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Impact of Emission Control Systems for Heavy Equipment and Power Plants on Global Warming

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Abstract

The article outlines the study on emission control systems from various diesel engines. The study was carried out for the heavy equipment and power plants operations to meet the environmental regulations. The purpose of this paper is to examine various emission control systems, how it operate at low emission level and their malfunctions. As the world strive for global warming regulations, there is a need to consider various emission control systems operating at low emission level to minimize the problems of the environment hazards. Internal combustion engines are characterized for producing exhaust emissions, mainly used in industries, transportation, power production and machinery.

CAT Caterpillar ET 2019C Diagnostic Electronic Tool was used on heavy equipment and Perkins EST 2018A v1.0 Diagnostic Tool used on the power generating plants to detect various faults on emission control systems. Most of the emission produce were from the defective emission control systems thus fuel injection pump, fuel injectors, induction and exhaust manifolds design, positive crankcase ventilating systems, turbocharger and catalytic convertors. The Study was conducted in Mali-Tombouctou Region within UN Mission area and to examine various types of heavy equipment and different capacity of power plants emission control systems, under Ghana Engineer Company serving and providing engineer support for the Mission.

The study recommend that the replacement of component or system used for repair be genuine service part to maintain the quality for emission control systems. All emission control system parts must be scheduled for regular inspections. Any part that fails under operation need to be replaced or repaired to reduce emission. Owners and operators normally don't comply with and report emission issues. The study adds to the existing knowledge of emission control in our environment to reduce associated environmental health issues and global warning.

Keywords: Emission Control System, Exhaust Emission, Environment, Internal Combustion Engines.

1. Introduction

Emission levels are growing high in the world and industries are finding ways to reduce it level to curtail pollutions released into the atmosphere. Considering climate change and greenhouse

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gas effects, the impact of various emission control systems such as fuel injection pump, fuel injectors, induction and exhaust manifolds design, positive crankcase ventilating systems, turbocharger and catalytic convertors were examined to consider the effects of exhaust emission produced. The focus was on improving the operational performance of heavy duty equipment and power generation plants emission control systems. Enhancing efficient combustion during operation and better performance of the various emission control systems to help reduce emission. Defective or faulty emission control systems will result in excessive fuel consumption and high exhaust emission that pose common problems to most internal combustion engines.
Emission control system helps reduce related toxic gasses like Carbon Monoxide (CO), Hydrocarbon (HC), Nitrous Oxide and Diesel Particular Matters (DPM). The main sources of emissions are from Injection Pump, Crankcase (blow-by vapour) and engine exhaust. Hydrocarbons are evaporated from the injection pumps working under high temperature and unburned hydrocarbons thus (blow-by vapour) in the crankcase. Exhaust from the engine contains unburned and burned hydrocarbons, carbon monoxide, nitrogen oxide and diesel particulars matters. Electronic controlled fuel injection systems provides more accurate air-fuel mixture, resulting in efficiency operations and reduce emissions. Most emission control systems are subjected to the effect of clogging.

Combustion & Emission of a diesel engine utilizing intake manifold designs (Bassians & Khraisheh, 2019).Importance of fuel injection System for low emission combustion noise and low fuel consumption (Petrea & Bujoreanu 2022). Emission control system, different types and how they work. (Saraswat, 2021). The use of Acoustic Emission to diagnosis of fuel injection pump of marine diesel engines (Beigen & Drzewieniecki, 2019).ASE PS2 Test Preparation Guide Emission Control Systems (Carley, 2010).

2. Materials and Methods

The study was conducted in Tombouctou Region of Northern Mali in UN (MINUSMA) operations and it was necessary due to the operational conditions of the heavy equipment and power plants in the terrain and issues of emission control to maintain environmental safety. Various heavy equipment such D7 Dozer, D6 Dozer, Roller, Backhoe, Wheel Loader, Skid Steer, Motor Graders (140K), Forklift, Mobile Crane, Excavators and Perkins power plants (400KVA, 250KVA, 160KVA, 8OKVA and 30KVA) were used in the study. Emission control systems on both heavy equipment and power generating plants were examined to check their efficiency to reduce exhaust emission into the atmosphere.

CAT Caterpillar ET 2019C Diagnostic Electronic and Perkins EST 2018A v1.0 Diagnostic Tools were used respectively on heavy equipment and power plants to detect various faults on emission control systems. Most of the exhaust emissions produce were from defective emission control systems, high Sulphur fuel (diluted fuel) etc.

The study involves the operational difficulties and problems the emission control systems encounters on the heavy equipment and power plants during operation. The study is to determine

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the associated problems with emission control systems on heavy equipment and power plants to maintain these systems to reduce harmful gases into the environment.

3. Results and Discussion

Various Emission Control Systems

3.1. Fuel Injection Pump

Fuel injection pump is an emission control system, its malfunction and fuel leakages from the pump may result in excessive fuel consumption to produce high exhaust emission. The effect of fuel injection pump pressure leads to produce exhaust emission for internal combustion engines. Efficient fuel injection pump pressure system is necessary during operation to reduce exhaust gas emission. Fuel injection pressure determines the injection of atomize fuel spray and combustion quality. Maintaining prolong use of fuel injection pump also leads to decrease pump performance and poor combustion.

Exhaust emissions occurs due to the performance change of fuel injection pump pressure that result in incomplete combustion. At high engine speed, fuel injection pump pressure increases and the higher presence of CO (Carbon- Monoxide) indicates the presence of an incomplete combustion. At low injection pressure HC (Hydrocarbon) emission are produce during incomplete combustion. Fuel injection pump mal-function timings can result in a delay of ignition for quality combustion leading to produce NOx emissions. The setting of engine default injection pump pressure, as engine speed increases the exhaust emission CO_2 becomes higher, that leads to efficient combustion process.

The deteriorating working condition of fuel injection pump can lead to the impact of exhaust emissions from the engine. The performance and reliability of the engine in emission reduction depends on efficient fuel injection pump. The degradation of fuel injection pump causes the reduction in its performance due to internal wear, fouling and mechanical problems. Changes in excessive fuel temperature, different use of fuel grades and the use of residual or distilled fuel are attributes to injection pump system emissions. Fuel injection efficient performance minimizes emissions and influence fuel economy.

Table 1. Shows the results of problems on fuel injection pumps, analysed using *(*CAT ET 2019C/ Perkins EST 2018A) on various heavy equipment and Perkins power plants. Types of fuel injection pump used are Common Rail Pump, Inline Pump and Distribution pump type.

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Table 1.Fuel Injection Pump - Diagnostic Troubleshooting *(*CAT ET 2019C/ Perkins EST 2018A)

SYMPTIONS	REASONS
Engine Stalling (Start & Dies)	Injection Pump needs servicing, Water in fuel, Restricted fuel flow, Air lock (Suction of air into fuel system)
Exhaust Emission while cranking	Pump ignition timings incorrect, Cranking speed low, Fuel with high Sulfur, Restricted fuel supply
Lack of fuel delivery to injector	No electric power supply to solenoid, Pump linkage in stop position, Insufficient fuel supply, Pump metering valve stick
White & Blue Exhaust Emission	Low fuel supply due to pump pressure, Injection pump worn, Low compression, Retarded injection pump timing
Black Exhaust Emission	Poor fuel quality, Excessive load on engine, Injection pump timings incorrect, Defective turbocharger
Fuel Knock	Injection pump timings incorrect, Injectors worn
Low fuel pressure	Clogged fuel filter, Weak pump
Lack of electric power	Defective relay, Damage wiring harness to pump

Source: Field data, June 2022

3.2. Fuel Injector

Fuel Injector is an electromechanical device, as electrical and mechanical faults may cause injectors to malfunction and result in exhaust emissions. Mechanical issues are internal O-ring failure and contamination, carbon deposit and fuel contamination restrict the flow of fuel. This restriction affects the injection spray pattern leading to poor atomization for incomplete combustion resulting in high emissions. Electrical failure may result from the ECU that controls the injectors for the entire duration of its operations (pulse of opening & closing). Current reduction flow or short–circuit will affect the injectors resulting in malfunction, affecting the combustion to produce high emission.

Deposit or clog on the injectors are due to low quality fuel or lack of regular maintenance, that may cause speed fluctuation or unsteady during idling, resulting in incomplete combustion for exhaust emission. Defective injectors can cause engine vibration and stuttering as a result of incomplete combustion due to lack of atomize fuel from injector and insufficient air. Injectors malfunction can increase and burn fuel consumption leading to excessive exhaust emission. All these unburn composition of fuel elements results in increase harmful emissions. As some fuel are not combustible (burnt off), harmful emissions are expelled to the exhaust system. Essential fuel injector's maintenance is required and imbalance fuel flow to each injectors can results in high exhaust emission.

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Table 2. Shows the results of problems on fuel injectors, analysed using *(*CAT ET 2019C/ Perkins EST 2018A) on various heavy equipment and Perkins power plants. Types of fuel injectors used are Direct Induction, Indirect Induction and Piezo type

Table 2.Fuel Injector - Diagnostic Troubleshooting (CAT ET 2019C/ Perkins EST 2018A)

SYMPTIONS	REASONS
Engine Misfires	Defective Injectors, Lack of fuel, Defective heater plugs
Exhaust Emission	Carbon deposit on injectors, Clogged fuel filter
Increase fuel consumption	Faulty Injectors
Difficult in starting	Defective Injectors
Engine Surges	Clogged Fuel Injectors
Injectors not working	Defective Injectors
Fuel smell and leakage	Fuel leaking from injectors, Faulty injection

Source: Field data, June 2022

3.3. Intake Manifold

Intake manifold is designed to evenly distribute sufficient air /fuel mixture or air into the cylinder. The designed of the intake manifold enables the better performance of engines to reduce exhaust emission. Configuration of inlet manifold with buttress thread has better air-fuel mixing process and enhance thermal efficiency for increase engine performance as exhaust emission are reduced. The intake manifold designed has the effect of steady and unsteady states of the air flow motion for turbulence in the cylinder. Most problems are due to the design of intake ports as uneven distribution of air or air-fuel mixture into the cylinder may cause high fuel consumption, engine power loss and lower compression efficiency. Intake manifold that doesn't produce swirl leads to poor air-fuel mixture for incomplete combustions of unburn carbons that produce exhaust emissions.

Intake manifold design enhance the turbulence of the air-fuel mixture into the cylinder to reduce emission and increase the performance of emission control systems. Turbulence is enhance by changing the design or geometry of the intake manifold. Much attention has not been given to new and efficient design for intake manifold for heavy equipment and power generators, as the only focus is on the vehicles. Intake manifold design increase the swirl of air/fuel mixture for better efficiency of combustion and it controls the combustion process, as the main duct through which air passes into the cylinder. The efficiency of the engine is attain through maximum compression ratio in the cylinder due to enhance induction manifold.

Table 3. Shows the results of problems on induction manifold analysed using *(*CAT ET 2019C/ Perkins EST 2018A) on various heavy equipment and Perkins power plants. Types of Intake manifold used are Dual Plane Manifold, Tunnel Rams and Single Plane Intake Manifold

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Table 3. Intake manifold - *Diagnostic Troubleshooting (*CAT ET 2019C/ Perkins EST 2018A)

SYMPTIONS	REASONS
Engine Misfires	Cracked Manifold, Air or Coolant leak into manifold
Difficult Idle	Insufficient air/fuel mixture, cracked manifold
Loss in engine efficiency	Milky engine oil in the manifold, cracked manifold
Engine overheating	Cracked manifold allowed leakage of coolant
White exhaust emission	Coolant leaks into manifold
Engine stalling	Defective intake manifold gasket, Vacuum leak
Defective intake manifold gasket	Oil leak, Vacuum leak, Coolant leaks

Source: Field data, July 2022

3.4. Exhaust Manifold

Exhaust manifold designed depends on the power consumption and emissions produce by internal combustion engines. Exhaust emission produce put load on the engine that leads to increase fuel consumption. The design of exhaust manifold helps to reduce emissions, allows few resistance of the emission and the exhaust gas back-pressure affect the engine performance at a minimum level. There is a need to reduce the back pressure of most engines. The type of designed in the exhaust manifold helps to reduce exhaust emissions as the Y – designed exhaust manifold also aids to improve engine operations.

As we have different designed of engine size and type that have different exhaust manifold designed. However due to different engines, various exhaust manifold have varied flow resistance where the effect of the exhaust back pressure affect engine operational performance. Engine with more exhaust emissions has lower performance efficiency. The better flow resistance of the exhaust emission may reduce the impact of exhaust back pressure which affect the engine performance for excessive fuel consumptions that may results in more emissions.

Table 4. Shows the results of problems on exhaust manifold analysed using *(*CAT ET 2019C/ Perkins EST 2018A) on various heavy equipment and Perkins power plants. Types of Exhaust manifold used are Cast Exhaust Manifold, Tubular Manifold and Four-In-One Exhaust Manifold.

Table 4. Exhaust manifold - Diagnostic Troubleshooting *(*CAT ET 2019C/ Perkins EST 2018A)

SYMPTIONS	REASONS
Exhaust Leaks Smell	Leak exhaust gasket, Cracked exhaust manifold, Broken bolts and studs, Noisy engine
Exhaust Manifold Visible Damage	Leakage at exhaust manifold joint, Black exhaust emission
Cracked Exhaust Manifold	Burning exhaust odor, Hissing and Tapping engine noise, Poor acceleration
Clogged Exhaust Manifold	Restricted catalytic convertor, bad fuel quality, Exhaust leaks

Source: Field data, August 2022

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3.5. Positive Crankcase Ventilation (PCV)

Positive Crankcase Ventilation is a system design to control emission caused by blow-by in the crankcase. The PCV system channel water vapour, oil vapour and direct them back to the intake manifold to support combustion as they are burn efficiently. Sometimes oil vapour can result in incomplete combustion. The signs of oily injectors, black smoke, increased oil consumption and misfiring are some signs of poor PCV system valve. The valve gets clogged up, if the valve not able to draw blow-by vapour from the crankcase, this build up pressure damage the seals.

Worn and over age engines has more blow-by vapour in the crankcase as a result of worn cylinders and pistons rings that allowed gases of hydrocarbon (HC) emission into the crankcase. PCV system valve maintains differences in vacuum level in the engine crankcase. Defective PCV valve leads to sludge formation in the crankcase as blow-by pressure forces seals out and oil past gasket. The valve allows loss air flow to cause the air/fuel mixture into rich mixture resulting in increased fuel consumption and emissions. When the PCV valve stack open much air flows into the intake manifold that causes lean mixture , resulting in misfires, hard starting and leading to increase emissions.

During idle engine run, lose or leak hose of PCV system causes adequate air to enter the manifold as these affect the fuel mixture. The blow-by consist of moisture, combustion by-products and unburned hydrocarbons. The PCV system direct the blow-by to be burned with the fuel – air mixture and it is illegal to remove or temper with PCV system to allow emission into the atmosphere which is against EPA regulations. Many operators and owners do forget to check or replace PCV system valve within the operational interval for wear or clog. We must consider the effect if technicians fix wrong PCV valve on the system during repair works, wrong valve results in much air flow. Considering its importance, note not to replace with cheap PCV valve. PCV helps reduce hydrocarbons emissions into the atmosphere for heavy equipment and power plants operation to meet emission standard.

Table 5. Shows the results of problems on Positive Crankcase Ventilation analysed using *(*CAT ET 2019C/ Perkins EST 2018A) on various heavy equipment and Perkins power plants. Types of Positive Crankcase Ventilation used are Close Crankcase and Open Crankcase Ventilation systems.

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Table 5.Positive Crankcase Ventilation- Diagnostic Troubleshooting *(*CAT ET 2019C/ Perkins EST 2018A)

SYMPTIONS	REASONS
Defective PCV Valve	White exhaust emission, Suction on oil cap, Noise from the engine, Residue underside of oil cap
PCV not working properly	Increase oil consumption, Oil leakage from seal and gaskets, Oil inside air filter, Engine stalling
Broken PCV Valve	Noise from the engine, Engine misfires while idling, Rough idle or run, Vacuum leaks
PCV Valve Blockage	Pinched hose, Sludge formation build up, Oil consumption and deposits, Poor fuel economy, Smoke from exhaust emission

Source: Field data, September 2022

3.6. Turbocharger

Turbocharger is an emission control system driven by exhaust gases, it increases more air into the intake manifold as more fuel is needed to get more power. This helps to burn air/fuel mixture efficiently and improve power to weight ratio for heavy equipment and power plants operations. Turbocharger fails to create high intake pressure at low speed. At high speed the excessive pressure may choke the engine with high exhaust manifold pressure.

Turbocharger improves the engine performance as the system increase power density, efficiency and emission reduction. There is an issues with fixing turbocharger to match the engine system for better efficiency. Technicians must know matching of turbocharger to an engine to help in the turbine efficiency. Better efficiency combustion requires air/fuel mixture that are sometimes difficult to handle by emission control devices, as reducing fuel consumption and emissions at the same time as one may affect the other. Turbine and compressor operation must match low torque, maximum torque and maximum power of the engine. The turbocharger need to have a higher efficiency during high pressure and low speed. Most engine performance and reduction in emission are due to optimize turbocharger to match the required or appropriate internal combustion engine system.

Table 6. Shows the results of problems on turbocharger analysed using *(*CAT ET 2019C/ Perkins EST 2018A) on various heavy equipment and Perkins power plants. Types of Turbocharger used are Single turbo, Twin-Scroll Turbo and Variable Twin-Scroll Turbo.

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Table 6.Turbocharger - Diagnostic Troubleshooting *(*CAT ET 2019C/ Perkins EST 2018A)

SYMPTIONS	REASONS
Defective Turbocharger	Lack of oil for lubrication, Deposits of particles
Turbocharger Failure	Loses of engine efficiency, Wear and tear for prolong use, Oil leakage into turbocharger
Blown Turbocharger	Loss of power, Whining noise in engine, Exhaust Emission Smoke, Leakage of oil into exhaust emission
Leak Turbocharger	Defective gasket, Loses fastener bolts
Turbocharger bearing seize and sludge	Lack of lubrication oil, Dirty engine oil, Clogged oil filter
Turbocharger oil drain line restricted	Damage compressor and turbine seal
Damaged Turbocharger	Turbocharger noisy, Lack engine power

Source: Field data, October 2022

3.7. Catalytic Convertor

Catalytic Convertor is an emission control system that contains ceramic pellets or honeycomb, coated with Platinum (Pt), Palladium (Pd) and Rhodium (Rh) as this helps in oxidation of the exhaust gases. These act as a catalysts that induce nitrogen oxide, hydrocarbons into water vapour, nitrogen and carbon dioxide. Convertor performs efficiently under heat and while under cold temperature it can't work efficiently to control exhaust emission to prevent the release of harmful gases into the environment. Catalytic converter can be defective by overheating while engine is burning oil and misfiring. This leads to partially or completely blockage of the converter in the exhaust system. The oxidation catalytic converter uses the oxygen in the exhaust to convert CO (Carbon Monoxide) to CO_2 (Carbon Dioxide) and Hydrocarbon (HC) into water (H_20) and CO_2. Presence of Nitrogen Oxide are reduce by the use of NOx absorber or trap and Selective Catalytic Converter in the system.

Table 7. Shows the results of problems on catalytic convertor analysed using *(*CAT ET 2019C/ Perkins EST 2018A) on various heavy equipment and Perkins power plants. Types of Catalytic Convertor used are Oxidation Catalytic Converter and Three - Way (Oxidation reduction) Catalytic converter

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Table 7.Catalytic Convertor - Diagnostic Troubleshooting *(*CAT ET 2019C/ Perkins EST 2018A)

SYMPTIONS	REASONS
Clogged Catalytic Converter	Smell of rotten eggs and Sulfur, Difficult to start, Engine stalling, Poor acceleration.
Inferior Catalytic Convertor	Not designed to meet the size and capacity specification of the exhaust system, High exhaust emission
Convertor Leakage	Rusted converter due to prolong use, Smell of Sulfur like rotten eggs, Loss of engine power
Broken Converter	Structure striking the converter, Engine efficiency reduced
Contaminated Convertor	Leakage of oil and coolant from engine into exhaust system, faulty head gasket
Failed Catalytic Converter	Excessive rich mixture condition, Rise temperature of catalytic converter
Catalytic system low efficiency operation	Excessive exhaust emission smell, Residual harmful pollutants, Low engine power

Source: Field data, November 2022

Emission Control Systems Pollutant Products

Emission control systems produce pollutant such as Hydrocarbon (HC), Carbon Monoxide (CO), Nitrogen Oxides (NOx) and Particulate Matters (PM) on the internal combustion engines during operations.

Hydrocarbon (HC)

Hydrocarbon emissions are produce due to unburned fuel because of low temperature. Hydrocarbon emission from diesel fuel occurs at light engine load (Lean air/fuel mixture and the concentration of fuel type and engine adjustment during operation produce hydrocarbon. High level of engine speed, excessive nozzle cavity volume, injection needle bounce and untidy injections causes unburned fuel to pass into the exhaust (Payri et al. 2009). Hydrocarbon emission have the effect on the environment and human health, as the toxic produce causes cancer and respiratory tract irritation.

Carbon Monoxide (CO)

Carbon Monoxide (CO) is produce during incomplete combustion due to poor oxidation process. This normally occurred during starting or instantaneous acceleration of diesel engine as carbon content cannot be converted to CO_2 as a result of rich mixture and lean air for combustion. When carbon monoxide is inhaled by human (lungs),it is transmitted into the bloodstream as it affect haemoglobin to transfer oxygen that result in asphyxiation affecting different organs functions.

Nitrogen Oxides (NOx)

Nitrogen Oxides (NOx) is emission produce and is formed as a result of the oxygen concentration in the air/fuel mixture and temperature during combustion. Nitrogen Oxides (NOx)

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contribute to acidification, nutrient enrichment, ozone and smog formation which have become problems in most major cities worldwide (Grewe et al. 2012). Nitrogen Oxides (NOx) is considered as toxic that causes respiratory infections and lungs disease. The environmental effects are acid rain that affect the aquatic ecosystem.

Particulate Matters (PM)

Particulate matter emissions are produce from combustion process of small particles in the exhaust as a result of incomplete combustion thus unburned fuel, cylinder lube oil and water in the air/fuel mixture. Particulate matter emissions is dependent on combustion and expansion process, lubrication oil quality and fuel quality (Sulfur and ash content)combustion temperature, consumption and exhaust gas cooling (Burtscher 2005). Diesel particulate matters emissions are soot, Soluble Organic Fraction (SOF) and Inorganic Fraction (IF), this not only after the environment but when inhaled it causes lungs cancer, cardiovascular issues, asthma that may result in death.

Recommendations

Emission Control Systems are mandatory components on internal combustion engines in reducing exhaust emissions. It is therefore recommendation that engine warranty for a period of 2 years from manufacturer are not enough as owner and operator don't comply with and report emission issues. Any emission control system that fails under operation need to be replaced or service to reduce emission. All emission control system parts must be scheduled for regular inspections and maintenance. Recommended to avoid the use of old and defective emission control parts that may results in excessive emissions. Adherence to the quality of fuel used, as high sulfur fuel (diluted or contaminated fuel) leads to excessive exhaust smoke, as internal combustion engines under emission control are designed to operate with low Sulfur fuel. Clean gasoline thus clean + P80 and diesel clean + P60 are concentrated detergents used in the fuel system to improve the efficiency of the injectors.

Experience technician needs to install genuine service parts for emission control systems as tampering and alteration of systems and components parts by unqualified technician may result in the damage of other components causing more emissions. Replacement of component or system maintains the quality operation of emission control systems. Recommended that the over age internal combustion engines needs to be replaced. Manufacturer and dealers must ensure warranty for emission control systems parts sold out with advice to technicians and operators.

Conclusion

Emission Control Systems reduces the level of hazardous gases that affect human health and also into the atmosphere for the risk of global warming. The aim of the impact of emission control system on heavy equipment and power plants was to examine how efficient these systems operate to reduce emissions into the environment by creating public awareness.

Emission control systems problems are aging of the equipment and plant causing ineffective of components to reduce emissions. Faulty injection pump, low fuel pressure and defective injectors, poor and bad positive crankcase ventilation system, contaminated catalytic convertor,

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defective turbocharger, clogged air filter, Intake manifold without enough turbulence are emission control systems problems experienced during operations.

Fuel injection pump pressure contribute to atomization of fuel for good combustion and emission quality. It is suggested that engines are operated in standard fuel injection pressure per manufacturer recommendation to reduce exhaust emissions. Piezoelectric injectors are recommended as it is a direct acting, faster in operation that leads to more accurate and better injection shape, efficient performance as the release of nitrogen oxides are reduced and good fuel consumption.

Improve the geometry design of the intake manifold to enhance engine volumetric efficiency. It is noticed that the exhaust pressure variation under full load, less load and idling affect the engine for more emissions. The exhaust tailpipe backpressure causes loss of power and engine stalling. There is a better improvement in high performance efficiency by matching the turbocharger to the appropriate internal combustion engines. Catalytic converter break the NOx in the exhaust resulting in less HC, CO expelling out of the exhaust pipe and reduced NOx. The emission control systems need optimum attained temperature and required oxygen to efficiently perform the emission control. Appropriate tuning of the emission control system is recommended for the system to perform efficiently.

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