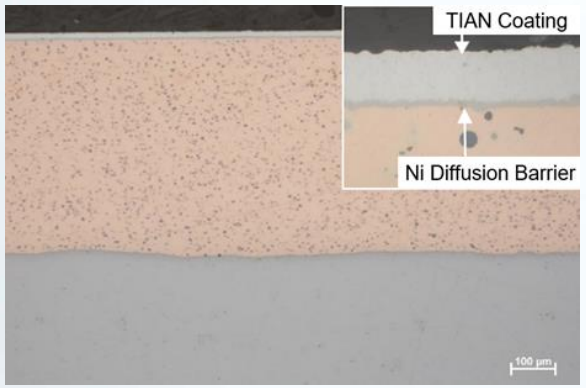
Miba 15 (NH_3-contaminated Oil)

Bearing Material Development

- To meet upcoming requirements for alternative fuel engine applications, new types of bearing material may be necessary.
  - Corrosion resistance against alternative fuels or water.
  - Cavitation resistance against higher water contents in the oil.
  - Improved wear resistance. (reduced wear capability of the oil)
- Not specifically for AF applications designed materials, can meet requirements that enhance bearing performance.
- Miba 2C (lead-free Bronze material)
  - Potential solution for aggressive oils with low TBN (causing Pb-Corrosion)
- Miba 4B (electroplated lead-free Bronze material)
  - Potential solution for Ammonia contaminations (Cu-Corrosion resistance)

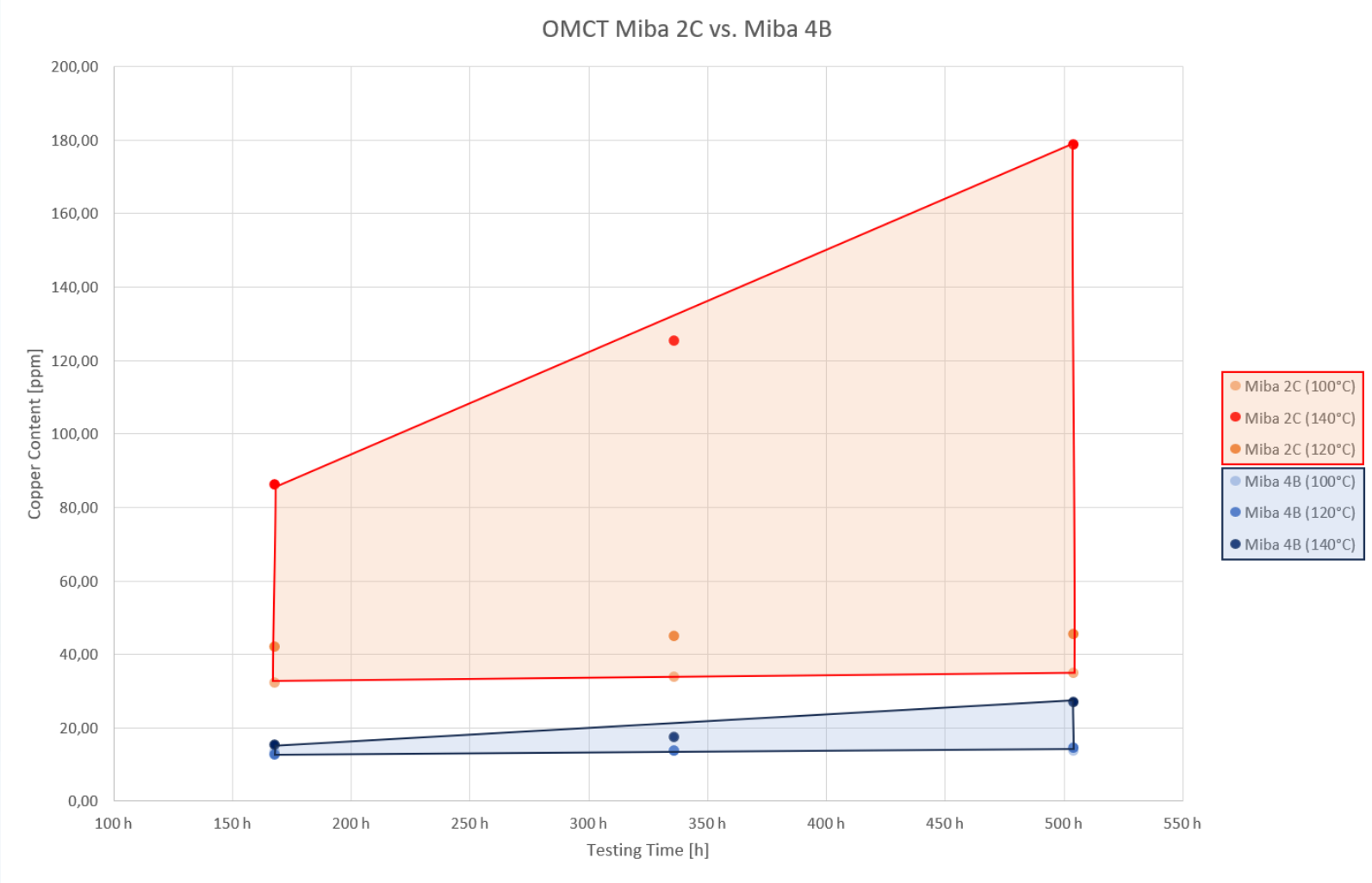


Miba 2C (Pb-free Bronze)



Miba 4B (Miba 2C + SnSbCu Electroplated)

Comparison Miba 2C – Miba 4B



The use of multi-layer bearing technologies can reduce the corrosion potential in AF applications.

Summary & Outlook

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Transformation

- Future fuel engine application market
- New combustion concepts (MeOH, NH_3 & H_2)
- Challenges for the Oil Material Compatibility

Development

- Standardized model test approach
- Understand friction and wear models
- Focus on oil & corrosion research

Evolution

- Development of new bearing materials
- Tribological system competence
- Field validation & data based prediction models

With further developments, Miba is preparing to successfully meet the upcoming trends in engine development.

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