Viscosity Modifiers Versus Bearing Torque in Greases with Re-Refined Oil

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Outline

- Trends & Opportunities
- Experimental Plan
- Preliminary 6204 Bearing Testing
- Apparent Viscosity and Grease ‘Softness’
- Future Work

6204 bearing and shields

Our Trend for Polymer in Grease R&D

- Conference paper focus for last 4 years:
  Overcome myths and perceptions about polymer in grease

- 2020 – mechanical stability and yield improvement from grease polymer
- 2021 – water resistance in H1 and biobased greases
- 2022 – low temperature fluidity of tacky grease with polymer
- 2023 – antiwear and EP of greases using viscosity modifier

Global Trends in Industry

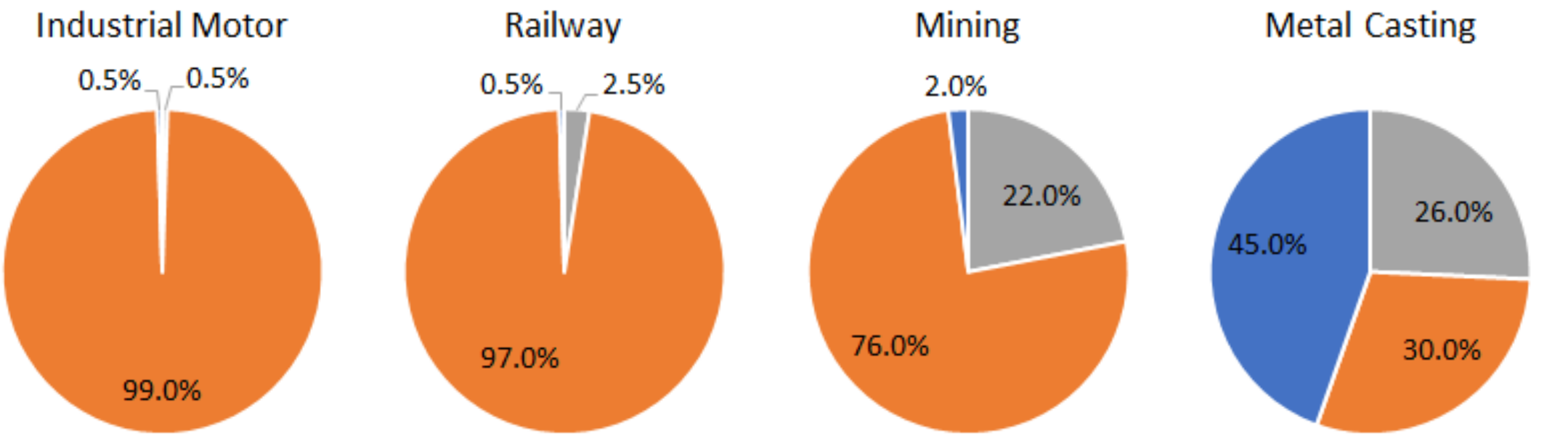
Sustainability

Emissions from **Production** → Re-Refined Base Oil (RRBO)

Emissions from **Operation** → Efficiency (Friction + Losses)

Grice, L. "Life Cycle Carbon Footprint of Re-Refined versus Base Oil That Is Not Re-Refined", *ACS Sustainable Chem. Eng.* **2014**, 2, 2, 158–164

Carbon Footprint of Bearing Technology



CO_2 Emissions from Energy Losses / Friction

CO_2 Emissions from Bearing Production

CO_2 Emissions from Lube/Grease Production

How is bearing selection affecting your industry's CO2 footprint? | SKF (CO_2 dashboard tool)

J. Leckner, R. Westbroek, and S. Glavatskih, "Improved sustainability with grease lubrication - Low hanging fruit?," ELGI Annual Meeting, 2023.

R&D Opportunity

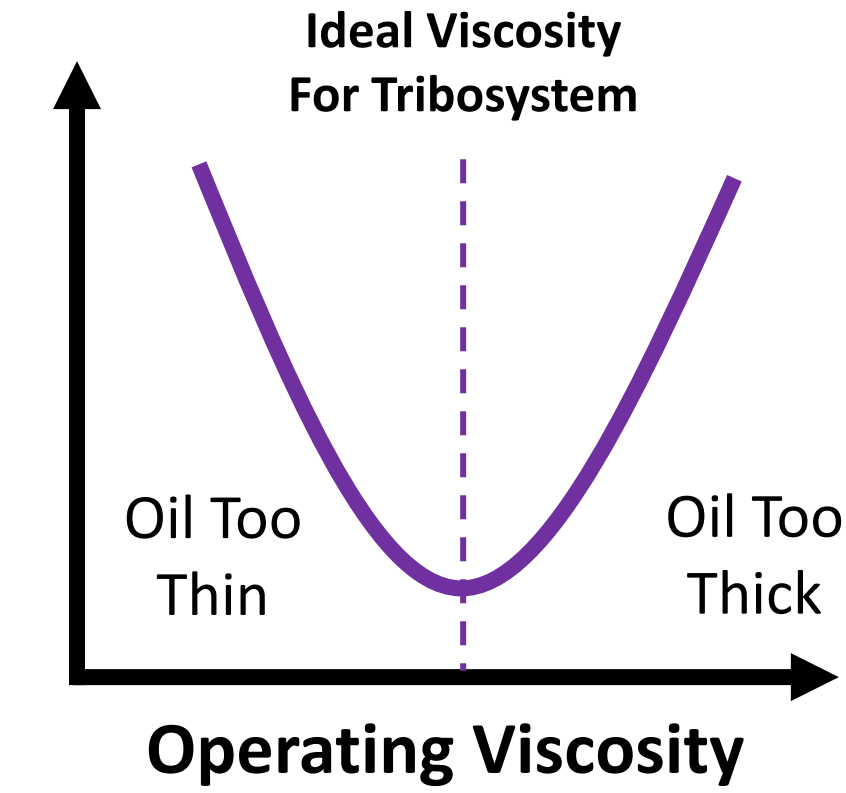
- Sustainable bearing greases using RRBO
- **But,** RRBO requires polymer and bearing greases avoid polymer

- We'll design an investigation specific to RRBO+polymer grease in bearings

Fit For Use Greases (Oil/Gas Service)	→	Multipurpose Grease	→	**Bearing Grease**
Polymers Used Frequently And Heavily		Polymers Used For Specific Performance		**Polymers Are Uncommon**

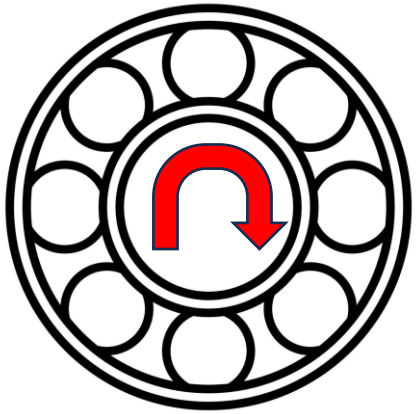
Building on Last Year's Findings

- RRBO + polymer to make EP grease (NLGI HPM-HL)
- Able to match Group I ISO 220
- **It's more important to deliver the <u>correct viscosity</u> than how you deliver it.**



What Are We Going to Look At?

- Does polymer in bearing grease add ‘resistance’ or ‘inefficiency’?
- We’ll quantify this as the amount of torque transmitted from the driven inner race to the outer race in an ASTM D1478-style approach



Ideal Bearing

- Inner race spins
- No torque on outer race

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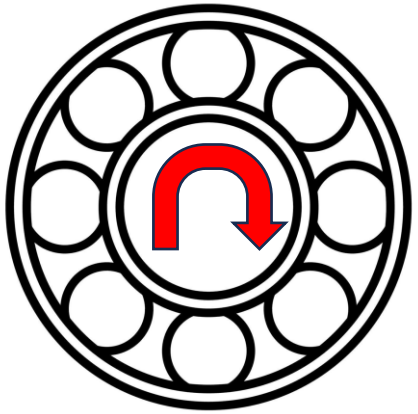

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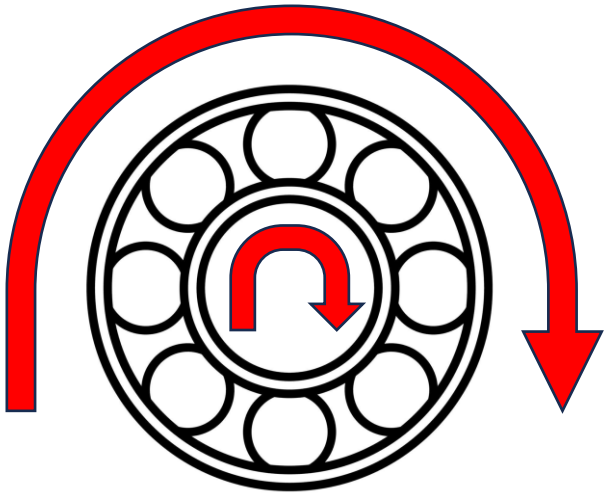

Ideal Coupling (Bad Bearing)

- Inner race spins
- All torque transmitted to outer race

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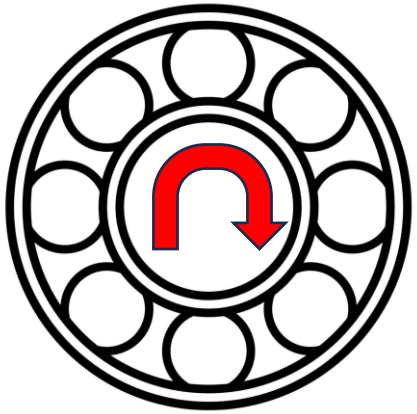
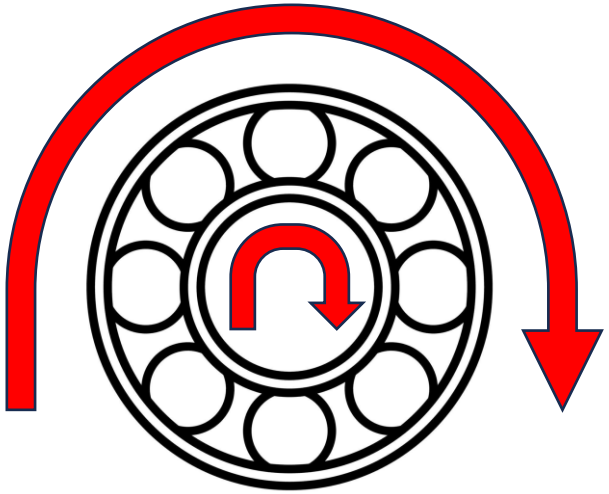


Ideal Bearing

<u>Real</u> Greased Bearing

- Somewhere between



Ideal Coupling (Bad Bearing)

Experimental Plan

1. Pre-formed #2 simple lithium greases
   - Controls – ISO 100 from heavy petroleum oil blends
   - Experimental – ISO 100 from ISO 25 RRBO + polymer

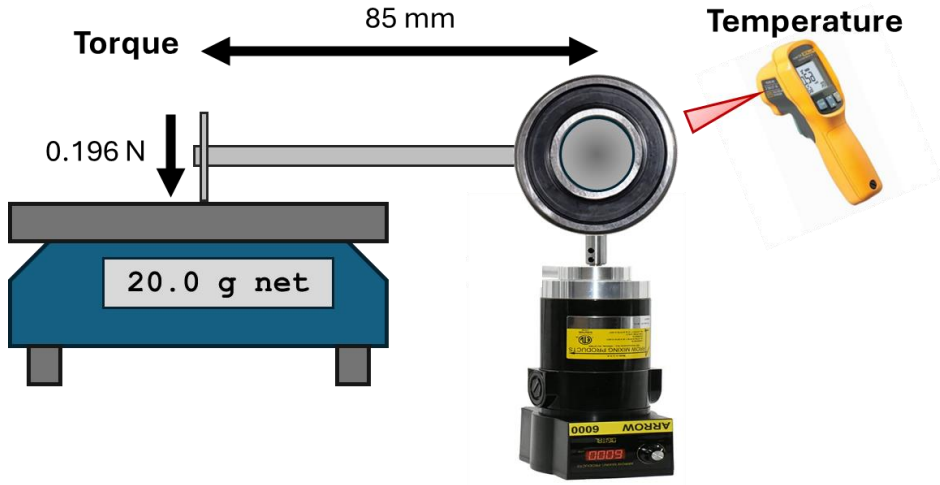
2. Simple bearing test rig – 6204 on electric spindle with lever arm
   - Heat vs. rpm
   - Bearing torque vs. rpm

3. Use physical properties to rationalize trends seen in bearing torque
   - Apparent viscosity (Pa vs. rpm in Brookfield)
   - Composition

Prototype Bearing Test Rig

- 100 – 800 rpm, 5 minute increments
- Temperature measured by infrared thermometer
- Torque measured by force of lever arm on lab scale (load cell)

Torque (mN-m) = Downward Force on Lever (mN) x Lever Length (m)



Preliminary Bearing Test Candidates

- Two controls
  - ISO 100 Group I – VI 100
  - ISO 100 Group II + Naphthenic – VI 82

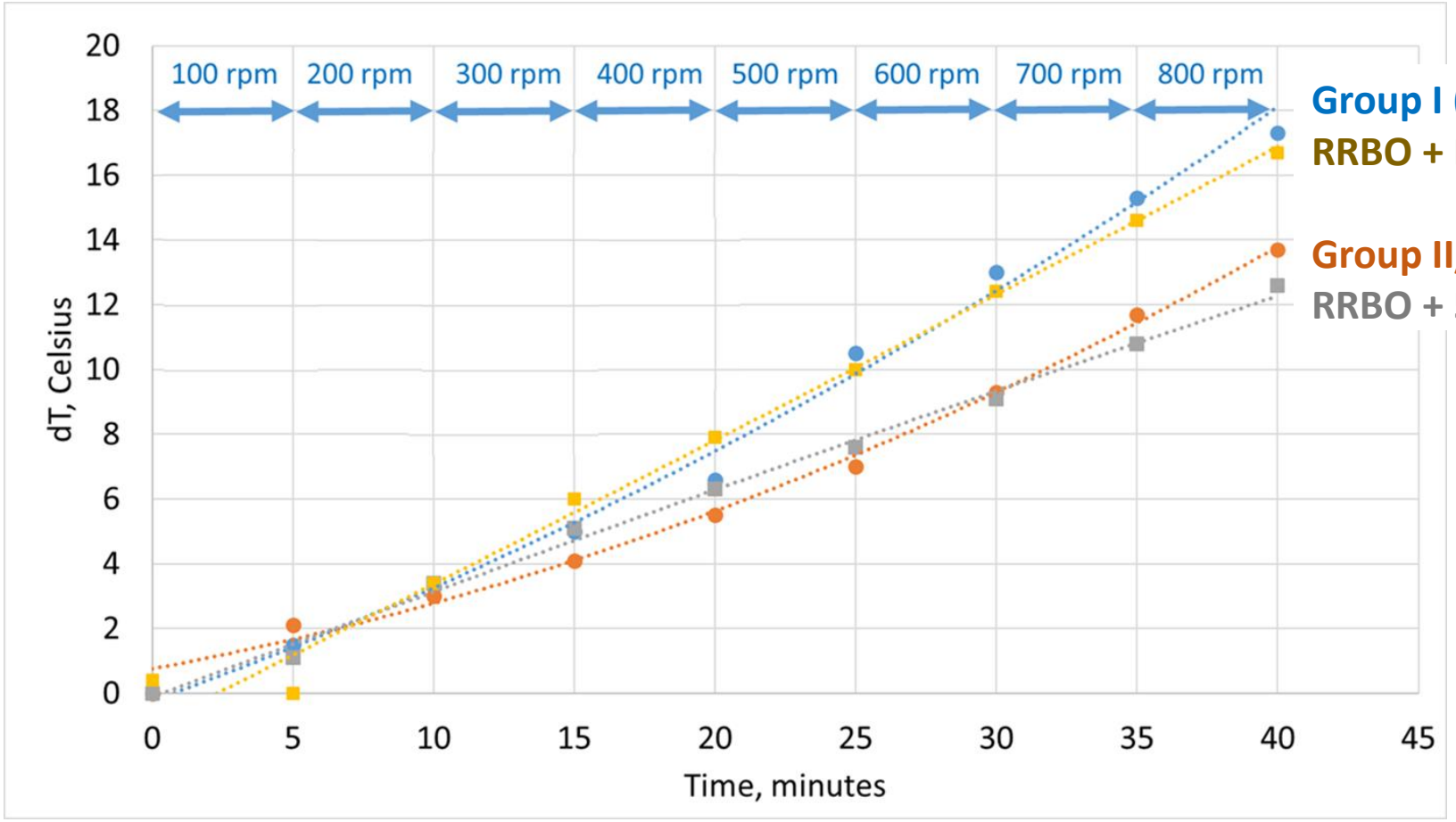
- Two very different RRBO + polymer formulations

  - **RRBO + "Low temperature polyolefin"** – VI 216
    - Concentrated, non-shear thinning VM, ~10wt% active polymer

  - **RRBO + "50 SSI OCP"** – VI 171
    - Dilute, shear thinning VM, ~1wt% active polymer

Bearing Test– Temperature Rise

- Experimental greases give similar temperature rise (dT) as controls

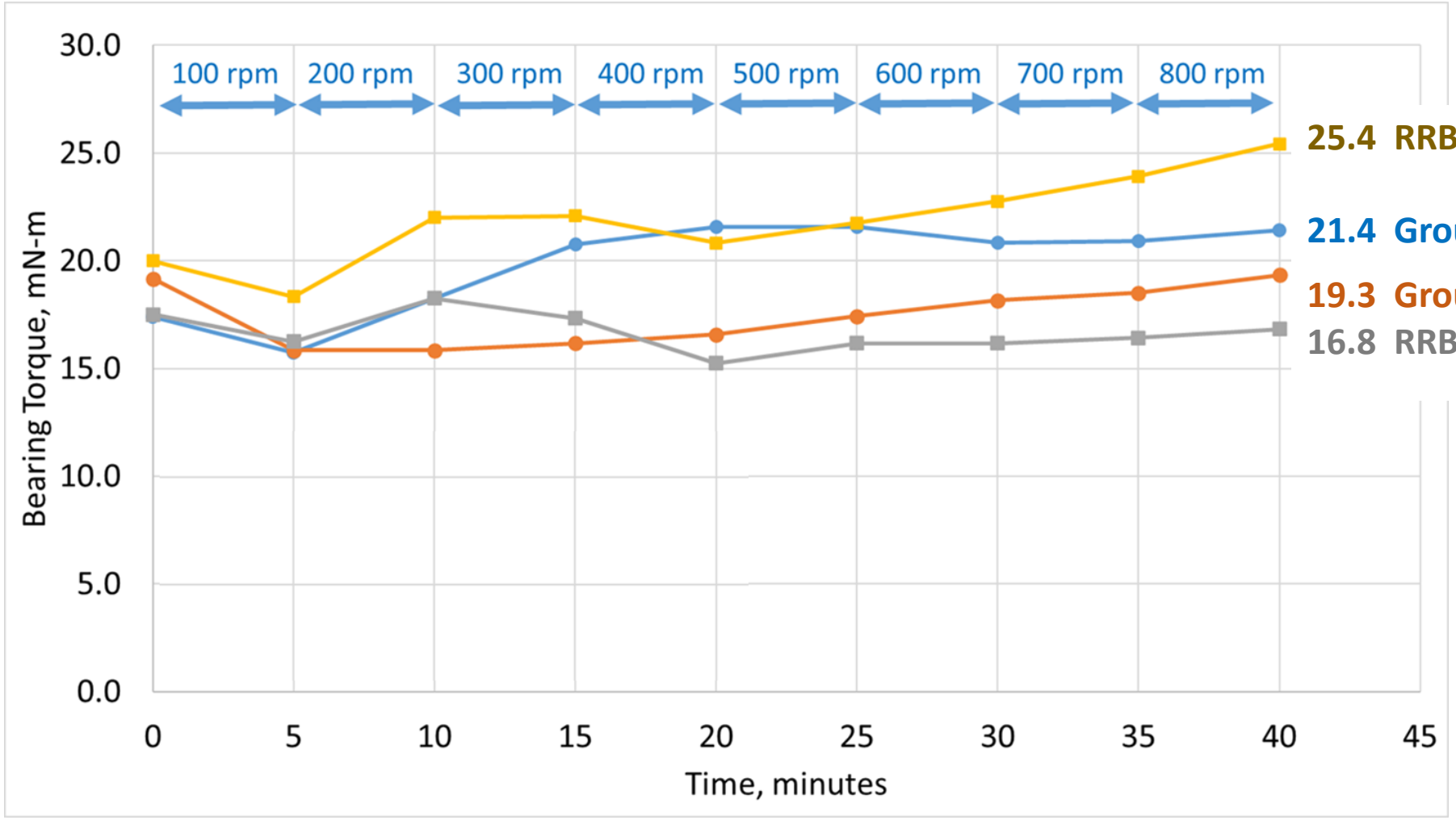


Group I (VI 100)
RRBO + Polyolefin (VI 216)

Group II/Naphthenic (VI 82)
RRBO + 50 SSI OCP (VI 171)

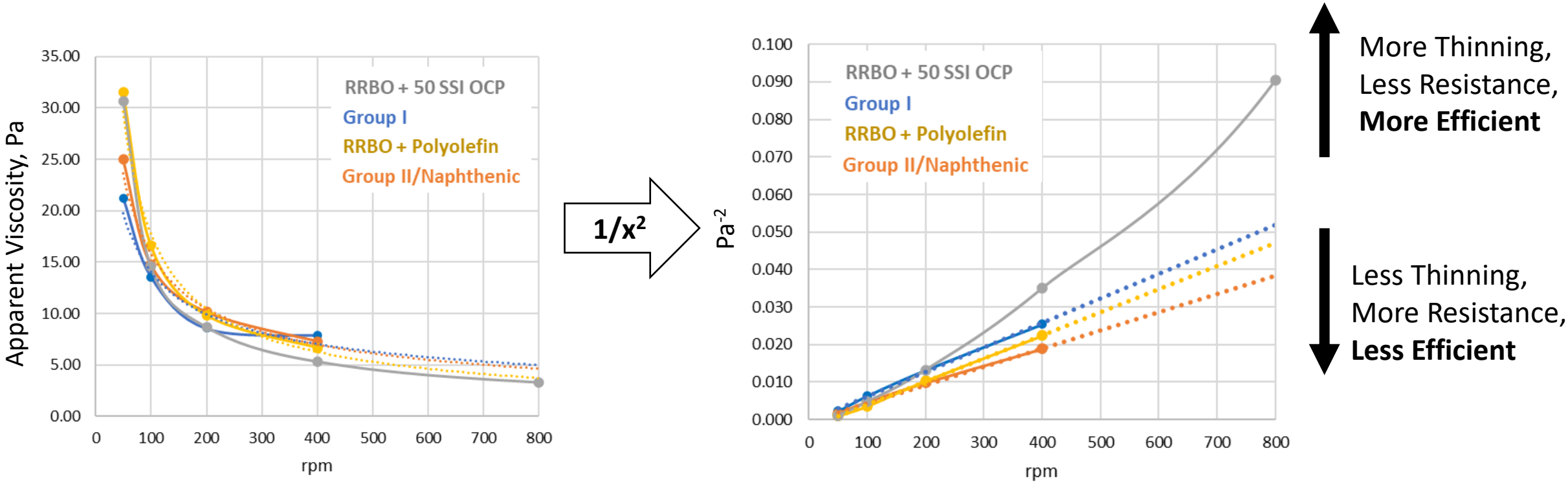
Bearing Test – Torque

- Lowest and highest torque exhibited by the experimental RRBO+polymer grease



Shear Thinning of Greases (Softness)

- Log plot of apparent viscosity vs. rpm was linearized by $1/x^2$ transform
- "**Softness**" in $Pa^{-2}\ rpm^{-1}$ = **slope** of $(\text{Apparent Viscosity})^{-2}$ vs. rpm

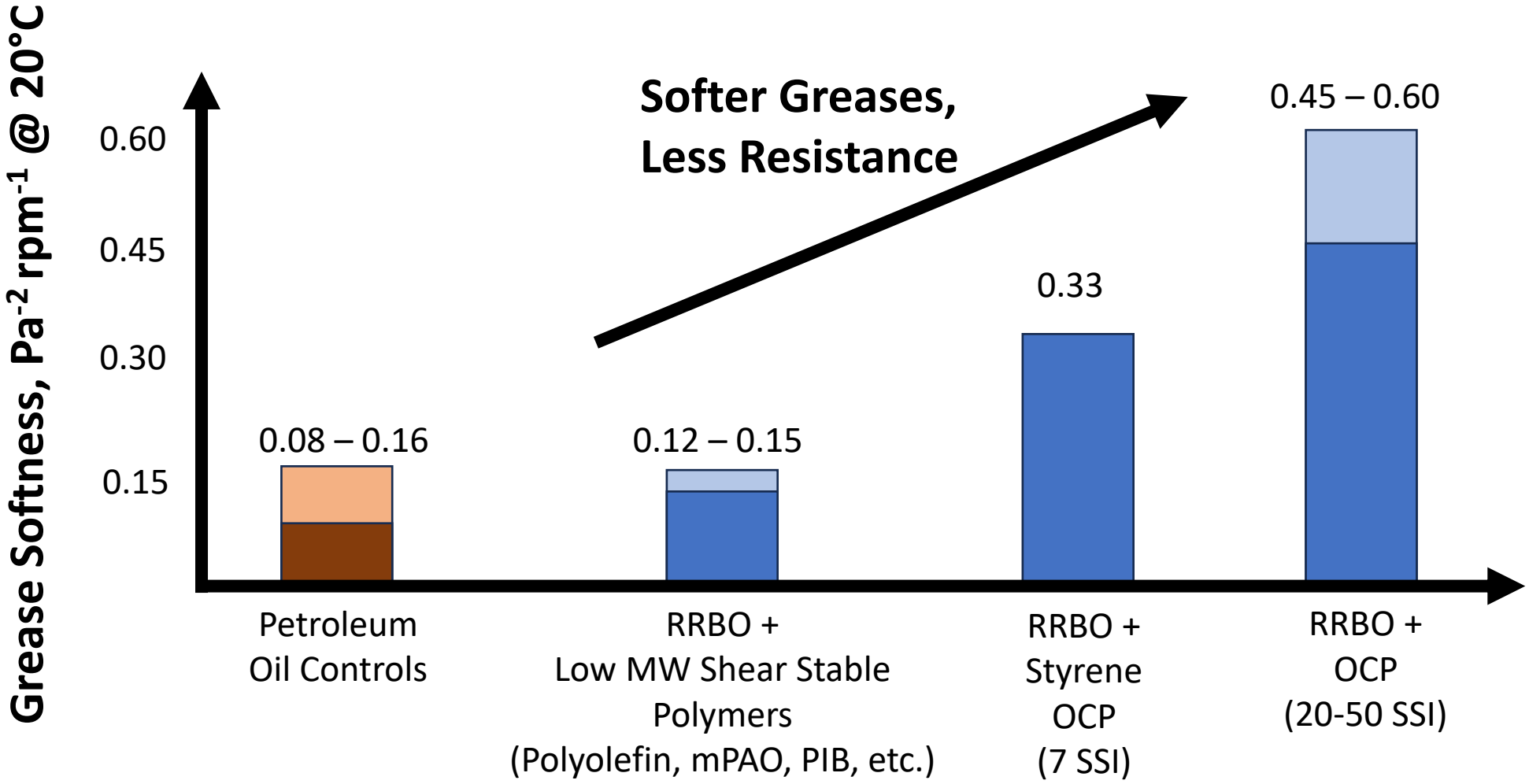


Why Softness Is Important

- Think of this ‘softness value’ as the slope of apparent viscosity vs. shear speed **but** via Brookfield viscometer instead of ASTM D1092
  - Same concept as Viscosity Index
- Higher ‘softness value’ implies you can engineer an NLGI #2 grease that shear thins to act like a #1 or #0 under high speeds
  - Same concept as high VI hydraulic fluids

Grease Softness vs. Composition

- Softness measured for 5 controls and RRBO with 9 polymers @ 20°C

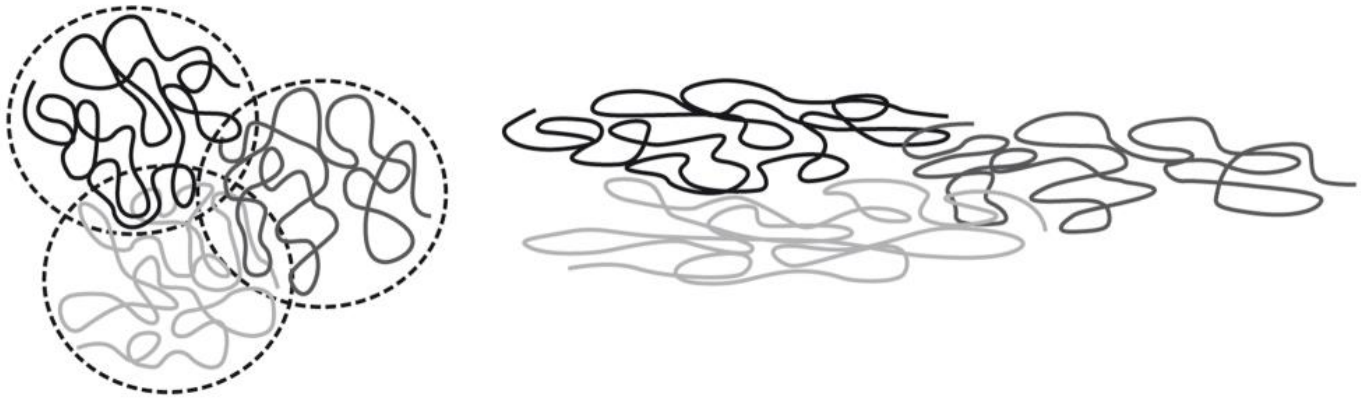


Polymer Effects to Consider

- Two effects that were real and important in last year's paper on tribology of polymer/oil blends

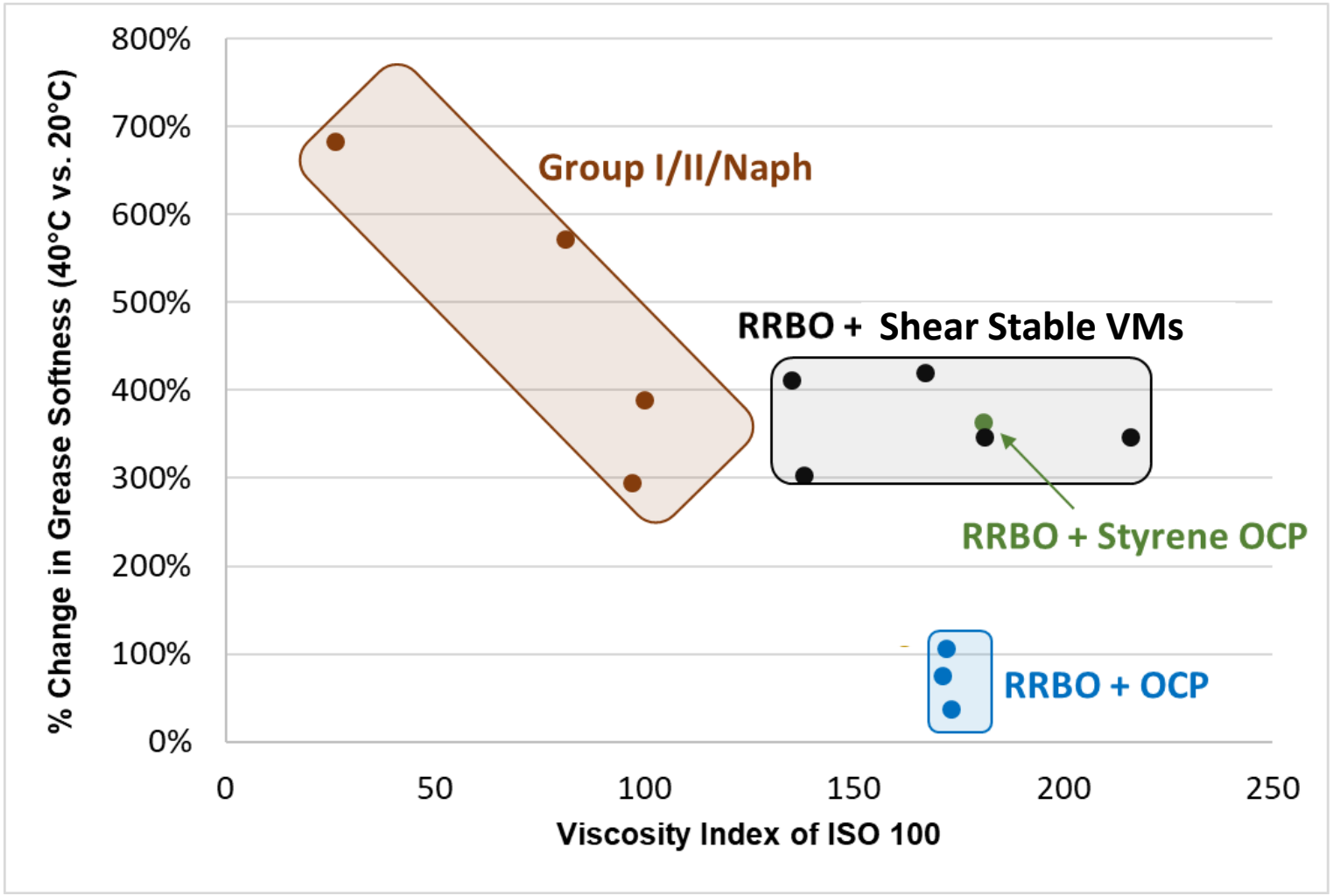
1. **High VI** implies higher viscosity and viscosity stability at higher temps

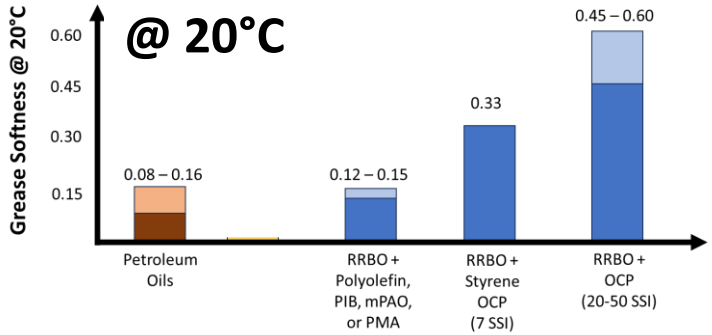
2. **Temporary shear thinning** of viscosity from polymers under shear
   - Activates above a critical rpm speed (or Hz shear rate)

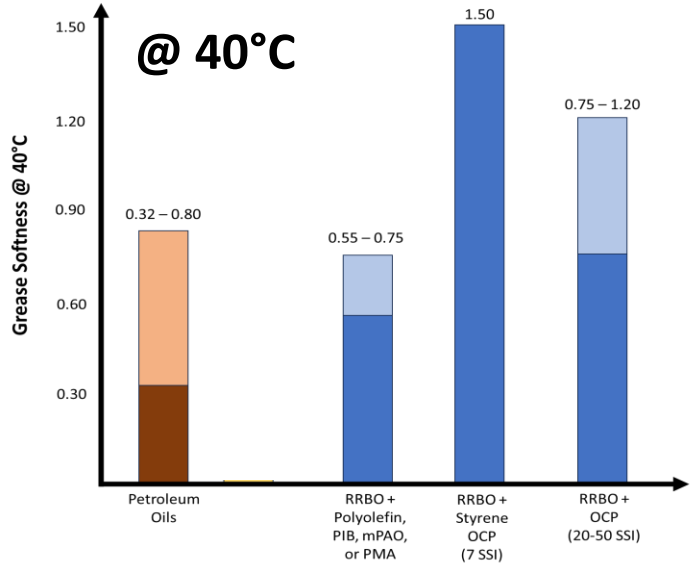


Grease Softness vs. Temperature

- Softness changes with temperature which correlates with viscosity index

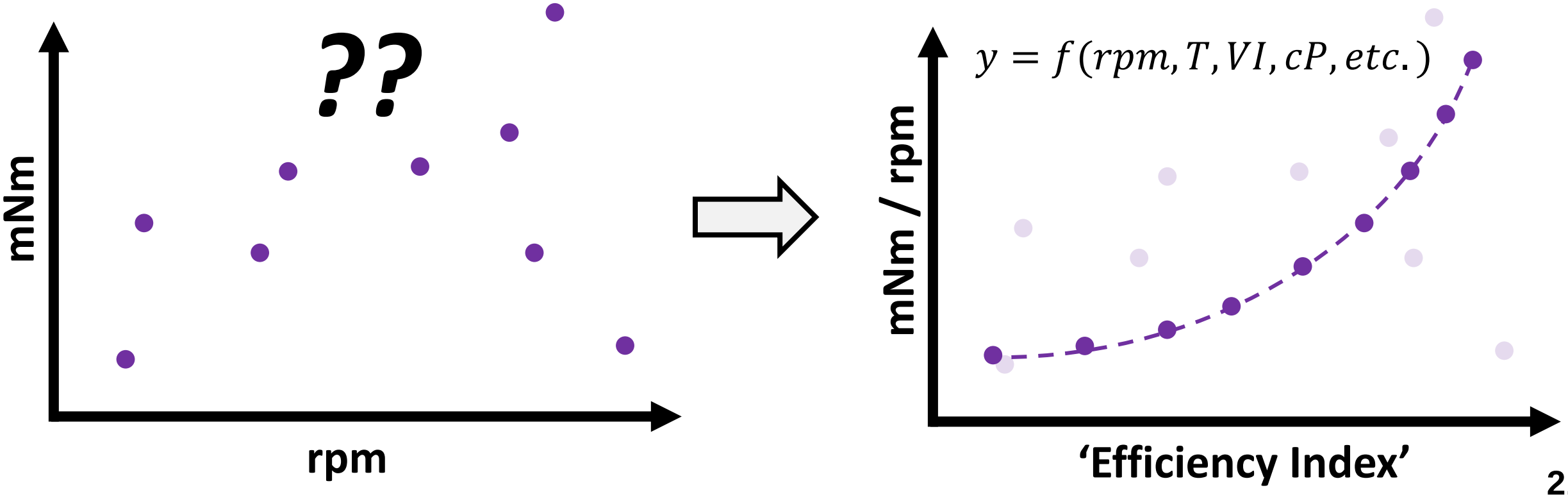






Future Work

- Method development – fitting data to properties of the control/expt. greases
- Goal is to relate inputs (physical properties) to outputs (torque, temperature rise)



Summary

- RRBO+polymer greases show similar range of behavior as control greases
- Grease softness (or resistance to motion) can be affected by polymer
- High MW polymers can shear thin and produce lower resistance at high rpm
- Changes in grease softness with temperature correlate with base oil VI
- Myth/perception of polymers in bearing grease can be overturned