Technion – Israel Institute of Technology
Faculty of Mechanical Engineering
Center for Research in Energy Engineering and Environmental Conservation
Internal Combustion Engine Laboratory

Effects of Motorsilk Oil and Fuel Additives on Fuel Consumption and Emissions of Diesel Engine

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Contents

1. Objectives

The objectives of this work were to assess effects of Motorsilk oil and diesel fuel additives on the emissions and fuel consumption of the ISUZU 4JA1 diesel engine.

The principal parameters, which have been measured, are: specific fuel consumption, NO_x and particulate matter (PM) emissions.

2. Testing system

The experimental work was carried out using the laboratory test bench with the following equipment:

- ISUZU 4JA1 diesel engine with the following technical data:

Displacement, [cc]	2499
Bore x Stroke [mm]	93.0 x 92.0
Number of cylinders	4
Compression ratio	18.4
Max. power output [kW/hp]	56/76
at [rpm]	3800
Max. torque [Nm]	160
at [rpm]	2300

- Eddy-current engine dynamometer SCHENCK (Germany) type E90. Accuracy of speed control: ±10 min^{-1}. Accuracy of torque control: ±1% of maximum torque.
- Fuel flow meter Brooks Model 4150. Accuracy of fuel consumption measurement: ±1%.
- Chemiluminescent NO_x Gas Analyzer, manufactured by California Analytical Instruments Inc. (USA), Model 400 CLD. Resolution: ±0.1 ppm NO/NO_x.
- TEOM Series 1105 Diesel Particulate Monitor, manufactured by Rupprecht & Patashnick Co., Inc. (USA) with portable micro-dilution system Horiba MDT905.
- Auxiliary measuring equipment.

3. Testing Procedures

The dynamometer was checked and calibrated. The ISUZU diesel engine (including injectors) was checked. The NO_x gas analyzer was checked and calibrated with a standard calibration gas. The TEOM diesel particulate monitor was checked. The auxiliary measuring equipment was also checked.

The test was performed by using available commercial diesel fuel with sulfur content of less than 50 ppm (see results of the fuel chemical analysis in Annex 1) and commercially available diesel motor oil 15W40 of SHPD type. A baseline test to determine the engine fuel consumption and emissions was done prior to adding the additives. This was performed after running-in the engine for 10 hours in intervals of 5 hours with an intermission after the first 5 hours of engine operation. After completing this engine operation of 10 hours, a performance test was performed at two engine speeds, 5 operation regimes at each speed.

After completing the baseline test, the oil and oil filter were replaced with fresh ones. The fresh oil was identical to the one used in the baseline test, and it was treated with Motorsilk engine oil additive (see Annex 2) at the ratio of 1:10. In accordance with the customer instructions, the oil additive was added to the warm oil (oil temperature was about 60C) by the representative of Logus Ltd. After the engine running-in for 10 hours with an intermission after the first 5 hours, a similar performance test (like the above mentioned baseline test) was performed at the same engine operation regimes. After the first 5 hours of engine operation, the fuel consumption, PM and NOx emissions were measured at only two different engine operation regimes.

After completing 10 hours of engine operation with treated oil and appropriate performance test, the diesel fuel was replaced by the same diesel fuel, treated with LubriSilk diesel fuel additive (FA). A technical description of the additive, as it was provided by the customer, is shown in the Annex 3 to this report. The duration of the test with additized fuel, was 30 hours as follows: the initial 10 hours with treated diesel fuel at a ratio of 1:500, and the latter 20 hours – with a fuel additized at a ratio of 1:1000. During these 30 hours of engine operation, the same short performance test (like above) was performed four times (after 5, 15, 20 and 25 hours of engine operation) at two different engine operation regimes. After 10 hours (with a fuel additized at a ratio of 1:500) and 30 hours (with a fuel additized at a ratio of 1:1000) of engine operation the same complete performance test was performed at two engine speeds and 5 operation regimes at each speed. The detailed test program is provided in Table 1.

Table 1: Test program

Stage number	Contents of the stage	The stage duration	Engine speed, rpm	Engine torque, Nm	Notes
1	Running-in	5 hours +intermission+ 5 hours	2000	100	
2	Baseline performance	As required	1500	30; 55; 80; 105; 120	
			2300	50; 80; 110; 125; 140	
3	Replace the engine oil by MOTORSILK 1:10 additized oil; Replace the engine oil filter by the fresh one				
4	Running-in	5 hours	2000	100	
5	Performance	As required	1500	80	FC;PM;NOx measuring
			2300	110	
6	Running-in	5 hours	2000	100	
7	Performance	As required	1500	30; 55; 80; 105; 120	
			2300	50; 80; 110; 125; 140	
8	Replace the fuel by the same with LubriSilk 1:500 additive				
9	Running-in	5 hours	2000	100	
10	Performance	As required	1500	80	FC;PM;NOx measuring
			2300	110	
11	Running-in	5 hours	2000	100	
12	Performance	As required	1500	30; 55; 80; 105; 120	
			2300	50; 80; 110; 125; 140	
13	Replace the fuel by the same with LubriSilk 1:1000 additive				
14	Running-in	5 hours	2000	100	
15	Performance	As required	1500	80	FC;PM;NOx measuring
			2300	110	
16	Running-in	5 hours	2000	100	
17	Performance	As required	1500	80	FC;PM;NOx measuring
			2300	110	
18	Running-in	5 hours	2000	100	
19	Performance	As required	1500	80	FC;PM;NOx measuring
			2300	110	
20	Running-in	5 hours	2000	100	
21	Performance	As required	1500	30; 55; 80; 105; 120	
			2300	50; 80; 110; 125; 140	

The engine oil filter was replaced by a fresh one twice: before the start of the work and after completion of the baseline test.

During performance tests on each of the engine operation regimes, the following main parameters were measured: engine speed, engine power, fuel consumption, concentrations of PM and NOx in the exhaust gases. Based on fuel consumption and power measurements, values of specific fuel consumption (sfc) were calculated for each tested engine operation regime. Many other parameters were also measured, like the temperatures of the: engine oil, cooling water (inlet and outlet), exhaust gases, etc. At each operation regime, measurements were repeated at least three times, in order to ensure repeatability of obtained results.

The measured values of engine power were corrected to the reference atmospheric conditions according to the ISO Standard 14396.

4. Test results

The values of the engine parameters, as were measured during the performance tests, are presented in Table 2. As can be seen from the Table, values of the lubricant and coolant temperatures at the same operation regimes were kept constant (within ±1C), in order to allow an appropriate comparison of specific fuel consumption and emissions.

Additives effects on the specific fuel consumption are shown in Fig. 1 for the engine speed of 1500 rpm and in Fig. 2 – for the engine speed of 2300 rpm.

Additives effects on the NOx emissions are shown in Fig. 3 for the engine speed of 1500 rpm and in Fig. 4 – for engine speed of 2300 rpm.

Additives effects on the PM emissions are shown in Fig. 5 for the engine speed of 1500 rpm and in Fig. 6 – for engine speed of 2300 rpm.

It should be noted that after additizing the diesel fuel by the LubriSilk fuel additive at the ratio of 1:500 and running-in the engine for the first 10 hours, reduction of the fuel flow rate through the fuel pump was observed. Such a reduction could influence the specific fuel consumption in diesel engines of the type tested; therefore, it was decided to replace the fuel filter before the performance test. This action led to the recovery of the fuel flow rate through the fuel pump and, therefore, allowed continuation of the tests. The most probable reason for the fuel filter plugging is deposits that have been cleaned-up by the fuel additive, which has detergent properties (see Annex 3), and blocked the filter.

Table 2: Values of engine parameters as were measured during performance tests.

Engine speed, rpm	Corrected engine power, kW				Oil temperature, C				Inlet coolant temperature, C				Outlet coolant temperature, C				Exhaust gas temperature, C			
	Ref.	Oil add	FA 1:500	FA 1:1000	Ref.	Oil add	FA 1:500	FA 1:1000	Ref.	Oil add	FA 1:500	FA 1:1000	Ref.	Oil add	FA 1:500	FA 1:1000	Ref.	Oil add	FA 1:500	FA 1:1000
1500	4.73	4.73	4.73	4.71	89	89	88	88	75	76	76	75	78	78	78	77	175	173	175	173
1500	8.67	8.67	8.74	8.72	91	90	90	89	74	74	74	74	77	77	77	77	236	234	237	235
1500	12.62	12.62	12.65	12.53	92	93	92	91	72	72	73	72	77	77	77	76	307	304	308	303
1500	16.57	16.57	16.54	16.54	94	95	94	94	71	72	73	73	77	78	78	78	387	388	388	381
1500	18.98	18.95	18.99	18.99	95	95	94	94	69	70	69	70	76	76	76	76	450	442	446	434
2300	12.10	12.10	12.13	12.14	99	99	99	99	76	77	76	77	80	80	80	80	260	257	257	253
2300	19.36	19.35	19.35	19.35	103	103	103	103	78	77	77	79	83	82	82	83	348	342	342	336
2300	26.61	26.61	26.67	26.52	106	106	106	105	77	77	78	78	82	82	83	82	453	443	441	433
2300	30.30	30.28	30.20	30.24	107	108	108	107	77	78	78	78	83	83	84	83	513	502	498	487
2300	34.11	34.05	34.48	33.24	108	109	107	108	76	76	76	78	83	83	83	84	606	586	582	545

Abbreviations:

Ref – Reference test;

Oil add – Test with engine oil additized by the Motorsilk oil additive;

FA 1:500 – Test with fuel treated by the LubriSilk diesel fuel additive at a ratio 1:500;

FA 1:1000 – Test with fuel treated by the LubriSilk diesel fuel additive at a ratio 1:1000.

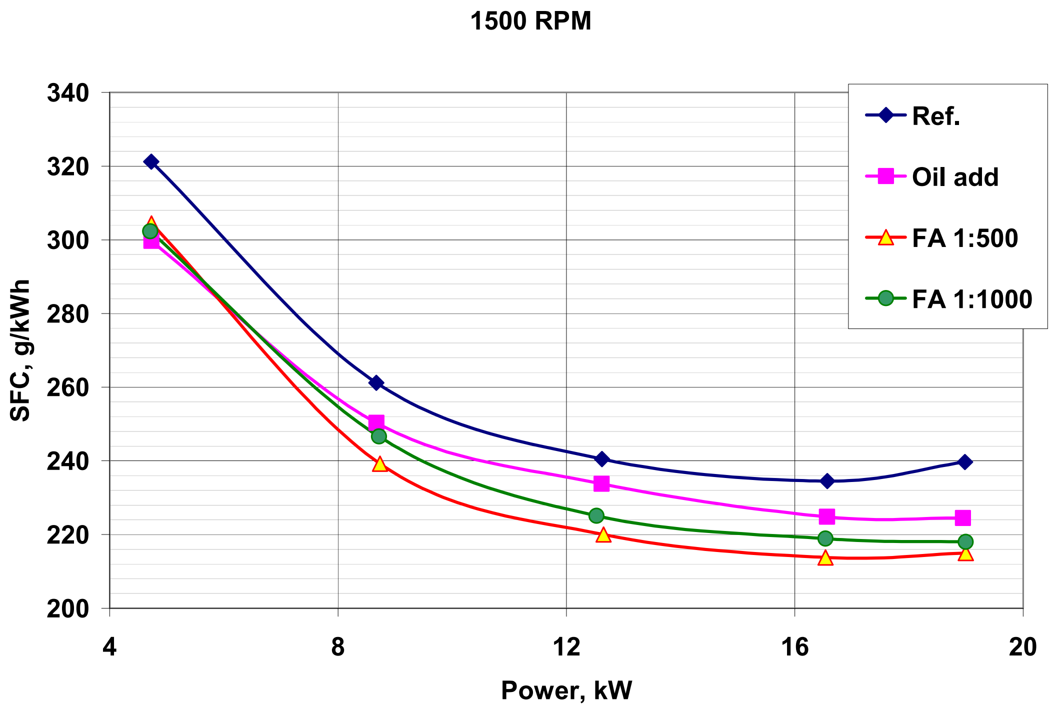

Figure 1: Additives effects on specific fuel consumption – engine speed 1500 rpm.

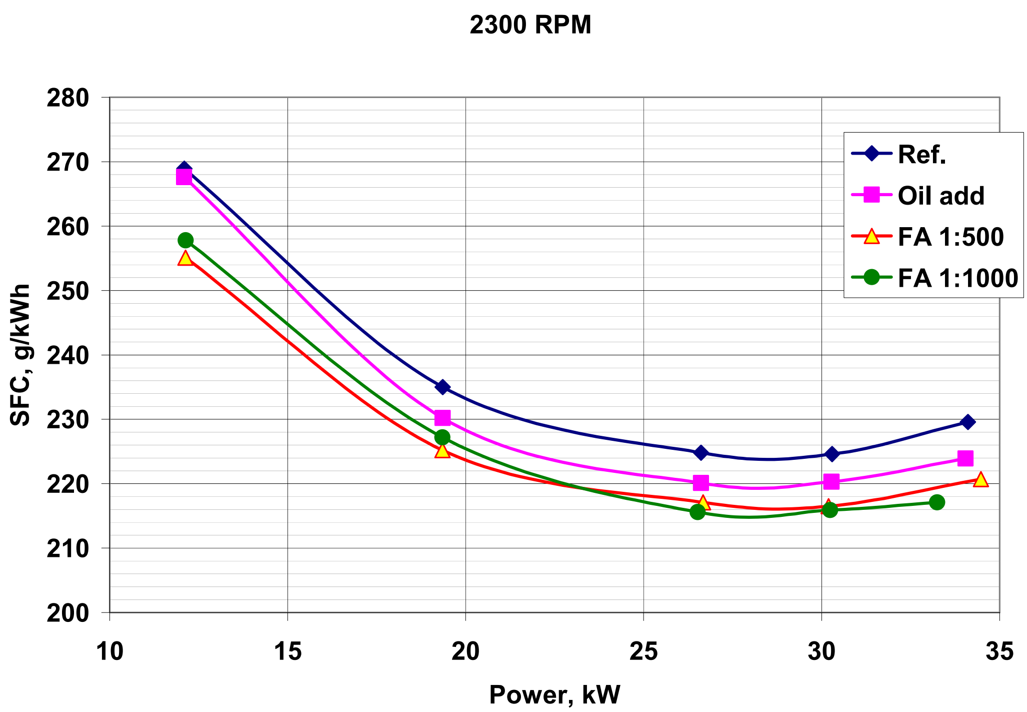

Figure 2: Additives effects on specific fuel consumption – engine speed 2300 rpm.

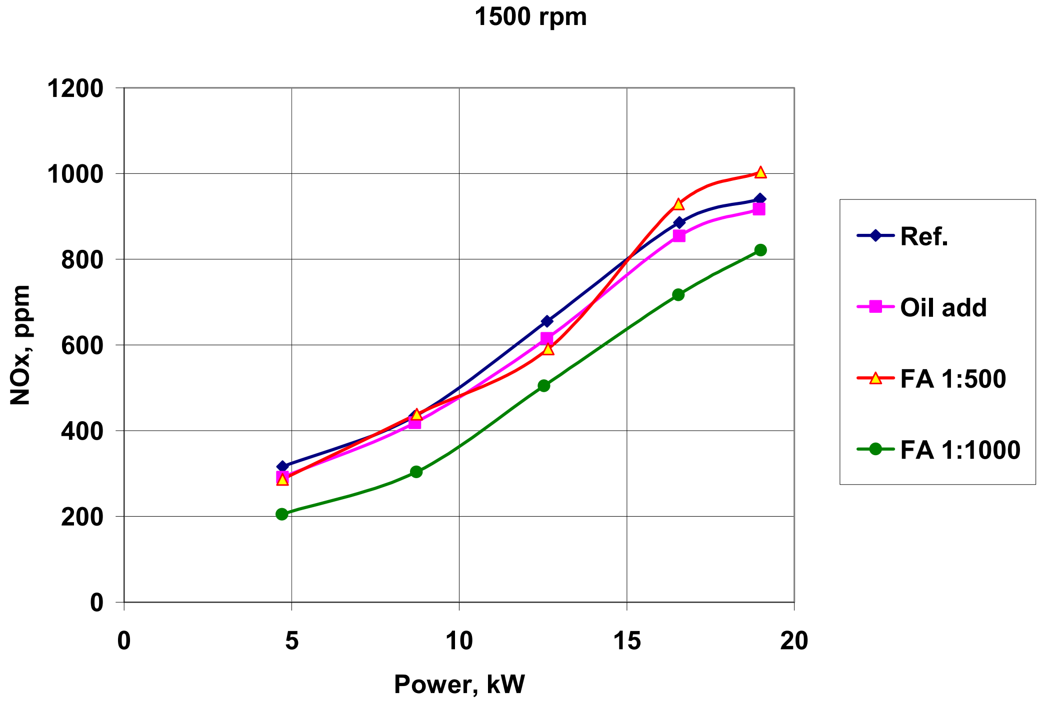

Figure 3: Additives effects on NOx concentrations – engine speed 1500 rpm.

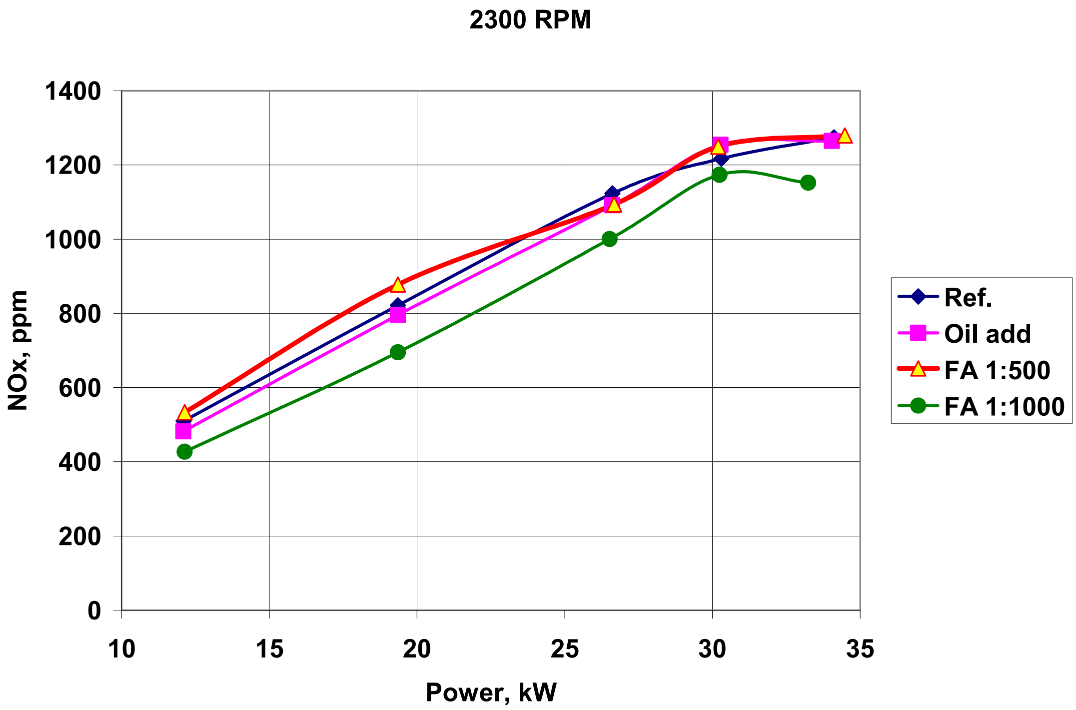

Figure 4: Additives effects on NOx concentrations – engine speed 2300 rpm.

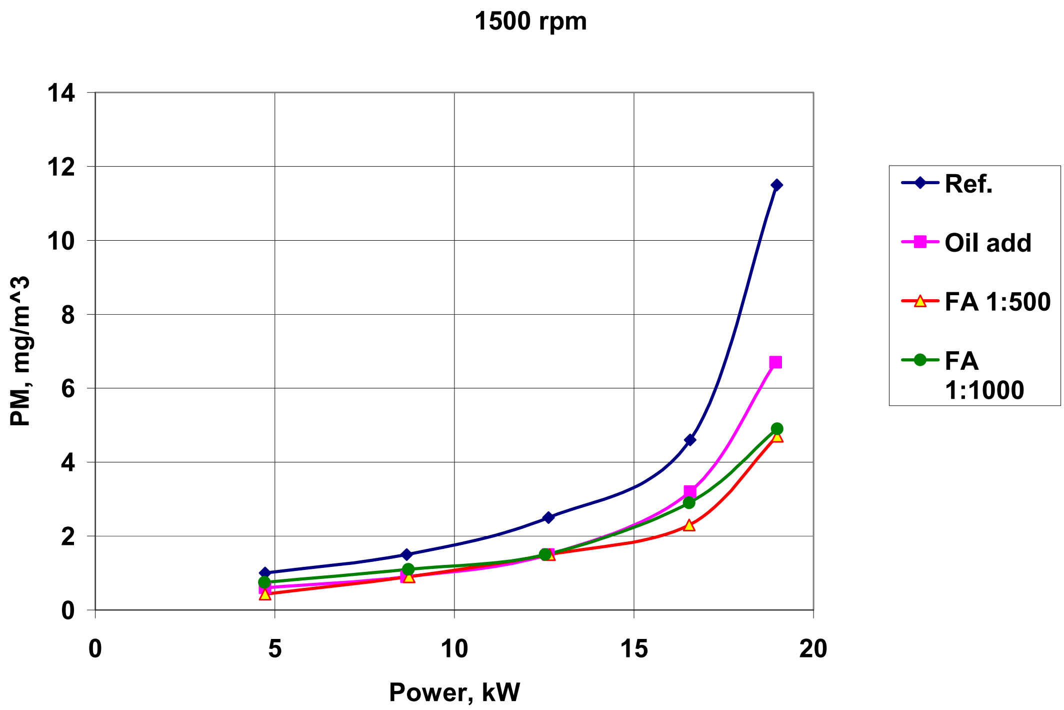

Figure 5: Additives effects on PM concentrations – engine speed 1500 rpm.

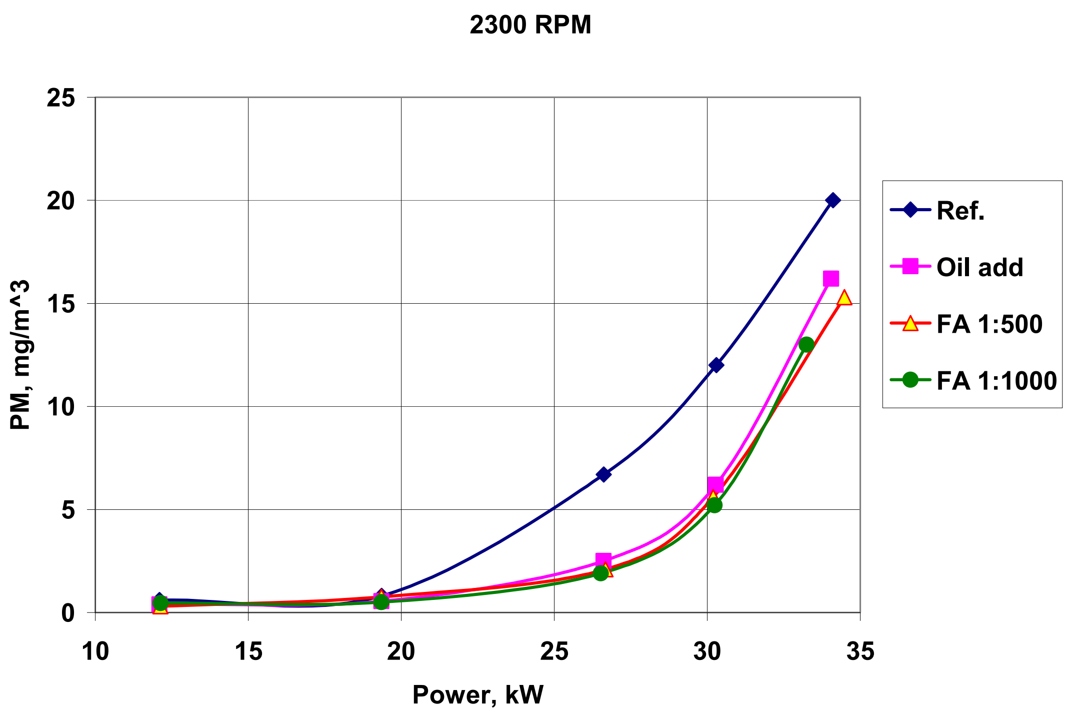

Figure 6: Additives effects on PM concentrations – engine speed 2300 rpm.

Fig.1 shows that at the engine speed of 1500 rpm, oil additizing by the Motorsilk oil additive leads to a reduction of specific fuel consumption in the whole tested range of operation regimes by 3 – 7% compared to the reference case. Oil additizing resulted in sfc reduction also at engine speed of 2300 rpm, by about 2% – see Fig. 2. The main reason for the higher engine sensitivity to the anti-friction additive at lower speeds is, probably, the prevailing rise of pumping losses with the increase of engine speed compared to friction losses. Further fuel additizing by LubriSilk additive with a treatment ratio of 1:500 resulted in fuel economy improvement of 5 – 10% at 1500 rpm (Fig.1) and 3 – 5% at 2300 rpm (Fig. 2). Fuel economy improvement did not change significantly after reduction of the treatment ratio to 1:1000: 6 – 9% of sfc reduction at 1500 rpm and 3 – 5% at 2300 rpm.

The analysis of additives effects on the NOx emissions (Fig. 3 and Fig. 4) indicates a tendency to reduction of NOx concentrations in the exhaust gases with fuel additizing by the LubriSilk additive. The most pronounced reduction of NOx emissions was achieved after 30 hours of engine running-in with additized fuel and treatment ratio of 1:1000: 13 – 30% at engine speed of 1500rpm and 4 – 15% at engine speed of 2300 rpm. The main reason for NOx emission reduction is, probably, the increase of the fuel cetane number, as a result of fuel additive use – see Annex 3. Oil additizing does not lead to any significant change in the NOx emissions of the tested engine.

As mentioned above, additives effects on PM emissions are shown in Fig. 5 for the engine speed of 1500 rpm and in Fig. 6 – for engine speed of 2300 rpm. It can be seen from these Figures that more or less significant PM emissions were observed only in the most loaded engine operation regimes that were tested. So, comparison of additives effects on PM emissions seems to be reasonable only at highest measured loads. Such a comparison shows that oil additizing leads to the reduction of PM concentrations by up to 40% at the engine speed of 1500 rpm, and about 20% – at the engine speed of 2300 rpm. Fuel additizing enabled further reduction of PM concentrations: about 50 – 58% at engine speed of 1500 rpm, and about 25% at engine speed of 2300 rpm.

5. Conclusions

The test results clearly show that oil additizing by the Motorsilk oil additive leads to a reduction of specific fuel consumption in the whole tested range of operation regimes by 2 – 7% compared to the reference case.

Further fuel additizing by LubriSilk additive resulted in fuel economy improvement compared to the reference case: of 5 – 10% at 1500 rpm and 3 – 5% at 2300 rpm.

The test results show some tendency of reduction of NOx concentrations in the exhaust gases with fuel additizing by LubriSilk additive. The most pronounced reduction of NOx emissions was achieved after 30 hours of engine running-in with additized fuel: 13 – 30% at engine speed of 1500 rpm and 4 – 15% at engine speed of 2300 rpm. Oil additizing does not lead to any significant change in NOx emissions of the tested engine.

Oil additizing resulted in the reduction of PM concentrations by 20 – 40%, depending on the engine speed. Fuel additizing enabled further reduction of PM concentrations: about 50 – 58% at engine speed of 1500 rpm, and about 25% at engine speed of 2300 rpm.

Annex 1: Results of diesel fuel chemical analysis

Chemical Testing Laboratory Ltd.
In the name of Ilieff and Bentur
Technion City - Haifa

המבדקה הכימית בע"מ
ע"ש איליוף ובנטור
קרית הטכניון-חיפה

יום שלישי 21 נובמבר 2006

תעודה מס': 108734

מזמין הבדיקה : מעבדת מנועי שריפה פנימית ק. הטכניון

סימון המדגם : 1 / 108734

המדגם נמסר בתאריך : 14/09/2006 מס' מדגם /מיכל: סולר תחבורה

חומר הבדיקה : מדגם מסומן: סולר תח' קייצי

סימוכין : הזמנה מתאריך 14/9/06

הערות : המדגם נבחר ע"י המזמין

תוצאות הבדיקה

(תעודה זו מתייחסת למדגם שנבדק בלבד. אין להפיץ תעודה זו אלא במלואה)

דרישות לפי:
ת"י 107 לסולר תחבורה קייצי

שם שיטת בדיקה	תיאור שיטת בדיקה	תוצאה לבדיקה	יחידות מידה	מינ'	מקס'
גפרית אי הוודאות ±9	ASTM D-2622	39	mg/Kg		50

הערות דגימה: -------סוף תעודה----

אריאלה כפיר
מ"מ ראש המבדקה

עמוד 1 מ 1

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טל: 04-8292744/5, 04-8292973 פקס: 04-8238454
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Annex 2: Engine oil additive description

MOTORSILK CLS BOND®
ENGINE TREATMENT

DESCRIPTION:

Motorsilk CLS Bond Engine Treatment additive is designed to extend the life and operating range of your engine. It blends with your existing engine oil and contains boron-based components that protect vital working parts from friction and corrosive elements.
Motorsilk CLS Bond Engine Treatment actually forms a near-diamond hard surface on metal parts, providing a super-slick surface. The new surface also blocks oxygen to prevent corrosive activity. This mcro-layer of protection is bonded to metal surfaces with strong covalent and ionic bonds. It provides long-lasting, low-friction surface impervious to most contaminants.

USAGE:

Motorsilk CLS Bond Engine Treatment works with any four-cycle engine when added to the crankcase oil at a 1:10 ratio. A single pint container treats a normal five-quart crankcase.

APPLICATIONS:

All internal combustion, four-cycle engines of any horsepower can benefit from this one-time treatment.

SPECIFICATIONS:

Color . . . . Translucent Tan
Base Fluid . . . . Full Synthetic
Viscosity . . . . 20 W 50
Flash point . . . . 180 C.
Solids . . . . Boron Variants
D.O.T. . . . . Unregulated
V.O.C. . . . . None
Biodegradable . . . . . Yes

Annex 3: Diesel fuel additive description

LubriSilk Diesel Fuel and System Treatment®

TECHNICAL BULLETIN

DESCRIPTION: MSDSL

LubriSilk Diesel Fuel Additive is a formulated additive for ULTRA low-Sulfur diesel fuels (Sulfur has been reduced from 500PPM to 15PPM). The product provides greatly enhanced lubricity to low sulfur diesel fuel because of an active chemical process which creates a micro layer of extremely low friction film. Cetane number in typical Ultra low sulfur diesel fuel is improved by 8 to 10 numbers; in addition Detergency, Corrosion protection and Fuel stability are improved. Reduced starting time, reduced injector pump wear, and Lower emissions and fuel consumption are byproducts of these features. Designed to protect injectors and pump with a Boric Oxide surface, producing under 0.01% friction coefficient.

Diesel Fuel Treatment

Today's low ultra sulfur fuels (15ppm) may cause premature pump and injector damage or failure resulting from the lack of lubricity which sulfur provides, also expect a drop in fuel economy of ½ MPG and power loss. The Hydrated Boron Molecules in the diesel fuel treatment provides a surface friction coefficient less that 0.01% while it protects 100% of the fuel system from the adverse affects of sulfur, corrosion and carbon. Any carbon or varnish deposits are permanently removed allowing for the highest injector performance .

The Cetane number increases 8-10 numbers for higher performance during ignition. Associated with higher Cetane fuels are easier startups, enhanced driving performance, better fuel combustion and less noise. Today's engines are designed for 50 Cetane fuel and anything above that is usually a waste, at a level of **Cetane 40, delayed ignition, noise, and fuel and power loss occur.**

"Deposit control is a crucial part of brand differentiation strategies designed to enhance diesel engine performance and reduce emissions. Efficient operation of diesel engines depends on proper operation of the fuel injectors, so control of deposits in this critical area is necessary to ensure optimum performance, minimize fuel consumption, and control engine smoke". –Chevron

Benefits

- Eliminate diesel knocks and rough starts
- Easier cold starts at low temperatures
- Maintain the correct pressure rise rate in the combustion chamber
- Permanently remove any carbon, coke or varnish buildup
- Less emissions produced
- Better fuel economy of 5% plus as a result of a shortened ignition delay, surface cleanliness, and lubricity
- Metal scarring dramatically reduced to fewer than 300
- Greatest surface lubricity available to ensure the highest performance and component life in the fuel system

Cetane

This colorless, liquid hydrocarbon holds excellent ignition qualities, and is a term closely associated with diesel operation in cold weather. Fuels are compared to Cetane to determine their ignition quality. Higher Cetane values improve the engine's cold-starting performance and reduce white smoke. When diesel fuel first enters the combustion chamber, there is a lag time until the fuel ignites, but that lag time can be shortened with a high Cetane number. Most electronic diesel engines require a Cetane rating of 45 or higher. In cold temperatures, a vehicle will respond to a high Cetane rating with better engine performance, better fuel economy, and better exhaust emissions.
Inversely, a low Cetane fuel (below 40) will cause white smoke, poor fuel economy, and the lack of power in cold weather. Minimally, 40 Cetane is desired, and can be found at most fueling stations, but premium diesel fuel (above 45 Cetane) will provide increased power and fuel economy. You will not find the Cetane number on fuel pumps, but can ask the attendant at your area fuel stations to determine which location carries premium fuel.

Lubricity

In addition to providing energy, diesel fuel doubles as a lubricant for diesel injection equipment, such as rotary distributor pumps and injectors. Fuel must be capable of lubricating the system components in order to prolong the fuel system. Because of the diesel's dual purpose, the viscosity or weight of the fuel is vital to its performance. In normal temperatures, higher viscosity fuels, such as Diesel Fuel Number Two, or DF2, will perform better than the thinner, lower-viscosity fuels in automotive diesel engines, which can be hard on the injectors. International's Power Stroke Diesel engine's electro-hydraulic fuel system design is much less vulnerable to lower lubricity fuel than mechanical systems. And this bodes well for the vehicle's performance in cold weather.

A test called SL BOCLE, which can be performed at your local International dealership, will measure the fuel's ability to lubricate and express the lubricity in grams of load. Many engine manufacturers require a minimum SL BOCLE rating of 3,100 grams, and that is the common rating found at diesel fuel stations, **the higher the value, the better the lubricating ability, Lubri-silk diesel is 5,800 grams.**

Detergency

Reduced injector nozzle coking as demonstrated in: Cummins L-10 125 Hour injector Carboning Test and Fleet Trials.

Antirust

Helps reduce rust formation in fuel storage and delivery systems. Passes ASTM D-665A

Fuel Stability

Helps Reduce thermal and oxidative degradation of fuel which can result in fuel darkening, deposits and filter blockage.

Demulsibility

No harmful effects to base fuel quality

Thermal Stability

Less than 80% reflectance in typical base fuels – ASTM D-6468 (180 minutes)

EPA Transient Emissions

Additized Fuel provides reduction in HC, NOx, CO, and PM after 300 gallons use. (Testing conducted on Cummins L-10 engine)

Pour Point

Improves fuel pour point up to -45 C.

AntiFoam

Reduced Tank Fill time , increased fill volume & less diesel spillage

USAGE:

MotorSilk Diesel Fuel Additive may be blended to all diesel fuels. The additive is diluted 1000 to one in the final mix. Thus, one 55 gallon drum treats 55,000 gallons. One gallon treats 1000 gallons, one quart treats 250 gallons and one pint (16 0z) treats 125 gallons. One liter treats 1000 liters, one drum (208 liters) treats 208,000 liters and 16 0z treats 473 liters.

SPECIFICATIONS:

Lubricity (Falex B.O.T.D.) 195) — <.300

Lubricity (SL BOCLE) 5800 grams

Lubricity (HFRR at 60°) 0.165mm

Wear scar before 0.34 after treatment 0.165 (scar width cut in half)

Color ....Clear to slight translucent

Base Fluid ....Proprietary

Flash point......................181 deg. F. (ccc)

Viscosity ....32.6 - 40.0 SuS @ 100 deg. F.

D.O.T. ....Hazard Class 2.1, Packing group II

Marking:……………. None

Hazardous substance: ./RQ Not applicable

Auto ignition temp ....>500 Deg. F. / 260 Deg. C.

Vapor Pressure...............(mm Hg.) 0.40

Vapor Density ....(air=1) > 3

PourPoint / Gel Inhibitor....to -45 Deg. C.

PACKAGING:

Quart	Liter
55 gal drum	208 Liter drum

This diesel fuel additive complies with Federal UTRA Low Sulfur content requirements for use in motor vehicles and may be used in 2007 and newer model years. Registered with EPA as a fuel additive-#1899-0001 per 40CFR 79.24