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Efficiency of the Engine of Great Porte and Detection of Anomalies in the Operation of the Piston-Cylinder System through the Monitoring in Real Time

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***Abstract*— *From the goodness of internal combustion engines as primary drive They Have Been Increasingly more widespread in power generation, either isolated power plants in the working system-based systems. Engines of large size and Especially the Internal Combustion engine (IC), Increasingly are Becoming more widespread in the generation of electricity by the degree of perfection That is Increasing, however in the the powers of these Also higher, costs of parts que make it up, and done maintenance activities engines Become more expensive, for that reason the consideration During the exploitation is to monitor the operation of the same, in real time. In this article Describes some of the characteristics of the great internal combustion engine and indications.*
Keywords*— Combustion engines, thermal plants, energy efficiency, piston-cylinder system, real-time monitoring.

I. INTRODUCTION

Internal combustion engines, compared to other type of primary drive, offer the advantage of better performance. The use of diesel engines for power generation was widespread in stationary plants of medium size. Currently, the industrial sector has several challenges regarding their energy sources in particular energy costs, market competition increasingly intense, higher costs in the supply of primary energy including electricity, the need for greater efficiency among other they are realities facing the industry and therefore are the driving force to redesign their energy supply strategies. To meet these challenges, it is necessary to maximize process efficiency, reduce energy consumption, opt for cheaper sources of energy, machines reduce operating costs and, of course, at the same time contribute to a cleaner and greener world. from various manufacturers dual-fuel fuel and bi-fuel systems use a widely-known technology and engines developed diesel systems of conventional internal combustion adding a second fuel may be any type of gas, particularly natural gas, biogas, coal gas, LFG[1].

The significant drop of Domestic Energy Supply (DES). Consistent with the decrease of 3.6% in the economy was mainly inducing a reduction of almost 20% in transformation losses due to the lower thermal generation and the reduction of 5.3% in the energy sector consumption (7 loss % in ethanol). The total demand for petroleum products fell by 5.6% (-7.2% in 2015), there including end uses in the sectors of the economy and the uses in the generation of electricity. The consumption in light vehicles decreased by 1.6% (an increase of 6.2% in 2014 and stable in 2015). Some industrial sectors showed negative rates above 9.0%, like cement, steel and Pellet. The Internal Energy supply 2015 and 2016, in which it had a small increase in the share of renewable sources, as a result primarily of strong reduction of non-renewable (-7.3%). The aggregate "Other renewables" wind[2].

In 2016, the ratio of CO_2 emissions by use of energy and total energy demand remained at 1.48

TCO_2/toe, the bottom indicator 2015 (1.55 TCO_2/toe) because less energy generation electricity from fossil sources [3]. Although TCO_2/toe in 2016 was lower, the difference is only 0.07 TCO_2/toe, which is a small amount, mainly due to the use of renewable sources and not just due to a more efficient use of fossil fuels.

The above suggests that energy efficiency should be one of the strategies work in the energy sector, not only reducing emissions, but also by reducing the physical consumption of hydrocarbons and all costs associated with infrastructure. Among the many responsible for the use of hydrocarbons, thermal power plants with natural gas (HFO) engines, play a key role in meeting the needs of the use of electricity in the country, hence the importance of achieving higher levels of efficiency in these plants, not only in order to reduce emission levels, but also by the fact that lower levels of efficiency are the result of possible operating problems and operation of facilities[4].

II. LITERATURE REVIEW

Currently, most of the energy consumed in the world (for example, in transportation, power generation, heating) is supplied by the combustion process. Thus, the knowledge and use of this process are of great importance in many areas, especially for power plants (TPPs) holding the same for power generation. One of the key drawbacks is that an important part of the energy generated in the combustion process is sent to the atmosphere affects directly the efficiency of combustion and the environment, by issuing a volume of gas with a high content of toxic gases and for its high energy content[5][6]. In internal combustion engines, eg petrol, diesel, gas or combination of gas-HFO, the pair formed by piston-cylinder (shirt) is one of the most important systems because it is where is the energy transformation process fuel into mechanical work to the shaft, which is possible through the combustion of the fuel supplied[7]. Saving diesel fuel - by replacing up to 99% of diesel in original Dual-Fuel engines and 80% of diesel by gas Bi-Fuel engines converted:

- Possible reductions in emissions compared with 100% diesel operation of pollutants as CO_2, NO_x, SO_x and particulate matter.
- Potential economic benefits due to the difference in fuel prices.
- operational flexibility in the use of fuels.
- power and performance characteristics similar to those of diesel engines.
- Lower investment costs in equipment converted to dual fuel compared to generation of systems with internal combustion engines to 100% gas.

Internal Combustion (IC) diesel engines are among the most efficient simple-cycle power generationoptions available. Efficiency levels increase with engine size and range fromabout 35% for small high-speed diesels up to 55% (on an lower calorific value (LHV) basis) for the largebore, slow speed engines (33% - 52% on an higher heating value (HHV) basis)[8].

Diesel gensets in the 5 MW range will achieve operating efficiencies of between40% and 45% on an LHV basis depending on the type and technology. In terms ofrelative efficiency this is significantly better than open cycle gas turbines andslightly worse than the average combined cycle power station.Natural gas spark ignition engine efficiencies are typically lower than dieselengines because of their lower compression ratios. However, large, highperformance lean burn engine efficiencies approach those of diesel engines of thesame size. Natural gas engine efficiencies range from about 28% for smallengines (<50 kW) to 42% (on an LHV basis) for the largest high performance, leanburn engines (>3 MW) (25% - 38% on an HHV basis)[8].

The maximum efficiency of 50% for the best engines is one of the highest ratings in efficiency between the main existing engines. The improvement in efficiency is increasingly challenging as the emission requirements become more stringent. The manufacturer has several programs running simultaneously to ensure high efficiency of their engines and reduce engine emissions[9][7][10].

For example, the engines with power that can range between 4 and 19 MW of power have the following estimated energy balance, naturally, it depends on operating conditions and technical state of the installation, figure 1.

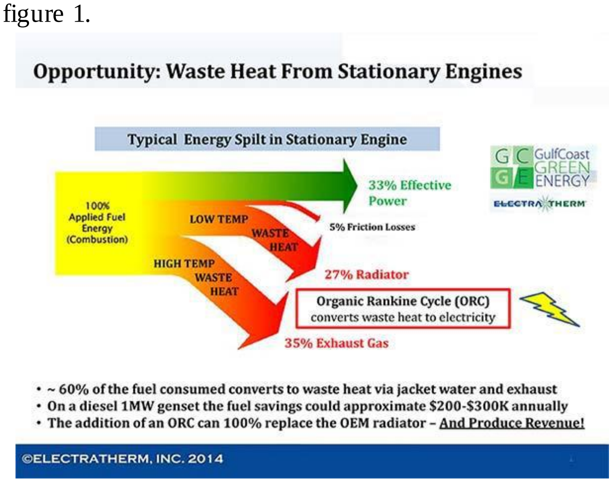

Fig.1: Waste heat from stationary engines.
Source: [11].

2.1 KEY FEATURES OF THE GENERATORS MOTORS

This type of engine is characterized by a low revolution, requiring generators with a large number of poles.

The frequency of the current is one aspect which must be met with great precision, in the case of Brazil is 60 Hz.

The number of pole pairs is directly proportional to the frequency of the supply current and inversely proportional to the sync speed, according to equation (2.1) [12].

$$P = \frac{60f}{N} \qquad (2.1)$$

where:
P: number of pole pairs;
f: frequency in Hz;
N: Speed of time in rpm.

It is known in Brazil that the frequency is 60 Hz and assuming an engine 514 rpm/min, the generator in this case have 14 poles as indicated above.

For the above mentioned generator, motors should take into account that the combustion is only one of the five component processes, although crucial, four times the thermodynamic cycle according to which they work: intake, compression, combustion, expansion and exhaust.

The process of periodic combustion is characterized by irregularities displayed in the mixture formation and physical proximity between the reactive (determined by the laws of aerodynamics and the motor geometry and its systems), the limited time available for carrying out chemical reactions (relevant for kinetic and chemical equilibrium) and the diffusion of gaseous components from the reaction zone and (also important to the overall speed of the combustion process).

2.2 DESCRIPTION OF THE MAIN COMPONENTS OF THE PISTON SYSTEM - CYLINDER OF THE COMBUSTION OBJECT OF ANALYSIS ENGINES

2.2.1 FUEL SUPPLY SYSTEM

In general, in the cases mentioned, this comprises storage tank, filters, fuel transfer pump, compressor and fuel tank for daily use. The fuel is provided on site of the plant through a pipeline, both the gas and the HFO. For daily storage tanks, fuel is pumped through filters to remove impurities and then is injected into the engine through the fuel injection pump[12].

2.2.2 AIR SUPPLY SYSTEM FOR COMBUSTION

This system provides air required for the engine manifold for combustion. The system has an air filter that removes dust particles which can act as an abrasive within the engine cylinder. The diesel engine requires close tolerances to achieve its compression ratio and because they are also turbocharged[12].

2.2.3 COOLING WATER SYSTEM

The engine cooling system removes heat generated by normal engine operation. Cooling is mostly done in the engine block, the turbocharger and charge air heat exchangers.

The cooling system consists of a single cooling circuit. This means that all heat sources are sequentially cooled by a common cooling water circuit. The cooling circuit is cooled by the radiators.

The water cooling system was set to be a load-dependent system, ie, heat can be recycled during low load operation to maintain adequate combustion temperature in the cylinders.

The internal system of the engine cooling water is a closed system which uses chemically treated fresh water. driven centrifugal pumps directly mounted on the engine, circulate the engine cooling water.

To prevent corrosion and formation of scale deposits or other deposits that occur in closed water circulation system, the water must be treated with additives.

2.2.3.1 ROLE SYSTEM

All engine heat sources are cooled in sequence by the single circuit cooling system. The cooling system operates in the following cooling sequence: cooler of the second charge air stage, lubricating oil cooler, the first charge air cooler stage and shirts and cylinder heads.

There are two points of independent temperature control. A set point is set to the output temperature of the jacket and the other for the water temperature at the inlet of the charge air cooler.

The cooling water circuit is cooled by radiators single circuit controlled by a frequency inverter. Moreover, the fan speed is set primarily in accordance with the temperature of the water after the radiators.

The cooling water circuit module Auxiliary Equipment motor (MI) has external water pipe, the thermostatic valve, the preheating unit, the lubricating oil cooler and instrumentation. The preheating unit is also mounted on the module. In addition, an attachment set for mixed cooling is connected to the EAM.

The purpose of the preheating unit is to preheat the engine block, the heating at the jacket temperature of cooling water required before starting the engine. The

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circuit is connected to the high-temperature circuit (HT) in parallel with HT circulation pump driven by the engine.

The preheating unit is formed of the following elements: electric centrifugal pump, a steam heater, closing and blocking valves, check valves and safety valves, and structure.

The preheating circuit has a check valve to prevent the flow of water in reverse. A safety valve with limit set at 6 bar, protects the circuit from a very high pressure. The system maintains a temperature of approximately 70 ° C in the jacket water of the engine while the engine is stopped. This allows fast loading and starting the generator set. The preheating is also used to warm the engine before a starting after a prolonged period of shutdown. The pump handle preheat the water in the engine cooling circuit HT output line and pumps this water through the preheated back to the motor circuit HT[13].

2.2.3.2 UNITS RADIATOR

The water cooling system is circulated in the radiator units through circulation pumps with direct drive, installed in the engine. cooling fans are actuated by motors CA. In addition, frequency inverters regulate the rotation of the fan and thereby the radiator capacity Figure 2. The fan rotation is controlled primarily in accordance with the water temperature at the outlet of the radiators[12].

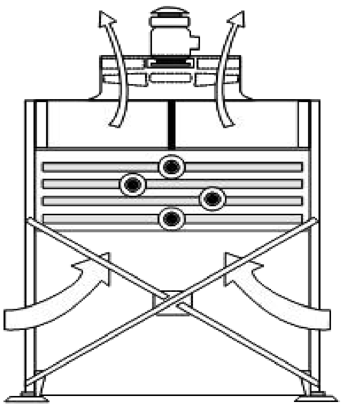

Fig.2: Unit radiator.
Source: [14].

2.2.4LUBE OIL SYSTEM

The primary purpose of lubrication oil to the engine system is to provide a sufficient amount of clean lubricating oil (OL) at the required pressure and temperature. It is important that proper flow is maintained throughout the system. The oil lubricates the motor and removes heat (cooling) and pollution generated by the combustion process (gas passing through the piston rings).

The proper functioning of the lubricating system of figure 3, the engine protects against breakage due to very low pressure, high temperature, very low pressure pre-lubrication or impurities in the oil[15].

This systemcan be divided into the following subsystems:

- lubricant oil circulation system;
- Storage systemand lubricant oil transfer.

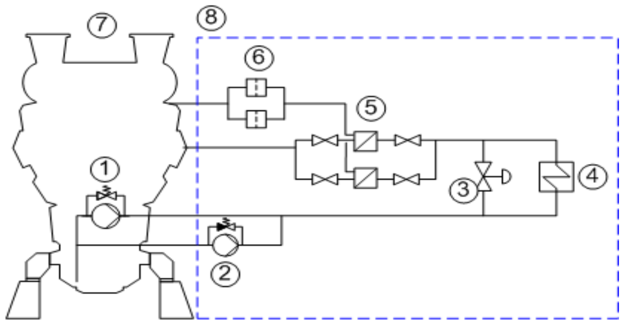

Fig.3. Simplified diagram of the lubricating oil circulation system
Source: [14].

The following components can be identified in the illustration above: pre-lubricating oil pump;l ubricating oil pump; Thermostatic valve; Lubricating oil cooler; Automatic Filter; wash filter; Motor.

2.2.5 EXHAUST GAS SYSTEM

The main function of the external exhaust gas systemis driving the exhaust gases out of the power plant. Emissions and nearby noise level must be below the values specified by local authorities figure 4[16].

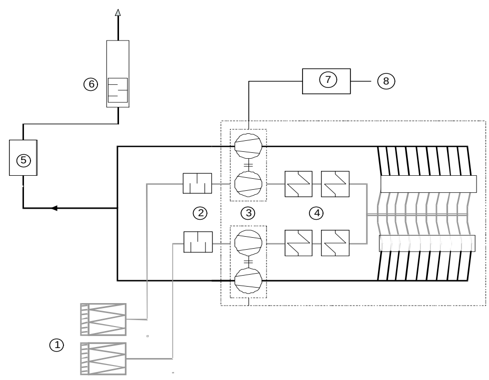

Fig.4: Simplified diagram of the charge air system and exhaust gas
Source: [14].

The following units and components are identified in the illustration above: charge air filter; Silencers charge air;
turbochargers; charge air coolers; Recovery boiler exhaust gas; Muffler exhaust gas; water supply unit for cleaning the turbine and compressor and natural water supply.

2.3 ENERGY CONSERVATION

The thermodynamic analysis of the combustion process seeks to clarify the forms and amounts of energy involved in it from the application of the law of conservation of energy or the first law of thermodynamics. A characteristic of the combustion in the comparatively small volume of the combustion chamber of an engine, although large as in the case considered is that the reactions do not occur at constant pressures near atmospheric, such as a boiler, but in a case the nearest higher pressures the isovolumetric (V≈const), as the piston movement in times of occurrence of chemical reactions resulting combustion is negligible[17].

The principal amounts of energy involved in this process are as follows:

- air internal energy state at the beginning of the combustion, corresponding to the end of compression, characterized by a reduced volume and moderately high values of pressure and temperature;
- internal energy of the (s) fuel (ies) in the state in which he (s) enter (m) in the combustion chamber. In a first approximation, the value of the workflow (p · V) can be ignored for the liquid fuel because its low specific volume. However, gaseous fuel injected into the cylinder, the work flow comes from power consumed by injection compressor and can reach considerable values;
- Existing chemical energy in the fuel component compounds that can enter during the reaction process. The external effect of the chemical energy is evaluated by the magnitude of specific heat of combustion, also known as calorific value or calorific value, determined by standard laboratory tests and expressed in units of energy per unit weight, volume or mole, according to the system units in use;
- internal energy of the products obtained as a result of the combustion process;
- Heat transfer through the walls of the chamber. Since the temperatures involved much higher than ambient, heat is typically rejected to the outside. In a first approximation, the adiabatic process can be considered (with negligible heat);
- The end of the energy balance during the combustion process aims usually get the final condition of the goods from the knowledge or assumption of the composition and speed of reactions (total combustion time). This final state is characterized by high values of pressure and temperature, and total or almost total completion of combustion reactions. When for various reasons the process does not end completely and extends to a part of the following process (expansion) while the energy released can equal as much as possible, to convert them into work, which is the ultimate goal of the motor is achieved incompletely.
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2.4 FUEL INJECTION AERODYNAMICS

Being a diesel internal formation of air-fuel mixture that forms inside the cylinder in a process that starts with only the entry of a liquid or gas jet (depending on the fuel used). Thus, the formation of the mixture will come determined by the penetration of the jet into the chamber volume and the actual aerodynamic air movement within it. The first will mainly depend on the fuel injection pressure, in addition to the geometric characteristics of the nozzle (nozzle). The second chamber is dependent on the geometry and intake valves.

In the dual operating system, it will be necessary to consider two different jets: the fuel gas jet, which must ensure the homogeneous mixture as possible and the liquid jet, whose main purpose and initiate combustion of the gaseous mixture.As it produces the penetration of the jet into the air volume or gas mixture, the evaporation is observed along with the diffusion of fuel within the mixture. The diffusion processes play an important role in the formation of the mixture in both the liquid fuel system, as in the dual.

Simultaneously occurs intensive heating of the fuel, which quickly reaches the ignition temperature and after a time delay, the ignition or beginning of combustion in some regions of the diffusion boundary where appears the favorable local conditions (temperature and composition of the mixture). The propagation of the combustion to the rest of the chamber is a complex phenomenon which results different to the case of only liquid fuel (air atmosphere) for the case of dual fuel, where the atmosphere is it a flammable mixture of air and fuel, and intermediate gaseous products of combustion.

In the first case, the liquid combustion occurs as they leave the nozzle, because once started, the temperature is raised to just inflammation heat the fuel exits, and the amount of air is excessive, ensuring oxygen requirements. In the second.Case, combustion is initiated shortly with inflammation of the liquid jet spreads throughout the chamber volume following a complicated phenomena sequence.

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As the combustion process in diesel engine limited by the time available, since it must complete before the start of the piston descent from the PMS, the kinetics of chemical reactions seeks the greatest interest. However, the high temperatures normally reached in the process ensure high reaction rates, are present but the diffusion phenomena which influence the overall kinetics. Hence the importance of making the mixing processes achieve the highest degree of perfection possible.It is clear that the kinetics and distribution play different roles in the liquid jet and the hot air atmosphere of the scene from a single fuel, a jet tens of times lower, which is thrown into a gaseous fuel mixes with hot air, and also in propagating a front of the flame combustion chamber between regions of the gaseous mixture warmed [18].

2.5 COMBUSTION REACTIONS

Combustion reactions are chemical reactions involving the complete oxidation of a fuel. Materials or Compounds are considered as industrial fuel oxidation can be done with sufficient energy to release industrial use. The main chemical elements that constitute a fuel are carbon, hydrogen and in some cases, Sulfur. These elements react with oxygen, and in its pure form have the following heat release[19]:

$C + O_2$---------- CO_2---- 393.5 kJ/kmol

$H_2 + ½\, O_2\ H_2O$ --------- 241.8 kJ/kmol

$S + O_2\ SO_2$ ---------------29.3 kJ/kmol

2.6 CHARACTERISTICS PAIR OF WORKING-CYLINDER PISTON AND, INDICATIONS, EFFECTS, EFFECTS, CAUSES THE PRESSURE AND TEMPERATURE WITHIN THE CYLINDER

The combustion takes place in a closed space defined by the shell wall, piston head, the head surface and the intake and exhaust valves. Its effectiveness depends on multiple factors that affect the performance of the engine as a whole.Knowing how the combustion process is developed is of great importance to correct possible problems, which can be done through the use of an indicator diagram or pressure indicator that describes the combustion curve and its deviations.

2.7. GRAPHIC PRESSURE INDICATOR IN THE COMBUSTION

The graphical display of pressure in the combustion figure 5, shows how the combustion is taking place within the cylinder. Good working conditions indicate that the pressure inside the combustion chamber continuously increases due to piston compression work. During the compression process, the temperature rises continuously and finally the fuel injected burns which may be indicated by a peak at exactly the moment of ignition, then the rich mixture will rapidly increase its volume (expansion process) delivering work to axis.

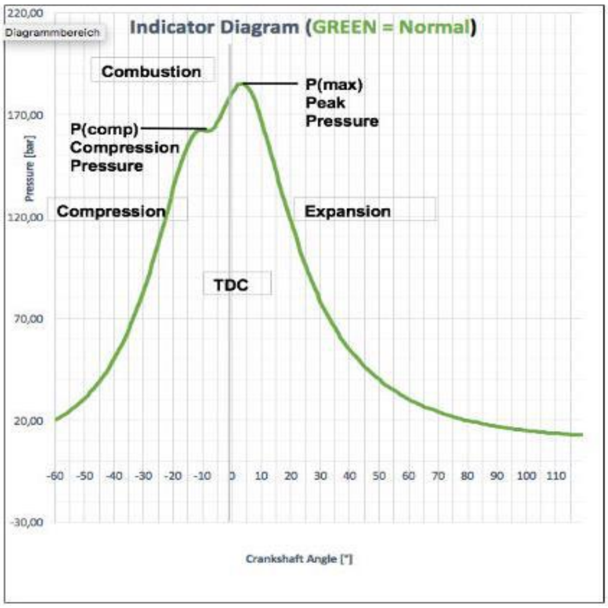

Fig.5: Combustion Pressure graph.

Source: [20].

Any deviation from the diagram shown to be given by the pressure deviations from previously obtained curve can cause irregularities in engine operation, such as:

- Higher fuel consumption;
- Higher temperatures of the exhaust gases;
- Increased wear of the components involved in the combustion process;
- Incomplete combustion with a higher carbon residue content that creates scale mainly in the piston crown, the exhaust valve and the turbocharger;
- The air supply may not be adequate and the combustion efficiency decreases.

2.7.1 DISTORTIONS IN GRAPHIC INDICATOR OF THE PRESSURE IN THE COMBUSTION

Possible causes of indicator chart distortions of combustion pressure:

- cylinder liner and / or worn piston rings
- Wear injection pump, which causes low injection pressures.
- Wear or the injection nozzle fouling.
- advanced injection or delayed due to poor regulation of the injection time.
- Decreased air supply to the cylinder.
- Ignition delay
- With the correct interpretation of the specific character of these deviations, possible failures or

faults can be located and eliminated in both the engine itself and in the auxiliary equipment.

- The data and the measurement of indicated diagram form must be continuously compared with the data of the "New Engine" or with the new motor parameters after a "general repair" and trends should be observed and analyzed.

During engine operation, always observe any pressure difference for the different engine cylinders, which can oscillate around 2.5% of the working pressure, all that must be observed and it is desirable to make measurements every three months before a repair, and with the engine running at 100% of its load (SECO GmbH. Quedlinburg. Germany).

2.8 DELAYED IGNITION

Indications:

- peak pressure down and after the injection start;
- High temperature of the exhaust gases;
- Combustion during expansion;
- black smoke in the exhaust gas;
- Sometimes a power loss.

Consequences:

- Increased fuel consumption;
- reduced service life of exhaust valves;
- reduced service life of the piston crowns;
- environmental contamination due to the high emission of particles.

Causes:

Supply of fuel, very slow due to contaminated gun.

- Check the gun

Fuel quality, poor.

- Check your fuel treatment, send a sample to a laboratory

Cylinder, very cold.

- Check and adjust the temperature in the piston jacket

fuel pump, incorrect timing adjustment

- Check and adjust accordingly as to advise engine manufacturers

combustion pressure, very low due to worn cylinder and / or piston rings

- Compare dimensions and clearances to wear limits indicated

combustion air supply, very low

- Measure the content of the remaining oxygen in the exhaust or inlet of the combustion air filter and compare this measure -against the condition "as new".

In figure 6, the pressure in the combustion graph of late ignition.

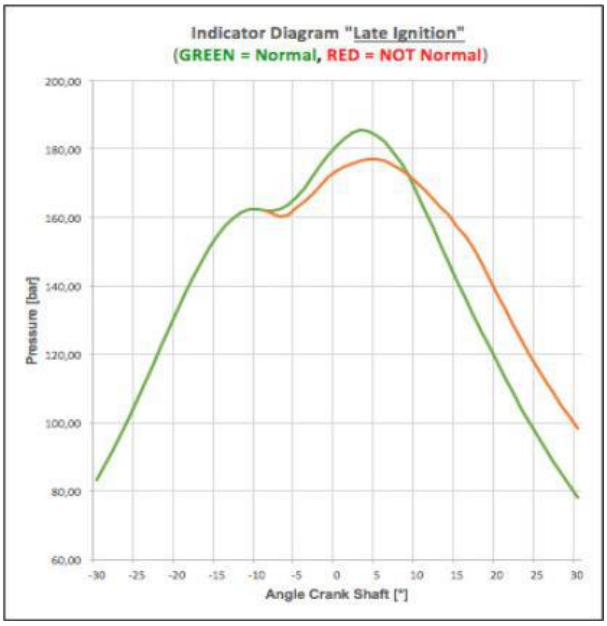

Fig.6: Graph Pressure in Combustion Ignition in late. Source: [20].

2. 9 GUN LEAKING

Indications:

- The maximum pressure is too low
- Pressure after the start of injection, oscillating during expansion
- Disturbance after combustion
- Increased fuel consumption
- High vibration levels in the fuel lines
- frequent noise

Consequences:

- Damage by vibration at the injection tubes
- reduced service life of the piston rings
- Increased fuel consumption

Causes:

Fuel injector leak

- Check the gun on the test bench, replace it if necessary.

Worn spray nozzle injection holes clogged or

- Check the nozzle on the test bench of the workshop and replace if necessary

In figure 7, the pressure in the combustion graph: Gun leaking.

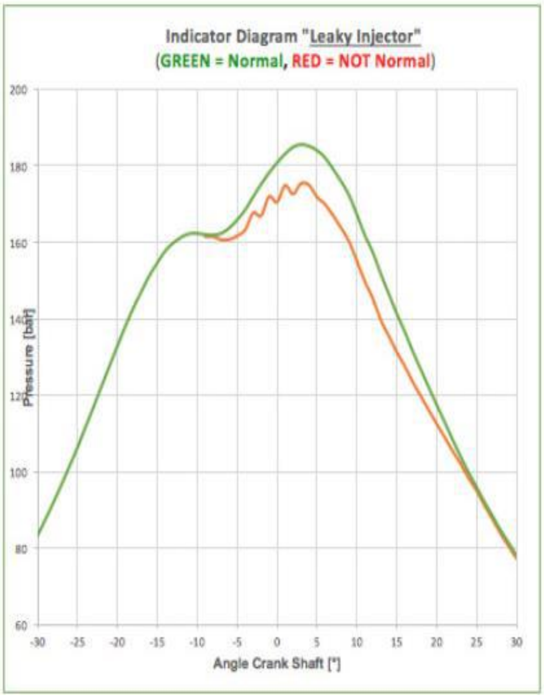

Fig.7: Graph Pressure in Combustion: Injector leaking.
Source: [20].

2.9.1 EARLY IGNITION

Indications:

- Peak very high pressure.
- Very low temperature of the exhaust gas.
- Reduces fuel consumption.
- Increasing NOx emissions.

Ignition in advance- Consequences:

- The parts inside the combustion chamber will be overheated.
- The life of the engine affected components will be reduced.
- The rate for heavy loads are transmitted to the bearings through the transmission.
- shock loads and vibration can result in engine damage.
- The exhaust temperature will be lower because the combustion starts earlier than expected.

Early ignition - Causes:

Incorrect adjustment or accidental change the fuel pump timing

- Check and adjust

Improper adjustment or fuel injector valve or damaged

- Check and adjust

Fuel with flammable components

- The quality of the fuel must be controlled by an independent laboratory (can be harmful components that are mixed with fuel for disposal of illegal waste)

In figure 8, the pressure in the combustion graph:. Early ignition.

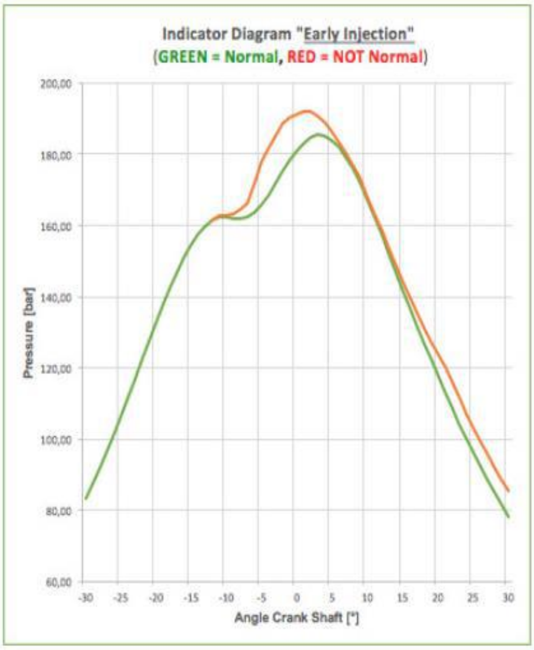

Fig.8: Pressure in Combustion Chart Early ignition. Source: [20].

2.9.2 PARTIALLY CLOGGED FUEL VALVE

Indications:

- maximum pressure, very low.
- exhaust gas temperature, too low.
- engine power loss due to the low fuel consumption.

Consequences:

- engine power loss.
- broken gun, caused by very high pressure at the nozzle tip.

Causes:

Fuel oil contamination and / or inadequate purification

- Check and adjust the tabs
- Check and replace the filters
- Perform a fuel oil analysis by an independent laboratory

Carbon formation on the injector tip

- Check and clean.
- Check the cooling efficiency

Carbon deposits in the fuel valve due to overheating

- Check the injector cooling

In figure 9, the pressure in the combustion graph:. Partially clogged fuel valve.

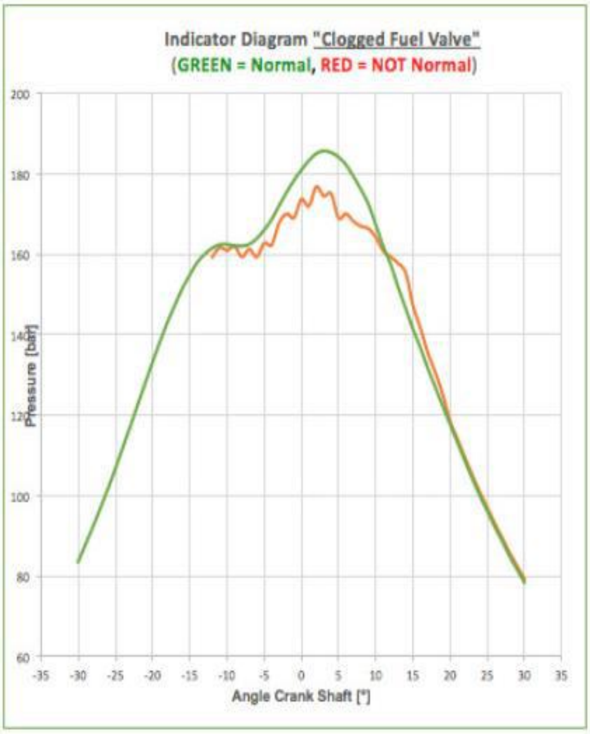

Fig.9: Graph of pressure in the combustion: fuel valve partially obstructed.
Source: [20].

2.9.2 AFTER COMBUSTION

Indications:

- exhaust gas temperature, too high.
- maximum pressure, very low.
- Pressure at the end of combustion, very high.
- Growth of exhaust emissions.
- Increased temperature in the cylinder liner.

Consequences:

- Increased emissions to the environment

Very high temperatures in the combustion chamber cause:

- Combustion additional lube oil
- Increased wear of the cylinder liner, the piston crown and piston rings.

Carbon deposits unburned cause:

- Failure of the exhaust system
- Damage to the exhaust valve seat valves

Causes:

Slow process of fuel combustion

- Run a Fuel Combustion Analysis.

Poor quality of fuel oil

- Perform a fuel oil analysis by an independent laboratory.

The temperature of the fuel oil is very low

- Check the final pre-heater and the viscosity controller through fuel analysis and measure the temperature.

In figure 10, the pressure in the combustion graph: After combustion.

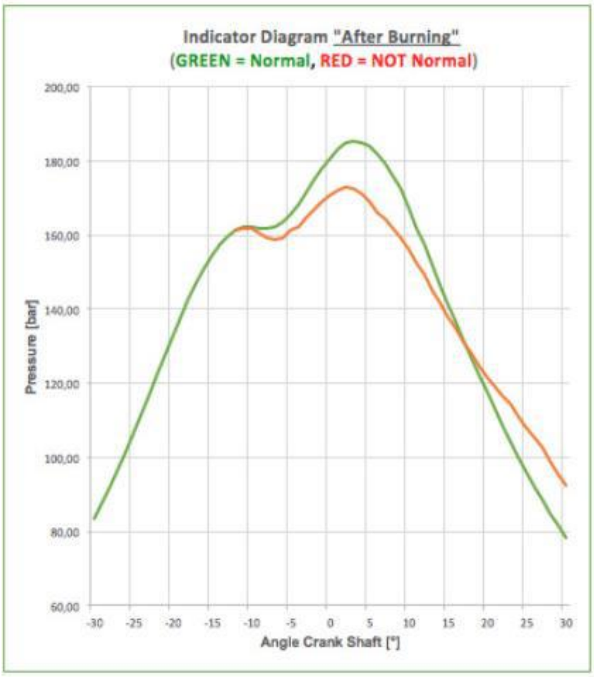

Fig.10: Graph Pressure in Combustion: after combustion. Source: [20].

2.9.3 LOW COMPRESSION

Indications:

- Compression pressure, very low.
- Peak pressure, very low.
- Engine power decreasing.

Consequences:

- Increased fuel oil consumption
- Engine power loss

Causes:

Inadequate combustion.

- Run a Fuel Combustion Analysis.

Very low combustion air supply

- Measure the content of the remaining oxygen in the exhaust gas or air velocity at the entrance of the combustion air filter and calculate the flow rate and compare with the "As-New" condition.
- Check the drop in air pressure of the cooler.
- Check the speed of the turbo compressor, if it is too high, clean the nozzles.

Air leaking between the liner and the piston rings

- Disassemble the cylinder head and piston. Check the dimensions of the piston rings and cylinder liner, checking that the wear limits exceeded the threshold value.

In figure 11, the pressure graph in combustion:. Low compression.

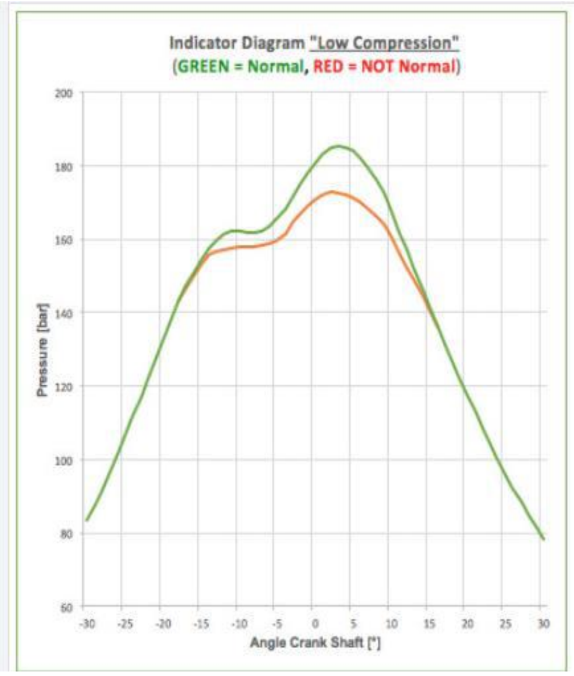

Fig.11: Pressure in Combustion Chart: Low compression. Source: [20].

The above information shows how important and significant indicators are diagrams of pressure inside the combustion chamber.

You can detect many faults that influence engine efficiency and life of their components and other systems.

By regularly performing this measurement or monitoring of cylinder pressure, the management of a thermal power plant has a powerful tool for reducing operational costs and plan maintenance work in advance.

2.10 PISTONS, TYPICAL CONSEQUENCES AND DAMAGE

The piston engine component is a sometido to greater stresses during operation of the engine, it has built to withstand the increased stresses resulting from high injection pressures and aggressive compounds of heavy fuel oil (HFO).

With the passage of time, the piston construction technology aims to:

To ensure sufficient fatigue resistance and withstand the static, dynamic and thermal loads which generate large stresses during operation.

The design must be considered to ensure its operation in up to 1800 0C environments. Drawing that is sufficiently precise to ensure airtightness of the combustion chamber exposed to high injection pressures also to ensure that the lubricating oil penetration in the chamber does not occur.

To guarantee this, together with the piston compression rings, lubrication and sealing gasket between the cylinder head and they are also involved.

On the other hand, the pistons must be designed and constructed to maintain stability under the action of aggressive compounds in the fuel.

With the correct interpretation of the specific character of each of the deviations from design parameters, it is possible to prevent failure or malfunction of the motor itself or ancillary facilities.

One of the most common causes of premature wear on the piston, piston ring grooves and other engine components is caused by an insufficient fuel treatment for some reason, not always known.

Unfortunately, in many power plants, does not seem to be true, the attention given directly to the engine is the same, which lends itself to the characteristics of the fuel supplied and their treatment.

2.10.1 TYPICAL DAMAGE DUE TO INSUFFICIENT TREATMENT OF FUEL:

- The crown of the piston due to burning fuel burn on the surface of the piston crown;
- Piston rings are breaking because the residues are blocking free movement of the ring groove;
- The heat transfer from the piston crown is disturbed due to oil residues added cracks on the internal surface of cooling the piston crown.

From the operating experience of the engines, it was possible to prove that one of the most common causes of premature wear on the piston and hence the grooves of the pistons (and other engine components, of course) are insufficient treatment of the fuel.

2.10.2 CONSEQUENCES OF INSUFFICIENT FUEL TREATMENT

As mentioned above, insufficient fuel treatment, of course, not only damages the piston crown, but also affects the fuel injectors. Some of the holes in the injector nozzle will be blocked and as the fuel flow is constant, the result is a faster rate of fuel through the holes of the nozzles that are not blocked. When this happens, the injected fuel is fast reaching the surface of the piston crown creating hot spots with continuous overheating of the piston crown surface.

In these conditions the piston crown warming is strongly disturbed the cooling oil in the piston crown of the cooling chamber, cannot fulfill its function of keeping the temperature recommended values and can reach values up to 1800 0C as previously mentioned.

All this means that these elements are subjected to harsh conditions because they are subject to high working temperatures and pressures, in addition to this friction tribological pair. The system also comprises lubricating rings and two compression rings, the sealing ring between the head and the upper part of the cylinder and the intake and exhaust valves. The sealing ring is responsible for ensuring tightness between the cylinder head and being subjected to high temperature and pressure occupying the position in the system.

The situation described above has been confirmed during operation of the engine in TPP.

One of the key objectives in research and search for solutions in large motors installed in power generation plants to keep the thermal efficiency levels at the highest possible levels, for which constantly monitor you need your order to detect in good time any deviation of their nominal operating parameters, as well as thermal efficiency, reduces maintenance costs while working on the basis of a predictive maintenance system.

One of the parameters that may be affected during operation of the engine and its rate compression.Any one of the directions, causes and consequences mentioned above has a negative influence on the compression ratio and therefore in thermal performance engine.O engine efficiency diesel can be calculated by equation (2.2).

$$\eta = \frac{Pot}{Q_a} \qquad (2.2)$$

Heat absorbed, equation 2.3.

$$Q_a = M_c VCI \qquad (2.3)$$

At where:

Pot - machine power
Q_a- Absorb Heat
Mc- Fuel Mass
VCI - Net calorific value of fuel

Derived from the general equation, yields a more detailed view equation for the influence on the compression ratioγ_k in the engine thermal efficiency. compression ratio is calculated as in equation (2.4):

$$\gamma_k = \frac{V_1}{V_2} \qquad (2.4)$$

And the isobaric expansion rate (combustion process)γ_c, Admission closing rate.

After several mathematical and thermodynamic transformations, we obtain an equation of the thermal efficiency of the diesel engine as follows (equivalent air motor diesel), equation (2.5).

$$\eta_t = 1 - \frac{1}{\gamma_k^{k-1}}\left[\frac{\gamma_c^k - 1}{k(\gamma_c - 1)}\right] \qquad (2.5)$$

For the same compression ratio, the gasoline engine would have a higher thermal efficiency than diesel, but such a situation will never occur in practice, since in the case of the diesel engine is compressed air only and autoignition never happen before reaching the point top dead center of the piston, but the gas is compressed a mixture of air-fuel and the possibility of autoignition always be present. In the above, it is shown that as the ratio of isobaric expansion increases the factor in brackets does this and the efficiency decreases. So lower rates of fuel inlet closure theoretically lead to higher efficiency but a higher value of the indexes results in higher power. [15]

III. CASE STUDY

3.1 MONITORING THE PRESSURE OF COMBUSTION PRESSURE AND TEMPERATURE OF THE COOLING WATER

For engine generators, planning of maintenance activities is done according to the established, as verified at the plant and not according to the actual characteristics presented by the engines. The once exposed is valid during the technical warranty period for an installation, however when the generators engine generators have a running time that exceeds the technical warranty period, then maintenance activities must be performed in accordance with the diagnosis that would have be done during the operation, and depending on the actual technical condition, adjust the length of time between maintenance activities, this is not done and at the end of the maintenance activities become fundamentally in a period in which engine parts and systems are exchanged without further analysis than defined by provider.

The permanent monitoring of the combustion pressure and the pressure and temperature of the cooling water are diagnostic parameters to reverse the situation that sometimes it has been presented with the plants in the cylinder piston and cylinder head system.

The monitoring system based on conditions is able to identify potential problems and development failures while the engine is in service. This engine monitoring

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system is the cornerstone of predictive maintenance and complements the scheduled maintenance programs, allowing longer intervals between overhauls. The system helps reduce damage, unnecessary maintenance activity and therefore helps to minimize the cost of any repair.

The monitoring system is a continuous measuring instrument that monitors the status, health and efficiency of a combustion engine. The system should be designed to recognize the functional deviations in engine operation in order to measure their mechanical and thermal state.

The monitoring also reduces the amount of fuel consumption due to monitoring of engine efficiency, which also extends the life of the installation.

3.1.1 SOME BENEFITS OF THIS MONITORING SYSTEM:

- Early detection prevents damage and the consequences.
- The monitoring increases the reliability of the mechanism.
- Keeping engine efficiency within the set values, which contributes to lower fuel consumption for the same power
- Maintenance based on engine performance instead of hours of operation.
- Extends the life of a monitored engine.
- Reduce downtime

In order to corroborate the feasibility of using monitoring software in the field level, it has been tested in a real engine in the laboratory level.

Engine features:

- bike generator 150 kW;
- Engine: 6-cylinder in-line;
- Fuel: Diesel;
- Generator: Three-phase.

To make measurements in the actual engine in laboratory level from the use of the corresponding sensor and software that will monitor the combustion pressure, temperature and pressure of the cooling water, the aforementioned cylinder head was removed and a hole was made by the front of the inwardly head head located in the space between the intake and exhaust valves housed in the engine block. In the figures (12, 13 and 14), it is possible to appreciate the location where the hole was made as well as the communication pipe between the inside and the outside of the cylinder where the pressure sensor is connected.

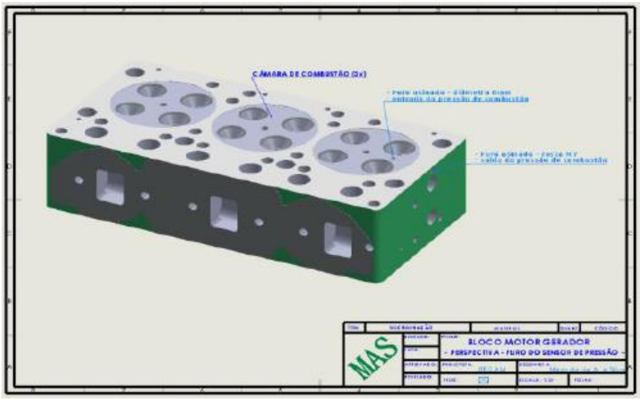

Fig.12: Engine head.
Source: Authors, (2018).

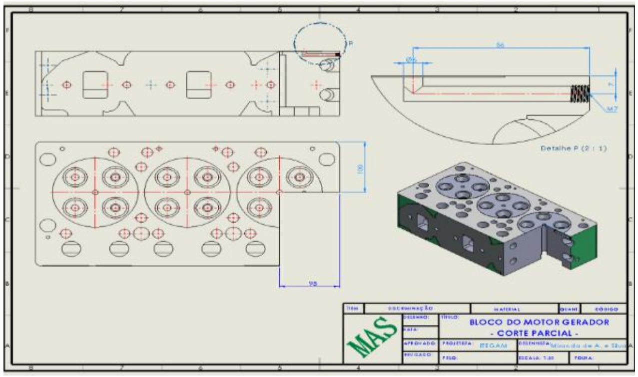

Fig.13: Engine head.
Source: Authors, (2018).

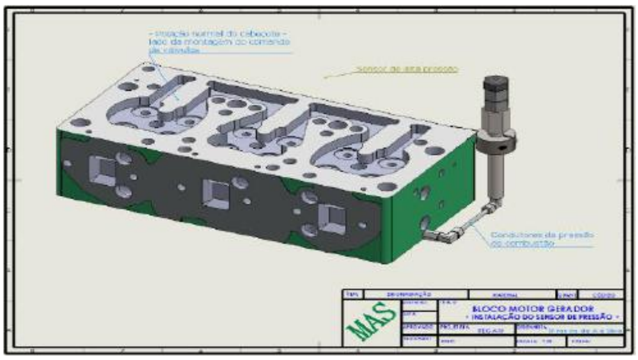

Fig.14: engine head.
Source: Authors, (2018).

3.1.2 RESULTS OF THE MEASUREMENTS

The software developed for the monitoring screen of the three quantities: the combustion pressure, pressure and cooling water temperature, is shown in figure 15, figure 16 and figure 17.

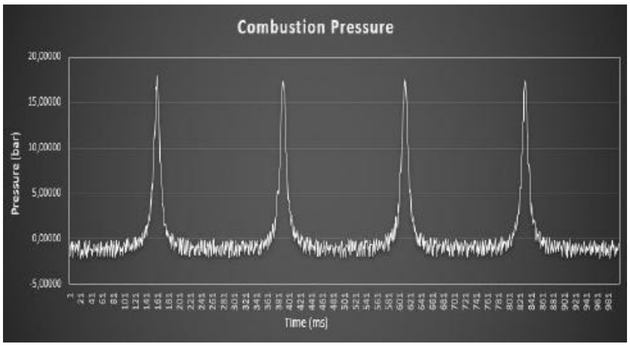

Fig.10 - Figure 15: Pressure in the combustion engine in the actual laboratory.
Source: [21].

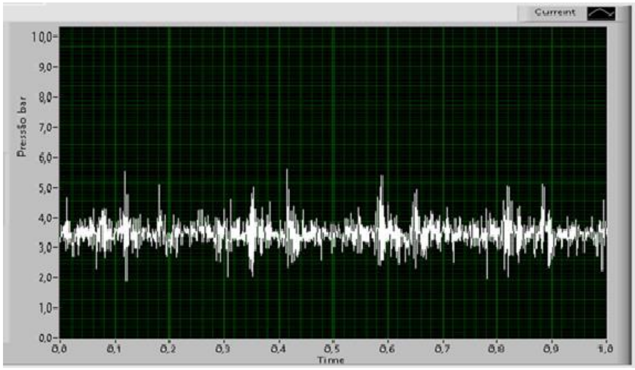

Fig.16: Cooling Water Pressure
Source:[21].

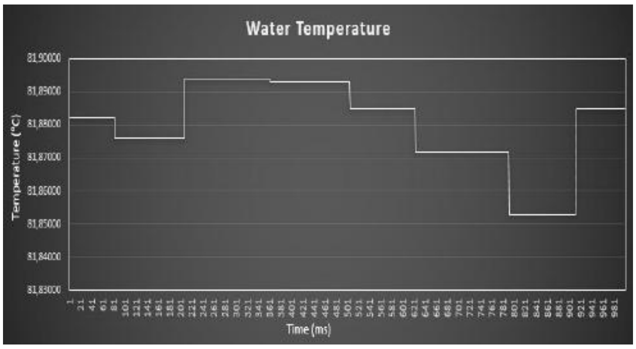

Fig.17: cooling water temperature.
Source:[21].

IV. CONCLUSIONS

The monitoring system in real time allowed to know the deviations of the measured parameters, with the possibility of taking the measures required by the operator, if necessary. Both a very high combustion pressure in addition to the nominal values and low values is an indication of malfunction of the cylinder and is a clear indication of possible causes that can cause major damage to the piston-cylinder system and its sealing accessories.

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