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IMPORTANCE OF OIL CONDITION MONITORING IN STATIONARY GAS ENGINE APPLICATIONS

Christian Schmied[1], Bernhard Simmerer[1], Franz Novotny-Farkas[2], Denise Kaltenböck[2]
[1]LEC-Large Engines Competence Center, Austria, christian.schmied@lec.at, bernhard.simmerer@lec.at
[2]OMV Refining and Marketing, Competence Center Lubricants, Austria, franz.novotny-farkas@omv.com, denise.kaltenboeck@omv.com

Abstract: *The scope of this paper is set on reliable lubrication of large stationary combustion engines fuelled with biogas. The protection of these engines against oil-related failure has to be ensured via proper oil condition monitoring (OCM). Hereby essential lubricant parameters are determined troughout the operating life-time in order to maintain the oils tribological performance. In the common Off-Site oil trend analysis in specialized laboratories, any responses to changes in oil parameters are far away from real time. In the given experimental program various analytical devices have been investigated. Important data is gathered On-Site with portable analytical equipment, especially the portable infrared (IR) spectrometer. The subsequent Off-Site spectra interpretation in lubricant laboratories currently seems to be the most practicable method. The recomended On-Site procedure allows faster actions, close to real time. Furthermore these developments in OCM offer environmental and economical benefits.*

Keywords: *stationary gas engine, lubrication, oil condition monitoring (OCM), infrared (IR) spectroscopy, On-Site analysis, portable analytical equipment*

1. INTRODUCTION

Lubricating oil is a crucial functional element of each internal combustion engine such as stationary gas engines. Rising lubricating oil loads due to engine requirements, increasing use of non conventional fuel, stricter exhaust emission regulations and the need for after-treatment systems require an exact tuning and advancement of lubricating oils [1]. Especially in the field of biogas applications (in this work the terminus "biogas" is used for all gaseous products of renewable sources), for decentralized power generation, which have become of more essential over the past years, the proper oil condition is very important to avoid engine damage. The continuous development of oil formulations helps to expand the operating lifetime of the gas engine oil [2], which is one part of improving the performance of gas engines in these days. Furthermore, the routine monitoring of the physical and chemical properties of the lubricating oil remains essential.

In stationary biogas engines the fuel gas may vary over a wide range whereas it can contain several aggressive components which have negative impact on the lubricating oil performance. Hereby the amount of oil in the system is large enough to demand condition monitoring, often up to 1000 liter. Regarding the oil drain interval of 350 to 2500 hours, up to 8000 hours a year, depending on fuel gas type, oil temperature, and engine type, it is likely that the operator can save oil and money on expanding the oil change interval. Oil condition monitoring helps to extend the lifetime and to reduce the operation costs. Furthermore it helps to protect our environment by reducing the overall oil consumption.

Operating lifetime coming along with maintenance and spare parts costs is important for operators and manufacturers. Routine analytical methods to monitor the performance characteristics of lubricating oil are nowadays used in aircraft turbines [3], trucks [4] and other turbine applications. Tests for On-Line sensors in engine oil applications have been developed [5]. The results of these On-Line tests show significant differences to viscosity data received by established, laboratory viscometers, due to the difference in the measuring principle. The cited microacoustic viscosity sensor [5] does not consider the behavior of viscosity index (VI) modifiers as non-Newtonian fluids. It does not provide all the necessary information needed to characterize the oil quality. The viscosity alone is not sufficient to qualify a used lubricant.

Routine oil condition monitoring methods do not cover the important oil aging characteristics, the oxidation and the nitration, based on infrared (IR) spectroscopy. Routine analytics in this case is highly accurate and demands expensive laboratory equipment which is mostly used Off-Site. On-Line IR measurement of the above mentioned two parameters still remains the future aim. Due to expenses for On-Line measurement setup and eventualities of its plugging by deposit formation during long term use, there is the need for a reliable, less cost consuming and rapid analysis to determine the oil condition. On-Site analysis for oil condition monitoring (OCM) requires obtaining data quickly on a less expensive field suitable instrument. For this purpose a portable IR-analyzer can be more convenient than On-Line measurements, because it combines all the advantages - easy to handle, low running costs, robustness, and low impact of the surrounding environment - in one apparatus.

During this work a portable IR-spectrometer has been investigated more closely to cover the possibility of fast and accurate OCM On-Site, which has major advantages to On-Line analytics.

2. OIL CONDITION MONITORING OF BIOGAS ENGINE OILS

2.1 Challenges in biogas application

In the scope of biogas applications the fuel gas composition may vary strongly. This has a direct impact on the lubricating oil, which has to maintain its chemical properties and its tribological performance over the total lifetime, to ensure optimum lubrication and to protect the engine from wear and failure. Being able to react to changes in the oil the same day the oil is inspected is of great advantage, concerning operating lifetime, which then can be expanded.

If the operator of a gas engine has to wait several days for the results of a oil analysis (due to shipment and duration of the analysis) the status of the oil might already have changed in the meantime, leading to the assumption that he/she never knows the actual condition of used lubricant. The closer it comes to the critical time before the oil change, the more important it is to know about the condition of the oil in real time. It is then where money and servicing costs can be saved trough expanding the oil drain interval. No one wants to risk standstill, breakdown or expensive maintenance. Information about the oil condition in real time can prolong the operating lifetime of an oil cycle for several days or even weeks, hand in hand with reducing the amounts of fresh oil makeup. The operator is able to earn money of the constant output, as long as the engine is running.

It is evident that gas engines, especially biogas engines need to be operated according to the original equipment manufacturers' (OEM) guidelines [6]. With regard to the specifications of handling a gas engine, the problems of various fluctuating fuel gas types, as well as their impurities, are not considered. Natural gas hereby behaves differently than the range of biogases converted to power and heat [2, 7]. For every different gas type it would be necessary to implement a unique used oil analysis program, which should be specially designed to cover the challenges of the given application [6].

Typical biogas engine oil characteristics [8] of some OEMs are shown in Table 1.

Table 1. Typical biogas engine oil characteristics

Oil	Q8 Mahler MA 40	Shell Mysella 40	Mobil Pegasus 705	BP Energas NGL	OMV gas HD SAE 40	OMV gas LEG SEA 40	OMV gas LF SAE 40
SAE 300 J- class	40	40	40	40	40	40	40
Density 15°C	891	887	887	n.a.	899	892	895
Viscosity 40°C	141,2	139	126,2	130	154	150	144
Viscosity 100°C	13,86	14	13,2	13,5	14,8	14,9	14,3
Flashpoint	254	265	252	n.a.	247	250	256
Pourpoint	-12	-21	-18	n.a.	<-15	<-15	-18
Total Base Number	5,5	5,5	5,6	5,1	9,5	6,7	11,2
Sulfated Ash	0,5	0,45	0,52	0,45	0,9	0,45	0,88

Table 2 shows the standards for typical analytical parameters which are in use to analyze these biogas engine oils and to outline changes due to aging processes.

Table 2. Standards for typical analytical Parameters

	DIN	ASTM	Unit
SAE 300 J- class	51511	-	-
Density 15°C	51757	D 1298	kg/m3
Viscosity 40°C	51562	D 445	mm2/s
Viscosity 100°C	51562	D 445	mm2/s
Flashpoint	ISO 2592	D 92	°C
Pourpoint	ISO 3016	D 97	°C
Total Base Number	ISO 3771	D 2896	mg KOH/g
Sulfated Ash	51575	D 874	%M

2.2 Role of oil condition monitoring

Failure-free running of stationary gas engines has to be assured whereas several factors have to be focused on. On the one hand there are hardware factors, which are not dealt with in this work, and on the other hand there are the physical - chemical properties of the gas engine oil which have to be considered. High temperatures, stresses, combustion gases as well as high pressures lead to oil aging, which might result in deposit formation or loss of optimum lubrication. By using routine laboratory analysis it is possible to monitor the tribological performance of the oil and to recommend an oil change if necessary. There are several parameters which give an overview about the oil status, and whether it can be further used or has to be changed. These major oil change criteria [7, 9] are e.g. viscosity, IR-spectra interpretation (oxidation, nitration), total base number (TBN), as shown in Table 3. They are never evaluated alone as a single characteristic and only specified in OEM requirements.

Table 3. Major oil change criteria

	WearCheck	Mobil	
Visc. 100°	min. 12, max. 18 + max. 3	+ max. 3,5	mm²/s
Oxidation	20	Group I: 20 Group II: 30	A/cm
Nitration	20	Group I: 20 Group II: 30	A/cm
TBN	> 50% fresh and >2	2,0	mg KOH/g

Changes in these parameters can be ascribed to different mechanisms in the engine. If any of these parameters are not checked over the oil lifetime cycle any more, in order to reduce costs, sustaining the chemical properties and ensuring the tribological performance still has the highest priority. Under this point of view oil induced engine failure is no option.

2.3 Current routine experiences

The common way of OCM, to ensure the chemical and physical performance of the lubricating oil in gas engines is as follows: During the operation of the engine several oil samples are drawn in fixed operating hours (e.g. ten times in one oil change cycle). These samples are sent to an Off-Site analytical laboratory to be analyzed. The measured parameters are used to ensure the operator and the manufacturer of the functionality of the engine and to prevent it from oil induced failure.

Hereby the shipment of the used oil sample takes the longest time, often more than 3 or even 5 days (more than 72 or even 100 hours). The analysis takes at least one day, if there is no delay. That is a minimum of 100 hours from sampling to responding to the condition of the oil. For typical oil drain intervals of 350 hours in biogas application the waste of responding time is almost one third. During this period it is feasible that engine failure might occur. It is evident that only a shorter response time can prevent the operator from lubricant inducted shutdowns and the associated extra costs.

The response time has to be shortened in order to expand the operating lifetime of the oil, reduce the costs and also to optimize usage of oil, chemicals and the analysts’ manpower.

2.4 New approach for IR-spectroscopy for On-Site analytics

Time efficiency is a very important fact in these days because waste of time is a waste of money. Enormous sums of money can be saved by reducing the sampling time of the oil from the gas engine.

Determining the oil quality On-Site with the portable IR-spectrometer [10] is the best fitting solution on the way to reliable On-Line measurement. The procedure of sampling does not differ from the common procedure. Only the sample size in this application is much smaller and the faster test procedure. Oil sampling is done according to the OEMs reference but the shipping is not done.

Approximately five milliliter of the oil are used in a syringe to be injected in the apparatus after a background spectra is recorded. A sample name has to be entered and the measurement started. The analysis including rinsing the spectrometer, excluding warm-up time, takes less than ten minutes. The electronically recorded sample can then be sent for interpretation per email. Sampling and sending the spectra can be done in 15 minutes. For urgent cases the interpretation of the results can be enforced by a phone call, so that the status of the oil will be known within 30 minutes after the sampling. The responding time is reduced by approx. 99.5 % (referred to 2.3).

Oxidation and nitration are very important indicators for oil condition. Normally their interpretation is done according to DIN 51453 [11]. For the portable IR-spectrometer the measuring-range is smaller due to constructional reasons and therefore the interpretation has to be adapted. Table 4 shows that a variation in the spectra interpretation is only done in the baseline of the oxidation value. The baseline set point at 580 cm^{-1} has been moved to 640 cm^{-1} to determine the oxidation of the oil without any influence of the reduced spectra in the portable IR-spectrometer.

Table 4. Parameter for spectra interpretation on portable IR-spectrometer

Spectra interpretation (difference spectra)				
Oxidation				
	DIN		portable IR	
Peak	1710	cm^{-1}	1710	cm^{-1}
Baseline	1970-580	cm^{-1}	1970-640	cm^{-1}
Nitration				
	DIN		portable IR	
Peak	1630	cm^{-1}	1630	cm^{-1}
Baseline	1645-1615	cm^{-1}	1645-1615	cm^{-1}

Due to the strength of the IR-light beam, and a weaker detector built into the system, the result of the small IR-unit differs from the result of the laboratory equipment. The influence of the strength in the signal varies over the measuring range. For oxidation a factor of 0.83 has been found as shown in Figure 1.

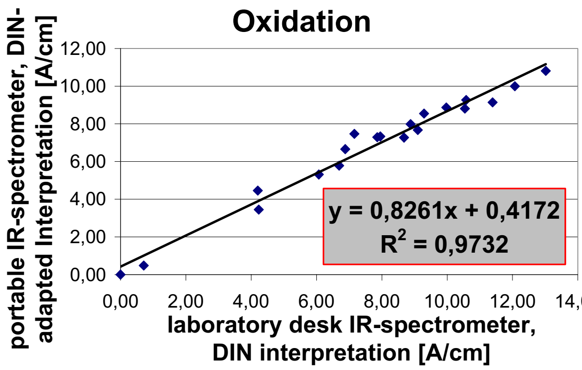

Figure 1. IR-Oxidation, Correlation of portable IR-spectrometer with laboratory desk IR-spectrometer

In case of the investigated used oil the factor found for nitration is 0.41 times the value found in the laboratory spectrometer, as shown in Figure 2.

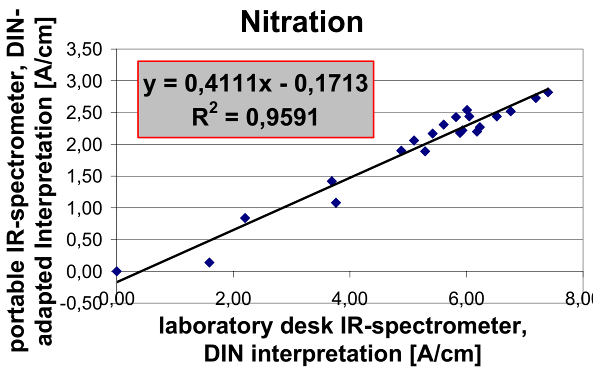

Figure 2. IR-Nitration, Correlation of portable IR-spectrometer with laboratory desk IR-spectrometer

For oxidation and nitration the correlation (R^2) of the portable IR-spectrometer to the laboratory IR-spectrometer is over 95% (see Figure 1 and Figure 2).

It has to be kept in mind, that this result is only suitable for this specific oil in combination with the used fuel gas type in this specific gas engine, which is the source of the lubricant samples, unless further research evaluates the findings also for different oils and conditions. Then the shortened procedure of oil condition monitoring can be used in different gas engines with different oils.

3. CONCLUSION

In stationary gas engine applications the way towards On-Line oil condition monitoring (OCM) is evident. Without a doubt, oil condition monitoring is demanded for engine operation reliability and offers the possibility to extend and optimize the oil drain interval. Even the recently introduced On-Line measurements often do not cover the whole range needed to describe the physical and chemical parameters as accurately as intended. Nowadays and in the near future the focus is set on On-Site analytics. As investigated, the portable IR-spectrometer shows a huge potential for On-Site measurement. Interpretation of the spectra can be done Off-Site, until automation of the interpretation is provided.

For biogas application in the field of stationary gas engines the most important parameters, such as oxidation and nitration are analyzed On-Site with the portable IR-spectrometer. Interpretation of the spectra is done Off-Site by oil experts to determine the status of the lubricating fluid. The operator receives a professional report via email and is able to respond within a day.

Considering the total number of oil samples requested by OEMs which do not have to be analyzed in lubricant laboratories, plus the saved manpower, the break even point of a portable IR-spectrometer will be reached shortly. Furthermore, solvents and chemicals for analysis will be saved and any possible negative impact on the environment by wrong use or disposal is excluded.

In order to establish the portable IR-spectrometer for OCM in field applications further research has to be done. The results of the portable IR-spectrometer have to be correlated to the laboratory desk IR-spectrometer, in order to exclude any influence of the oil and biogas type used in the application on the measurement.

Newly developed portable analytical apparatus, covering a wider range of parameters, could be used for additional On-Site oil condition monitoring.

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