Development of High-Performance, Environmentally Acceptable Gear Oils

Innovation and sustainability are key values at Biosynthetic Technologies (BT) that drive the strategic direction of the company's development programs. The research team at BT spends most of their time at the interface of these domains, looking for creative ways to solve the world's sustainability challenges.

The purpose of this initiative was to develop a set of commercially viable, high-performance, environmentally acceptable gear oils from sustainable ingredients, capable of competing with other high-end gear oils on the market today. The formulations contain (1) BT's estolide base oils, (2) an EP gear oil additive, and (3) an antifoam additive from a major lubricant additive supplier. A description of the three formulations is shown in Table 1.

Gear oils are primarily defined by their viscosity grade. In the case of the gear oils described in this paper, three different viscosities were achieved by adjusting the ratio of the estolide base oils. The additives and their respective treat rates were kept the same.

Ingredient	Company	ISO 68	ISO 100	ISO 150
BT4 (Estolide)	Biosynthetic Technologies	42.85	19.00	-
BT22 (Estolide)	Biosynthetic Technologies	54.25	78.10	97.10
EP Gear Oil Additive	Major Additive Company	2.90	2.90	2.90
Antifoam Additive	Major Additive Company	0.05	0.05	0.05

***Table 1**. Gear oil formulation details.*

Basic Physicals

As shown in Table 2 below, all three gear oils passed the basic physical tests, including specifications for viscosity, flash point, pour point, water content, and impurity content.

		Requirements			Results		
	Method	ISO 68	ISO 100	ISO 150	ISO 68	ISO 100	ISO 150
BASIC PHYSICALS							
Appearance	Visual	Transparent			Clear and Bright		
Kinematic Viscosity at 40°C, cSt	ASTM D445	In Grade			64.4	100.3	142.4
Kinematic Viscosity at 100°C, cSt	ASTM D445	Report			11.2	15.7	20.7
Viscosity Index	ASTM D2270	Report			168	167	169
Brookfield Viscosity at -20°C, cP	ASTM D2983	Report			48,700	24,625	20,335
Flashpoint (COC), °C	ASTM D92	180 min	200 min	200 min	250	247	264
Pour Point, °C	ASTM D97	-12 max	-12 max	-9 max	-18	-18	-18
Water Content, %	ASTM D6304	Trace			0.028	0.017	0.016
Mechanical Impurities, %	GB/T 511	0.02 max			Nil	Nil	Nil

***Table 2**. Basic physical properties of the ISO 68, ISO 100, and ISO 150 gear oils.*

Performance Data: AGMA 9005-F16 AS Standard

Each of the grades was evaluated against the American Gear Manufacturers Association (AGMA) standard, 9005-F16 AS. This includes tests such as steel pin corrosion, copper corrosion, demulsibility, foam, and FE-8 bearing testing. The data is shown below in Table 3.

		Requirements			Results		
	Method	**ISO 68**	**ISO 100**	**ISO 150**	**ISO 68**	**ISO 100**	**ISO 150**
AGMA 9005-F16 AS							
Cleanliness	ISO 4406		Report		24/22/15	23/22/17	24/20/14
Steel Pin Corrosion, 24h @ 60°C	ASTM D665		-		-	-	-
Deionised Water	"		Pass		Pass	Pass	Pass
Copper Corrosion, 3h @ 100°C	ASTM D130		1B max		1A	1B	1B
Oxidative Stability at 121°C, %	ASTM D2893		6 max		4.6	5.1	5.3
Demulsibilty Procedure B	ASTM D2711		-		-	-	-
Total Free Water, mL	"		80 min		84	81.8	80.2
Emulsion Volume, mL	"		1 max		0	0	0
Water in Oil, %	"		2 max		0.7	0.3	0.4
Foam Properties	ASTM D892		-		-	-	-
Sequence I, mL	"		50-0 max		0-0	0-0	20-0
Sequence II, mL	"		50-0 max		20-0	10-0	20-0
Sequence III, mL	"		50-0 max		0-0	0-0	10-0
FZG (A/8.3/90), fls	ISO 14635-1	12 min	12 min	>12	-	-	-
FE-8 Bearing Test	DIN 51819-3		-		-	-	-
Roller Weight Loss (mw50), mg	"		30 max		5.2	-	-
Cage Weight Loss, mg	"		Report		115.5	-	-

***Table 3**. AGMA 9005-F16 AS testing results.*

Performance Data: Chinese GB 5903 L-CKD Standard

Another dataset was created against the Chinese GB 5903 L-CKD standard. Tests like steel pin corrosion (using salt water instead of the deionized water), oxidative stability, Timken OK Load, shear stability, and both 4-ball wear and EP were passed. In Table 4 below, test requirements and results are detailed.

		Requirements			Results		
	Method	**ISO 68**	**ISO 100**	**ISO 150**	**ISO 68**	**ISO 100**	**ISO 150**
Chinese GB 5903 L-CKD							
Steel Pin Corrosion, 24h @ 60°C	GB/T 11143		-		-	-	-
Synthetic Salt Water	"		Pass		Pass	Pass	Pass
Oxidative Stability at 121°C, %	SH/T 0123		-		-	-	-
KV100 Change, %	"		6 max		4.6	5.1	5.3
Precipit. Number Change, mg KOH/g	"		0.1 max		0	0	0
Timken OK Load, lbs	GB/T 11144		60 min		-	-	-
Shear Stability	SH/T 0200		-		-	-	-
KV40 after Shear, cSt	"	61.2 min	90 min	135 min	63.6	99.5	143.7
4-Ball EP	GB/T 3142		-		-	-	-
Sintered Load (PD), kgf	"		250 min		250	315	315
Integrated Wear Index, kgf	"		45 min		56	68.9	70.6
4-Ball Wear (20kg, 1800 rpm, 54°C, 1 hr)	SH/T 0189		-		-	-	-
Wear Scar Diameter, mm	"		0.35 max		0.28	0.24	0.25
FZG (A/8.3/90), fls	SH/T 0306		12 min		>12	-	-

***Table 4**. Chinese GB 5903 L-CKD testing results.*

Other Test Results

In addition to passing the AGMA 9005-F16 and the Chinese GB 5903 L-CKD, the gear oils also passed strict requirements for the following standards:

- David Brown S1.53.101 Type E
- DIN 51517-3
- Indian Standard IS 8406 EP
- ISO 12925-1 CKES
- Reintjes Gears BV1597/2; BV1597/4; BV1917/2; BV1917/4; BV2060/2; BV2060/4
- Schuler Pressen gmBH DT 55 005/1
- SMS SN 180-3
- US Steel 224

Additional test data from these standards is outlined in Table 5, below. Notably, all three gear oils passed ASTM D2893 KV100 increase at both 95°C and 21°C, and ISO 12152 Flender Foam, with excellent results.

		Requirements			Results		
	Method	**ISO 68**	**ISO 100**	**ISO 150**	**ISO 68**	**ISO 100**	**ISO 150**
Other Testing							
Air Release at 50°C, min	ASTM D3427	12 max	18 max	30 max	11.9	16.1	25
TOP, %	IP 280		Report		0.68	0.68	0.86
Demulsibility, sec	IP 19		Report		675	285	990
Demulsibility at 82°C, min	ISO 6614	30 max	n/a	n/a	41-38-1 (20)	-	-
Demulsibility at 82°C, min	ASTM D1401		Report		40-38-02 (5)	42-38-0 (5)	41-39-0 (10)
KV100 Increase at 95°C, %	ASTM D2893		10 max		2.1	5.1	5.3
KV100 Increase at 121°C, %	ASTM D2893		Report		4.6	5.1	5.3
Neutrailization Number, mg KOH/g	DIN 51558-1		Report		0.6	0.63	0.69
Flender Foam	ISO 12152		-		-	-	-
Volume Increase at 1 min, %	"	n/a	15 max	15 max	n/a	3	4
Oil Air Dispersion at 5 min, %	"	n/a	10 max	10 max	n/a	2	2
Elastomer Compat., (NBR 28/SX, 168h/100°C)	ISO 1817		-		-	-	-
Shore A Hardness Change, pts	"		Report		-8	-7	-4
Volume Change, %	"		Report		16	12	8
Tensile Strength Change, %	"		Report		-15	-8	-12
Elongation at Break Change, %	"		Report		-34	-27	-31
FVA 54 Micropitting Resistance at 90°C	FVA 54		-		-	-	-
Load Stage	"		Report		=10 High	>10 High	-
Endurance Stage	"		Report		GFT High	GFT High	-

***Table 5**. Additional performance data results for the three gear oils.*

Environmental Characteristics

In addition to performance, the gear oils also have favorable environmental profiles. As noted in Table 1, the three gear oils are 97% estolide, BT4 and BT22. Environmental data for each of these products is shown below, in Table 6.

	Method	**BT4**	**BT22**
Environmental Characteristics			
Biodegradability, %	OECD 301B	88%	79%
Renewable Carbon Content, %	ASTM D6866	68%	86%
Ecotoxicity, mg/L	OECD 201	>1000	>1000
Ecotoxicity, mg/L	OECD 202	>1000	>1000
Ecotoxicity, mg/L	OECD 203	>1000	>1000
Ecotoxicity, mg/L	OECD 209	>1000	>1000

***Table 6**. Environmental data for BT's base oils used the gear oil formulations.*

Conclusion

The ISO 68, ISO 100, and ISO 150 gear oils jointly developed by BT and their partner showcase the potential for BT's base oil technology in demanding industrial applications. While the gear oils meet the performance criteria for ten of the most common standards, they are also biodegradable, bio-based, and non-toxic.

If you're interested in commercial opportunities related to manufacturing these products, or any other projects, please contact Matt Kriech at mkriech@biosynthetic.com.