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GUIDELINE ON THE RELEVANCE OF LUBRICANT FLASH POINT IN CONNECTION WITH CRANKCASE EXPLOSIONS

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The International Council
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Conseil International
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Contents

Investigation on the relevance of lubricant flash point in connection with crankase explosions

1 Introduction

The first major crankcase explosion was noted in 1947 when 28 people lost their lives in an engine explosion that occurred on board the ship “Reina del Pacifico” . This occurred during her post refit sea trials in the Irish sea [1].
The primary cause of the explosion in the main machinery space was overheating within one of the cylinders. This overheating ignited gases within the crankcase of one engine causing an explosion which subsequently detonated the other three engines. This case raised industry awareness of the potentially severe consequences of crankcase explosions.

Although there have been many occurrences of crankcase explosions recorded since 1947, there is no official body to whom they can be formally reported. As a consequence these occurrences have been reported randomly which has made it difficult to statistically analyse the number, the root cause and the severity of the explosions.
The severity and the number of crankcase explosions also appears to have increased in recent times. The main reasons for this observation may be the overall increase in vessel population combined with the demands for higher power density which have led to new engine designs. In particular the mechanical and thermal loads on particular engine components have been increased and so any small deviation from the minimum quality requirements can lead to an increase in the risk of component damage.

To avoid an increase in risk of crankcase explosions occurring, the engine makers and classification societies have developed common rules for oil mist detection and crankcase relief valves.

Concerns have also been raised over the use of the flash point of the lubricant as a reliable indicator for the risk of crankcase explosion. The flash point test has been adopted by all major used oil laboratories as a service standard to vessel operators.

It is now well understood that there are many contributing factors to crankcase explosions and that there has been an over reliance on the flash point as an indicator for crankcase explosion.

2 Conditions required for crankcase explosion

The following conditions are required for a crankcase explosion to occur:

- Ignitable substance
- Oxygen
- Source of ignition

2.1 Ignitable substance

2.1.1 Oil mist generation by lubricating oil

A mist of lubricating oil is always present in the crankcase of an engine during normal operation. The oil mist formation is influenced by engine design, gas and oil pressures, temperatures and oil flow rates. The critical conditions required to create a crankcase explosion however are the presence of a hot spot and for the formation of specific sizes of oil mist droplets.
Specifically the risk for crankcase explosion increases when the oil mist meets the following criteria of [5]:

- droplet size <5 µm
- concentration above the lower explosion limit (LEL) of ~50 mg/l

2.1.2 Oil mist generated by oil with fuel contamination

As the ignitibility of fuel is almost equal to that of lubricating oil, the same operating conditions are present. Therefore any contamination of oil by fuel does not increase the danger of explosion. This assumption is based on the typical behaviour of hydrocarbons.

2.1.3 Gas, particularly in gas fuelled engines or dual fuel 4 stroke engines

It is well known that the final composition of the atmosphere within a crankcase environment is determined by the blowby gas entering past the piston rings during the compression stroke. Measurements taken by Germanischer Lloyd have shown oxygen content of ~20%. Therefore in gas fuelled engine operation with low pressure gas supply (i.e. 4T Otto cycle) it can be assumed that the flammable gas concentrations (oxygen and fuel) within the crankcase atmosphere could be as high as 100% of the relevant Gaseous LEL's.
Further investigations are recommended in order to evaluate the existence of any higher risks. This item is subject to development of a new IGF-Code.

2.1.4 VOC (Volatile Organic Components) and degradation products of lubricant.

Crankcase explosions may start from the ignition of gases which develop during either the heating of lube oil or during the thermal degradation of lube oil. Further investigation is needed however to determine which VOCs could contribute to the formation of a critical atmosphere (also refer 6.3).

2.2 Oxygen

Scientific investigations by Germanischer Lloyd have shown that oxygen levels in a crankcase environment are similar to those in ambient air. This is partly due to piston blowby as previously reported and also because the lube oil return line from the turbo charger can introduce oxygen into the crankcase via the labyrinth seals. The design and efficiency of the crankcase ventilation system is an influencing factor.

2.3 Source of ignition

The source of ignition in general is a spark or a hot spot caused by:

- Damaged pistons (seizures or holed piston)
- Damaged bearings
- Sparking (metal against metal)
- Damaged stuffing box seals (piston rod)
- Damaged drive components of high pressure fuel pumps.

3 Detection of risks for crankcase explosion

3.1 Oil mist detection

Oil mist can be monitored and quantified by oil mist detectors, they use mist opacity as a measurement principle. The oil mist detection systems have to be type approved by classification societies [3] and tested in accordance with IACS Unified Requirement M67 [5].

Installation of oil mist detectors are required in engines with a cylinder diameter >300 mm or a rated power of ≥2250 kW [3] and must be capable of detecting oil mist concentrations in the range of 0 – 5 mg/l. This allows the engine operator to set alarm levels and they are typically set at the 2.5 mg/l level. Although this alarm limit is only 5% of 50 mg/l LEL, oil mist concentrations can rapidly increase to levels that could lead to a crankcase explosion.

When correctly mounted oil mist detection units have shown that they are effective in predicting critical oil mists in service. Typical problems experienced with their operation can be a consequence of mounting failure, poor operating / maintenance and inappropriate location of the suction point.

3.2 Splash oil temperature measurement

This system is based upon temperature measurements of the main bearings and oil temperature measurement of the crankpin bearings in 4-stroke engines. High oil temperature could be an indicator of bearing overheating.

3.3 Bearing shell temperature and wear monitoring by Condition Monitoring Systems

Most modern engines are equipped with bearing monitoring systems, these are able to detect the beginning of bearing damage before it develops further into hot spots. Measurements taken include the shell temperature of the main bearing and crankpin bearing amongst others, and with wear monitoring of all crank-train bearings.
Bearing wear monitoring systems are available on the market for low-speed 2-stroke crosshead engines. They use a comparatively simple measurement principle: two proximity sensors are installed inside each crankcase compartment, the crosshead position is measured at bottom dead centre (BDC) during each crankshaft revolution. In this way the overall clearance of the key crosshead bearing, the crankpin bearing and the two adjacent main bearings, can be permanently monitored.

3.4 Gas detection sensors

Gas detection sensors such as “explosi-meters” & EXMeters are available but have not been used in marine diesel engine applications for preventing crankcase explosions. EXmeters used by fire brigades are usually calibrated to measure explosive gases, such as methane and ethane. The two mostly commonly used technologies are based upon:

- Catalytic heat signature
- Infrared (IR)

Both these technologies have limitations that would need to be considered when applied to marine engines. In critical applications the use of gas detection sensors should be considered in addition to the use of oil mist detectors.

4 Prevention of CCE and minimizing the effects

4.1 Monitoring of crankcase condition

By monitoring those crankcase conditions that are related to the risk of crankcase explosions the overall risk of crankcase explosions can be minimised. This is done through the measurement of abnormal levels of:

- Concentration of oil mist
- Concentration of explosive gases generated through the decomposition of lubricant and fuel
- Bearing temperatures

Reaching abnormal levels in any of the above should trigger pre-defined emergency actions such as engine slow down or shut down and or other OEM recommended measures -for example use of Nitrogen blankets.

4.2 Crankcase ventilation arrangement

Venting pipes should have a minimized clear opening and should not interconnect with other engines' crankcases [3].
The airing of the crankcase or any arrangement which results in air intake into the crankcase during engine operation is not allowed [3], [6]. Additionally air intake via lubrication oil which has passed the turbocharger sealing should be minimized.

Specific exceptions exist however for gas fuelled engines [7], where ventilation can be necessary to prevent the accumulation of leaked gas.

4.3 Demands on crankcase design

The crankcase has to be operate safely with air intake under normal service conditions. Crankcase doors and sight holes have to withstand the overpressure levels up to the trigger level of the pressure relief valves. They must also withstand negative pressure after the event of a crankcase explosion.

4.4 Crankcase relief valves

Crankcase relief valves vent the crankcase overpressure during a crankcase explosion and also quench the flames of burning oil mist. The demands made on, the examination of and the installation of crankcase relief valves are described in IACS rules as well as in class rules [2] [3] [4]. Crankcase relief valves have to be type approved [2].

4.5 Maintenance

Mandatory engine maintenance procedures can decrease the risk of crankcase explosion. This includes the detection of potential bearing damage as well as monitoring key parts of the combustion chamber (piston, piston rings, cylinder liner/ cover and injection valves). Bearing monitoring systems are able to detect failures quite reliably.

5 Rules, standards and regulations

Rules, standards and regulations are covered by:

- IACS Unified Requirements
- Classification Societies Standards

6 Secondary explosions

According to latest experience secondary explosions in case of 2-stroke engines have been detected in the engine room, causing extensive damage. It is imperative to discuss these phenomena because there is a high risk for the crew and the ship.

6.1 Crankcase explosion – theories and facts

Areas of explosive atmosphere are created near a hot spot; due to the condensation of small droplets on engine walls and oil splash they do not incorporate the whole crankcase itself.
With the exception of the hot spot area itself, condensation also keeps the dangerous droplet size in the crankcase below the LEL which lowers the explosive power.
Investigations made in 2006 showed that most of the hot spots which had led to crankcase explosion developed in specific compartments of the engine - such as the chain chamber, camshaft housing or in supply units of common rail engines. These compartments have connection to the entire crankcase but the contained oil mist should condense according to the above mentioned theory. However crankcase explosions sometimes occurred with a secondary explosion outside of the engine; in these cases the crankshaft bearings were not harmed.
Secondary explosions are not often observed in 4-stroke engines- probably due to the smaller volume of their crankcase.

6.2 Crankcase explosion – assumption

The reference above to explosions occurring within an apparently inert crankcase atmosphere could be an indication that not only is the size and concentration of oil droplets important but that the amount of all potentially explosive crankcase components (oil & gas derived) should be considered.

6.3 Crankcase explosion – research

Recent investigations by the German Institute für Sicherheitstechnik / Schiffssicherheit e.V. [8] have raised doubts about the common view that only oil mist causes crankcase explosion. These doubts are supported by the fact that oil mist droplets have a very short life span due to their fast evaporation within a hot crankcase environment.
However, the thermal degradation of hydrocarbons in hot lubricating oil creates explosive gases which can be seen as the root cause for a crankcase explosion. It has been observed that the initial explosion is caused by hydrocarbon gases and/or hydrogen gas and is often followed by an ignition of other combustibles such as splash oil droplets and the oil film on crankcase walls.
Measurement of explosive gas concentrations is therefore recommended to reduce the risk of a crankcase explosion in a safe way.

7 Flash point

Investigations have shown that fuel contamination of lubricating oil does not enhance the creation of dangerous droplets or gases.

Additionally fuel contamination of lubricating oil has not been detected or reported in any of the reported cases of crankcase explosions occurring in recent years.

The latest research results also demonstrate that fuel contaminated oil does not increase the risk of a crankcase explosion.

As such flash point measurement of a lubricating oil is not a reliable or an early indicator for detecting the risk of a crankcase explosion, neither is it deemed to be a suitable test whose results can be depended on for this purpose.

Flash point measurements however may still be useful as a screening tool for detecting fuel contamination for other reasons, specifically:

- For engines which alternate between heavy fuel and distillate fuel usage, flash point measurements can be used to monitor the origin of possible fuel contamination (the contamination of heavy fuel and distillate fuel can compensate the resulting changes in viscosity).
- For engines running exclusively on distillate fuel the flash point measurement can be used to confirm lubricant viscosity decrease caused by fuel contamination.
- In certain countries (mainly for fresh oils) the flashpoint test can be required by law.

For engines which are exclusively running with heavy fuel, the flash point measurement can be omitted; the lubricant viscosity increase will indicate fuel contamination.

8 Conclusions

- Flash point testing of lubricating oils as an accurate or early indicator of the potential risk of a crankcase explosion has not been proven and so it is no longer recommended for this purpose.
- Use of a combination of oil mist sensors, gas detection sensors, and bearing temperature monitors are recommended as an early warning system for the risk of a crankcase explosion.
- Regular scheduled maintenance of the crankshaft and its driven parts can reduce the risk of a crankcase explosion.

In summary the lube oil flash point is not relevant for predicting a potential crankcase explosion.

9 References and further reading material

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[5] IACS Unified Requirement M67
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[7] IACS Unified Requirement M59
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