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Effect two grades of octane numbers on the performance, exhaust and acoustic emissions of spark ignition engine

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HIGHLIGHTS

- Using gasoline with octane grades higher than the requirement will decrease the engine performance.
- Volumetric efficiency of octane 95 is more 5% than octane 90 due to higher latent heat.
- NOx and CO emission concentration of octane 95 is lower than octane 90 by 11% and 17% respectively.
- Increase of divergence between the two values of SPL at higher speed for both octane gasoline fuels.
- Using octane ratings higher than the requirement is nosier disturbing than of octane fuel required.

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ABSTRACT

This study presents a comparative analysis of performance, exhaust and noise emissions for a one-cylinder, four-stroke, spark-ignition engine powered by gasoline fuels of two different grades of research octane numbers (RONs), namely octane 90, and octane 95. During the experimental works, each fuel test was performed by varying the engine speed within the range from 1000 to 3600 rpm. The SI engine was connected to eddy current dynamometer with electronic control unit (ECU), an exhaust gas analyzer and the sound level meter (SLM) to determine engine performance, exhaust emissions, and measuring the sound pressure level (SPL) in decibels (dBA) and one octave frequency bands in the audible human range at different engine speeds, respectively. The experimental results showed that the using gasoline with octane grades higher than the requirement of an engine will decrease the engine performance. On average, the brake power and thermal efficiency for the SI engine fuelled with octane 90 is higher than that of gasoline octane 95 by 6% and 11% respectively, and improvement of BSFC by 14%, which is mainly due to higher heating value. Even though, the volumetric efficiency of octane 95 is more 5% than octane 90 due to higher latent heat and heat capacity. In general, the exhaust emission profiles for NOx and CO of the engine improved for octane 95 by 11% and 17% respectively. On the other side, the HC and CO_2 emissions concentration of gasoline octane 90 is lower than that of gasoline octane 95 by 18% and 12% respectively. Finally, the noise levels showed a trend of the increase of disturbing for higher octane number and the increase of divergence between the two values of SPL at higher speed for both fuels.

1. Introduction

Currently, there are many attempts to achieve higher levels of specific power output, increase its efficiency; increase reliability and reduction of exhaust pollutants, which made an increasing of the complexity of the engine design processes and its management systems. The improving of the chemical and physical characteristics of available fuels is becoming a promising research area in the automobile industries [1,2]. The octane number is considered as one of the main attributes of gasoline fuel and it is considered as one of the most important parameters to determine the fuel quality. Several studies have been carried out during the last decades, to recognize how different compounds as methanol, ethanol, ether, etc. can be improved the knock resistance for SI engine applications by the increase of the octane number for gasoline fuel, since the octane number of a gasoline is a measure of its resistance to detonation [3,4]. There are many ways to control or prevent knocking problem as (i) use higher octane grade of gasoline fuel,

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Nomenclature

A/F	air fuel ratio
BP	brake power (kW)
BSFC	brake specific fuel consumption (kg_{fuel}/kW h)
CO	carbon monoxide
dBA	decibels
ECU	electronic control unit
$\bar{h}^o_{RP}$	enthalpy of combustion (kJ/kmole)
$\bar{h}^o_f$	enthalpy of formation (kJ/kmole)
$\Delta\bar{h}$	difference in enthalpy between at any given state and the enthalpy of reference state at 298.15 K, 0.1 MPa (kJ/kmole)
HC	unburn hydrocarbon
h_f	enthalpy of formation (kJ/g)
KS	knock sensors
LHV	lower heating value (kJ/kg)
$\overline{LHV}$	lower heating value (kJ/kmole)
$\dot{m}$	mass flow rate (kg/s)
MTBE	methyl-tertiary butyl ether
n	number of revolutions per cycle
$\dot{n}$	mole flow rates
N	engine speed (rpm)
NIOSH	national institute of occupational safety and health
OWT	open wide throttle
RONs	research octane numbers
$\dot{Q}_{C.V.}$	rate of heat transfer (kW)
RONs	research octane numbers
SI	spark ignition
SLM	sound level meter
SPL	sound pressure level
T	engine torque (N m)
V	volume (m^3)
W_R	error
$\dot{W}$	power output (kW)
X	variable
ρ	Density (kg/m^3)
Φ	equivalence ratio
∂	change
[ ]	exhaust emission gas level (g/kg of fuel)
η_c	combustion efficiency
η_{th}	brake thermal efficiency
η_v	volumetric efficiency

which increases the ignition temperature of the fuel and reduces the tendency to detonate; (ii) use rich of air–fuel ratios which reduces the combustion temperature; (iii) reduce the peak cylinder pressure; (iv) decrease the manifold pressure by reducing the throttle opening or boost pressure; (v) reduce the load on the engine; and finally (vi) reduce ignition timing which is called retarding [5–7].

A general gasoline fuel is usually a blend of many hydrocarbon compounds derived from distillation of crude oil. The main components of typical gasoline are the paraffins (50–80 vol%), olefins (0–15 vol%) and aromatics (15–40 vol%). Several additives are blended with gasoline to enhance certain properties necessary for satisfactory performance [1,3,4,8].

The two most important characteristics of gasoline are its volatility and octane number [5]. The addition of oxygenates to gasoline can improve the fuel volatility, enhance combustion and decrease the exhaust emissions in terms of carbon monoxide, unburned hydrocarbon [9,10]. Al-Farayedhi [8] examined the effect of octane number for three oxygenated fuels MTBE, methanol, and ethanol on exhaust emissions of a gasoline engine. He found as the increase of the octane number for the gasoline fuel, the exhaust emissions of CO and HC will decrease and the NO emission will increase. Hamdan and Al-Subaih [11] stated the RON was increased continuously and linearly with of methyl-tertiary butyl ether (MTBE) when it is added to gasoline, and showed the optimal engine performance and emission reduction achieved at 10% MTBE content. Abu zaid et al. [12] showed the addition of methanol to gasoline will increase the octane number, which the engine can be operated at higher compression ratios.

The effect of octane number grades on the engine performance and exhaust emissions was investigated by several researchers; Sayin et al. [13] performed the energy and exergy analysis for four cylinders, four stroke gasoline engine. The test engine was fuelled with gasoline fuels of 91, 93 and 95.3 RONs. The results showed the engine will be operated in less energy and exergetic efficiencies when it is powered with a fuel with an octane rating higher than the design rating required. Khalifa et al. [14] carried out the experimental and theoretical investigations to compare the effect of using two gasoline blends octane 91 and octane 95 on the performance and exhaust emissions for SI fuel injection engine. The results proofed the using of octane 91 resulted in small improvements in terms of brake power and lower in brake specific fuel consumption compared to octane 95, and the same trends for exhaust emission for CO and NOx. Binjuwair et al. [15] compared experimentally two rates of gasoline RON91 and RON95 from Saudi Arabian with respect to port injection and direct injection engines. The results showed that the engine brake power is higher for RON91 regardless of type of fuel systems. The exhaust emission of NOx and CO of RON91 is higher than gasoline RON95 in most cases. Mohamad and Geok [16] tested two Malaysian octane blends namely RON95 and RON97 to show the effect on the engine performance and exhaust emission. The RON95 has an average higher than of brake torque and brake power. On the other side, the BSFC of RON97 is 2.3% is lower than for RON95 but RON95 is 2.3% more efficient specifically at higher engine speeds and loads. The effect of varying spark timing at different octane numbers on the performance and emission characteristics in SI engine was examined by Sayin [17]. The author stated that the performance and emissions were improved with varying spark timing according to octane number in a gasoline engine. For example, the performance for higher octane number as RON97 and RON98 was improved with the increase of spark timing and the emissions were reduced.

After surveying the published papers, many researchers try to improve the fuel properties and characteristic to increase the engine performance and reduce the exhaust emission without taking care to acoustic emission. Primarily, the investigation of noise emissions in internal combustion engines have been focused on CI engines since these engines produce higher than noise levels. However, the investigations into understanding the development of knock in SI engines have become more prevalent in recent years. According to the best of author's knowledge, it is the first time that the influence of octane rating on the noise pollution has been studied in a gasoline-fuelled engine. The noise is the term used for unwanted sound; some sounds produced by the engine or related automobile systems as rattles, ticks, clicks and pops indicate to malfunctions or faults. These malfunctions will affect in future on the automotive engine performance and then can lead to more emissions, more fuel consumption, and may cause engine damage or it can be a threat to safety of both human beings and the environment [18–20]. There are various sources that contribute to the