SERBIATRIB '11

Serbian Tribology Society

12th International Conference on Tribology

Faculty of Mechanical Engineering in Kragujevac

Kragujevac, Serbia, 11 – 13 May 2011

LUBRICATING ENGINE OILS FOR SPECIFIC MARINE APPLICATIONS

Anca-Gabriela Marin[1], Ortansa Florea[2], Ion Petre[2]

[1]SC Georom Inspect Consulting SRL Ploieşti, Romania, anca.marin@georomserv.ro
[2]SC ICERP SA Ploieşti, Romania, oflorea_305@icerp.ro

Abstract: *Marine or oceanic ships have different engines types with specific characteristics that require special lubricants. Depending on capacity and purpose, ships are provided with one or two powerful propulsion engines, three or more auxiliary engines, emergency engines and several low power engines for lifeboat. In order to formulate adequate lubricating oils for marine engines must take into account the fuels quality with high sulfur content, the special working conditions in humid and salt environment and the specific operating conditions at constant load and speed. Furthermore, the crankcase lubricating oils for marine engines, cooled with sea water, may form emulsions by accidentally inmoving of cooling water in the oiling circuit. Therefore, these lubricants must have fast desemulsioning capability, condition not required for other engine oils.*

The paper presents the formulation of lubricating oils for two stroke low speed marine engines and four stroke medium speed marine engines, the physico-chemical characteristics of these, the performances level resulted from laboratory stand tests and the real working conditions results. For lubrication of two-stroke marine engines two different types of oils were elaborated and for medium-speed trunk piston engines, two oils were also elaborated, corresponding to the fuels sulphur content.

All the obtained lubricating oils exhibit a very good working behaviour and satisfy all the requirements imposed by specified operating conditions..

Keywords: *lubricants, engine oil, marine, two strokes, four strokes.*

1. INTRODUCTION

Marine lubricants are oil formations with proper additives, that are used in various machinery located on different types of ships.

Depending of capacity and purpose, ships are provided with one or two powerful propulsion engines, three or more auxiliary engines, emergency engines and several low power engines for lifeboat. The most used for propulsion are two cycle low speed engines with crosshead, which need two lubricating oils:

- cylinder lubrication oil, consumed by burning
- bearings and crosshead lubrication oil, changed periodically

The rest of ships engines, such as auxiliary, emergency lighting and lifeboat engines call for a single type of lubricating oil.

In order to formulate adequate lubricating oils for marine engines must take into account the fuels quality with high sulphur content, the special working conditions in humid and salt environment and the specific operating conditions at constant load and speed. Furthermore, the crankcase lubricating oils for marine engines, cooled with sea water, may form emulsions by accidentally in moving of cooling water in the oiling circuit. Therefore, these lubricants must have fast water separation properties, condition not required for other engine oils.

From total among of annual worldwide lubricants needs, only 5% are marine engines oils [1], (Figure 1), but quantities are important and the consumption is constant.

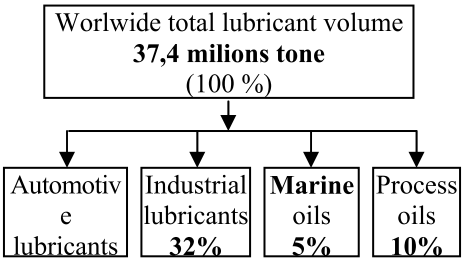

Figure 1. Worldwide marine lubricants consumption from total lubricants

2. EXPERIMENTAL

Our proposal was to formulate and test four types of lubricating oils for oceanic and marine ships:

- system lubricating oil **NL 30-8**, used in crankcases for oiling and cooling the cross-head and bearings of engine; this lubricant is similar to conventional oils used in automotive engines and it is periodically changed.
- cylinder oil **NC 50-70,** with a very high alkalinity level for neutralisation of the acid products resulted from fuel combustion; this lubricant is use up and burn completely in burning room.
- four-strokes engine lubricating oil **NS 40-12**
- four-strokes engine lubricating oil **NS 40-25**

Both four-stroke engine lubricating oils are formulated for medium-speed trunk piston engines, corresponding to fuels sulphur level.

The above oils are designed for lubrication of all types of ships that require different types of Diesel fuels, from gas oils or marine Diesel oils with sulphur content lower then 1,5% to intermediate fuel oils” and up to bunker fuel oils with sulphur content higher then 2,5 % (used on low speed two cycle engines).

2.1 Characteristics and performances of new formulated lubricants

The characteristics of obtained lubricants are presented in Table 1 and Table 2.

Table 1. Two-stroke marine engine lubricating oils

Characteristics	Lubricating oil types		Test methods ASTM D
	NL 30-5	NC 50-70	
Viscosity grade, SAE J 300	30	50	-
Quality level, API	CC	-	-
Kinematic viscosity at 100°C, cSt	11,3	18,6	445
Viscosity index	95	85	2270
Flash point, °C	225	245	92
Pour point, °C	- 21	- 15	97
Total base number, mg KOH/g	5,2	70	2896
Sulphated ash, %	0,75	9,5	874
Copper corrosion, 3hrs/ 100°C	1b	1b	130
Wear scar diameter (4 ball test, 1hr at 40 daN), mm	0,40	0,32	4171

Table 2. Four stroke marine engine lubricating oils

Characteristics	Lubricating oil types		Test methods ASTM D
	NS 40-12	NS 40-25	
Viscosity grade, SAE J 300	40	40	-
Quality level, API	CD	CF	-
Kinematic viscosity at 100°C, cSt	14,7	15,2	445
Viscosity index	90	90	2270
Flash point, °C	230	230	92
Pour point, °C	- 21	- 21	97
Total base number, mg KOH/g	12	25	2896
Sulphated ash, %	1,75	3,5	874
Copper corrosion, 3hrs/ 100°C	1b	1b	130
Wear scar diameter (4 ball test, 1hr at 40 daN), mm	0,39	0,37	4171
Foam properties, tendency-stability, ml - seq. I - seq. II - seq. III	5-0 30-0 5-0	0-0 20-0 10-0	892

All the new lubricating oils was formulated from parafinic base and special high performance additives.

The performances of formulated oils were tested on special laboratory stands (Table 3) related to antioxidant, anticorossion and antiwear properties, the varnish / carbon deposit and rings sticking tendency, as follows:

- oxidation resistance, on Labeco stand, measured by Cu - Pb bearing weight loss, set to max. 40 mg and the lake deposits formed on the piston skirt limited to min. 9.0;
- detergent-dispersant properties, evaluated on Petter AV-B stand by engine cleanliness at the end of the performed test;
- no deposit properties of oils were evaluated on MWM KD 12 E stand, assessed by the degree of freedom of the segments in piston channels and by the amount of carbon deposits formed on the piston;
- lubrication and antiwear properties were evaluated on Caterpillar 1-G_2 stand.

Analyzing the results it is found that the tested oils behaved properly and the data obtained are registered in the acceptable limits of international methods used for certifying their performance levels.

Cylinder oil **NC 50-70** was tested in collaboration with the manufacturer and supplier of additives on a two-stroke, slow speed cross-head engine, type K 6 SZ 90/160° with six-cylinder. The engine lubricating system allowed the separate supply of each cylinder, which made it possible to simultaneously use different oils.

Table 3. Results from special laboratory stand testing

Test stand label	Limits	Labeco L-38			Petter AV-B			MWM KD 12 E			Caterpillar $1G_2$		
Test methods		ASTM D5119			CEC L-24-A-78			CEC L-05-A-78			ASTM STP 509A		
Marine lubricating oil type		NL 30-5	NS 40-12	NS 40-25	NL 30-5	NS 40-12	NS 40-25	NL 30-5	NS 40-12	NS 40-25	NL 30-5	NL 40-12	NL 40-25
Cu-Pb bearing weight loss, mg	max. 40	22,0	27,6	29,5									
Piston skirt varnish, merit note	min. 9,0	9,3	9,1	9,8									
Deposit, merit note: -on ring grooves					8,9	9,2	9,5						
- on ring land					9,3	9,4	9,3						
- on piston skirt					9,6	9,9	9,7						
Total evaluation notes	min. 70				79	85	83						
Deposit, merit note – on piston skirt								8,9	9,3	9,2			
- on piston crown								9,0	9,2	9,4			
Total evaluation notes	min. 70							89	90	92			
Deposit on superior ring groove, %	max. 80										64	68	75
Reduction of piston-ring gap, µm	max. 12,7										11,0	11,8	12,0
Total cleanliness evaluation notes	max. 300										211	217	228
Tested properties	-	oxidation stability			detergency-dispersancy			anti-deposit properrties			lubricity and antiwear properties		

The NC 50-70 oil was used at the lubrication of cylinders 1,3,5 and 6 in parallel with a reference oil, used in cylinders 2 and 4 in the same operating conditions.

At the end of testing, engine pistons have been removed and then visually examined and measured with micrometer. The results are presented in Table 4 comparatively with standard oil.

Table 4. Results from cylinder oil testing

Evaluation parameters	Cylinder no.					
	1	2	3	4	5	6
Mobility of piston rings	free	free	free	free	free	free
Cylinder surface aspect, note	9	10	7	11	8	12
Cleanliness of space among rings, %	100	97	98	96	97	98
Deposit on cylinder port, % vol.	14,0	15,0	14,0	14,0	14,0	15,0
Oil consumption for cylinders lubrication, g/kWh	1,16	1,17	1,10	1,11	1,13	1,07

From the analysis of presented data, indicates that the oil cylinder NC 50-70 tested behaved similarly to the reference oil, the difference being made due to the cylinders operating conditions (temperature control, fuel oil), quality oils and / or allowable evaluation errors.

2.2 Evaluation of demulsification properties

Besides physico-chemical characteristics presented in Table 1, common to all engine lubricants, marine oils have to meet a very important condition that refers to their ability to separate the contained water. The water can often get into marine engine crankcase oil in significant amounts through the cracks from heat exchangers due to corrosion or under normal atmospheric from condensation of atmospheric wateriness.

This water can lead to oil emulsification, as well as to hydrolysis and precipitation of additives, with worsening of the conditions of lubrication and engine protection. Therefore water must be evacuated as soon as possible from oil for not having time to contribute to the hydrolysis, precipitation and elimination of contained additives. The most used means of removing water from oil is centrifuging, but with water you can remove a part of the additives. Therefore, in the manufacture of marine oils should be used additives with high water resistance, that does not hydrolyse rapidly, to allow removal of therein water, without altering the lubricant quality.

To evaluate the capacity of oil-water separation, ie demulsification were used two laboratory methods,

One according to ASTM D 1401, with static action of separation and the other, according to OMD 113, with dynamic action of separation. In both tests the water quantity is an indication of the capacity of oil-water separation. The OMD 113 is closer to the conditions of oil-water separation from existing marine engines and vessels so that test is more appropriate for evaluating, while ASTM D 1401 is more easily to apply.

NC 50-70 cylinder oil has no such condition because it is fully consumed durring lubrication process and does not come in direct contact with water.

In Table 5 are presented the results of demulsification for tested oils, obtained by the two methods .

Table 5 Results from demulsification tests

Testing methods	Lubricating oil types		
	NL 30-5	**NS 40-12**	**NS 40-25**
OMD 113 (dynamic conditions, 10 minutes, 2 ml sample) - oil - water (ml) - sediment (ml)	 0,7 1,3 0	 0,9 1,6 0	 0,5 1,5 0
ASTM D 1401 (static conditions, 60 minutes, 40 ml sample) - oil (ml) - water (ml) - emulsion or cloudy oil (ml)	 40 39 1	 40 36 4	 40 37 3

2.3 Testing in real working conditions

The oils testing real operating conditions was conducted in collaboration with maritime operators, on engines vessels provided by these.

Oil cylinder NC 50-70 and crankcase oil NL 30-5 were tested on two propulsion engines K 6 SZ 90/160 A for a duration of 1000 hours of operation. Engine cylinders were examined periodically during the experiment, at each 100 hours of operation to assess the deposits formed in the exhaust windows and spaces between the rings. Results from cylinder oil testings are presented in Table 4.

The oil NL 30-5 introduced in the same engine crankcase was periodically investigated by laboratory methods for setting the service life and in terms of the cleanliness of the engine parts.

Physico-chemical characteristics of oil were in the allowable limits throughout the investigation, as shown by the data in Table 6.

Table 6. Results from crankcase oil NL 30-5 testing

Physico-chemical characteristics	Fresh oil	After 1000 hours	Test method ASTM-D
Density at 20 ºC,g/cm3	0,890	0,895	1298
Kinematic viscosity at 100°C, cSt	11,3	13,3	445
Viscosity index	95	90	2270
Flash point, COC, °C	225	224	92
Pour point, °C	- 21	-23	97
Total base number, mg KOH/g	5,2	4,0	2896
Total acidity number, mg KOH/g	2,1	4,7	664
Copper corrosion, 3hrs/ 100°C	1 b	-	130
Sulphated ash, %	0,75	1,30	874
Water content,%	0	0,20	95
Toluene insoluble, %	-	1,80	893

The results obtained both through periodic evaluation of the oil and the final examination of the engines after their partial removal, showed that the oil NL 30-5 behaved normally.

NS 40-12 oil was tested on two types of propulsion engines four-strokes SKL 82 D 72/48 AL-1, taking into account periodic and final examination at the engine and oil. As shown by the data in Table 6, oil characteristics have changed during the experiment, as follows:

- increased oil viscosity due to oxidation products formed in the oil and from fuel combustion;
- total acidity number grew to 2.6 mgKOH / g due to the combustion products;
- basicity number decreased after neutralizing the acids resulted from the fuel combustion.

However, the highlighted changes sign up in acceptable limits for lubricanting engine oils.

Table 7. Results from NS 40-12 oil testing

Physico-chemical characteristics	Fresh oil	After 1000 h	Test method ASTM-D
Density at 20 ºC,g/cm3	0,890	0,910	1298
Kinematic viscosity at 100°C, cSt	14,7	16,3	445
Viscosity index	90	-	2270
Flash point, COC, °C	232	224	92
Pour point, °C	- 23	-	97
Total base number, mg KOH/g	12,2	7,0	2896
Total acidity number, mg KOH/g	1,1	4,7	664
Copper corrosion, 3hrs/ 100°C	1 b	-	130
Sulphated ash, %	1,85	1,70	874
Water content,%	0	0,20	95
Toluene insoluble, %	-	1,54	893

The results of the periodic investigations of oil and the final examination of the engine concluded that the lubricant behaved similarly with reference oil experienced the same conditions.

Oil NS 40-25 was tested on a vessel equipped with two propulsion engines type MAN L 52/55 A: at the portside of the vessel was equipped with a reference oil and at starboard with the tested oil. The obtained results are similar (Table 8).

Table 8. Results from NS 40-25 oil testing and reference oil

Physico-chemical characteristics	Portside Oil		Starboard oil	
	fresh	used	fresh	used
Density at 20 ºC,g/cm3	0,905	0,912	0,925	0,911
Kinematic viscosity at 100°C, cSt	14,30	15,30	15,19	15,80
Viscosity index	90	92	90	95
Flash point, COC, °C	238	232	230	225
Pour point, °C	-15	-15	- 21	-21
Total base number, mg KOH/g	22	14	27,00	16,19
Total acidity number, mg KOH/g	-	-	3,5	5,8
Copper corrosion, 3hrs/ 100°C	1 b	-	1 b	-
Sulphated ash, %	2,8	-	3,3	-
Water content,%	0	0,6	0	1,2
Toluene insoluble, %	-	2,0	-	1,9

3. CONCLUSION

The tests carried out showed that marine lubricants made from paraffinic base oils and additives, fit in terms of quality imposed by the service areas.

From laboratory investigations data by physico-chemical characterisation and special stands as well as from testing in real working conditions, the following conclusions were drawn:

- the formulated lubricating oils covers the engines lubrication conditions from commercial and fishing shipping vessels;
- selected additives were found appropriate, including their demulsification ability;
- the formulation of above lubricants were taken into account construction and operating characteristics of engines and the types of fuel used;
- the obtained oils provide proper engine lubrication in all operating conditions of the vessel;
- the formulated crankcase oils NL 30-8, NS 40-12, NS 40-25 and the cylinder oil NC 50-70 for marine engines exhibit good working behaviour and satisfy all the requirements imposed by these special operating conditions.

REFERENCES

[1] D.T. Mang, W. Dresel: Lubricants and Lubrication, Lubricants and their Market, pp.2, e-books Willey 2007;

[2] A.G. Marin, I. Petre, L. Bogatu: Vegetable Oils in Engine Lubricants Formulations, Proceedings of the Conference on Materials Engineering and Technologies, Mitech '07, 26 – 27 June 2007, Prague;

[3] *, "A rationalized additive package for marine trunk piston engine oils and crosshead system oils", Infineum UK Limited, Oxfordshire, 1997, England;

[4] Pevzner, L., "Aspects of Marine Low-Speed, Cross-Head Diesel Engine Lubrication" J. of the Society of Tribologists and Lube. Eng., June 1998, 16-21.