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Reducing Emissions and Promoting Environmental Sustainability in Spark-Ignition Engines with Isopropyl Alcohol Blends

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Abstract – Researchers employ various methods to reduce the emissions of pollutants emitted from engines. One approach to decrease the emission levels from spark-ignition engines without making any structural modifications is using alternative fuels. Isopropyl alcohol is used as an alternative fuel in spark-ignition engines. In this study, the effects of using different ratios of gasoline-isopropyl alcohol blends as fuels on exhaust emissions were investigated experimentally in spark-ignition engines. Mass percentages of 10% and 20% isopropyl alcohol were blended with gasoline fuel in the experiments. The experimental results revealed reductions in HC emissions at all engine speeds when different ratios of isopropyl alcohol blended fuels were used compared to gasoline fuel. The maximum reduction in HC emissions was observed with the 20% blend ratio. Reductions in NOx emissions were also obtained with 10% and 20% isopropyl alcohol-gasoline blends. The study concluded that the use of 10% and 20% isopropyl alcohol blended with gasoline fuel resulted in reduced exhaust emissions from the engine. This leads to lower emissions released into the environment and provides an alternative fuel option to petroleum-based fuels.

Keywords – Isopropyl Alcohol, Engine Emission, Alternative Fuels, Environmental Sustainability

I. INTRODUCTION

The environmental impact of vehicle emissions has become a pressing global concern due to its detrimental effects on air quality and climate change. The combustion of fossil fuels in internal combustion engines releases significant amounts of greenhouse gases, nitrogen oxides, particulate matter, and other harmful pollutants into the atmosphere. This has led to the deterioration of air quality, the formation of smog, and the acceleration of climate change [1,2].

Reducing harmful emissions from internal combustion engines has been the subject of extensive research and development. Various methods have been proposed to address this environmental challenge, including the fumigation of alcohols into the intake air or using alcohol-fuel blends. Alcohols, due to their higher oxygen content and higher latent heat of vaporization compared to petroleum-based fuels, have gained significant attention as a potential solution for reducing emissions and improving engine performance [2,3].

Alcohols, such as methanol, ethanol, and isopropyl alcohol, offer several advantages when used as fuel additives or blended with conventional gasoline or diesel fuels [4]. The higher oxygen content in alcohols promotes complete combustion, reducing carbon monoxide (CO) emissions and unburned hydrocarbons (HC). The higher latent heat of vaporization also contributes to improved fuel atomization and vaporization, enhancing combustion efficiency and reducing particulate matter emissions [6].

Research studies have demonstrated the positive impact of alcohol fumigation, and alcohol-fuel blends on reducing harmful emissions. These studies have explored the effects of various alcohol types, concentrations, and injection strategies on engine performance and emissions. The results have consistently shown reductions in CO, HC, and nitrogen oxide (NOx) emissions, as well as improvements in fuel efficiency [6,7].

The use of alcohols as fuel additives or blended fuels has gained attention not only for their potential to reduce emissions but also for their renewable nature [8]. Alcohols can be produced from various renewable feedstocks, including biomass and agricultural residues, offering a more sustainable alternative to fossil fuels. Furthermore, the production of alcohols emits fewer greenhouse gases than traditional petroleum refining processes, contributing to overall environmental benefits [9].

Rejendran and Gavindasamy conducted an experimental study investigating the effects of adding isopropyl alcohol and rubber seed oil methyl ester to diesel fuel. The experimental results showed a reduction in emission values [10]. Srinivasan and Saravanan experimentally investigated the effects of ethanol-gasoline blends in spark-ignition engines. They prepared fuel blends with toluene different alcohol (toluene, methanol, isopropyl alcohol, acetone, and xylene). The experimental findings revealed reductions in CO, HC, and NOx emissions compared to gasoline fuel [11]. Uslu and Çelik examined the effects of isoamyl alcohol-gasoline blends on engine performance and exhaust emissions through experimental measurements. The experimental results demonstrated a decrease in exhaust emissions for all compression ratios when using isoamyl alcohol. With A30 blend, CO, NOx, and HC were reduced by approximately 12.2%, 35.6%, and 6.45%, respectively, compared to gasoline [12]. Çelik investigated the effects of different compression ratios and ethanol-gasoline blend ratios on performance and emissions through experimental analysis. The experimental results showed approximately 53%, 10%, 12%, and 19% reductions in CO, CO2, HC, and NOx emissions, respectively [13].

This study aimed to reduce harmful emissions released from the engine by using isopropyl alcohol-gasoline blends at different ratios. The experimental investigation was conducted under full load conditions and at various engine speeds.

II. Materials and Method

In the experiments, a twin-cylinder, naturally aspirated, electronically fuel-injected, four-stroke, water-cooled engine of Lombardini brand was used.

The experimental setup is schematically shown in Figure 1. The experiments were conducted under full load conditions at 1400, 1800, 2200, 2600, 3000, and 3400 RPM. Before the measurements, the engine was operated idle for 10 minutes, followed by running at 2/3 load for half an hour to reach the steady-state temperature. The engine was allowed to stabilize before the measurement of exhaust emissions. The outlet temperature of the cooling water was maintained at a constant value of 82°C.

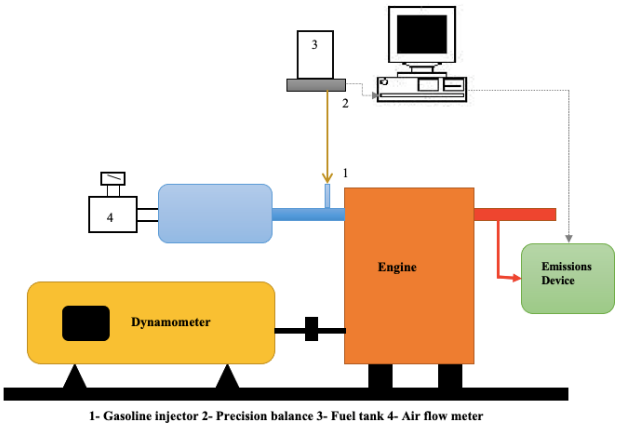

Fig. 1 Schematic view of the experimental setup

In the experiments, an electric dynamometer with a power absorption capacity of 20 kW was used. To measure the emission values from the exhaust, an MRU Delta 1600L brand emission measurement device was employed. The emission device measures CO emissions in percentage (%) and HC and NOx emissions in parts per million (ppm).

Both gasoline and blended fuels were used in the experiments. The blended fuels were prepared by mass, ensuring no phase separation during the preparation process by using a magnetic stirrer. Table 1 provides the technical specifications of gasoline and isopropyl alcohol. The experiments included using a 10% isopropyl alcohol and 90% gasoline blend (I10), as well as a 20% isopropyl alcohol and 80% gasoline blend (I20).

Table.1 Technical specification of gasoline and isopropyl alcohol

Fuel Properties	Gasoline	Isopropyl
Chemical formula	C8H18	C3H7-OH
Intensity (g/cm3 20°C)	0.72-0.76	0,786
Lower calorific value (kj/kg)	44300	30.200
Research octane number	95	100
Ignition temperature (°C)	228-470	362

For comparison purposes, the experiments were initially conducted using gasoline fuel alone. Subsequently, isopropyl alcohol was blended with gasoline at 10% and 20% ratios. The experiments were repeated under the same conditions for each blended fuel.

III. DISCUSSION

In order to reduce exhaust emissions and mitigate their environmental impact, isopropyl alcohol-gasoline blends have been used as alternative fuels in spark-ignition engines. When different ratios of isopropyl alcohol-gasoline blends are used as fuel in spark-ignition engines, the resulting HC emissions are presented in Figure 2. Upon examination of the figure, reductions in HC emissions are observed for all blend ratios. The maximum reduction is achieved with the I20 fuel blend. In the I20 fuel blend, the maximum reduction in HC emissions is 11% at 2200 rpm. On the other hand, the reduction in HC emissions is comparatively lower for the I10 fuel blend. The decrease in HC emissions is attributed to the different chemical and physical properties of alcohol compared to gasoline, which affects the combustion efficiency. Alcohol is an oxygen-rich fuel with a high combustion rate, which improves combustion efficiency. As a result of the improved combustion efficiency, the H and C atoms in the fuel react rapidly with the air, resulting in their combustion without being converted into HC emissions. Additionally, the high flame speed inside the cylinder leads to faster combustion, reducing heat loss from the cylinder walls. These factors contribute to the reduction in HC emissions.

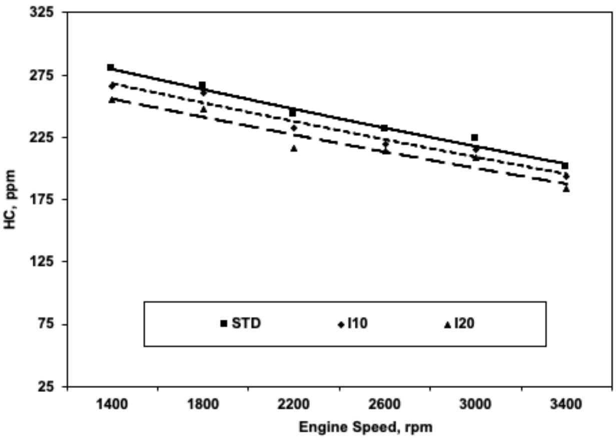

Fig. 2 HC emission changes

Figure 3 presents the NOx emission values from the exhaust when using gasoline and blend fuels in the engine. When isopropyl alcohol blend fuels are sed in the engine, reductions in NOx emissions are observed at all engine speeds and blend ratios. In the I10 fuel blend, the maximum decrease in NOx emissions is 10% at 1400 rpm. Using the I20 fuel blend, the maximum reduction in NOx emissions is 18% at 1400 rpm. The decrease in NOx emissions is attributed to the high latent heat of vaporization of alcohol fuels, which lowers the cylinder gas temperature and thus the maximum combustion temperature in the mixture. Additionally, the alcohol blend fuel sprayed into the intake manifold during the intake process helps lower the manifold temperature. Decreased temperatures contribute to the reduction in NOx emissions.

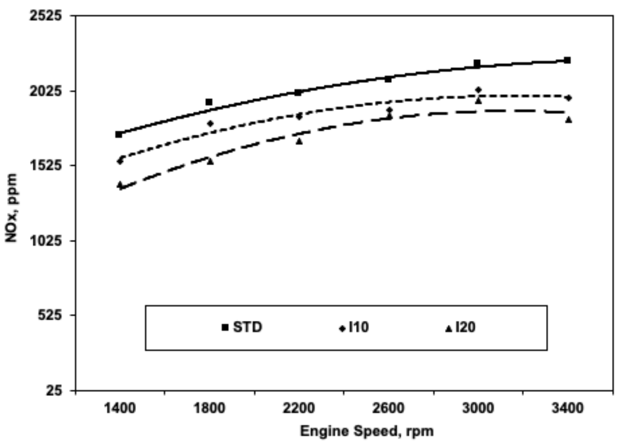

Fig. 3 NOx emission changes

Figure 4 displays the CO emission values from the exhaust when gasoline and blend fuels are not used in the engine. When I10 and I20 blend fuels are used in the engine, reductions in CO emissions are observed. The improvements in CO emissions are attributed to the oxygen-rich nature and high combustion rate of alcohol fuels. As a result, the rapid completion of combustion prevents the conversion of carbon particles in the fuel into CO emissions.

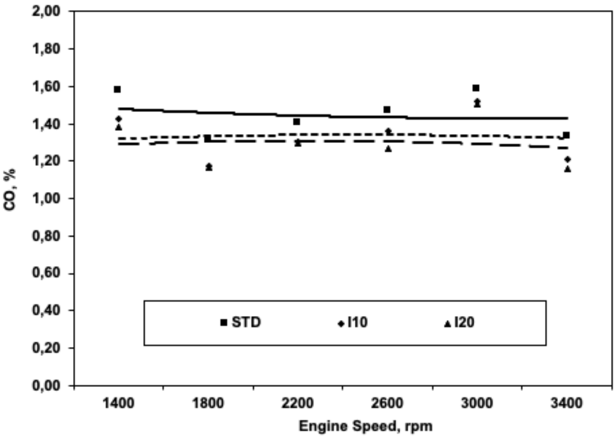

Fig. 4 CO emission changes

IV. CONCLUSION

This study investigates the experimental effects of isopropyl fumigation on exhaust emissions in spark-ignition engines. The literature and findings indicate that isopropyl alcohol has the potential to improve engine performance and reduce exhaust emissions.

In terms of exhaust emissions, reductions in NOx emissions were achieved with isopropyl blended fuels. The low latent heat of vaporization of isopropyl alcohol leads to lower combustion temperatures, helping to prevent the formation of NOx. Additionally, the oxygen content and high combustion rate of isopropyl alcohol contribute to reducing HC emissions. The experimental results showed the following:

- The maximum reduction in HC emissions was 11% for the I20 fuel blend.
- The maximum reduction in NOx emissions was 18% for the I20 fuel blend.
- Reductions were also observed in CO emissions.

Isopropyl alcohol can help reduce harmful compounds commonly found in gasoline engines and meet more stringent exhaust emission standards. Utilizing isopropyl alcohol as a fuel additive in gasoline engines yields several positive environmental outcomes. It reduces emissions, mitigates greenhouse gas production, and enhances engine fuel efficiency. Moreover, isopropyl alcohol can be sourced from renewable materials, making it eco-friendly. Using this greener alternative can lead to a more sustainable and environmentally friendly way of transportation.

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