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Progress in performance analysis of ethanol-gasoline blends on SI engine

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ABSTRACT

Alternative fuel has become very significant and has an important role to play for both spark ignition and compression ignition engines, so the need to trim down dependency on gasoline as a fuel and its economic aspects has emerged as the reason of prime importance. Various investigations carried out have primarily focused on using alternative fuel to see the diminishing effect on the fuel consumption. The aim of this review is to study and analyze the range of opportunities and future prospects of introducing blend of gasoline-ethanol, gasoline with all other alcohol derivative and subsequent alternative fuel in varying percentage ratios in the existing SI engines by diagnosing various aspects such as air-fuel ratio, operating cylinder pressure, ignition timing and compression ratio related to the performance parameters only.

1. Introduction

The reserves of the petroleum based fuel are directly correlated with the increasing demand of humans for energy production. With the growth in world population, industries, vehicles, and equipment, energy demand lead to the search for the substitute of petroleum fuel which can cater to the need of people today. Considering the current global economic crisis, the curiosity in alternative fuel is extremely high [1]. It is very important to examine that the alternative fuel used as substitute must be produced from the renewable sources and ways and means should be devised to use this fuel without bringing any modifications in the geometry of the engine. Alcohol has provided an answer to this problem. So Ethanol is well thought-out to be the most fitting fuel for spark ignition (SI) engines [2]. The dependencies on the fossil fuel are reduced by the researchers and various efforts are being made to find the alternative economical fuel source. Various researches have contributed towards generating few alternative and cost-effective viable fuel which is also environment friendly [3]. One of the goals of researchers is the development of high efficiency and clean engines. Therefore, alternative fuel sources are sought. Some of the most important fuel is natural gas, biogas, vegetable oil, esters alcohol derived from vegetable oil and hydrogen. Alcohol fuels such as methanol and ethanol has emerged as good entrants as alternative fuel for the vehicles equipped with the SI (spark ignition) engines because they are fluid and have several physical and combustion properties quite analogous to gasoline [4]. Major research work on the evaluation of the performance parameters of the engines, operated on alternative has given us food for thought to either replace petroleum reserves by alternative fuel or use them in varying percentage ratios with gasoline. This will indirectly help us in saving the energy sources which are depleting at a fast rate and thus keeping human mankind at pace with the growing needs of energy.

This review paper aims to study the progresses made by researchers in the past to improve the performance of the run engine with varying percentage of blends of gasoline-ethanol, gasoline with all other alcohols derivative and subsequent alternative fuels by considering various aspects such as air-fuel ratio, operating cylinder pressure, ignition timing and compression ratio related to the performance parameters.

2. Reasons for advocating ethanol

Ethanol (C_2H_5OH) is a natural fuel, as it is obtained from renewable energy sources. It is a colorless, transparent, neutral, volatile, flammable, oxygenated liquid hydrocarbon, which has a pungent odour and a sharp burning taste [5]. Some fuel properties of ethanol, such as the octane number, heating value, latent heat of vaporization, flame velocity, specific gravity, Reid vapour pressure and distillation curve, are quite different from those of gasoline. Therefore it becomes very crucial to understand the effects of these properties on the performance characteristics of SI engines [6]. An ethanol-fuelled engine is less likely to spark off as compared with gasoline–fuelled engine as the self –

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ignition temperature of ethanol is higher than that of gasoline at the same compression ratio. This permits for higher detonation-free compression ratio for SI engines, ensuing higher overall efficiency and shaft power [7–9]. On contrary the volumetric efficiency improves due to higher heat of vaporization which causes more cooling of fresh cylinder charge [10,70]. So Ethanol is considered as the most suited fuel and can be readily used in present engines without modifying the engines [11,12]. Engine power is enhanced abruptly on the usage of ethanol; the sole reason behind is its Octane number which is very high as compared to gasoline. Fuel with higher Octane number can undergo a higher compression ratio before blowing off, thus giving the engine the ability to generate more power. Ethanol when considered as a fuel for SI engines had better antiknock characteristics. Ethanol fuel burns more cleanly than regular gasoline does and has high heat of vaporization; therefore, it reduces the peak temperature inside the cylinder and increases the engine power [13–19]. Generally, ethanol or bio ethanol is more reactive than gasoline [20]. Ethanol can effortlessly dissolve in non-polar (e.g. gasoline) and polar (e.g. water) substances as it contains hydroxyl radicals as the polar fraction and carbon chains as the non-polar fraction as its main constituents [21]. Due to regenerative and ecological characteristics of ethanol, it is extensively used as an alternative fuel at present. The use of gasoline containing 3–10 vol%bioethanol is being encouraged in many parts of the world for last few years [22].Tables 1, 2 shows the merits and demerits of using ethanol over gasoline.

3. Comparison of physiochemical properties

The quality of fuel to be used in the engine is dogged by its physical and chemical properties. Engine combustion quality, performance and emission characteristics differ on large if quality of fuel deteriorates. Table 3 shows the comparison of gasoline and ethanol as a fuel when related to combustion. The comparative features of ethanol and gasoline are listed below [23].

1. Owing to gasoline's higher heating value of approximately 1/3 times than that of ethanol, more amount of fuel is required for ethanol in order to achieve same engine power output.
2. As ethanol contains 34.7 wt% of oxygen, the combustion temperature is augmented which helps in achieving higher combustion efficiency.

Table 1
Merits of ethanol fuel over gasoline [23].

Ethanol is a renewable fuel.
Ethanol could reduce petroleum imports, improve the balance of payments, improve national energy security, and reduce the reliance on petroleum from unstable areas of the world.
Bioethanol if cheaply produced can reduce demands for fossil fuels and the growth in fossil fuel prices.
Bioethanol could create stronger demands for feedstocks, thus boosting agricultural prices and producer's incomes.
Ethanol has high octane number.
Higher latent heat of ethanol increases volumetric efficiency.
Ethanol provides more oxygen in the combustion process, which assists in complete burning.
Lower vapour pressure of ethanol reduces the evaporative emissions.
Ethanol has high laminar flame propagation speed, which makes combustion process to be finished earlier and broadens its flammability limit.
Ethanol increases thermal efficiency.
Ethanol increases engine torque output.
Ethanol allows the use of high compression ratio without knocking.
As oxygenated produce cleaner emission.
Ethanol is used in direct injection gasoline engine to avoid knocking.
Ethanol burn reduces greenhouse gas emission significantly.
Ethanol is easily miscible in gasoline.
Ethanol is used widely as an oxygenated portion in gasoline.
Ethanol is less toxic than gasoline.

Table 2
Demerits of ethanol fuel over gasoline [23].

Energy content of ethanol is lower.
Lower vapour pressure of ethanol can contribute to produce unregulated pollutants like aldehydes.
Ethanol use can enhance corrosion on ferrous components such as fuel tank.
Ethanol is a triatomic molecule that results in higher gas heat capacity and lower combustion gas temperature.
Low vapour pressure of ethanol makes starting cold engine difficult.

Table 3
Comparison of gasoline and ethanol fuel properties [23].

Property	Unit	Gasoline	Ethanol
Chemical formula	–	C_5-C_{12}	C_2H_5OH
Molecular weight	Kg $kmol^{-1}$	114.15	46.07
C-fraction	mass %	87.4	52.2
O-fraction	mass %	0	34.7
H-fraction	mass %	12.6	13.0
H/C	atom ratio	1.795	3
O/C	atom ratio	0	0.5
Specific gravity	–	0.7–0.78	0.794
Density(at 15 °C)	kg m^{-3}	750–765	785–809.9
Stoichiometric air-fuel ratio	W/W	14.2–15.1	8.97
Kinematic viscosity	mm^2/s	0.5–0.6	1.2–1.5
Reid vapour pressure at 37.8 °C	kPa	53–60	17
Research octane number	–	91–100	108.61–110
Motor octane number	–	82–92	92
Cetane number	–	8	5–20
Enthalpy of formation			
(a) Liquid	$kJmol^{-1}$	−259.28	−224.1
(a) Gas	$kJmol^{-1}$	−277	−234.6
Higher heating value	$MJkg^{-1}$	47.3	29.7
Lower heating value	$MJkg^{-1}$	44.0	26.9
LHV at stoichiometric mixture	$MJkg^{-1}$	2.77	2.70
Latent of vaporization	$kJkg^{-1}$	380–400	900–920
Specific heat			
(a) Liquid	kJ/kgK	2.4	1.7
(a) Gas	kJ/kgK	2.5	1.93
Freezing point	°C	−40	−114
Boiling point	°C	27–225	78
Flash point	°C	−45 to −13	12–20
Auto ignition temperature	°C	257	425
Vapour Flammability limits	vol%	0.6–8	3.5–15
Laminar flame speed at 100kPa, 325 K	cm/s	−33	−39
Distillation			
(a) Initial boiling point	%	45	78
(a) 10	%	54	78
(a) 50	%	96	78
(a) 90	%	168	79
(a) End boiling point	%	207	79
Water solubility	%	0	100
Aromatics volume	%	27.6	0
Vapour toxicity	–	Moderate irritant	Toxic in large doses
Smoke character	–	Black	Slight to none
Conductivity	–	None	Yes
Color	–	Colorless to light amber glass	Colorless