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A Study of Performance of SI Engine Using Ethanol-Gasoline Blend

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***Abstract*— Significant efforts must be made to increase combustion efficiency while meeting the requirements for emission quality because of the harsher international emission legislation and increased expectations for lower fuel consumption and anthropogenic CO2 emissions. A particularly promising yet, at the same time, difficult strategy is provided by ethanol fuel mixed with petrol. Due to the advantages of its high-octane rating and self-sustaining concept, which can be supplied regardless of the fossil fuel, ethanol is frequently utilised as an alternative fuel or an efficient additive of petrol. The impacts on engine performance and emission have thus been the subject of extensive research. The potential use of fuel ethanol as a petrol alternative is covered in the first section of this article. The comparative physicochemical characteristics of petrol and ethanol are next covered. The characteristics of ethanol and petrol are just slightly different, yet this is enough to significantly alter the combustion process as well as the behavior of SI engines. The fundamental mechanisms by which ethanol impacts NOx emission are complicated and interdependent as a result of these effects. To lay the groundwork for further discussion, general NOx generating mechanisms are next covered. The paper also examines a mathematical method for NOx prediction using ethanol and the impact of various fuel compositions, engine parameters, and engine modifications on NOx generation.**

***Keywords*— SI Engine, Ethanol,Gasoline, Blend, NOx.**

I. INTRODUCTION

After the starting of energy catastrophe in the 1970s, world researchers focused on the study and utilization in the area attributed to renewable energy. As fossil fuels are depleting day by day, researchers are switching towards alternative sources of energy or renewable energy. Among the 196 countries fossil fuel is a major concern topic for environmental and climate change. Due to combustion of fossil fuel is affecting the environment and healthcare. India reserved the third position in the world in fuel production.

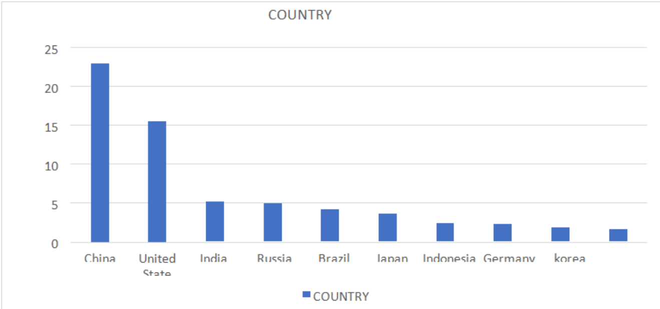

Fig 1.1: Report of the largest CO2 emission in peak 10 countries

Above mention table show the percentage of CO2 emission in different-different country.CO2 emission higher in China and lower in Canada. International Energy Agency (IEA) published the emission report in 2020 mentioned CO2 emission 92% more than 1990. And also concluded 9 billion metric ton CO2 emission will emitted from 2020 to 2035 by the road transport [polo indic]. CO2 is the chief constitute gas of greenhouse effect. So many researchers concluded ethanol gasoline blend reduces the CO2 emission. Global warming phenomenon occurs due to CO2 gas.

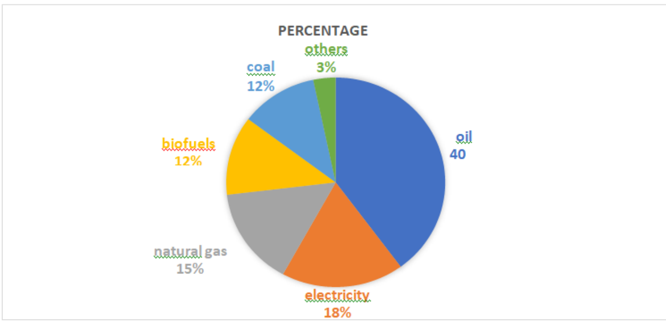

Fig 1.2: Domination of conventional fuel consumption in 2018

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Above chart show the consumption of energy source. It shows, oil (fossil fuels) is widely used for transportation vehicle in the world compared to other sources. But fossil fuels emitted so many harmful particles like HC, CO, NOx at the time of burning, that is disbalance environment and effect the human life. Therefore, so many researchers are going on alternative fuels for balancing the environment. So many experiments have been performing on the alcohol group, and mostly ethanol blended with gasoline. Because ethanol having so many properties to reduce harmful emission. It can easily be produces by experimental methods and by the biodegradable materials like sugarcane straw agricultural waste

II. COMBUSTION PROCESS IN S. I. ENGINE

In combustion process flame will promulgate on hydrocarbon mixture fuel, when the combustible mixture burned at the 1500K temperature. In hydrocarbon-based fuel stoichiometric air fuel ratio is 15:1. In hydrocarbon-based fuel air fuel ratio in the range between 30:1 to 7:1. Higher and lower ignition limits depends on air fuel ratio range and temperature of the mixture. At higher temperature, ignition flame development range is higher. That causes are higher rate of reaction between atoms of fuel and higher fuel diffusivity.

According to Ricardo combustion process occurred in two

stages

1. Combustion flame growing in a form of semi propagating is known as ignition lag or preparation phase.
2. After the flame growing, flame will span over the whole combustion chamber.

Flame development process anticipates on the character of fuel, temperature of combustion chamber as well as pressure of the combustible mixture. Flame propagating is depending on acceleration of oxidation or burning. In internal combustion engine fuel basic properties require are combustible time is very short in the combustion chamber and during combustion maximum heat energy produce. Boiling range of gasoline is 303K to 473K and ethanol boil at 351. 35K.Gasoline content various types of hydrocarbons like paraffins, olefins and aromatics.

III. ETHANOL FUEL USE INSTEAD OF GASOLINE

Raw material such as sugar cane, sugar beet potatoes sweet straw cotton and other biomass, produced ethanol by fermentation process and by the fermentation of glucose in sugar and starchy biomass, ethanol is produced.

85.985 billion liter than oils produce.

Three main kinds of feedstocks may be distinguished among the world's ethanol production:

1. Ethanol produced from biomass that contains sucrose, including sugar cane, sugar beets, sweet sorghum, and fruits.
2. Ethanol produced from biomass that contains starchy ingredients including corn, milo, wheat, rice, potatoes, cassava, sweet potatoes, and barley.
3. Ethanol produced from lignocellulosic biomass, which includes grasses, straw, and wood The ethanol made from the aforementioned feedstocks is divided into two categories :

- First-generation bioethanol, which is composed of both ethanol from starchy biomass and ethanol from biomass that contains sucrose.
- Bioethanol produced from lignocellulosic biomass or second generation bioethanol.

By the two-methods ethanol produced easily

1. First one is by the formation of alcohol

$C_{12}H_{22}O_{11}$ H_2O XC_2H_2O + (2-X) $C_6H_{12}O_6$ $C_6H_{12}O_8$ $2C_2H_5OH + 2CO_2$

2. Second one is ethane reaction with stream C_2H_4 + H_2O C_2H_5OH

In Canada, Thailand Brazil, are widely used ethanol gasoline blend. In Brazil maximum 90 % cars are designing on flex fuel engine and contain 20-25% anhydrous ethanol in fossil fuel. Due to presence of hydroxyl radicals such as polar fraction and non- polar fraction like carbon chains, dissolved easily in water.

IV. PHYSICOCHEMICAL PROPERTY COMPARISONS

The fuel's quality to be burned in an engine is indicated by its physical and chemical qualities. They affect engine combustion quality, efficiency, and emission characteristics.

Table 4 compares certain combustion-related characteristics of ethanol with gasoline. The following list compares the characteristics of ethanol to gasoline:

1. The heating value of ethanol is roughly one-third that of gasoline. Hence, more gasoline is needed for ethanol to produce the same amount of engine power.

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2. Ethanol's 34.7 weight percent oxygen concentration encourages high combustion temperature and combustion efficiency.
3. Ethanol vaporises with a higher heat than gasoline. As a result, charge needs more heat to evaporate, which is taken from the environment inside the cylinder. The engine's volumetric efficiency consequently rises as a result.
4. Because ethanol has a little lower density than gasoline, fuel pumps that operate on volumetric pressure inject a smaller volume of alcohol fuel than gasoline fuel.
5. Hydrocarbons that are mono- or poly-aromatic are not present in ethanol.
6. The temperature of the adiabatic flame is lowered by ethanol's lower C/H atom ratio.
7. Gasoline and ethanol both have higher octane numbers (ON). The more compression the fuel can sustain before detonating, the higher the octane number. Engine damage can result from premature fuel ignition, which is a regular occurrence for lower ON fuel.
8. Because ethanol burns more quickly than gasoline, the combustion process is completed quicker, increasing engine thermal efficiency.
9. By producing low-grade gasoline with lower ON, petroleum refineries can make it at a reduced cost by mixing ethanol with gasoline.

Differentiate Gasoline and Ethanol Properties.

Table 1.1 Properties of Gasoline and Hydrous Ethanol

Properties	Gasoline	Hydrous Ethanol
Density (15 °C, kg/l)	0.7–0.79	0.81
Self-ignition temperature (°C)	420	420
Low heating value (MJ/kg)	44.15	25
Latent heat of vaporization (kJ/kg)	349	992.1
Kinematic viscosity (40 °C, St)	0.6	1.5
Stoichiometric air-fuel ratio	14.7	8.7
Research Octane Number	88-100	106
Motor Octane Number	80-90	87

Ethanol and the U.S. Biofuel Policy

According to environmental survey of 2019, 75% of total energy consumption of the U.S., is utilize in automobile fuels. And it is the main source of CO_2 emission. RFS program was conducted by Congress in 2005 under the Energy Policy Act (EP Act) and after this program expanded by under the EISA (RFS2). mainly focus in this program was to get an annual production of renewable source is around 36 billion up to 2022. Economical fuels to be blended with fossil fuels by oil refineries and importers enhance the prerequisite of renewable fuel demands. The responsibility for implementing the program and publishes the annual RFS volumes for related to total renewable fuel, advanced biofuel, cellulosic biofuel and biomass- based diesel is taken by The Environmental Protection Agency (EPA).

Drawback of Ethanol Properties of Di-ethyl ether Di Ethyl Ether (Ethyl Ether)

Diethyl ether is simple ether belongs to steroid in kind of ether. Formula (C2H5)2O. Di ethyl ether is colorless liquid. It is more volatile, having sweet smelling ("Ethereal odour") and extremely flammable properties. Di ethyl ether is solvent and starting fluid in some engines. Formal used as general an aesthetics until non-flammable drugs were elaborated such as halothane. Recreational drug to cause intoxication made by the di-ethyl ether.

Table 1.2: Properties of Di-ethyl ether

Density	713^3kg/m
Molecular weight/Molar mass	74.12g/mol
Melting point	-116.3^{0}C
Boiling point	34.6^{0}C
Compound formula	(C2H5)2O

Table 1.3: Physical properties of Diethyl ether

Odour	Sweet, pungent odour
Appearance	Colorless liquid
Vapour pressure	439.8mm Hg at 20^{0}C
Solubility	Ether is polar in nature so they are moresoluble in water than alkanes

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Chemical properties of Diethyl Ether (C2H5) O

1. COMBUSTION – Highly flammable liquid and undergoes combustion reaction resulting in the formation of carbon dioxide and water.

$$C_2H_5OC_2H_5 + 6O_2 \longrightarrow 4CO_2 + 5H_2O$$

2. HALOGENATION-Ether reacts with halogens like chlorine or bromine forming halo substituted ether undergoes substitution reaction in the absence of sunlight.

$$C_2H_5OC_2H_5 + Cl_2 \longrightarrow C_2H_4(Cl)OC_2H_4(Cl)$$

Emission

When the fuel is burn in S.I. Engine so many emissions contents released. The chief hazardous waste of gasoline engines are CO, HC, NO_x and particulate matter (PM). Oxides of nitrogen and coarse grained coming into being in the combustion chamber of the gasoline engine are antithetical. At a time cannot be reduce together Oxides of nitrogen and coarse grained coming into being exhaust. Various research are going on to minimize the emissions and make better the fuel conversion efficiency of SI Engines.

Evaluation of Motorcycles and Scooters

If we compare motorcycles and automobiles, motorcycles registrations are more. According to transportation ministry survey motorcycles registered 145,323,771 units and registered automobiles are 27,144,875units in 2016 to 2020.

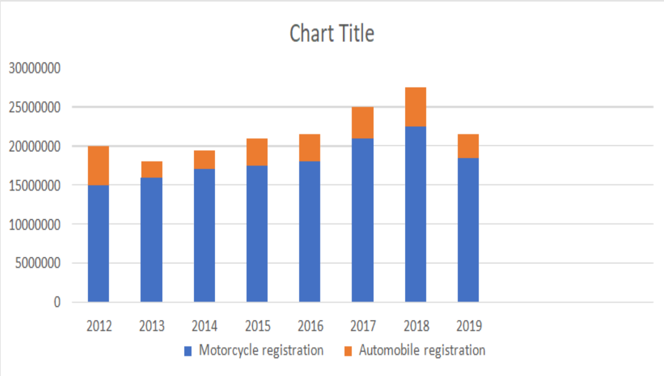

Fig 1.3: Motorcycle and automobile registrations in India from 2016–2020

V. LITERATURE SURVEY

The literature that is now available on emission controls and its performance under various categories is provided in great detail. The next section includes a few papers that are specifically pertinent to the research question.

In comparison to the preceding blend, combustion is slowed down by adding 5% more water to the ethanol. Due to the 20% water addition to the ethanol blend, the flame shape is deformed and the combustion process is delayed. In comparison to pure gasoline, a maximum of 12% water is significant for a minimum flame distortion and good combustion Using an early stratified injection technique will result in complete combustion as opposed to incomplete combustion caused by a delayed injection approach. NO_x emissions and total hydrocarbon and CO emissions both decrease in leaner mixtures with higher oxygen percentages [2]. When ethanol and isobutene are blended, torque is increased in comparison to pure gasoline. E10iB10 fuel mix has a higher torque increase of 3.77%. Reduce the CO concentration in isobutene-blend fuel. The average CO concentration in E10ib10 mixed fuel is 11.21%. Hydrocarbon emissions are reduced by isobutene addition; on average, an E10iB10 ternary mix reduces HC emissions by 17.13%. Engine torque increases along with an increase in NOx emissions. Maximum NO_x emission is at 60Nm of torque [3]. Compared to pure gasoline, ethanol gasoline blends have a lower Reid vapour pressure. Cold start issues are caused by lower Reid vapour pressure. The percentage of NO_x emission varies depending on the temperature of the atmosphere [4]. When isobutanol is added, the entire combustion process is improved, as is the brake power. At 5000 rpm engine speed, brake-specific fuel consumption also decreases. Isobutanol addition raises the temperature of exhaust gases. With the addition of ethanol and isobutanol to gasoline, CO and HC emissions are reduced [5]. Only certain balance ratios make the addition of water and efficiency increases valid. Water content addition lowers gasoline costs [6].

Due to the higher oxygen content of ethanol and the higher percentage of oxygen that turns into CO_2, adding ethanol to gasoline reduces CO emission. Pure ethanol helps to cut down on CO emissions. Water addition increases overall fuel consumption while

slowing down the rate of fuel combustion. A higher water content lowers the calorific value of the fuel. Best fuel for efficiency is E70W30 [7]. At E10 and E5 blends, greater brake efficiency is seen. Increased brake-specific gasoline consumption in E5 and E10 mixes was 2.8% and 3.6%, respectively. Ethanol addition of 10% decreased CO output by about 30% [8]. The density of the mixture is increased by the addition of ethanol, which increases volumetric effectiveness. E40 blend produced the highest brake thermal efficiency [9].

Methanol, ethanol, and butanol addition reduce the thermal efficiency of the brake. Due to increased proof oxygen, it dropped. Under stoichiometric conditions, however, the addition of ethanol, methanol, and butanol increases CO emissions [10]. As engine speed is increased, CO and HC emissions are reduced. With E30, CO_2 emissions are lowest at 2000 rpm, and E0, they are highest at 3000 rpm [11]. The disadvantage of ethanol is mitigated by employing hydrogen as CO, HC, and CO_2 emission percentages decrease with increasing hydrogen. The percentage of hydrogen increases when it is present. E40 and E50 blend have maximum thermal efficiency of 58-73% between 2000 and 2500 rpm. Brake thermal efficiency of 70–100% is seen at 1000–4000 rpm for an E20 and E40 blend [13]. The use of bioethanol fuel in gasoline reduces the need for brake-specific fuel. The percentage of CO and HC emissions attributable to bioethanol also decreased [14]. Diethyl ether also fixes the engine's cold start issue. CO emission percentage is higher at low load conditions and ambient temperature compared to pure gasoline [15]. The largest proportion of NO_x emissions are reduced by ethanol blends up to 85% before ethanol is added, which increases emissions. Nevertheless, HC emission increased when the peak in the cylinder temperature was added [16]. For all engine conditions, E5 and E10 blends are preferred, and the intake air temperature is 20°C. But, compared to other blends, E20 and E40 blends lower HC, CO, and NOx emissions more significantly. Using E30 blend at 120s results in a 50% reduction in CO emission, a 20% reduction in HC emission, and a 10% reduction in NOx emission. Using ethanol as a percentage in gasoline reduces cold emissions [17].

NOx production

Nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), dinitrogen trioxide (N_2O_3), dinitrogen tetroxide (N_2O_4), and dinitrogen pentoxide (N_2O_5) are among the substances that make up NO_x. Nitric oxide (NO) and nitrogen dioxide (NO_2) are the two that stand out the most among them. Although they are present in extremely small amounts, the remaining five nitrogen oxides are known to exist. The gas nitric oxide has no colour or smell. Typically, it has an ambient concentration of much less than 0.5 ppm. A caustic, corrosive, and reddish-brown gas, nitrogen dioxide. In adequate levels, it is quite apparent. As a byproduct, NO_x is produced when nitrogen molecules oxidise at a high temperature inside the cylinder. This article discusses the processes that lead to the creation of nitrogen oxides, including thermal, prompt, fuel, and intermediate N_2O mechanisms.

NO_x thermal

The Zeldovich process is a set of chemical steps that atmospheric nitrogen and oxygen undergo during combustion at temperatures higher than 1800 K. The primary source of total NO_x is thought to be this thermal mechanism of NO_x production. The fundamental kinetic equations for the generation of thermal

NO_x.O+N2↔NO+N

N+O2↔NO+O
N+OH↔NO+H

As NO_x creation requires high temperatures to continue due to its high activation energy (314 KJ/ mole), this stage dictates the formation of NOx. The oxidation of hydrocarbons occurs more quickly than the thermal method for producing can be used to express the NO generation rate.

Quick NO_x

First discovered by Fenimore, prompt NO_x is a second mechanism that contributes to the creation of NO_x. In the laminar premixed flame zone, during the combustion of hydrocarbon fuels, prompt NO_x is a type of NO_x that forms shortly before thermal NO_x. There is strong evidence that in some combustion circumstances, such as low temperature, fuel rich conditions, and if residence time is short, quick NO_x can be produced in substantial amounts. Rich flames are where prompt NO_x is most common. A complicated set of events and numerous potential intermediary species are involved in the actual production.

$CH+N_2 \leftrightarrow HCN+N$

$CH_2+N_2 \leftrightarrow HCN+NH$

$N+O_2 \leftrightarrow NO+O$

HCN+OH↔CN+H2O

$CN+O_2 \leftrightarrow NO+CO$

Mid-level N2O

Another crucial mechanism in a combustion process occurring under high pressure and lean is the NOx generation via this pathway. Low temperatures or an air-fuel ratio compared to Fenimore NO, as well as a modest role for the thermal NO process in the creation of NO_x.

$O+N_2+M \leftrightarrow N_2O+M$

$H+N_2O \leftrightarrow NO+NH$

$O+N_2O \leftrightarrow NO+NO$

In this case, the reaction needs the presence of M, a general third body. The mechanism is

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favoured for oxygen-rich environments or lean conditions since reaction speeds substantially depend on O, OH, and H radial concentrations.

Engine NO_x

Fuel NO_x is created during combustion when nitrogen-containing fuel compounds are oxidised to NO_x. Fuel nitrogen content correlates with an increase in fuel NO_x. Additionally, it is connected to the hydrocarbon's oxidation and the chemical kinetics of that process. However, because there is very little nitrogen in petrol or ethanol fuel, very little fuel NO_x is formed.

Impact of the fuel's content

In SI engines, researchers have investigated ethanol-gasoline blends with ethanol concentrations ranging from 5 vol% to 100 vol%, or pure ethanol. Table 5 lists the

physicochemical characteristics of several ethanol-gasoline mixtures. These data were acquired using various test techniques used by the researchers. The addition of ethanol to petrol concurrently raises its density, latent heat of vaporisation, and octane number while lowering its heating value. To determine the impact of these modifications on emission characteristics, particularly on NO_x emission due to variations in ethanol concentrations, numerous research have been conducted.

Compression ratio's impact

Because of its increased thermal efficiency, a high compression ratio (CR) enables an engine to extract more energy from a given mass of air-fuel mixture. Higher CRs allow for a longer expansion cycle while yet allowing for the same combustion temperature to be reached with less fuel. When a fuel with a lower octane number is utilised in an engine with a high compression ratio, detonation increases. Ethanol has a higher octane rating than petrol, with a value of 108.6 (see Table 4). The high octane number increases knock tolerance and provides a high compression ratio without knocking. Additionally, it was discovered that high CR can improve the efficiency of ethanol fuel mixes, which can minimise the fuel economy penalty related to E85's lower energy content by roughly 20%. Forced induction can produce larger NO_x percentages because high combustion temperatures result in higher NO_x emissions. Increases in CR cause an increase in NO_x emission, particularly under high engine load. The increase in NO_x emissions with increasing CR at high engine loads is caused by the comparatively high burning rate of the total rich mixture combustion and a high-temperature environment.

VI. CONCLUSION

Due to the depleting fossil fuel sources and environmental concerns, alternative fuels are becoming more and more crucial for cars. Since it is made from renewable resources and emits better emissions, ethanol is one of the alternative fuels that has been used for many years in a number of nations. Ethanol combustion in SI engines lowers emissions of CO, HC, and other pollutants, yet numerous investigations have found minor discrepancies in NO_x emissions. The key findings of a systematic assessment of the published literature on how fuel qualities, composition, and operating conditions affect ethanol NO_x emission have been summarised below.

- The NO_x production in SI engines is mostly caused by the physicochemical characteristics of ethanol-gasoline blends, such as heating value, latent heat of vaporisation, oxygen content, laminar flame velocity, etc.
- According to numerous researches, thermal NO_x production is the primary mechanism for NO_x emission from SI engines using both petrol and ethanol fuel.
- Ethanol blended fuels can employ a greater CR in SI engine due to their higher octane number. Using the greater percentage ethanol blend, a higher CR can be applied without increasing the NO_x emission.
- For rich mixes produced by higher engine loads and speeds, ethanol with a higher flame speed aids in full combustion. As a result, ethanol-gasoline mixtures emit more NO_x than pure petrol does. When ethanol is used in engines with modest engine loads, no substantial change or a slight decrease in NO_x emission is seen.
- For cold-starting engines, pure ethanol fuel is not recommended. When using ethanol- blend petrol instead of regular petrol, an engine can start up easily in cold weather and emit less HC, CO, and NO_x. However, in cold start conditions, heated air-fuel mixture is more efficient.
- In comparison to petrol and anhydrous ethanol blends, hydrous ethanol blends are more effective at reducing NO_x emissions because the water component absorbs heat and lowers the peak in cylinder temperature.
- In order to use greater water contents with ethanol without experiencing phase separation issues, separate alcohol injection is used. Water content greatly reduces NO_x emission, however premixed

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water and ethanol is more effective in reducing NO_x than separate water injection.

- TBC is used to reduce heat rejection to coolant and to recover energy in the form of usable labour, however its use increases NO_x emission. Given that ethanol is an oxygenated fuel, low concentrations of ethanol blends with TBC speed up combustion and the production of NO_x. Due to the reduced heating value of the blend, TBC can be used with a greater ethanol-gasoline blend without causing an additional rise in NO_x emissions.

REFERENCES

1. Mohammadmohsen Moslemin Koupaiea , Alasdair Cairnsa, Hassan Vafamehrb , Thompson DiordinisMetzkaLanzanova "A study of hydrous ethanol combustion in an optical central direct injection spark ignition engine" Applied Energy 237 (2019) 258-269.
2. Roberto Berlini Rodrigues da Costaa,⁎ , Fernando Antonio Rodrigues Filhob , Christian J.R. Coronadoa , Alysson Fernandes Teixeirac , Nilton Antonio DinizNetto"Research on hydrous ethanol stratified lean burn combustion in a DI sparkignitionengin" Applied thermal engineering 139 (2018) 317-324.
3. M.N.A.M. Yusoff a, * , N.W.M. Zulkifli a, **, H.H. Masjuki a , M.H. Harith a , A.Z. Syahir a , L.S. Khuong a , M.S.M. Zaharin b , Abdullah Alabdulkarem "Comparative assessment of ethanol and isobutanol addition in gasoline on engine performance and exhaust emissions" journal of cleaner production 190 (2018) 483-495.
4. Paolo Iodice⇑ , Giuseppe Langella, Amedeo Amoresano "Ethanol in gasoline fuel blends: Effect on fuel consumption and engine out emissions of SI engines in cold operating conditions" Applied Thermal Engineering 130 (2018)
5. M.S.M. Zaharina , N.R. Abdullaha,⁎ , H.H. Masjukib , Obed M. Alic , G. Najafid , Talal Yusafe "Evaluation on physicochemical properties of iso-butanol additives in ethanol-gasoline blend on performance and emission characteristics of a spark-ignition engine" Applied Thermal Engineering 144 (2018) 960-971.
6. R.L. Saria,⁎ , D. Golkea , H.J. Enzweilera , N.P.G. Salauc , F.M. Pereirab , M.E.S. Martins "Exploring optimal operating conditions for wet ethanol use in spark ignition engines" Applied Thermal Engineering 138 (2018) 523-533.
7. J.L.S. Fagundeza , R.L. Sari b , F.D. Mayer a , M.E.S. Martins b , N.P.G. Salau , "Determination of optimal wet ethanol composition as a fuel in spark ignition engine" Applied Thermal Engineering 112 (2017) 317-325.
8. Prakhar Chansauria, R. k. Mandloi "Effect of ethanol blends on performance of spark ignition engine- A review" Material today: Proceeding 5 (2018) 4066-4077.
9. Amit Kumar Thakur, Ajay kumarKaviti, Roopesh Mehra, K. K. S. Mer " Progress in performance analysis of ethanol-gasoline blends on SI engine Renewable and Sustainable Energy Reviews 69 (2017) 324-340.
10. Yu Li a,b , Jinke Gong a,⇑ , Yuanwang Deng a,⇑ , Wenhua Yuan b , Jun Fu b , Bin Zhang "Experimental comparative study on combustion, performance and emissions characteristics of methanol, ethanol and butanol in a spark ignition engine" Applied Thermal Engineering 115 (2017) 53-63.
11. BattalDogˇana ,DervisErol , HayriYaman b , EvrenKodanli "The effect of ethanol-gasoline blends on performance and exhaust emissions of a spark ignition engine through exergy analysis" Applied Thermal Engineering 120 (2017) 433-443.
12. Selahaddin Orhan Akansua,* , Selim Tangoz€ b , NafizKahraman a , Mehmet _ Ilhan _ Ilhak a , Salih Ac¸ıkgoz "Experimental study of gasoline-ethanol-hydrogen blends combustion in an SI engine" International journal of hydrogen energy 42 (2017) 25781-25790
13. S. phuangwongtrakul, W. Wechsatol, T Sethaput, K. Suktang, S. Wongwises "Experimetal study on sparking ignition engine performance for optimal mixing ratio of ethanol gasoline blended fuels"Applied Thermal Engineering 100 (2016) 869-879.
14. G. Najafi, B. Ghobadian, A Moosavian, T. Yusaf, R Mamat, M.kettner " SVM and ANFIS for prediction of performance and exhaust emissions of a SI engine with gasoline-ethanol blended fuels."Applied Thermal Engineering 95 (2016) 186-203.
15. Chen Liang, Changwei Ji ⇑ ,Binbin Gao "Load characteristics of a spark-ignited ethanol engine with DME enrichment" Applied Energy 112 (2013) 500-513
16. B.M. Masum n , H.H. Masjuki, M.A. Kalam, I.M. Rizwanul Fattah, S.M. Palash, M.J. Abedin "Effect of ethanol–gasoline blend on NOx emission in SI engine" Renewable and sustainable energy reviews 24 (2013) 209-222.
17. Rong-Horng Chen a,*, Li-Bin Chiang a , Chung-Nan Chen a , Ta-Hui Lin "Cold-start emissions of an SI engine using ethanolgasoline blended fuel" Applied Thermal Engineering 31 (2011) 1463-1467.