15th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2011, Prague, Czech Republic, 12-18 September 2011

EXHAUST GAS BOILER FIRE PERVENTION

Branko Lalić, dipl.ing
mr. Ivan Komar, dipl.ing
mr. Đorđe Dobrota, dipl.ing
Faculty of Maritime Studies - Split
Zrinsko-Frankopanska 38, 21000 Split, Hrvatska

ABSTRACT

Today's demands for better overall usability of fuel oil in large two-stroke low speed marine diesel engines greatly influenced their development, and the purity of their exhaust gases. With this paper we would like to indicate on to factors which directly influence on soot forming, deposition and cause of occurance of fire in exhaust gas boiler (EGB). Due the fact that a fire in the EGB can result in complete destruction of the boiler, and a longer interruption of the vessel commercial operations, crew must be familiar with the main reasons of soot deposition on the boiler tubes and elements and origination of fire, and to have taken proper and timely protection measures[1].

Keywords: soot, exhaust gas boiler, occurrence of firer, crew familiarization

1. INTRODUCTION

Today's demands for better overall usability of fuel oil in large two-stroke low speed marine diesel engines greatly influenced their development, and the purity of their exhaust gases. Because of reduction of exhaust gases temperature, nowadays in ranges from 240° to 270°C, measured after the turbochargers, and the growing need for steam, today's exhaust gas boilers have a high degree of usability. In fact, their heat transfer surfaces increases (water tube elements) and are designed as boilers with low-speed velocity. Modern large two-stroke low speed marine diesel engines use poor quality heavy fuel oil, which contain significant amounts of asphalt and sulphur that pollute exhaust gas emissions and increase the risk of soot deposition on the boiler tubes. Therefore increases the risk of fire, which for ultimate consequence could be the complete destruction of the boiler. Just the facts, reduction of fuels quality and increasing the exhaust gas boiler efficiency had resulted in a recent year’s increase of incidents of fire. Figure No. 1 shows the statistical representation of exhaust gas boiler fire on ships under the DNV supervision [1]. Data for the 1993rd and 2003rd were not collected, and so even after the 2005th year. Due the fact that a fire in the exhaust gas boiler can result in complete destruction of the boiler, and a longer interruption of the vessel commercial operations, crew must be familiar with the main reasons of soot deposition on the boiler tubes and elements and origination of fire, and to have taken proper and timely protection measures.

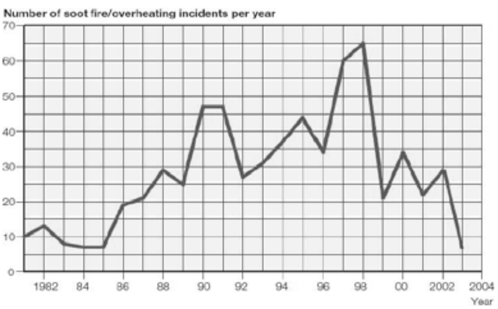

Figure 1. Number of soot fire-damaged exhaust gas boilers in DNV-classed vessels

[1] The results presented in the paper have been derived from the scientific research project 250-2502209-2364 „New Technology in Diagnostic and Management of Marine Propulsion Systems “ supported by the Ministry of Science, Education and Sports of the Republic of Croatia

2. CAUSE OF OCCURANCE OF SOOT AND FIRE IN EGB

The main cause of origination of fire in the boiler is a large content of soot in the exhaust gases generated by combustion of fuel in the engine cylinder. Presence of particulates in the exhaust gas emission cannot be avoided but applications of new technologies can decrease it. Harmful particulates in the exhaust gas emission resulting from the following sources: agglomeration of very small particles of partly burnt fuel, ash as content of fuel oil and cylinder lube oil, partly burnt lube oil, peeling-off of combustion chamber/exhaust system deposits, sulphates and water. The amount of particles in the exhaust gas varies depending on the heavy fuel oil quality and quality of cylinder liner lubricating oil and its dosage. Engines that use heavy fuel oil approximately produce between 120-150 mg/Nm^3 of harmful particulates, which would correspond to a specific cylinder oil consumption of 0.8-1.0 g/kWh. About 90% of particles have a size smaller than one micron, while the other 10% consists of flakes of deposit formed in pilling-off process. Particles also include fly ash from oil and traces of metals. A test of the soot deposits in a boiler with gilled tubes has shown that about 70% of the soot is combustible. The content of unburnt hydrocarbons in exhaust gas can be up to 300 ppm, but depends very much of the fuel injection system condition and of the cylinder oil dosage. If overcome poor maintenance and poor quality fuel, for whatever reason, there is increased deposition of particles on the heating surface of the boiler and thus leads to the formation of soot deposits. Furthermore, as the temperature of exhaust gases and heating surface of boiler is lower, leads to rapid deposition of soot in harder form. Explanations for hard deposits lie in the fact that the soot at lower temperatures is wet due to the presence of unburnt fuel or condensation of some gases, which also enhances the deposition. Soot ignition took place in the presence of oxygen from the exhaust gases when the soot deposits have a enough high temperature at which release large amounts of combustible gases. Ignition can occur by spark or flame. Increased deposition of soot act at frequent main engine starting (at manoeuvring) and run at reduced engine speed. The potential danger of soot ignition is expressed at soot layers temperature between 300-400°C. The presence of unburned fuel oil and cylinder oil lowers the ignition temperature to abt. 150°C, and in extreme cases even down to 120°C. This means that ignition may also take place after stop of the main engine as a result of glowing particles (sparks) remaining on the boiler tubes. We distinguish the following types of exhaust gas boiler fire: small soot fire and high-temperature fire as hydrogen fire and iron fire.

Small soot fires in the exhaust gas boiler are localized and occur during manoeuvring or engine low load operation. This type of fire usually does not cause any damages, but the fires should be carefully monitored. In practice this is achieved by temperature sensors on each section of the exhaust gas boiler. "Shutdown" of such a fire is carried out by forced circulation of boiler water in duration of 6 hours after the shutting down of the main engine [2]. In certain circumstances, small fires can turn into a high-temperature fires in which the consequences can be measured in complete destruction of exhaust gas boiler (Figure No.2). Hydrogen fire occurs because dissociation of water into hydrogen (H) and oxygen (O) or, in connection with carbon (C), into carbon monoxide (CO) and hydrogen, may occur under certain conditions. A hydrogen fire may start if the temperature is above 1000°C. The water comes from burned pipes or from soot blowers (steam based soot blower).

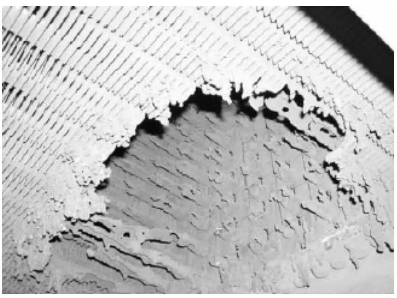

Figure 2. Example of exhaust gas boiler evaporator section damage caused by high temperature fire

$$2H_2O \rightarrow 2H_2 + O_2 \quad ; \quad H_2O + C \rightarrow H_2 + CO \quad \} \quad H_2 \text{ i } CO \text{ are combustible}$$

Iron fire means that the oxidation of iron at high temperatures occurs at a rate sufficiently high to make the amount of heat release from the reactions sustain the process. These reactions may take place at a temperature in excess of 1100°C. It is important to realize that also water may go in chemical reaction with iron, i.e. the use of the steam based soot blower by ignorance crew in order to put out resulting fire, will feed the fire.

$$2Fe + O_2 \rightarrow 2FeO + heat \quad ; \quad Fe + H_2O \rightarrow FeO + H_2 + heat \quad \} \quad \text{The boiler tubes are burning}$$

3. EGB FIRE OCCURRENCE PREVENTION AND PREVENTIVE MAINTENANCE

Manufacturers of large two-stroke low speed marine engines striving to meet guidelines of Regulation 13, MARPOL 73/78, Annex VI., what have for direct consequence reduction of the concentration of particles in the exhaust emission and exhaust gas boiler deposition and the potential occurrence of fire. Unfortunately, measuring methods of soot and transparency of emissions vary, and the results of different methods cannot be compared. Some of standard methods for evaluating the visibility of emissions are [4]: Bosch Smoke Number, Bacharach Smoke Number, Hartridge Smoke Number, Ringelmann Smoke Number and Opacity in general. When taking into consideration transparency, so say exhaust emission, should be taken into account that a bigger engine have larger emissions with greater visibility, that is, the larger the diameter of the emission are (larger engine produces a larger amount of exhaust gases, and thus has a larger diameter flue) will absorb a greater amount of light. Some of the technologies that help reduce the concentration of particles in the exhaust gases, which are now used daily, are [3,4,5,6]: fuel valve and nozzle optimization, injection intensity, ALPHA lubricator, fuel emulsification.

The content of hydrocarbons (HC) in exhaust gases are directly connected to fuel quality, design of injection elements, and to injection timing. Reduced sac volume in the fuel valves has greatly reduced HC emissions. It is well known that at fuel oil high pressure pumps pressure varies due to engine speed. This means that during vessel manoeuvring or low load steaming, the quality and injection pressure are inadequate and therefore within the cylinder engines incomplete combustion takes place. This causes the occurrence of large amounts of soot. Using a common-rail technology for marine engines ensures injection constant pressure which is independent of engine rpm, and what for end result have a decrease of soot concentration and colourless exhaust. Consumption of cylinder lub oil directly affects the amount of particles in exhaust gases, and reducing the dosing of cylinder oil reduces the amount of particulate matter. Alpha lubricator is electronically controlled high pressure lubricator which injects cylinder oil in a specific time and position of a piston, when the lubricating effect is optimal, i.e., with smaller quantities of oil is made better lubrication. Fuel oil emulsification reduces the peak combustion temperature on account of evaporation. With Evaporation of the water evaporates the fuel that surrounds the "droplets" of water which results in increased surface of fuel. Lowering the peak temperature of combustion and better mixture quality (increased surface of fuel) leads primarily to reduction of NOx emissions, but also to a significant reduction in the amount of harmful particulate matter in exhaust gas emissions. This has direct consequences for the reduction of soot deposition on the surfaces of exhaust gas boiler.

4. EGB CONTAMINATION MONITORING AND MAINTENANCE AS FIRE PREVENTION

Development and application of new technologies achieve significant reduction of the concentration of soot in the exhaust gas emission, but not its complete elimination from emission. This fact raises the need for soot deposition monitoring on pipes and pipe elements in a way to achieve in time cleaning of boiler and avoid a potential fire. No matter how the ship's modern and sophisticated is the first method is to monitor differential pressure of exhaust gases through exhaust boiler at a commercial speed of vessel. The maximum allowable differential pressure is 350 mm WC. Recommendations of the boiler manufacturer to wash boiler with clean water should be carried out at the end of each vessel voyage [2]. Often it is not technically applicable; so on the basis of experience, boiler cleaning should be carried out at least once every three months with daily soot blowing. In order to improve protection against fire in the boiler is now installed parameter analyser which is in direct dependence of engine load (differential pressure, exhaust gas temperature and boiler water circulation), which assessed optimal time for boiler cleaning.

5. EXHAUST GAS BOILER FIRE SIMULATION

Occurrence of fire in the EGB and its development has been done on the simulator, "Kongsberg ERS-L11 MAN B&W-5L90MC -VLCC Version MC90-IV", which is installed on the Maritime Faculty in Split. The simulation, shown in Figure No.3, began with 50% of soot contaminated boiler during manoeuvring, which corresponds to the real conditions for origination of fire. Area in diagram marked with "A" shows the change in parameters due to changes in the regime of the engine and they are relatively stable until the advent of the "small fire" occurs (after vertical black line). Area in diagram marked with "B" shows the beginning and growth of fires that reflect with growth of exhaust gas temperature after the feed water economizer and the second evaporator section, and likewise the increase of temperature of metal (pipes) causing increases heat transfer and increase of pressure in the auxiliary boiler until the steam reach the value that opens the steam relieving pressure valve. Since the feed water and circulating pump are no longer able to provide sufficient cooling water leads to burnout of pipes, and manifesting the fall of water level in the auxiliary boiler. The leaking water "feed" the fire that grew into a Hydrogen fire and Iron fire, which is evident from the temperature values after the second evaporator section (1287.9°C) and the values of temperature after boiler feed water economizer section (1495.1°C).

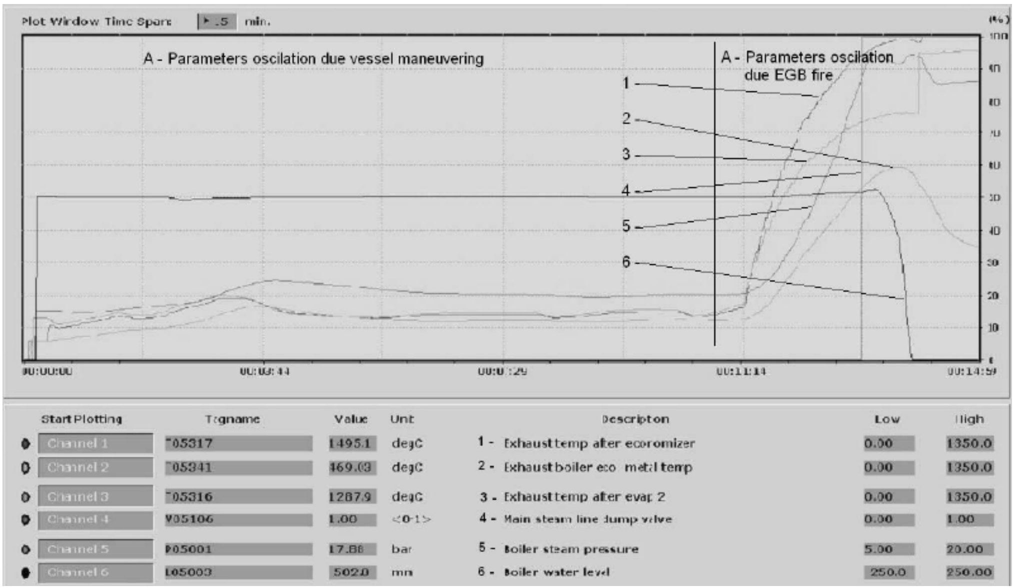

Figure 3 Diagram of Exhaust gas boiler fire with relevant parameters

6. CONCLUSION

Over the past years the problem of soot deposition has been greatly reduced by introducing new technologies that result from the application of Regulation 13, MARPOL 73/78, Annex VI. Knowing that harmful particles cannot be completely eliminate from the exhaust gas emissions, force shipping companies to better educate the crew about the problem. Education of the crew reduces the chance of origination of exhaust gas boiler fire which in a short period of time can develop from a small fire in a high temperature fire that could lead to unexpected boiler breakdown causing to owner considerable financial costs of repair and stoppage of vessel.

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