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Comparative analysis of engine running performance with and without thermostat

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Abstract

The rate of removal of internal combustion (IC) engine thermostat when engines are imported to Ghana and other part of African continent is alarming. Such phenomenon calls for an experiment to compare the performance of IC engines imported here in Ghana running with and without engine thermostat. The analysis was done by determine engine performance characteristic such as engine torque, indicated power (Ip), brake power (bp), frictional power (fp), fuel consumption, exhaust gas temperature (EGT) as well as exhaust emission at engine speed of 1500 rpm for engine running with thermostat (WT) and without thermostat (WOT). Descriptive statistics and analysis of variance (ANOVA) were done using GenStat software (VSN International, 2021). Statistical significance was carried out at $p \leq 0.05$. The best fuel mean value of 103 ml was recorded for engine condition WT at EGT of 283.2 °C while fuel consumed for engine condition WOT was 170 ml at EGT of 155.4 °C. The recorded mean exhaust emission gases for Ex, O_2, CO, H_2S were 13.2%, 16.2%, 1000 ppm and 35.2 ppm and 0%, 18.38%, 393.2 ppm and 0.4 ppm for engine condition WOT and WT respectively. There was significant difference ($p \leq 0.05$) in mean values of EGT, Fuel consumption and exhaust emissions for engine condition WOT with the exception of O_2. The removal of engine thermostat affect engine working temperature which result in incomplete combustion, high fuel consumption and high exhaust emissions.

Keywords: Engine cooling system; Mechanics; Performance; Thermostat

1. Introduction

Internal combustion (IC) Engine thermostat is an auxiliary part of IC engine designed to incorporate to the engine cooling system to maintain the operational temperature of the engine through controlling the circulation of coolant in the engine. It also through its function, improves engine characteristics such as engine torque, indicated power, brake power, fuel consumption, mechanical efficiency and exhaust emissions etc [1]. Despite functional requirement of thermostat to support engine performance, mechanics remove engine thermostat when engines are imported to most African countries like Ghana [2]. The removal of engine thermostats is a common phenomenon in Ghana and some part of West African Countries.

Automotive engines run at about 80-200 °C [3]. When the operating temperature is below 80 °C, the engine is considered cold, but engine reached its working temperature when is 200°C [4]. When the operating temperature is above 200°C, the engine needs more fuel and attention to run correctly. About 25% of heat generated by an IC engine is required to convert into mechanical energy for engine's performance, while the remaining 40% passed out through the exhaust, 28% through cooling system, and 7% through the lubrication system to avoid engine overheating [3],[5].

Overheating of an engine can be avoided according to Missan and Keswani [6], by ensuring an efficient cooling system of an engine to enable engine run at its ideal performance. Improvement of fuel economy in internal combustion engines required optimization of engine subsystems like heat management [7]. The cooling system as an auxiliary unit in engine

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operation plays a critical role in engine performance. According to Sivard [8], poor cooling system lead to overheating, reduces engine efficiency and in the worst-case damage the engine. The thermostat serves three (3) important purposes in the engine: restrict coolant flow to promote more even cooling, help an engine to reach operating temperature more quickly and regulate engine temperature to prevent overheat. Several researchers like [2], [6], [7], complained about automobile engine thermostat removed by mechanics. The reasons assigned to the engine thermostat removal include the following: (1) "thermostat was not necessary in Africa; it only cause engine overheat" and (2) "thermostat was designed for much colder countries to keep the water and engine oil from freezing" [6]. All these claims were made without any scientific backing. In Uganda, mechanics referred to removal of engine thermostat as "tropicalizing" that is, to them is by means of circumventing engine overheating [8]. Researchers, Missan and Keswani, [9] and [10], have argued that the thermostat in an automobile engine can't be the cause of engine overheating when the engine is in good condition. Since there is no scientific proof or basis of thermostat removal by mechanics and other argument that, engine thermostat causes engine overheating. There is a need to perform an experiment to analysed the performance of an engine with and without thermostat to buttress the claims. Therefore, the objectives of the study were to estimate (1) engine characteristics and (2) exhaust emissions of the engine with and without thermostat in place. The relevance of this study will establish the consequence of engine performance with and without thermostat.

1.1. Engine Characteristics

Characteristics of an engine is a measure of an engine functional performance. The operational requirement of an engine performance was characterized by Szybist et al. [13] and [14] in terms of speed-load area, indicated power, brake power, fuel consumption, noise, mechanical, emissions and thermal loading. The actual power produced in the engine cylinder is shown by the indicated power and the power available at the flywheel (brake power). The number of revolutions in an engine is a measure of its speed. Engines are rotating machines whose rotational speed is expressed in revolutions per minute. A tachometer is a device that measures the speed of rotation of a shaft or disk. Engine consumption is when engine consumes significantly more fuel than similar engine under typical operating conditions [15].

1.2. Exhaust Emission

The level of various air contaminants present in the exhaust gas is exhaust emission. When these readings are analyzed, it informs whether the exhaust gas includes excessive contaminants. It gives fair idea about engine running condition [16]. The concentrations of hydrocarbon (HC) and NO are measured in parts per million (ppm). A reading of 200 for HC or NOx suggests that there are 200 parts of HC or NOx in every million parts of exhaust gas. Carbon monoxide (CO), carbon dioxide (CO2), and oxygen (O2) are all measured as a percentage of their volume. A CO value of 1%, for example, signifies that CO makes up 1% of the exhaust gas [17]. The amount of hydrocarbons (unburned gasoline or other fuel) in the exhaust gas is measured by the hydrocarbon (HC) meter. This is expressed in parts per million (ppm). Newer vehicles' exhaust gas has fewer than 100 parts per million of HC. Older automobiles emit far more pollution. They may give 400 ppm or more even in perfect conditions. High HC levels can be caused by problems with the emission controls, fuel system, or ignition system. Misfiring can occur when the air-fuel mixture is either rich or too low. It's possible that the ignition system is out of synchronize. Partial combustion produces carbon monoxide (CO). CO concentration is expressed as a percentage of total volume. At the exhaust, some automobile engines produce less than 0.5 percent CO. Additional CO is emitted by a rich mixture with insufficient oxygen to burn all of the fuel. The oxygen content of the air human breathe is around 21% gas [18]. A good condition engine releases exhaust gas comprises less than 2% oxygen during idling. The amount of NOx in the air is measured in parts per million. It originates as a result of a high combustion temperature of more over 137 ^{0}C. The possible causes of NOx include inappropriate spark timing, high coolant temperature, and carbon deposits [19].

2. Material and methods

2.1. Experimental set-up

The experimental set-up comprised of a four stroke, carburetor spark ignition (S.I) Ford engine. The engine was connected to a hydraulic dynamometer to measure torque and other engine performance indicators. The assessment method employed was based on a comparison of the results of engines with and without thermostat in place. Tables 1 and 2 show the test engine and hydraulic dynamometer specifications respectively. Measurement of performance indicators were done with the help of underlisted devices in Table 3. The following assumptions were considered for the study:

- Mechanical efficiency of 85% was used throughout the experiment.

- Constant engine speed was used.
- The engine was exposed to room temperature of 27°C.

Table 1 Test engine specifications

Engine Model	Ford VSG 413
Serial No/Date	E7890/187
Build No	D 000 041 403
Compression Ratio	7.4:1
Fuel	Petrol
Engine Lubrication	Wet Sump Lubrication
Engine	Water cooling

Source : [2]

Table 2 Hydraulic dynamometer – Specifications

Model	E-50
Motor / pump capacity	Motor / pump capacity
Crank position measurement	By rotary encoder
Water pressure gauge	Bourdon berg gauge
Overall Dimension	3800 x 2500 x 1500

Table 3 Measuring devices and measurements

Measuring Tool	Measurement
Calibrated measuring cylinder	Fuel (ml)
Tachometer	Engine speed (rpm)
Inferred Temperature gun	Temperature (0C)
Exhaust gas detector	Exhaust emission

2.2. Fuel Consumption

Calibrated measuring cylinder was used to measure fuel consumption. Amponsah et al. [20], directly measured fuel consumption of the tractor for field operation. The quantity of fuel used was determined by filling the fuel tank to the brim before and after each trial. Quantity of fuel in liters required to refill the tank after the test run was recorded as the fuel consumed for the trials.

2.3. Engine Torque

Torque of the engine was recorded directly from the screen of the test bench in the sequence of running the engine.

2.4. Exhaust Temperature

Temperature of the exhaust gases was measured using Infrared thermometer. The thermometer was placed 35 cm away from the vehicle tailpipe to prevent melting of the plastic part of the thermometer.

2.5. Exhaust Emission

Gas detector was used to determine exhaust gases. Detector was placed 40 cm away from the vehicle tailpipe to prevent the plastic part of the gas detector from melting.

2.6. Indicated and Brake Power

Equation (1) and (2) were used to determined indicated power (Ip) and brake power (bp) of the engine respectively with respective to engine conditions. Where frictional power of the engine is the difference between indicated and brake power. Mechanical efficiency (ME) was assumed to be 85% when the engine is in good condition [21].

$$\text{Ip} = \frac{bp}{ME} \quad (1)$$

$$\text{bp} = 2\pi \frac{\omega T}{60} \quad (2)$$

Where; Brake power (bp) = Torque (T) x rotational velocity (ω)

2.7. Experimental design and data analysis

The experiment was complete randomized design (CRD) with five (5) replications. The experimental factor was engine condition with respect to thermostat in position. A constant speed of 1500 rpm was matched to the conditioning of the engine thermostat which was in two levels (with and without thermostat in place). Engine was run for idling speed with and without thermostat for running time of 10 min to heat the engine. The measuring of fuel consumed, engine torque, exhaust temperature and exhaust emissions were taken within 5 min at 1500 rpm of engine speed. Other characteristics such as indicated power, brake power, frictional power, and mechanical efficiency were calculated.

Data obtained from the trials were statistically analysed. Descriptive statistics and analysis of variance (ANOVA) was done using GenStat software (VSN International, 2021). Means were obtained using the least significant difference (LSD). Statistical significance was carried out at $p \leq 0.05$. Tukey and Fisher's approach was used to determine any differences in treatment measured.

3. Results and discussion

Table 1 presents the means of variables determined for the engine with thermostat (WT) and without thermostat (WOT) at constant engine speed of 1500 rpm. The best fuel mean value of 103 ml was recorded for engine condition WT at exhaust gas temperature of 283.2 °C while fuel consumed for engine condition without thermostat was 170 milliliters at exhaust gas temperature 155.4 °C. There was a significant difference ($p \leq 0.05$) in fuel consumption (FC) and exhaust temperature for engine condition WT and WOT. There was no significant difference ($p \geq 0.05$) among other engine characteristics like engine torque (tq), indicated power (Ip), brake power (bp) and frictional power (fp) for engine condition WT and WOT. Since engine temperature plays a role in combustion, high temperature recorded during running of the engine with thermostat could result in significant difference in fuel consumption for engine conditions with and without thermostat. This agrees with the assertion by Essuman and Baidoo [2] that engine consume more fuel when thermostat is not in place.

Table 4 ANOVA for engine characteristics

	Engine performance parameters						
	Torque (KNm)	**IP (Kw)**	**BP (Kw)**	**FP (Kw)**	**M.E. (%)**	**FC. (ml)**	**Temp. (°C)**
WT	0.0584a	10.782a	9.166a	1.616a	85a	103b	283.2a
WOT	0.0648a	11.964a	10.172a	1.792a	85a	170a	155.4b
LSD	Ns	Ns	Ns	Ns	Ns	11.78	94.013

*Values followed by the same character in the same column are not significantly different at p≥0.005.

The relationship between engine condition with thermostat (WT) and without thermostat (WOT) for engine characteristics (indicated power, brake power, fuel consumption, and temperature for exhaust gas and engine torque) were presented in Fig. 1. The constant speed of 1500 rpm reflects torque developed for both engine conditions WT and

WOT. There was no significant difference ($p \geq 0.05$) among engine characteristics like engine torque, indicated power (Ip), brake power (Bp) and frictional power (Fp) for engine conditions WT and WOT.

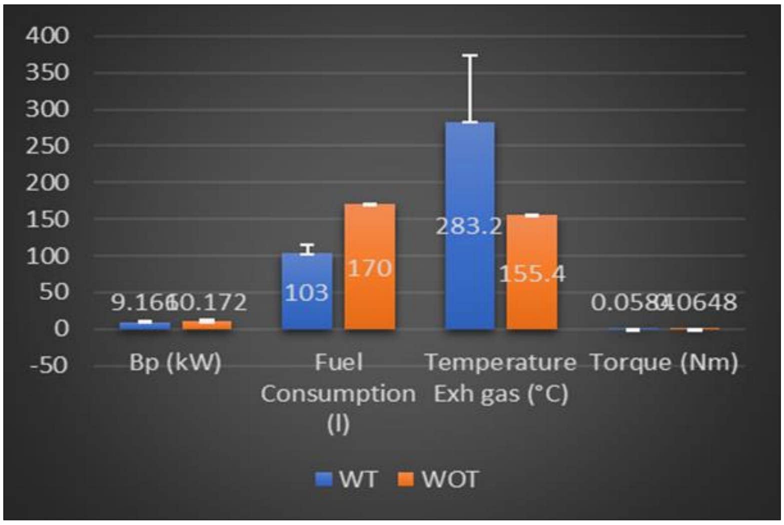

Figure 1 Relationship for engine characteristics

The mean values of exhaust gases; hydrogen sulfide (H2S), carbon monoxide (CO), oxygen (O2) and explosive gas (Ex) results for engine condition WT and WOT were shown in Figure 2**.** The recorded mean exhaust emission gases for Ex, O2, CO, H2S were 13.2%, 16.2%, 1000 ppm and 35.2 ppm and 0%, 18.38%, 393.2 ppm and 0.4 ppm for engine condition WOT and WT respectively. There was significant difference ($p \leq 0.05$) in Ex values in the exhaust gas emission. The high CO reflect the high fuel consumption value (170 ml) recorded for engine condition WOT. Generally, the trend of the results shows significant ($p \leq 0.05$) high mean values of exhaust emission for engine condition WOT with the exception of O2. These results confirm that removal of engine thermostat affect engine working temperature which lead to incomplete combustion, high fuel consumption with high exhaust emissions. The result also support Sivard [12] that there are other factors like poor cooling system, problems with the emission controls, fuel system, or ignition system of the engine lead to overheating. The result also disagree assertion by Davis et al. [6] that "thermostat was not necessary in Africa; it only cause engine overheat" and "thermostat was designed for much colder countries to keep the water and engine oil from freezing.

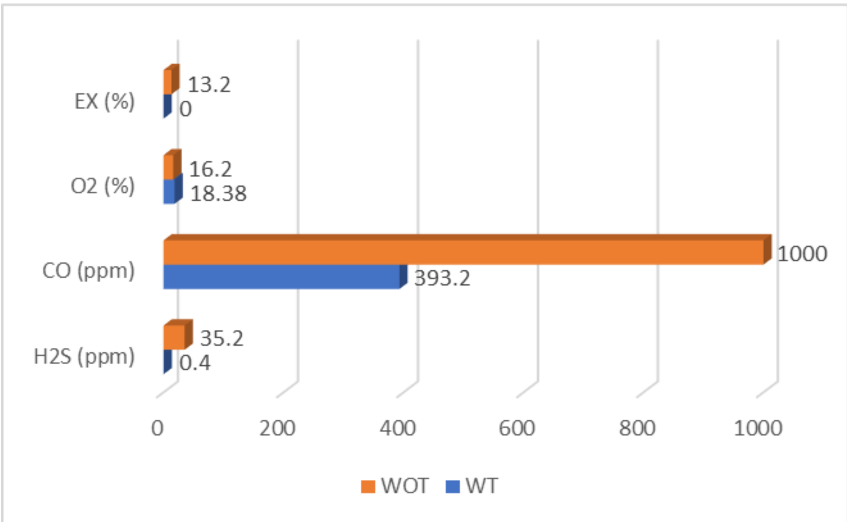

Figure 2 Exhaust gas emission with and without engine thermostat

4. Conclusion

The following conclusions were made based on the objectives of the study:

- The best mean fuel used of 103 ml was recorded for engine condition WT at exhaust gas temperature of 283.2 °C while fuel consumed for engine condition without thermostat was 170 ml at exhaust gas temperature 155.4°C.
- The recorded mean exhaust emission gases for Ex, O2, CO, H2S were 13.2%, 16.2%, 1000 ppm and 35.2 ppm and 0%, 18.38%, 393.2 ppm and 0.4 ppm for engine condition WOT and WT respectively. There was significant difference ($p \leq 0.05$) in mean values of exhaust emission for engine condition WOT with the exception of O2.
- The removal of engine thermostat affects engine performance like working temperature which result in incomplete combustion, high fuel consumption with high exhaust emissions. The conclusions were based only on the type of engine used, therefore required further work on any other engine type.

Compliance with ethical standards

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Disclosure of conflict of interest

All Authors declare that there is no conflict of interest

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