Perfad™ NG 2500

Next generation friction modifier to boost MoDTC performance in engine oils

Cargill®

Introduction

Government legislation and regulations are driving change within the automotive industry, setting challenging targets for improving fuel economy and reducing exhaust emissions.

OEMs (original equipment manufacturers) worldwide are looking to reduce emissions through electrification (e.g. batteries and fuel cells) but also through optimisation of internal combustion engines, including in hybridised vehicles, which run cooler and more infrequently than conventional ICE (internal combustion engine) powered vehicles.

Innovation for future generations

Well-balanced, high performing engine oils allow OEMs to deploy new combustion engine technologies. Friction control is crucial in helping formulators and OEMs to meet the strict engine test criteria required to prove fuel economy performance.

Molybdenum dithiocarbamate (MoDTC) is an inorganic friction modifier that is commonly used to achieve maximum fuel economy savings. However, we recognise that there are industry limitations of using MoDTC including short lifetimes and deposit formation.

We have developed Perfad™ NG 2500, a new organic friction modifier based on polymer chemistry, which delivers low initial friction and works in synergy with MoDTC to improve friction durability. The physical properties of Perfad NG 2500 are shown in Table 1.

Perfad NG 2500 helps boost MoDTC performance, enabling formulators to develop engine oils that improve fuel economy and reduce emissions.

Perfad NG 2500 and lower viscosity engine oils

OEMs now recommend lower viscosity engine oils and 0W-XX oils are commonplace in the automotive engine oil market.

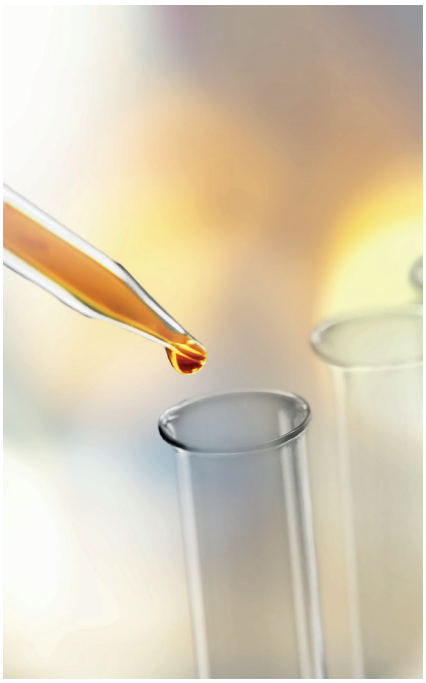
This downward trend in viscosity is underpinned by the need for friction reduction and improved performance at lower temperatures, as well as the need to meet tightening fuel economy requirements.

The performance of Perfad NG 2500 has been showcased in an EU-style 0W-20 engine oil, formulated using Group III/IV base oils, a viscosity index improver and a European commercial additive pack. The performance of this oil has been used as the baseline reference fluid in all tests throughout this brochure.

Typical physical properties

Property	Unit	Value
Physical form		Viscous liquid
Colour		Amber
Dynamic viscosity at 40°C	mPa.s	3300
Dynamic viscosity at 60°C	mPa.s	1100
Dynamic viscosity at 80°C	mPa.s	520
Dynamic viscosity at 100°C	mPa.s	260
Iodine value	gI/100g	4
Acid value	mgKOH/g	1
Density at 20°C	g/ml	0.98
Flash point	°C	>200°C
Pour point	°C	-11
SAPS	% w/w	zero

Table 1 Typical physical properties of Perfad NG 2500



Low friction, for longer

SRV – pure sliding contacts

Mechanical movements in engines include both ‘sliding and rolling’ and ‘pure sliding’ contacts. Frictional characteristics of Perfad NG 2500 have been exemplified in this brochure using a selection of laboratory bench tests.

The SRV is widely used by many OEMs and lubricant formulators to demonstrate performance in automotive applications and offers a precise study of friction and wear between metal components.

The frictional performance of MoDTC can degrade through oxidation, but also by mechanical means such as rubbing. We were able to model this using the SRV ‘durability’ test. Steel test specimens were assembled into a cylinder-on-disc configuration (Figure 1) and both the reference oil, and the oil containing Perfad NG 2500 were subjected to the test conditions shown in Table 2.

Figures 2 and 3 show the SRV durability results. The graphs demonstrate that Perfad NG 2500 promotes the formation of a longer lasting low friction tribofilm, which can extend the friction reducing properties of the MoDTC-containing reference oil.

Perhaps most noteworthy is the performance of Perfad NG 2500 at 50°C. Given that the ICE within hybrid vehicles will run at cooler temperatures and will run less frequently, the lower initial friction and the improved frictional durability at lower temperatures is vital.

Typical physical properties

Parameter	Value
Time (hr)	48
Temperature (°C)	50 and 80
Frequency (Hz)	50
Load (N)	150
Stroke length (mm)	1

Table 2 SRV test parameters

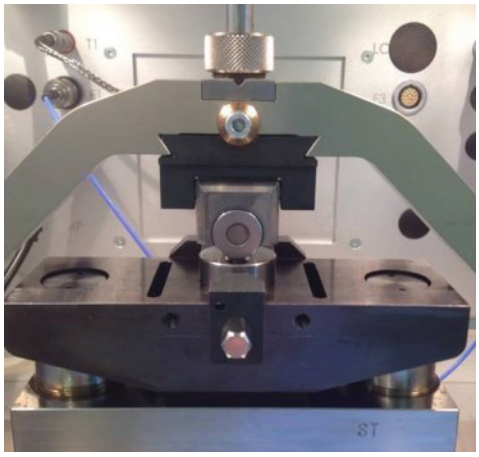


Figure 1 SRV set up in a cylinder-on-disc configuration

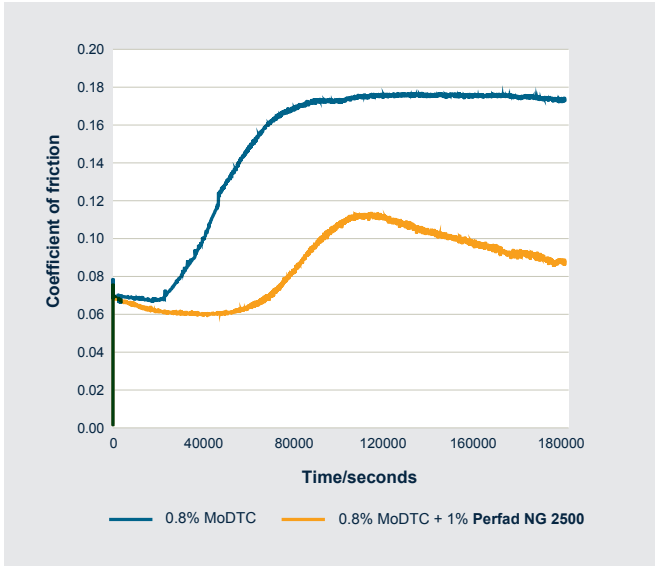


Figure 2 SRV durability test results for the EU 0W-20 engine oil formulations at 50°C

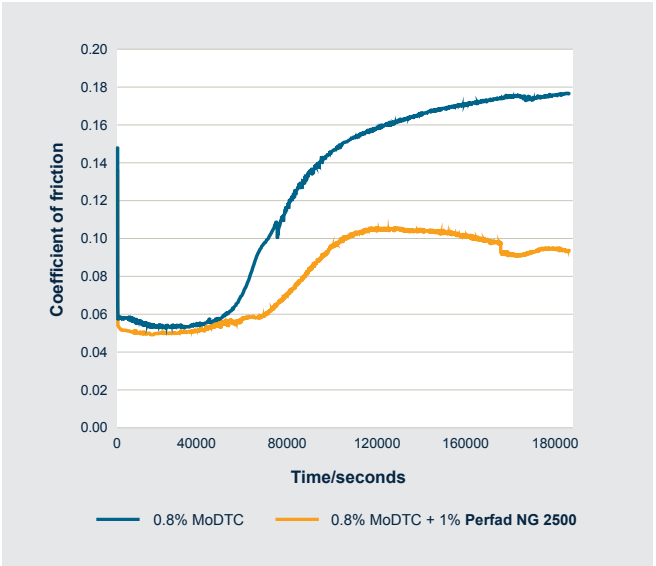


Figure 3 SRV durability test results for the EU 0W-20 engine oil formulations at 80°C

Rolling/sliding conditions

MTM – rolling sliding contacts

Formulations tested on the SRV were also subjected to MTM testing at 50°C and 80°C, using the sliding-rolling conditions shown in Table 3.

In its standard setup the Mini Traction Machine (MTM), shown in Figure 4, allows a precise measurement of friction by loading a steel ball against a steel disc using highly controlled parameters.

In order to determine the film forming and frictional characteristics of friction modifiers, it is important to run tests on virgin surfaces and also on surfaces which are conditioned through opposing surface contact. Our testing protocol includes a rubbing profile which involves bringing the ball and a smooth disc into contact at slow speeds for a period of 120 minutes. This rubbing profile allows the development of anti-wear films, which may not be formed when running an initial Stribeck curve and which can lead to higher frictional contacts between opposing surfaces. Figures 5 and 6 show results at 50°C and Figures 7 and 8 show results at 80°C.

Figure 4 Mini Traction Machine set up in a ball-on-disc configuration

Typical physical properties

Parameter	Value
Applied load (1.01 GPa)	36 N
Lubricant temperature (°C)	50 and 80
Slide/roll ratio (%)	50
Entrainment speed	Stribeck curve: 50mms^{-1} - 4000 mms^{-1} Rubbing: 500 mms^{-1}
Disc material	AISI 52100 steel
Disc surface finish	< 0.01 um Ra
Disc hardness	720 - 780 HV
Ball material	AISI 52100 steel
Ball surface finish	< 0.02 um Ra
Ball hardness	720 - 780 HV

Table 3 MTM test parameters

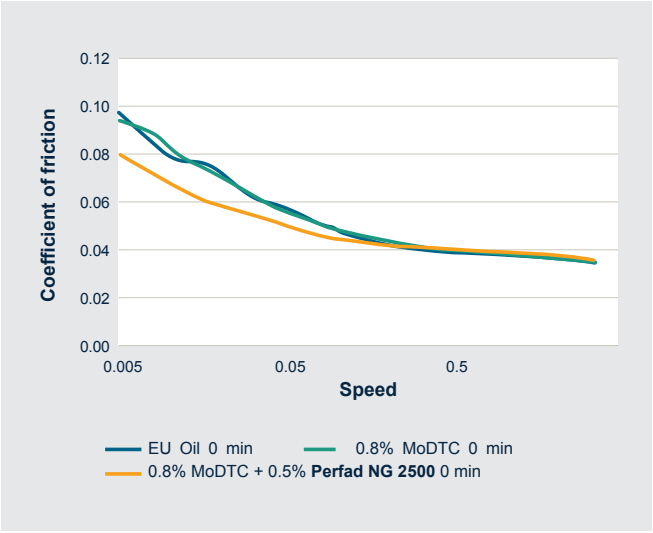


Figure 5 MTM results for EU Oil + friction modifiers at 50°C, 0 mins rubbing

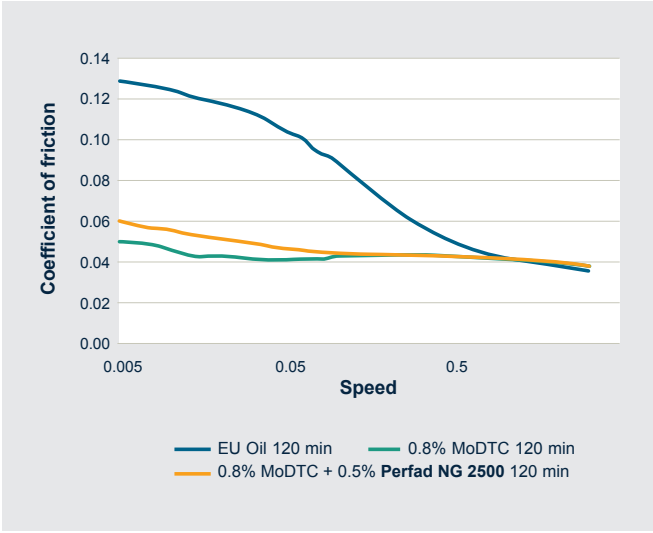


Figure 6 MTM results for EU Oil + friction modifiers at 50°C, 120 mins rubbing

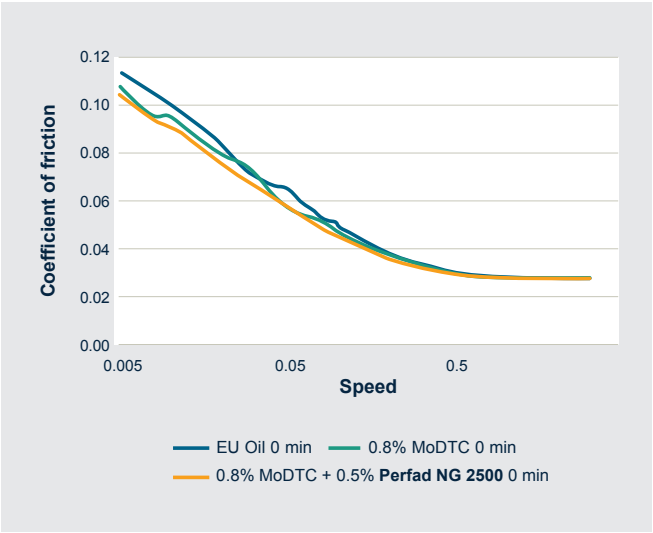


Figure 7 MTM results for EU Oil + friction modifiers at 80°C, 0 mins rubbing

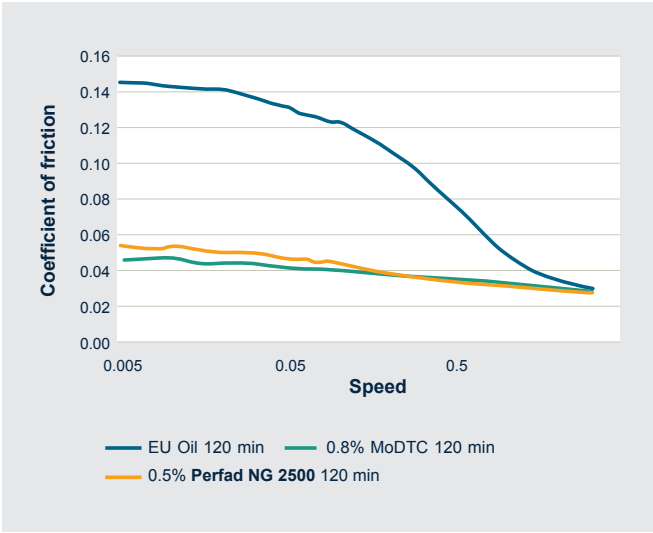


Figure 8 MTM results for EU Oil + friction modifiers at 80°C, 120 mins rubbing

No harms testing

Perfad NG 2500 exhibits the following features and benefits:

- Negligible effects on low temperature viscosity
- Negligible effects on HTHS viscosity
- Excellent shear stability
- No negative effects on foaming
- Good oxidative stability

Once again for demonstration purposes, the reference EU 0W-20 formulation was top-treated with 1% Perfad NG 2500 and typical global specification tests were conducted. Tests were also conducted with 0.8% MoDTC as well as combinations of both ingredients. No negative interactions between the two components were observed.

Low temperature pumpability

Formulation	MRV viscosity -35°C (mPa.s)	Yield stress (Pa)
EU Oil	6800	<35
+ 0.8% MoDTC	7400	<35
+ 1% **Perfad NG 2500**	8000	<35
+ 0.8% MoDTC + 1% **Perfad NG 2500**	9600	<35

Table 4 Aged oil low temperature pumpability (MRV) results (CEC L-105)

Viscometrics in both 0W-8 and 0W-20 formulations

Formulation	HTHS viscosity			Kinematic viscosity			Cold cranking viscosity (mPa.s)
	80°C (cP)	100°C (cP)	150°C (cP)	KV40 (cSt)	KV100 (cSt)	VI	
JP Oil (0W-8)	4.61	2.96	1.12	23.8	5.01	142	2839
1% **Perfad NG 2500**	4.88	3.13	1.36	25.3	5.27	146	3008

Table 5 HTHS results (CEC L-36-A-90)

Formulation	HTHS viscosity		Kinematic viscosity			Cold cranking viscosity (mPa.s)
	HTHS 100°C (cP)	HTHS 150°C (cP)	KV40 (cSt)	KV100 (cSt)	VI	
EU Oil	4.11	2.83	43.08	8.74	187	4805
0.8% MoDTC	4.09	2.83	42.99	8.78	189	4831
1% **Perfad NG 2500**	4.27	2.93	44.72	9.19	191	5132
0.8% MoDTC + 1% **Perfad NG 2500**	4.26	2.94	45.09	9.15	190	5208

Table 6 HTHS results (CEC L-36-A-90)

HTCBT

Formulation	Level of metals in lubricant oil after corrosion test (ppm)			Cu strip rating
	Cu	Pb	Sn	
EU oil	4	4	0	1b
+ 0.8% MoDTC	545	2	3	4a
+ 1% **Perfad NG 2500**	5	2	0	1b
+ 0.8% MoDTC + 1% **Perfad NG 2500**	332	0	2	4a

Table 7 HTCBT results (ASTM D6594)

Ball rust

Formulation	Average gray value
EU oil	109
+ 0.8% MoDTC	112
+ 1% **Perfad NG 2500**	110
+ 0.8% MoDTC + 1% **Perfad NG 2500**	107

Table 8 Ball rust testing results (ASTM D6557)

Oxidative stability

Formulation	Oxidation induction time (min)
EU oil	29
+ 0.8% MoDTC	30
+ 1% **Perfad NG 2500**	29
+ 0.8% MoDTC + 1% **Perfad NG 2500**	28

Table 9 PDSC results (ASTM D6186)

Emulsion retention

Formulation	Emulsion retention at 24 hours	
	0°C	25°C
EU oil	100	100
+ 0.8% MoDTC	100	100
+ 1% **Perfad NG 2500**	100	100
+ 0.8% MoDTC + 1% **Perfad NG 2500**	100	100

Table 10 E85 emulsion retention test (ASTM D7563)

Foaming

Formulation	Sequence I (24°C)		Sequence II (94°C)		Sequence III (24°C)		Sequence IV (150°C)	
	Tendency (ml)	Stability (ml)	Tendency (ml)	Stability (ml)	Tendency (ml)	Stability (ml)	Tendency (ml)	Stability (ml)
EU oil	0	0	0	0	0	0	100	0
1% **Perfad NG 2500**	0	0	0	0	0	0	100	0
0.8% MoDTC	0	0	0	0	0	0	110	0
0.8% MoDTC + 1% **Perfad NG 2500**	0	0	0	0	0	0	100	0

Table 11 Foaming results (Sequence I, II, III – ASTM D892. Sequence IV – ASTM D6082)

Seal compatibility

Formulation	Fluorinated (FKM)		Acrylic (ACM)		Nitrile (HNBR)		Ethylene (AEM)	
	Volume change (%)	Change in elongation at break (%)	Volume change (%)	Change in elongation at break (%)	Volume change (%)	Change in elongation at break (%)	Volume change (%)	Change in elongation at break (%)
EU oil	0.5	-15	0.2	-31	2.3	-45	3.2	-27
1% **Perfad NG 2500**	0.6	-29	0.2	-30	2.4	-38	3.1	-27
0.8% MoDTC	0.6	-17	0.2	-27	4	-30	3.7	-7
0.8% MoDTC + 1% **Perfad NG 2500**	0.7	-18	0.2	-23	3.7	-24	3.5	-12
All current ACEA A/B/C grades	-5.5 < % < 2.2	-70 < % < 20	-1.8 < % < 8.9	-65 < % < 15	0.0 < % < 12.0	-51 < % < 9	-2.5 < % < 16	-65 < % < 19

Table 12 Seal compatibility test results (CEC L112-12)

Shear stability

Formulation	Fresh oil viscosity at 100°C (cSt)	Sheared oil viscosity at 100°C (cSt)	Viscosity loss (%)
EU oil	8.79	8.06	8.3
1% **Perfad NG 2500**	9.18	8.34	9.15
0.8% MoDTC	8.84	8.06	8.82
0.8% MoDTC + 1% **Perfad NG 2500**	9.21	8.36	9.23

Table 13 Shear stability characteristics (ASTM D6278)

Who are we?

The Energy Technologies business in Cargill Bioindustrial creates, makes and sells specialty chemicals and additives for the global energy market. Working in close collaboration with our customers, we apply sustainable concepts and deep scientific expertise so that together we can efficiently power the world of tomorrow.

At our core, we are experts in synthetic ester and polyalkylene glycol chemistries, taking products from lab scale through to full manufacturing. Investing in the development of new chemistries allows us to support our customers in meeting new industry challenges.

For those who dare to imagine a brighter future, we establish long lasting relationships and create bespoke industry solutions through our integrated research & development and global manufacturing capabilities. Being both global and local, you have direct access to our network of technical experts. We look forward to talking to you.

Further information

Cargill Bioindustrial sales and distribution are coordinated through an extensive worldwide network of technical and commercial experts. For further information or guidance please contact us:

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