

# **Formulating Gear Oils With Functional Products**

**September 2020**



- Wide range of lab and gearbox tests for most gear oil specifications
  - ANSI/AGMA 9005 industrial gear
  - SAE J306 automotive gear
- **First things** to get right at the start of a project are:
  - Shear Stability & Viscosity Index
    - Functional M Series polymethacrylate viscosity modifiers
  - Extreme pressure protection
    - Functional GA gear oil packages



- Tapered bearing roller (KRL) test
  - Also known as: “20 hr KRL”, CEC L-45-99-A, DIN 51350-6, ISO 26422
- Most industrial and OEM fluids require < 15% viscosity loss by 20hr KRL
  - Some OEMs may require < 10% viscosity loss instead
- Most Group I/II/III and bright stocks will have negligible shear
- Polybutenes and mPAO - < 5% loss in 20hr KRL
- Typically fluids VI < 140 are shear stable



- High VI gear oils
  - AGMA 9005 specifies proper ISO VG for application based on VI
    - VI 90, 120, 160, 240
  - Higher VI, less temperature effect on viscosity, wider operating temp.
    - “Multi-grade” or “all season”
  - Also tends to have low pour points, low temp fluidity, etc.
- To make higher VI fluids requires high MW polymers, “VI improvers”
  - Polymers are large enough to influence VI and give VI > 140
    - Also large enough to shear in KRL if not chosen carefully



- High VI gear oils require a balance between base oil viscosity and how much viscosity is added by shearable polymer

	<b>Benefit</b>	<b>Challenge</b>
<b>Add More VI Improver</b>	<p>Higher VI</p> <p>Better low temp Brookfield viscosity and pour point</p> <p>Higher solvency and clarity w/ synthetic base oils</p>	<p>Higher viscosity loss in KRL</p> <p>Added cost</p>
<b>Increase Base Oil Viscosity</b>	<p>Reduced viscosity loss by KRL</p> <p>Lower cost (situational)</p>	<p>Lower VI</p> <p>Requires more wt% VI improver to improve VI</p> <p>Worse low temp fluidity (Brookfield, pour point)</p>

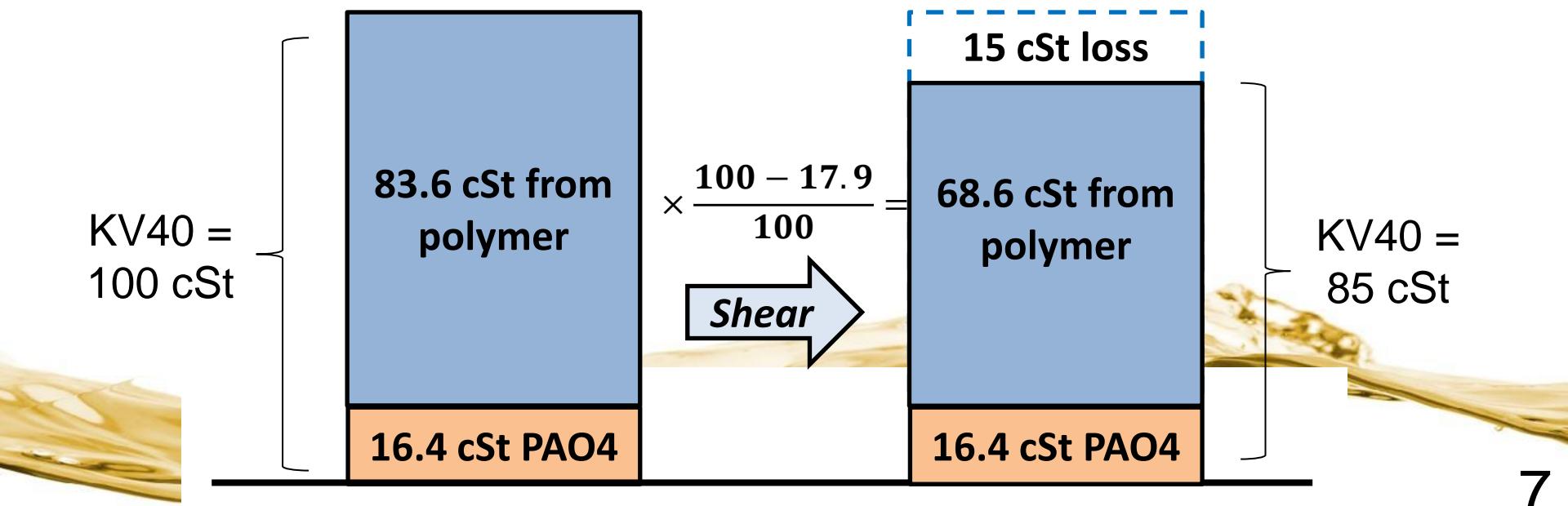
- Shear Stability Index (SSI)
  - Typically defined by Kurt-Orbahn diesel injector method (ASTM D6278)
  - Maybe also be defined with respect to sonic shear or KRL
- SSI = % of viscosity added by polymer that is lost in the shear method
  - SSI 25 means if you add 100 cSt then 25 cSt (25%) will be lost to shear



- What SSI do you need to get < 15% loss by KRL for a given ISO VG?
  - Need to know polymer SSI and what base oil you'll use
- Example: Making an ISO 100 from PAO4...

$$\% \text{ Visc Loss} = \% \text{ Visc from Polymer} \times \frac{SSI}{100}$$

$$SSI \text{ Required} = \frac{100 \times \% \text{ Visc Loss}}{\% \text{ Visc from Polymer}} = \frac{100 \times 15}{83.6} = 17.9$$



- Options at Functional:
  - M Series polymethacrylates
    - FUNCTIONAL MG-1000, MG-3000, MH-2000
      - 15 – 35% SSI by KRL
  - High viscosity synthetic base stocks
    - FUNCTIONAL V-736 / V-731 / V-732 ethylene propylene oligomers
      - 5 - 15 SSI by KRL
  - Exceptional shear stability in KRL to formulate a high range of low and high viscosity gear oils with high VI



	Thickening Efficiency	Shear Stability	Typical Applications				Preferred Base Fluid Type
KV100 (cSt)	KV100, 10wt% (cSt*)	KRL 20 hr.	ISO 32-150 Industrial Gear / HF	ISO 220+ Industrial Gear / HF	Auto Gear 75W-90	Auto Gear 75W-140	Group I/II      Group III/VI/V

## Industrial and Automotive Gear PMA

MG-1000	900	8.6	15%	X	X	PAO	VI
MG-3000	550	8.0	20%	X	X	PAO	I/II      III
<b>MG-1500</b>	1200	9.6	25%	X	X	PAO	I/II      III/VI
<b>MG-1860</b>	900	9.1	30%	X	X	PAO	VI/V

## Hydraulic Fluid PMA

MH-2000	1100	9.2	35%	X			I/II
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## Dispersant PMA

<b>MD-2200</b>	900	8.9	35%	X	X	PAO	I/II      III/VI
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**NEW** for 2020

## **PMA Comparison**

### **MG-3000**

Optimized for paraffinic  
automotive gear low temp.

20 SSI by KRL

### **MG-1000**

Optimized for PAO  
automotive gear low temp.

15 SSI by KRL

### **MG-1500**

Optimized for Gr. III/IV

25 SSI by KRL

### **MH-2000**

Workhorse PMA for Gr. I/II

35 SSI by KRL

### **MG-1860**

PAO-based MH-2000, no oil

30 SSI by KRL

### **MD-2200**

Dispersant MH-2000

35 SSI by KRL



- Functional MH-2000 - 35 SSI by KRL
  - Works best in Group I/II at ISO 32 – 150 for high VI gear
- Functional MG-1500 – 25 SSI by KRL
  - Optimized for Group III/IV automotive gear and low visc industrial gear
- Functional MG-1860 – 30 SSI by KRL
  - Prepared in PAO, no mineral oil content for 100% synthetic gear oil

## VI 140 EP Gear Oils, shear in grade by KRL

wt%	ISO 32	ISO 46	ISO 68	ISO 100	ISO 150
110N Gr. II	77.7	60.9	43.6	29.4	10.1
600N Gr. II	18.8	33.6	47.4	57.4	74.1
<u>MH-2000</u>	1.5	3.5	7.0	11.2	13.8
Gear Package	2.0	2.0	2.0	2.0	2.0
<b>KV40</b>	29.5	43.6	68	104.8	158.1
<b>KV100</b>	5.8	7.5	10.4	14.3	19.5
<b>VI</b>	141	140	140	140	141

- VI >140 at ISO 220+ requires very shear stable PMA
  - Heavy base oils can't produce high VI, requires light base oil
  - Light oil and high product viscosity requires very shear stable PMA
- Functional MG-3000
  - 20 SSI by KRL; use in Group I/II/III gear oils, gives best low temp flow
- Functional MG-1000
  - 15 SSI by KRL; use in Group IV gear oil or extra high shear stability

**VI 140 EP Gear Oils, shear in grade by KRL**

wt%	ISO 220	ISO 320	ISO 460	ISO 680	ISO 1000
110N Gr. II	13.0	7.0	--	--	--
600N Gr. II	64.0	65.0	67.5	60.8	54.4
<u>MG-1000</u>	21.0	26.0	30.5	37.2	43.6
Gear Package	2.0	2.0	2.0	2.0	2.0
<b>KV40</b>	219.6	320	473.6	702.2	1043.5
<b>KV100</b>	24.5	32.2	42.4	55.9	72.7
<b>VI</b>	140	141	140	140	140
<b>EP Weld (D2596)</b>	315	315	315	315	315

- Gears used to transmit mechanical power
  - Heavy loads applied over small gear teeth creates high pressure
    - High pressure can push through fluid film and cause metal contact
      - Scuffing or scoring of metal → gear damage and failure
- ASTM D2783 – 4-ball extreme pressure
  - One of many methods for evaluating EP protection
- EP protection level varies based on gear design and application
  - Typically denoted by API Service Category (GL-1 to GL-5)



API Service Category	Active Components Typically Used in the Gear Oil	Application	Typical 4-Ball EP Weld Load (D2783)	Functional Products Option
GL-1	Straight mineral oil (CI, AO, PPD, defoam)	<i>Obsolete</i>	≤ 100 kgf	0.3% CI-426 0.1% PD-610
GL-2	AW and FM allowed (fats/esters)	Worm gear (Brass/Steel)	Varies	1.5% WA-60SF
GL-3	Mild EP included (phos. and sulfur EP)	Manual transmissions, light to severe; spiral bevel gears	200 – 250 kgf	1.75% WA-64
GL-4 **	Strong EP included (active sulfur)	Most manual transmission; hypoid gears	315 - 400 kgf	2.8% GA-614
GL-5 **	Same as GL-4	High speed/torque hypoid, heavy duty vehicles	315 - 500 kgf	4.0% GA-614

\*\* GL-4 LS  
or GL-5 LS

Friction modifier added to  
GL-4 or GL-5

Limited slip differential  
(with clutch pack)

315 – 500 kgf



- **Functional GA-614**

- Metal-free industrial gear package
- 1.5 – 5.0wt% treat
- 2.8wt% meets US Steel 224; DIN 51517-3 CLP; ISO 6743-6
- 4.0wt% suitable for API GL-5 extreme pressure performance

- Light color, low odor
- FZG 12+ stage pass
- 60+ Timken OK load
- 620 kgf EP weld at 5wt%

Typical Properties	
Odor and Appearance	Mild, hazy liquid
Demulsibility (D1401) at 30 minutes	39/41/0
Lbs per Gallon	8.4
Flash Point (COC)	150°C
Kinematic Viscosity at 40°C	65 cSt
Copper strip corrosion (D130), 3 hrs., 100°C	1b
Sulfur	29.3 wt%
Phosphorous	1.4 wt%
Test Results - Formulated at 2.8% in ISO 220 mineral oil	
Turbine Oil Rust Test (D665A and B)	Pass
4-Ball Wear Scar (D4172, 20 kg)	0.33 mm
4-Ball Weld Load (D2783)	315 kg
Load wear Index (LWI)	66
Timken OK Load (D2782)	> 60 lbs
Oxidation Test (D2893), Viscosity change	0.28 %
Precipitation Number	0.02 ml
Foam (D892), Sequence I, II, III	00/00
FZG A/8.3/90 (D5182), Load stage	> 12

- FUNCTIONAL CI-426EP
  - Amine phosphate-based corrosion inhibitor with added EP protection
- FUNCTIONAL pour point depressants
  - PD-610 for ISO 46+ Group I/II
  - PD-620 for 4 cSt Group III
  - PD-630 for 6 and 8 cSt Group III
- Tackifiers for open gear and mist-resistant lubricants
  - V-176 for workhorse tackifier
  - V-188 for added shear stability and long service life
  - V-388 for synthetic and high temp gear oils



- Functional Products supplies products and insight to help formulators create high end industrial and automotive gear oils
  - Shear stable polymethacrylates for mineral oil and synthetic formulas
    - Functional MG-1000, MH-2000, etc.
  - Gear oil packages
    - Functional GA-614 package with variable treat rate
  - Individual components
    - Tackifiers, PPDs, corrosion inhibitors

