FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

40 Years 1985 2025

www.functionalproducts.com

Polymer Use in Industrial Lubricants

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29th ICIS World Base Oils and Lubricants Conference – Green Stage
13 February 2025, 11:15 – 11:45am

My Background

- PhD in Polymer Science (University of Akron)
- Material scientist running the Functional team as President since ‘22

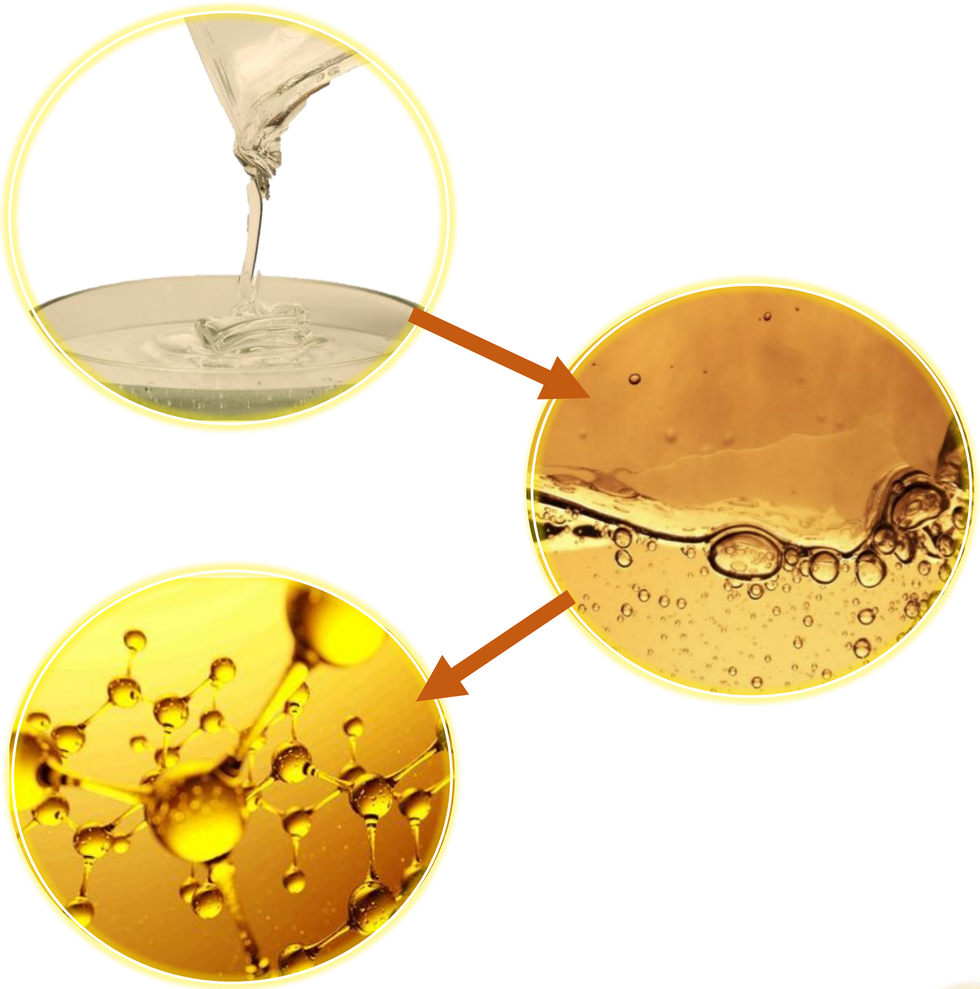
- Functional Products Inc.
  - USA-based lubricant additive supplier with global distribution
    - Tackifiers for tacky chain oils, greases, high speed lubes, etc.
    - Polymer-based additives
      - Chemistry agnostic – we offer every tool in the toolbox
    - Specialty additive packages
    - Low MOQ components

40 Years
1985 2025

Outline

The concept of **viscosity from polymers** in about three bites:

1. Viscosity modifiers
2. Viscosity index & efficiency
3. Choosing the right chemistry
4. Future things to talk about



Viscosity Modification

- As oil is refined, we refine out imperfections which create strong attractive forces that make oil viscous
- We still need that viscosity for ISO 100 – 50,000 industrial lubes

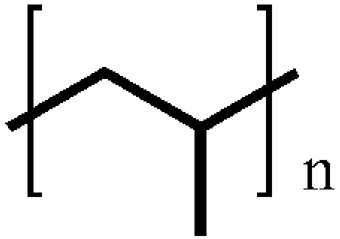
Purity / Refining

	Cost	ISO 15	ISO 22	ISO 32	ISO 46	ISO 68	ISO 100	ISO 460	ISO 1000
Group I	$	70SN	100SN	150SN	220SN	350SN	500SN	150BS	--
Group II	$	70N	100N	150N	220N	300N	600N	--	--
Rerefined	$	70N	100N	150N	240N	--	--	--	--
Group III	$$	3 cSt	4 cSt	6 cSt	8 cSt	--	--	--	--
PAO	$$$	PAO2	PAO4	PAO6	PAO8	PAO 10	--	mPAO65	mPAO100

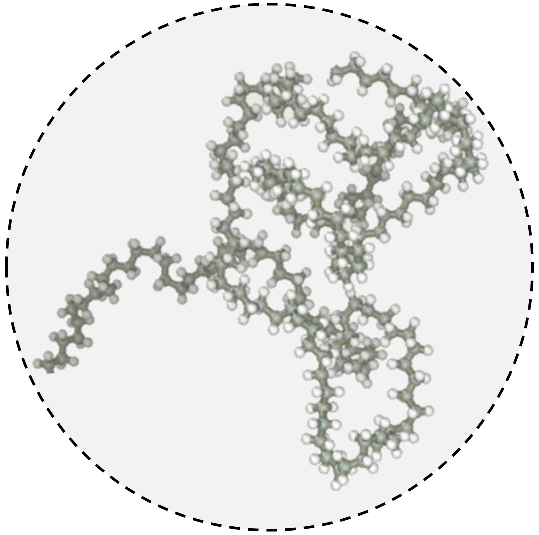
Viscosity Limit

Polymer Technology

- What if we weren't limited to an ISO 500 or ISO 1000 bright stock?
  - Viscosity modifiers commonly ISO 10,000 – 50,000
- What if we could get any VI we wanted in even a low VI base oil?
- What if we want synthetic behavior at petroleum price?
- Viscosity modifiers (VM) deliver **high molecular weight polymers** which increase viscosity rapidly



Shorthand



Space-filling model of coil

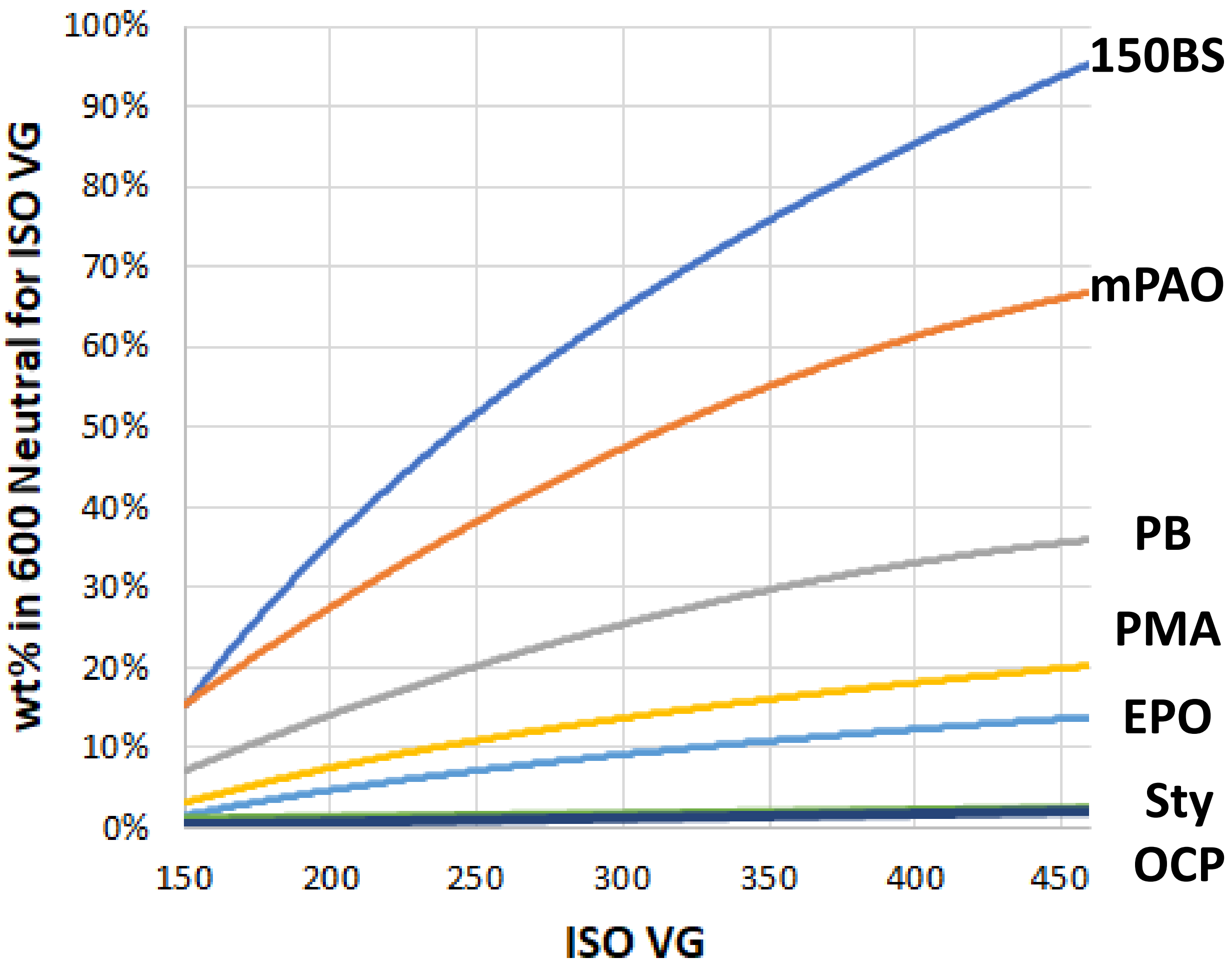
Molecular Traffic Jam

- Bigger size
- Less maneuverable
- Slower and slows the flow around it

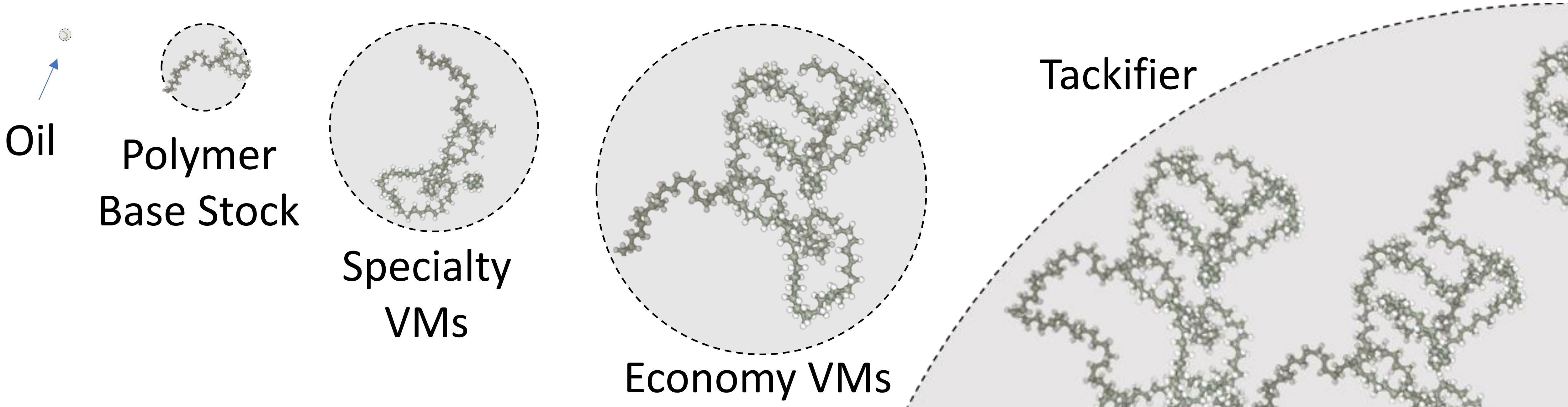
Viscosity Modifiers Are Efficient

- 600N Group II → ISO 460?

Viscosity Source	ISO 220	ISO 460
150 Bright Stock	55%	95%
mPAO	33%	67%
Polybutene	17%	36%
Polymethacrylate	9.0%	20%
E-P Oligomer	5.0%	14%
Styrene Copolymer	1.7%	2.4%
Olefin Copolymer	1.0%	2.0%



Sense of Scale



Material	MW	# of Carbons
Petroleum Oil	200 - 700	10 - 50
Polymer Base Stocks	1K – 20K	150 – 3K
Polymethacrylates	20K – 100K	3K – 15K
Olefin Copolymers	100K – 200K	15K – 30K
Tackifiers	500K – 6M	71K – 858K

Scaled by molecular radius, approx. $(\# \text{ carbon})^{0.5}$

Trade-Offs in Using VM

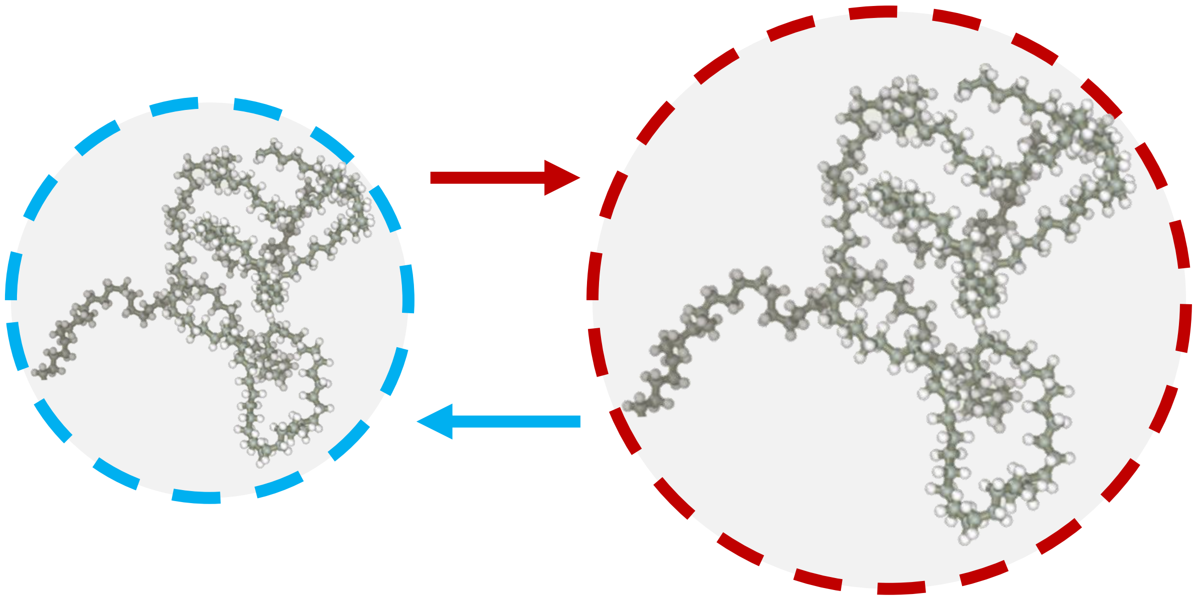
- Polymers can bend the rules for several material science trade-offs

- Advantages
  - Able to make any viscosity grade needed – stock one VG of oil
  - Higher viscosity index (VI)
  - More light oil – tends to have better low temperature fluidity

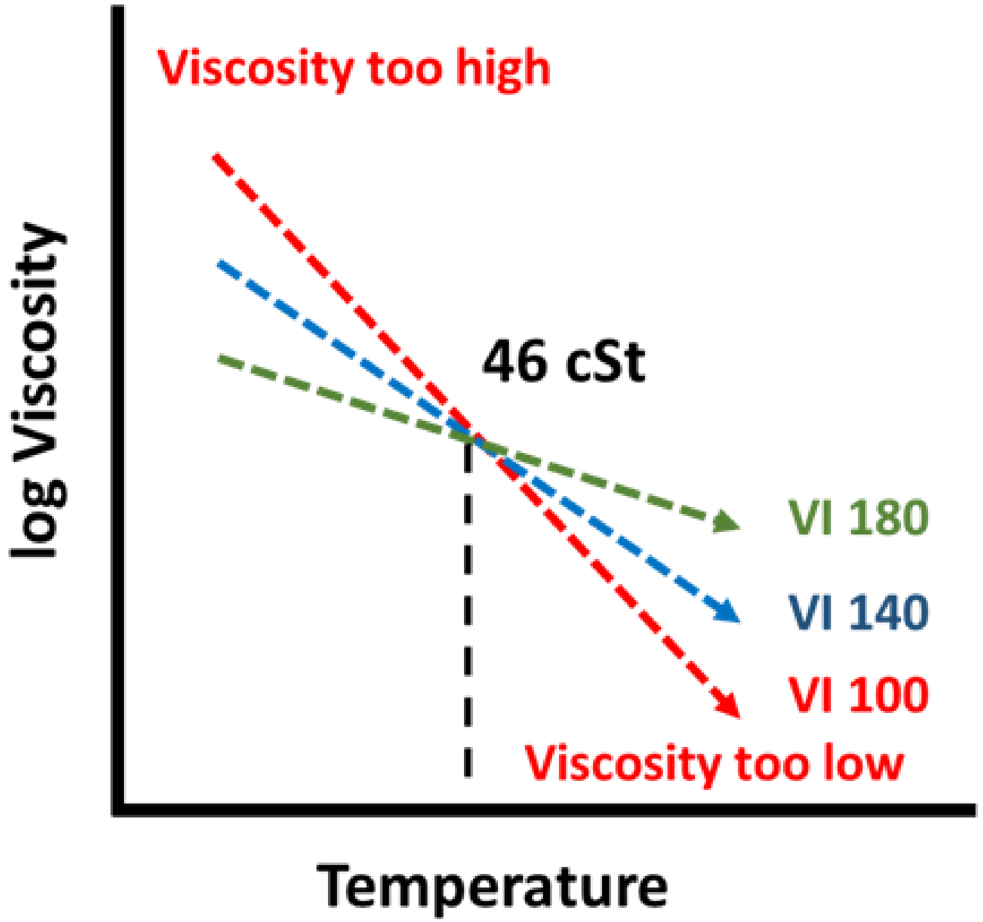
- Disadvantages
  - More complicated formulas
  - More light oil reduces flash point, increases volatility (NOACK)
  - Effects of shear

Viscosity Index from Polymers

- VMs are thermoresponsive
  - Expand with heat – more obstruction
  - Contract with cooling – more flow
  - Produces a net gain in VI

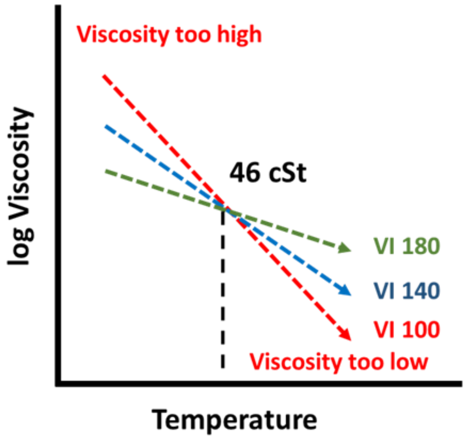


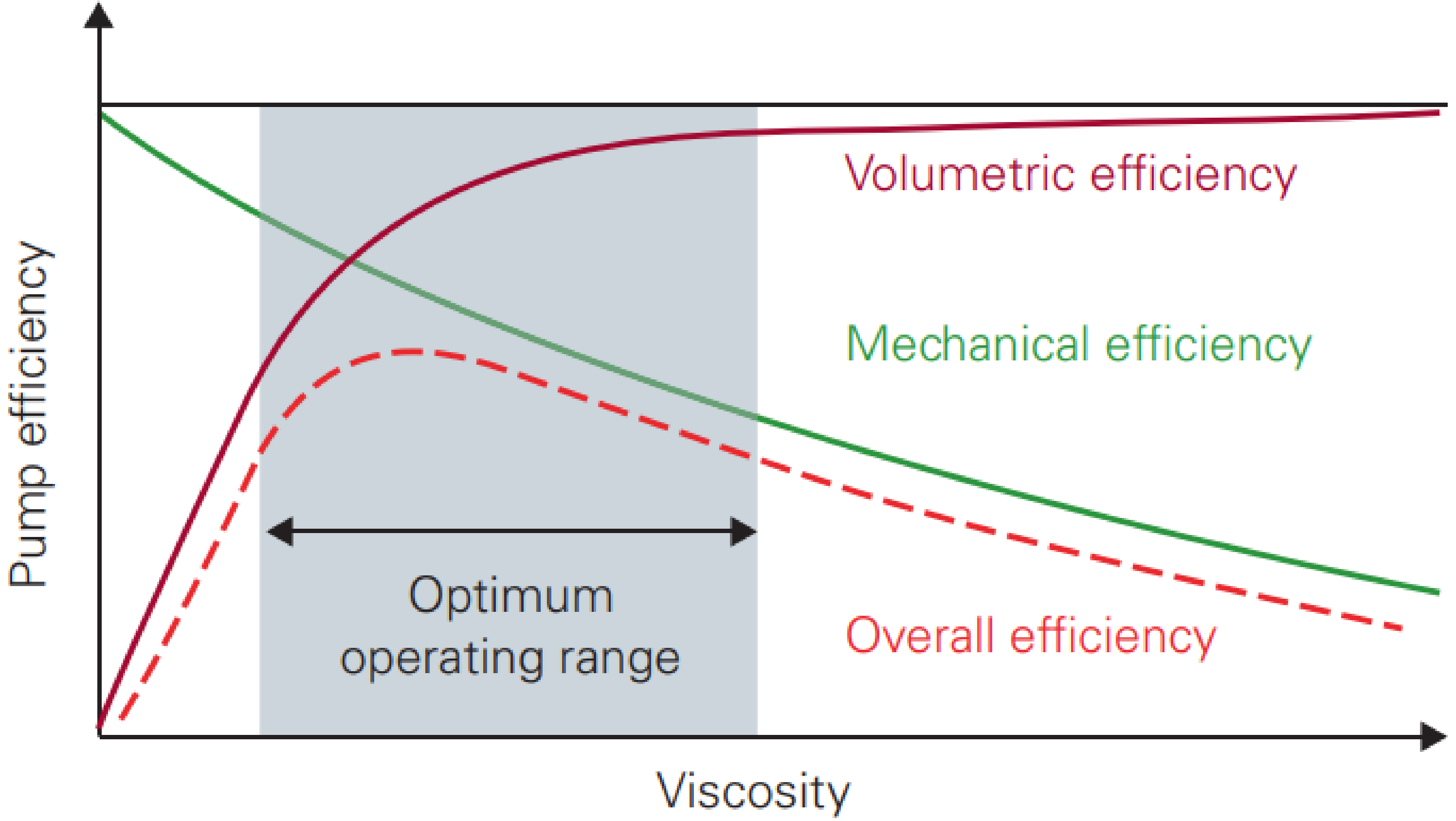
The Classic VI Plot



Why Does VI Drive Efficiency?

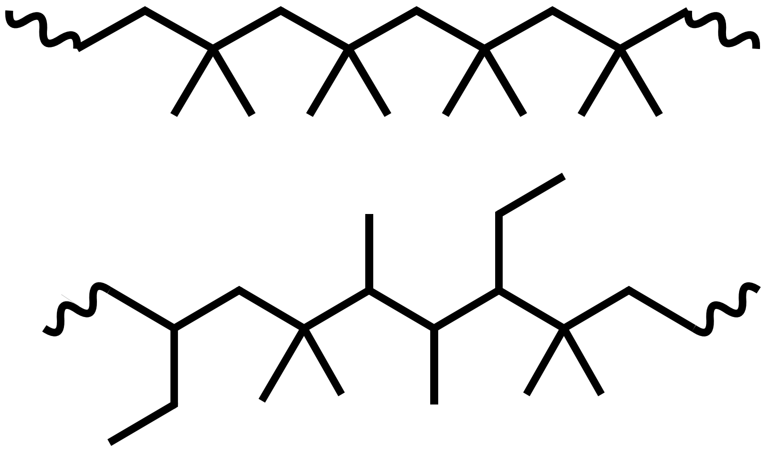
- Higher viscosity → **more power** carried per unit volume
- Lower viscosity → **more fluid** pumped per unit time
- **Overall efficiency** is power curve of **quality** x **quantity**



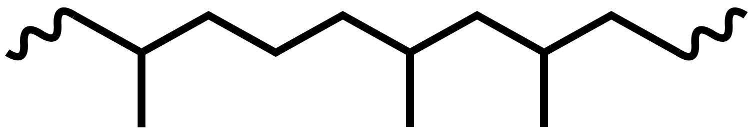


Comparing Viscosity Modifiers (Part 1)

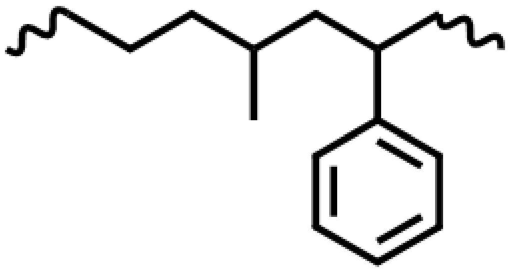
- Polybutenes (**PIB/PB**)



- Olefin Copolymer (**OCP**)
  - ~100K MW in block or pellet form



- Add 10-30wt% styrene, 50K MW, flake form = **Styrene Copolymer**

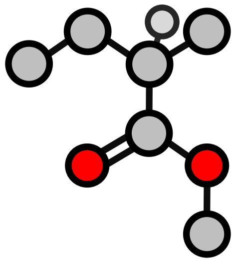


- Reduce to 10K MW, liquid form = Ethylene-Propylene Oligomer (**EPO**)

Comparing Viscosity Modifiers – The PMA Platform

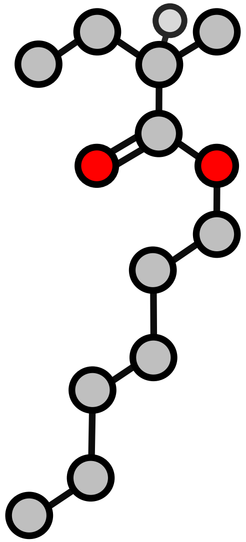
- Copolymer of two or more methacrylate esters to tune properties

"Short"
C1 – C5



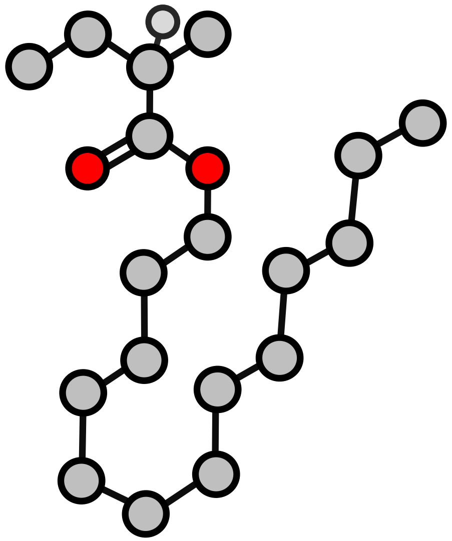
Improves Viscosity Index

"Medium"
C6 – C11



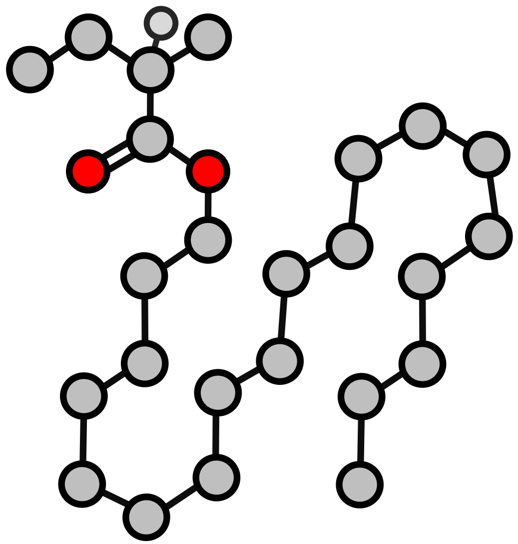
Thickening Efficiency

"Long"
C12 – C17



Oil Solubility, Wax Suppression

"Very Long"
C18+



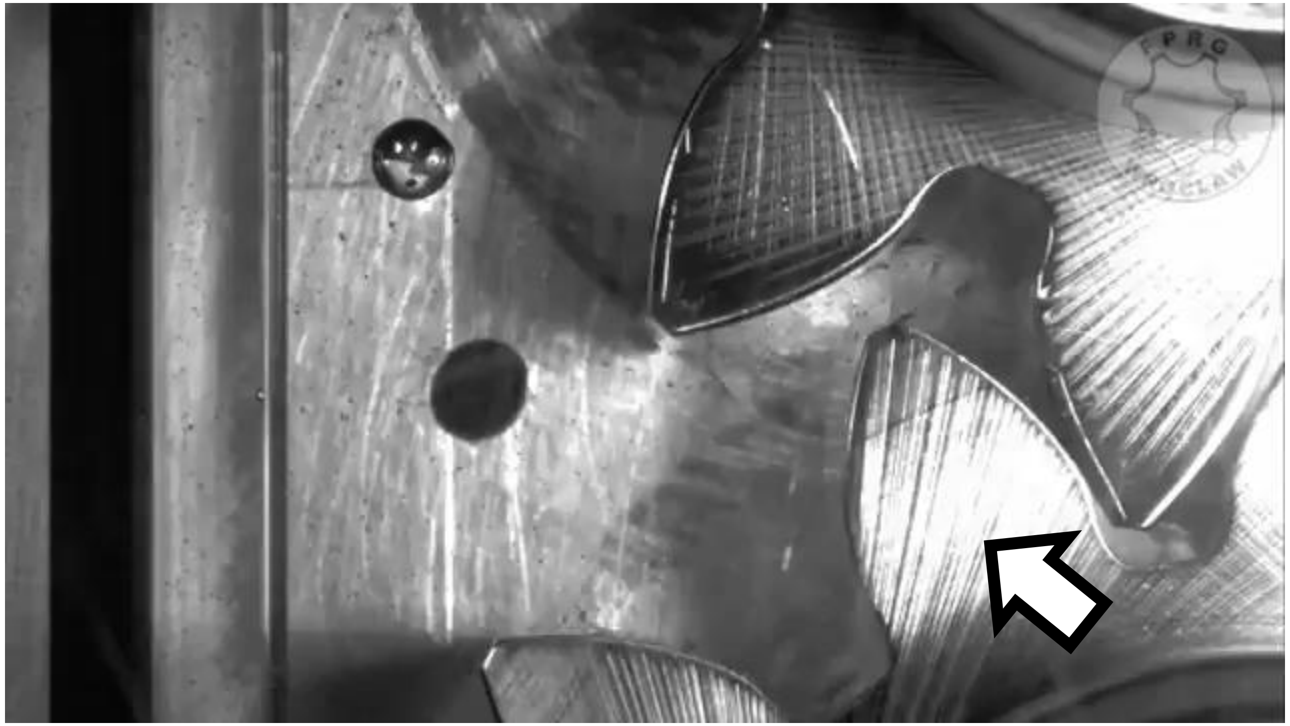
Wax Suppression

Florea, M., Catrinoiu, D., Luca, P. & Balliu, S. Lubr. Sci. 12, 31–44 (1999).

Which VM Should You Use?

- How aggressive is the operating condition?

Moderate: Sliding Wear & Heat



Severe: High Pressures and Cavitation

Ranking the Properties

- Based on our overall experience with 100+ customer development projects/year and evaluating dozens of polymers per year:

	Cost Per Treat	Thickening Efficiency	Viscosity Index	Shear Stable	High Temp.	Low Temp.	Dispersant
Olefin Copolymers (OCP)	★★★★★	★★★★★	140 – 160	★	★★★	★★	★
Polybutenes (PIB / PB)	★★★★	★★	120 – 150	★★★★★	★★	★★	★
Styrene Copolymers	★★★	★★★★	140 – 200	★★	★★★★	★★	★★★
Ethylene Propylene Oligomers (EPO)	★★★★	★★★	140 – 180	★★★★	★★★★★	★★★	★
Polymethacrylates (PMA)	★★	★★	140 – 220	★★★	★★★	★★★★	★★★★★

- But properties can vary depending on MW, monomer ratios, etc.

A Quick Look at Tackifiers in Action

- Take PIB or OCP polymer chain and make it 10-100 times bigger
- Viscoelastic response
  - Oil attracted to motion
  - Reduced fling
  - Anti-mist and improved air quality

Functional Products Inc. “Tack in Action – ILMA 2021” video - https://www.youtube.com/watch?v=I-wO4weZ8is

Summary

- Polymers in industrial lubrication – key concepts
  - Viscosity modifiers used to tune the ISO VG and VI of lubricants
  - Higher VI fluids to keep up with the demands of energy efficiency
  - A variety of viscosity modifiers are available with unique trade-offs
  - Tackifiers and other advanced polymers as further tools for you

Things I Didn't Talk About

- More advanced polymer topics for next time
  - Shear stability index
  - Formulation design and cost optimizations using VM
  - Surface active polymers - Demulsifiers & Defoamers
  - Dispersants and dispersant VMs
  - Polymer base stocks
  - Polymeric antiwear and chlorinated paraffin replacements

Thank you! Ready to start using polymer? Start a project with Functional Products

More online: www.functionalproducts.com

Ask me anything: ewillett@functionalproducts.com