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Review on The Effect of Alcohol Usage as A Fuel Additive in Internal Combustion Engine

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ABSTRACT

The transportation sector holds a big share of the emission to the atmosphere. The emission of Green House Gas (GHG) leads to the thinning of the ozone layer. This situation leads to global warming. An international summit in Kyoto 1997 decided to stabilize the Green House Gas (GHG) emission. Therefore, many types of research have been conducted to reduce emissions. Improving engine performance is another method to reduce the amount of gasoline usage. One of the methods is to reduce emissions is by using alternative fuels. hydrogen, alcohol, and biofuel are among the examples. Among the alternatives, alcohol is a very popular alternative used in an internal combustion engine. This paper aims at reviewing the effect of alcohol on the performance and emission of the use of alcohol inside the spark-ignition engine. This review has confirmed that alcohol serves as good alternative fuel, especially if it is mixed at a good ratio with gasoline. With a good blend of alcohol-gasoline, emission can be reduced significantly.

Key words: Alcohol, engine emission, engine performance, gasoline, spark-ignition engine.

1. INTRODUCTION

The transportation sector holds a big share of the emission to the atmosphere [1-6]. The emission of Green House Gas (GHG) effects leads to the thinning of the ozone layer [7, 8]. This situation leads to global warming [9-13]. The international summit in Kyoto 1997 decided to stabilize the Green House Gas (GHG) emission [14-18]. Therefore, many types of research have been conducted to reduce emissions [19-21]. One of the methods is to reduce emission is by using alternative fuels and additives such as hydrogen, alcohol, biofuel, and carbon nanomaterials [22-27]. Spark ignition engine first developed in late 1800 by Klaus Otto. The internal combustion engine has become the foundation for vehicles, agriculture, military operation as well as electricity generation [28-32]. However, the rapid use of the engine raises the issue of depleting fossil fuel [33-36]. Also, the emission from the engine impacts the atmosphere, ecosphere, and hydrosphere [37-40]. Alcohol family such as methanol, ethanol, propanol is frequently used. Methanol (CH_3OH) is preferable because of its availability and having good combustion behavior [41-45]. Another popular alcohol used is ethanol [46-50]. There is no modification required to the engine when using ethanol. By having high oxygen content, Ethanol increases the oxidation of harmful elements such as CO and HC. Propanol is the third member of the alcohol family [51, 52]. There are not many kinds of research that have been conducted on using it as an alternative fuel. The reason for this is the high production cost of propanol [53-55]. The other member of the alcohol family used as an alternative fuel is butanol [56-60]. There are four types of butanol namely $CH_3CH_2CH_2CH_2OH$ (n-butanol), secondary butanol $CH_3CH_2CHOHCH_3$ (2-butanol), isobutanol $(CH_3)2CH_2CHOH$ (i-butanol), and t-butanol $(CH_3)3COH$ (t-butanol) [61]. All the butanol has the same formula and energy content[62, 63]. Quite many works of literature have been published on the mixture of gasoline-alcohol as an effort to reduce dependencies on fossil fuel. This review serves the purpose of investigating the latest development of alcohol usage in the spark-ignition engine.

2. THE EFFECT OF GASOLINE-ALCOHOL MIXTURE TO THE ENGINE PERFORMANCE

Edwin Geo [64] identifies in an experiment that Benzyl Alcohol blended in gasoline improves combustion,

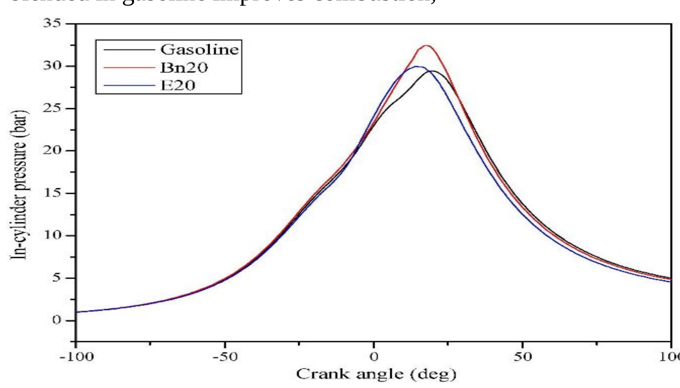

Figure 1. Comparison of in-cylinder pressure from different alcohol-gasoline blends [64] performance, and emission characteristics of the spark-ignition engine. The comparison of pressure produced from pure gasoline and gasoline-alcohol blend is illustrated in Figure 1.

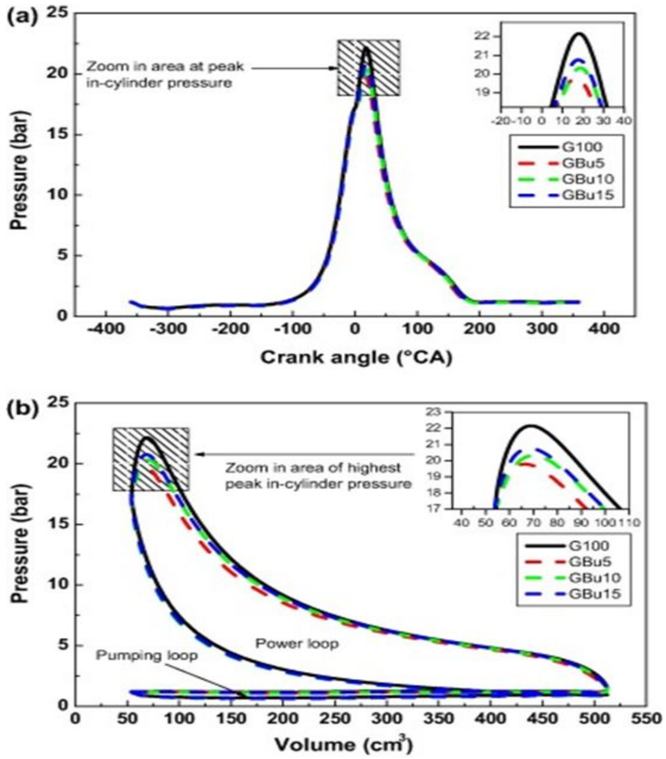

Figure 2. a) Pressure vs Crank Angle b) Pressure vs Volume [65]

In contrast, Balki[65] concluded that cylinder pressure from the Butanol-gasoline blend is lower than the engine running with pure gasoline. Figure 2 shows the different cylinder pressure produced by different blends.Using a single-cylinder gasoline engine, Mishra [66] demonstrated the effect of a gasoline-methanol mix on the performance and emission of a spark-ignition engine. It was noted that at lower rpm, the blend of alcohol-gasoline produced significantly higher power than pure gasoline. Figure 3 shows the difference between the power curves of the pure gasoline compared to the alcohol-gasoline blend at lower rpm.

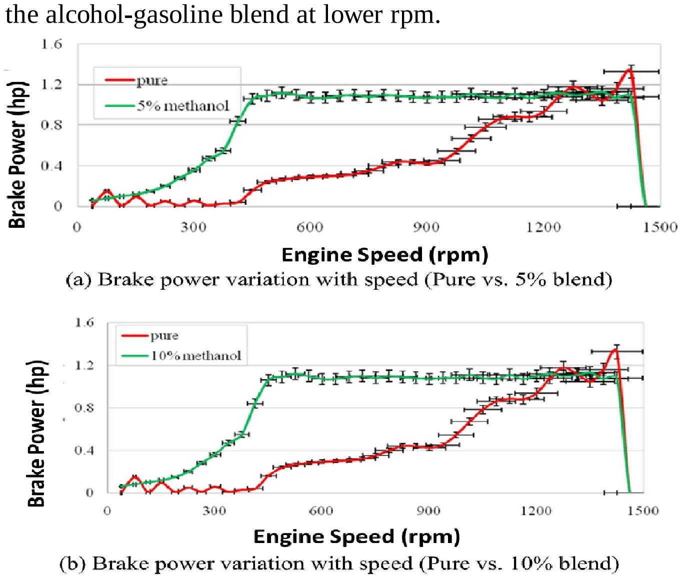

Figure 3. Power comparison between pure gasoline vs methanol-gasoline blend[66]

In another study by S. Phuangwongtrakul [67], a different mixing ratio of ethanol was investigated. Brake torque and brake specific fuel consumption (BSFC) were measured. The result from the experiment showed that proper ethanol-gasoline mixing ratio can improve engine torque. The result is shown in Figure 4.

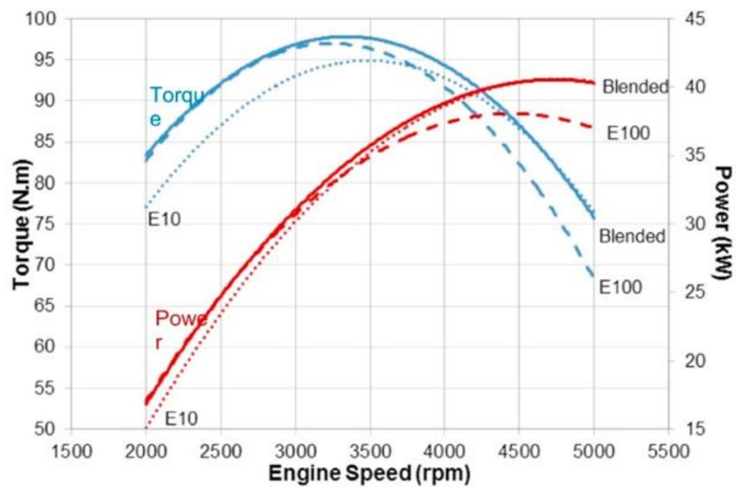

Figure 4. Torque and Power vs Engine Speed [67]

Yusri [68] experimented to find methods to improve energy management in Spark-ignition engines. Gasoline-butanol is used in the 4-cylinder Spark-ignition engine. It was found out that IMEP becomes higher with the addition of 2-Butanol. Besides, the emission produced by the engine also has been reduced. Sayin and Sarikaya[65] experimented using the DOE Taguchi method & ANOVA. The objective was to find optimum parameters that will give the maximum engine performance and acceptable exhaust emissions. In this experiment, a 1-cylinder spark-ignition engine was used. Engine speed, compression ratio, and ignition timing were set as the variables. From the analysis it is found that the 9.0 was the optimum Compression Ratio, optimum engine speed value was 2400rpm.

Najafi [69] experimented to estimate the performance and the exhaust emission of a four-cylinder spark-ignition engine. The engine operated on the different mixing ratios of ethanol-gasoline blends. A mixture of gasoline and bioethanol derived from potato peel 0%, 5%, 10%, 15%, and 20 have been employed. The mixture was called E0, E5, E10, E15, and E20. The engine performance and emission from the mixture have been compared with the performance and emission from 100% gasoline. The result from the experiment shows that Engine Torque, brake Power (BP), Brake Thermal Efficiency (BTE), and Volumetric Efficiency improved by applying ethanol blends. However, in contrast, the brake specific fuel consumption (BSFC) decreased.

In addition, Mourad [70] showed that the use of ethanol/butanol blend in as additive in spark-ignition has improved the characteristics of the performance and emission of the engine.

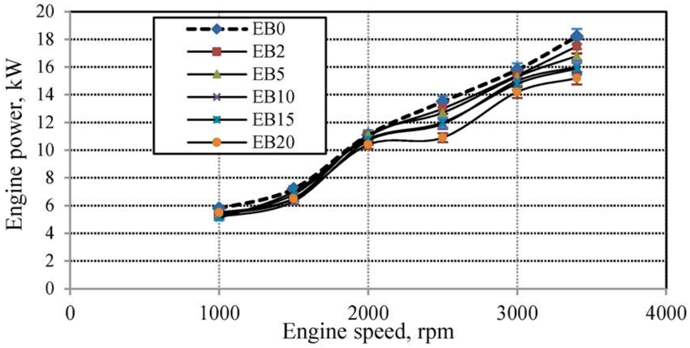

Figure 5. Engine power comparison between different ethanol-butanol blend [70]

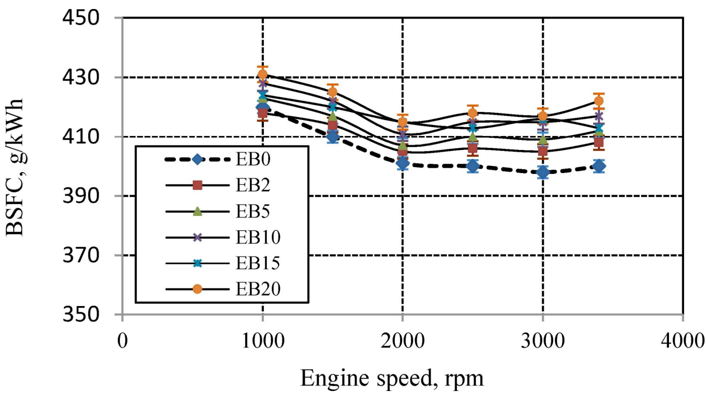

Figure 6. BSFC from different ethanol-butanol blends[70]

Figure 5 shows that the power produced from the blend is lower compared to power produced by 100% gasoline. The lower heating value of ethanol and butanol contributed to the result. In contrast, the BSFC of gasoline is about 5% lower than the blends resulting from the higher heating value of gasoline. This behavior can be observed in Figure 6.

In a different study, Efemwenkiekie [71] explored the different between spark ignition engine run with gasoline compared to gasoline-ethanol blend fuel. The ethanol was locally acquired in Nigeria. The finding shows that the blend of 3% ethanol and 97% gasoline give the best performance.

3. THE EFFECT OF GASOLINE-ALCOHOL MIXTURE TO THE ENGINE EMISSIONS

Mourad [70] performed an experiment to show the effects of alcohol on engine performance and engine emissions. Ethanol and Butanol were mixed with gasoline at 2%, 5%, 10%, 15%, and 20% of the mixture. The engine was run with different speeds at low load. Important findings suggest that the emissions significantly reduced when the engine run with the alcohol mixture. Figure 7 and Figure 8 show the lower emission of HC and CO from the alcohol-gasoline blend combustion.

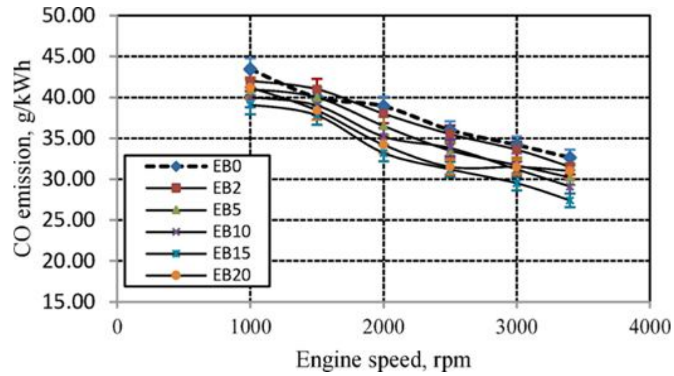

Figure 7. HC emission at different speeds [70]

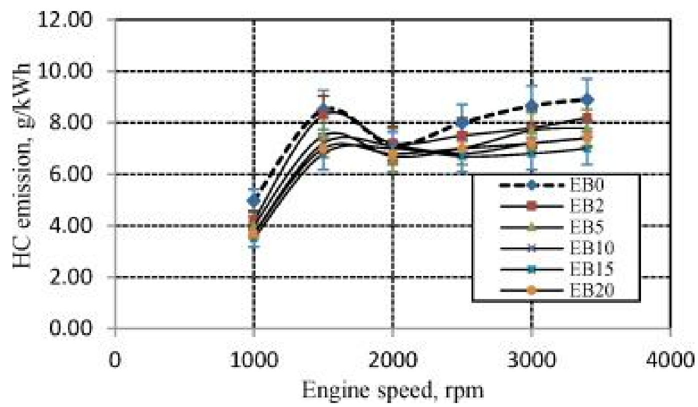

Figure 8. CO emission at different speeds [70]

From Najafi [69], the result from emission showed that the amount of CO and HC has been reduced, however CO_2 and NO_X emissions were higher.

According to a study by Amirabedi [72], Gasoline was mixed with 10% Ethanol. From the result, emission of NOx, HC, and CO all have been reduced. Only CO_2 increased. This is mainly due to the higher rate of complete combustions, reduced CO but then the molecules formed CO_2. This fact is good because CO_2 is not poisonous like CO.

Similarly, Edwin Geo [64]found that the CO and HC are less in alcohol blended fuel compared to the engine run with pure gasoline. The comparisons are illustrated in Figure 9 and Figure 10.

From the emission side of Mourad[70] study, the blends clearly reduced the harmful emissions such as CO and HC. The results are shown in figure 11 and figure 12. The reason for this result is the lower boiling points of the ethanol and butanol compared to gasoline. This property leads to the complete burning of the ethanol and butanol thus decreasing the emissions.

In a different study, Mehmet Ilhak [73] examined the effect of replacing gasoline with ethanol and acetylene. It was run at partial loads (25% and 50%). The speed was maintained at 1500rpm. Among notable result was that the UHC and NOx emission was lower than gasoline.

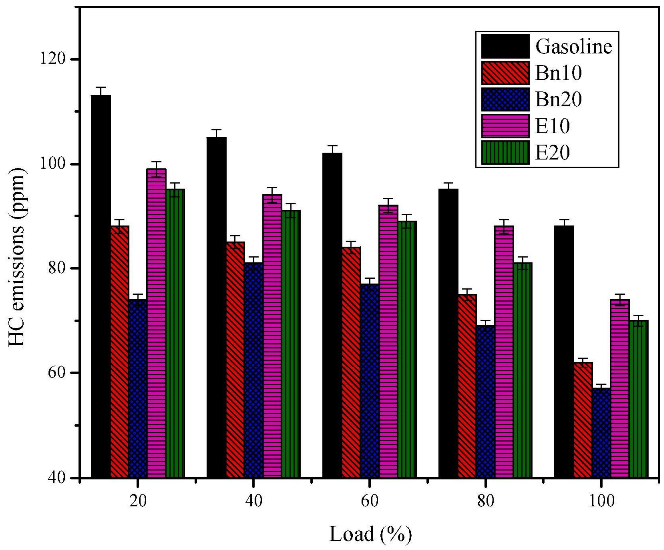

Figure 9. Comparison of HC emissions [64]

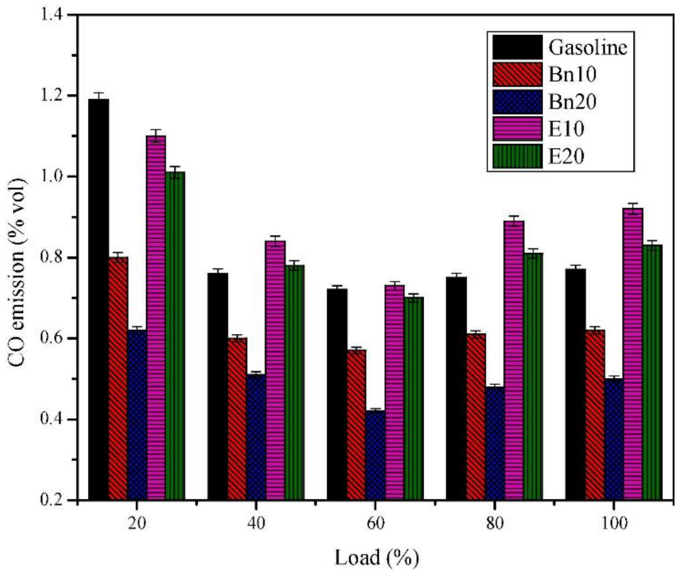

Figure 10. Comparison of CO emissions [64]

Another experiment conducted by Dogan in 2017 [74] to identify irreversible processes using energy and exergy analyses. The Fuels were blended at different ratios. 100% unleaded gasoline is called E0, and gasoline blended with 10% ethanol is called E10. 20% ethanol is called E20 and 30% ethanol is called E30. The fuel blends then applied into gasoline engines with different speeds, under different loads and under the same conditions for each fuel blends. The result from the experiments and theoretical calculations showed a reduction in carbon monoxide (CO), carbon dioxide (CO2), and nitrogen oxide (NOx) emissions without significant loss of power compared to the engine that runs fully on gasoline. However, the emission was increased. This was mainly due to the drop in the temperature inside the cylinder.

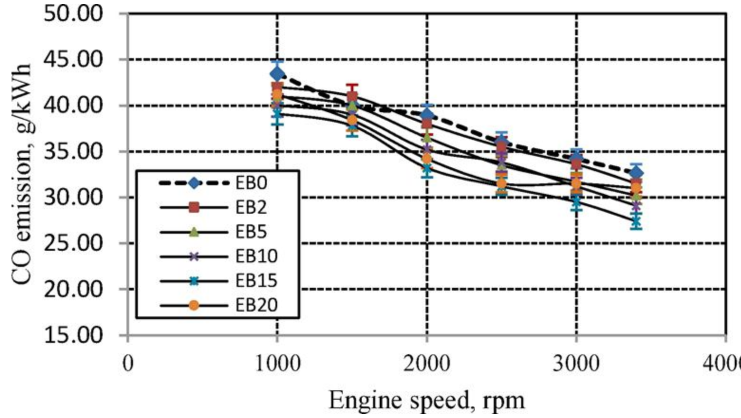

Figure 11. CO emissions from different ethanol-butanol blends[70]

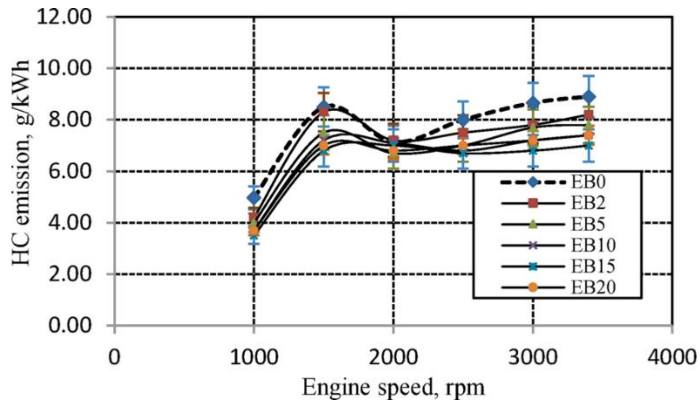

Figure 12. HC emissions from different ethanol-butanol blends [70]

To understand the concept further, Gravalos[75] experimented all popular alcohols (methanol, ethanol, propanol, butanol and pentanol) in a four-stroke spark ignition engine. The results are compared to the unleaded gasoline. It was observed that the CO emissions of alcohol blend is lower compared to neat gasoline. However, the result for CO_2 was increased. The reason is because of higher oxygen content in alcohol make the higher quantity of unused oxygen during combustion.

4. SUMMARY

The readings can be summarized as below table:

Table 1: The results from different experiments

Ref.	Engine Type	Fuel Blend	Result
[66]	Single-cylinder SI Engine	Methanol-gasoline 5%, 10%, and 15%	Blend % ↑, Power ↑
[70]	Four-cylinder SI Engine	Ethanol & butanol mixed evenly with gasoline. Ratios 2%, 5%, 10%, 15% and 20%	Blend % ↑, Power ↓ Blend % ↑, BSFC ↑ Blend % ↑, CO ↓ Blend % ↑, Nox ↓

N [76]	Single cylinder SI Engine	Ethanol 6%, 10%, 15% & 20%	Blend % ↑, IMEP ↓
[77]	Single cylinder SI Engine	-unleaded gasoline -pure ethanol -methanol	engine torque ↑ , (BSFC) ↑ , BTE ↑ , and combustion efficiency ↑
[67]	4-cylinder SI Engine (Toyota 3ZZ-FE).	E10, E20, E30, E40, E50, E60, E70, E85, and E100	At an engine speed below 3500 rpm, the Maximum Brake Torque (MBT) ↑ when ethanol content ↑ Above 3500 rpm, MBT ↓ when ethanol content ↑ BTE max at 58–73% of WOT; 2000–2500 rpm, using E40 and E50 fuels
[68]	4-cylinder SI-Engine	2-butanol+gasoline	2-butanol addition; Cylinder-Pressure ↑ Exhaust emissions: an average of lower Nox. Gbu5 → less 7.1%, Gbu10→less 13.7%, and Gbu15→ less 19.8%.
[65]	Single cylinder SI Engine	unleaded gasoline, pure ethanol, and methanol	optimum CR → 9.0 optimum engine speed → 2400 rpm for all fuels. Optimum IT → 20 crank angle (CA) for alcohol fuels, 26 CA in gasoline
[78]		Ethanol-gasoline blend between E0 and E100	Results show that the Power & Torque ↓ when the ethanol % ↑
[69]	4-cylinder SI Engine KIA 1.3 SOHC	ethanol-gasoline blends of 0%(E0), 5%(E5), 10%(E10), 15%(E15) and 20%(E20)	After the introduction of ethanol blends brake power ↑, the engine torque ↑, the brake thermal efficiency ↑, and the volumetric efficiency ↑ brake specific fuel consumption (BSFC) ↓ CO ↓ and HC ↓ CO2 ↑ and NOX ↑
[71]	Single cylinder SI Engine	100% gasoline 99% gasoline 1% ethanol 97% gasoline 3% ethanol 95% gasoline 5% ethanol	As ethanol content increase; BTE ↑ BP ↑ Torque ↑ BSFC ↓
[74]	4-cylinder SI Engine	100% unleaded gasoline (E0) 10% ethanol (E10) 20% ethanol (E20) 30% ethanol (E30)	Carbon Monoxide (CO) ↓, Hydrocarbon (HC) ↓
[75]	Single cylinder SI Engine	100% gasoline 90% / 85% / 80% / 75% / 70% gasoline + (methanol + ethanol + propanol + butanol + pentanol)	CO ↓ CO2 ↑

5. CONCLUSION

These findings suggest that in general that the alcohol-gasoline mixture is a proven alternative fuel to reduce our heavy dependencies on fossil fuel. Many experiments have been conducted. For the performance, Power, Torque, and cylinder pressure were measured. For the emission, CO, CO_2, NO_X, and unburned HC were measured. In general, the engine performance is better when running with pure gasoline compared to when running with pure alcohol. On the other hand, the engine emission when running with alcohol-blend gasoline is better when compared to an engine run on pure gasoline.

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