engineering proceedings

MDPI

Proceeding Paper

Optimization of Performance, Emissions, and Vibrations of a Port Fuel Injection Spark Ignition Engine Operated with Gasoline Ethanol Methanol Blends Using Response Surface Methodology †

Sekhar Chinthamreddy *, Domakonda Vinay Kumar and Shaik Subani

Department of Mechanical Engineering, VFSTR University, Vadlamudi, Guntur 522213, India; vnykrmr@gmail.com (D.V.K.); subanivig@gmail.com (S.S.)
* Correspondence: sekhar.chinthamreddy@gmail.com
† Presented at the 5th International Conference on Innovative Product Design and Intelligent Manufacturing Systems (IPDIMS 2023), Rourkela, India, 6–7 December 2023.

Abstract: IC Engines have played a vital role in past years and will in future years too. The only way that engines are made popular is the power they produce, which is useful in the transportation sector, with which humans' daily lives become easier concerning time and effort. The only issues with these engines are the depletion of fossil fuels and harmful emissions. To regulate these threats, in the current study an SI engine is modified to duel fuel mode in such a way that the engine runs with hydrogen gas at different flow rates along with air. Engine speed is varied from 1800 to 3400 rpm under constant load by letting an ethanol, methanol, and gasoline mixture enter into the cylinder. Performance parameters like brake thermal efficiency, HC emissions, and vibrations produced from the engine are in agreement with the blended fuels used in this study.

Keywords: performance; emissions; hydrogen reactor; petrol; GEM blend

Citation: Chinthamreddy, S.; Kumar, D.V.; Subani, S. Optimization of Performance, Emissions, and Vibrations of a Port Fuel Injection Spark Ignition Engine Operated with Gasoline Ethanol Methanol Blends Using Response Surface Methodology. *Eng. Proc.* **2024**, *66*, 40. https://doi.org/10.3390/engproc2024066040

Academic Editors: B. B. V. L. Deepak, M. V. A. Raju Bahubalendruni, Dayal Parhi, P. C. Jena, Gujjala Raghavendra and Aezeden Mohamed

Published: 24 July 2024

1. Introduction

Energy demand has risen in recent years in all countries and this is having an impact on researchers, who are focusing their attention on fuels that will produce high energy with little money and less pollution or no pollution to benefit humans, the world in which we live, and future generations [1]. So, focus was turned towards biofuels and alcoholic fuels like ethanol, methanol, compressed natural gas, etc. [2]. Ethanol and methanol have more advantages and their productions are versatile. Compared to gasoline alcohols like ethanol and methanol, they can exhibit more power and efficiency because of their properties, like their high octane number and high heat of vaporization [3]. Hydrogen has been used in spark ignition engines for many years and it has been observed that more power is produced with hydrogen utilization in SI engines than with pure gasoline because of the properties of hydrogen. The high flame velocity of hydrogen makes hydrogen much more noticeable and has received a lot of attention from authors [4]. Farooq SK et al. conducted tests on a petrol engine with E30 equivalent by varying its speed from 1700 to 3300 rpm with constant load and reported that performance parameters such as brake thermal efficiency and brake specific fuel consumption enhanced compared to those with pure gasoline [5]. Papla Venugopal Inbanaathan et al.conducted experiments on SI engines with E10, E30, and E50 along with gasoline and hydrogen by varying the speed of the engine. The authors noticed that E10 was better for the overall parameters of the engine when compared to E30 and E50. E30 + hydrogen has proved to have many promising results in terms of combustion, performance, and emissions [6]. Xiumin Yu et al. performed a series of tests and concluded that due to the unique properties of hydrogen combustion and the performance parameters improved, brake thermal efficiency enhanced by 1.96%. Emissions such as HC and CO were reduced by 32% and 0.91% with the addition of hydrogen into a petrol engine [7,8]. Farooq sk et al. conducted experiments on a port fuel injection spark ignition engine with a GEM blend at various speeds and noticed good results with the Gem blend. The authors used response surface methodology for the results [9]. So far, tests have been performed using ethanol, methanol, and hydrogen but a combination of GEM blends is very scarce in engine tests, and in the current study a PFI SI engine was modified into dual fuel mode to run the engine with petrol, ethanol, methanol, and hydrogen at various speeds, such as from 1800 to 3400 by an interval of 400 rpm. Results were obtained, RSM was carried out for the results, and promising conclusions were drawn.

2. Experimental Setup

For the investigations, as shown in Figure 1, a port fuel injection petrol engine was chosen and modified at inlet manifold into duel fuel mode in such a way that petrol and hydrogen could enter the engine cylinder to combust. Engine speed was varied from 1800 to 3400 rpm with an interval of 400 rpm; load was kept constant at 5 kg for the entire test. Hydrogen flow rates varied from 0 (Table 1).

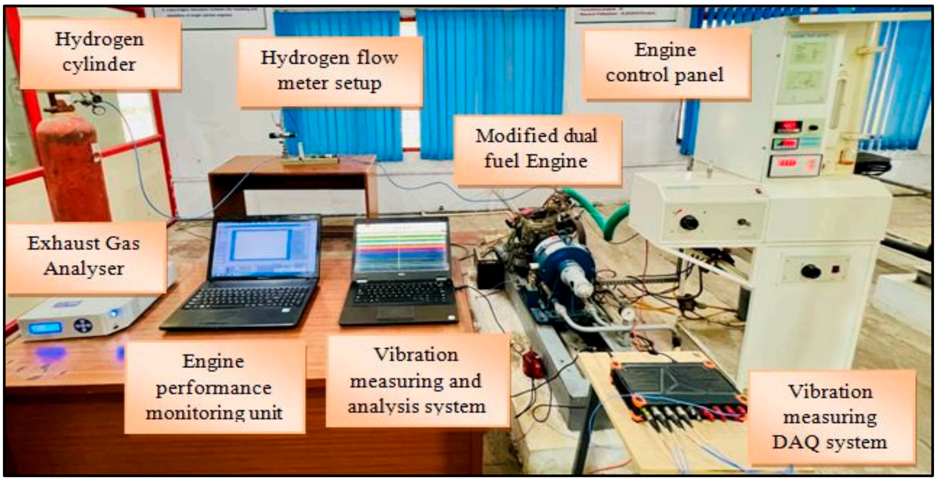

Figure 1. Experimental setup for 15 lpm with interval of 3 lpm. Tests were conducted with pure petrol, E20, and GEM blend. E20 blend was prepared by mixing 80% of pure gasoline with 20% of ethanol; GEM blend was prepared by adding 10% of ethanol and 10% of methanol with 80% of pure petrol.

Table 1. Conditions of engine.

S. No	Parameter	Description
1	Number of cylinders	1
2	Power	4.1 kW @ 3600 rpm
3	Compression ratio	8.5:1
4	Diameter of cylinder	68 mm
5	Type of cooling	Air
6	Length of stroke	54 mm
7	Connecting rod length	105 mm

3. Results and Discussion

3.1. Performance Parameters: Here, One Parameter Is Investigated and Discussed Below

Brake Thermal Efficiency (BTE)

Figure 2 represents a deviation in the BTE for fuel blends and speed. It can be noticed from Figure 2 that by increasing speed, the brake thermal efficiency is enhanced. Brake thermal efficiency is also enhanced with the change in fuel blend such that, here, pure petrol + 3 lpm hydrogen, E20 + 3 lpm hydrogen, and gasoline-ethanol and methanol + 3 lpm hydrogen are used, and when compared to these three fuel blends brake thermal efficiency was highest with GEM + 3 lpm hydrogen, because GEM + 3 lpm hydrogen exhibits a higher brake thermal efficiency than the other two blends, and also with the GEM blend without hydrogen [10], because the higher alcohol content caused oxidation of the blend and, therefore, the high latent heat of vaporization caused a rise in the brake power. Hydrogen's addition to the blend fuels also increased the brake thermal efficiency due to its higher flame velocity; the ignition energy of hydrogen is low, which makes the mixture easier to ignite [11].

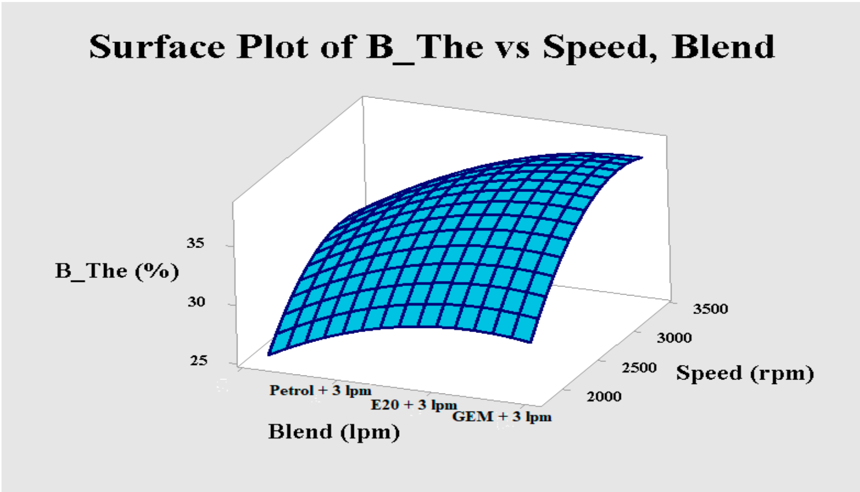

Figure 2. Deviation of BTE with speed and blend.

3.2. Emission Parameters: Variations in HCs Are Studied Here

Hydrocarbons (HCs)

The fluctuation in HCs at different speeds and fuel blends is shown in Figure 3. Here, we can observe that HC emissions decrease slowly with fuel blends. They are highest with petrol + 3 lpm hydrogen and lowest with GEM + 3 lpm hydrogen; this is due to the quenching distance of hydrogen, which is shorter than that of ethanol and methanol, so that flame will propagate to the walls of the combustion chamber. This makes the HC emissions reduce. Hydrogen does not contain carbon and so, with the addition of hydrogen HCs, emissions decrease. Higher oxygen in the GEM blend will result in lower HCs when compared to pure petrol and E20; this is the other reason for reducing HC emissions [11,12].

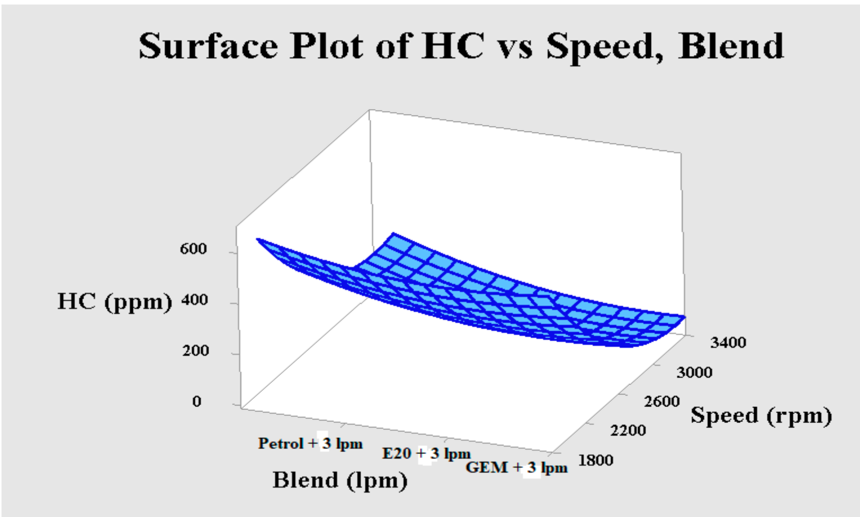

Figure 3. Deviation of HC emissions with speed and blend.

3.3. Vibrations

Engine vibrations are the discomfort factor for a vehicle rider at increasing speeds. Figure 4 describes the effect of vibrations concerning the speed of the engine and blend. Vibrations were raised with an increment in speed and lowered with GEM + 3 lpm hydrogen compared to the other two blends due to the higher oxygen content in the fuel blend, and this leads to healthy combustion which, in return, improves the performance of the engine and avoids a large amount of knocking [13,14].

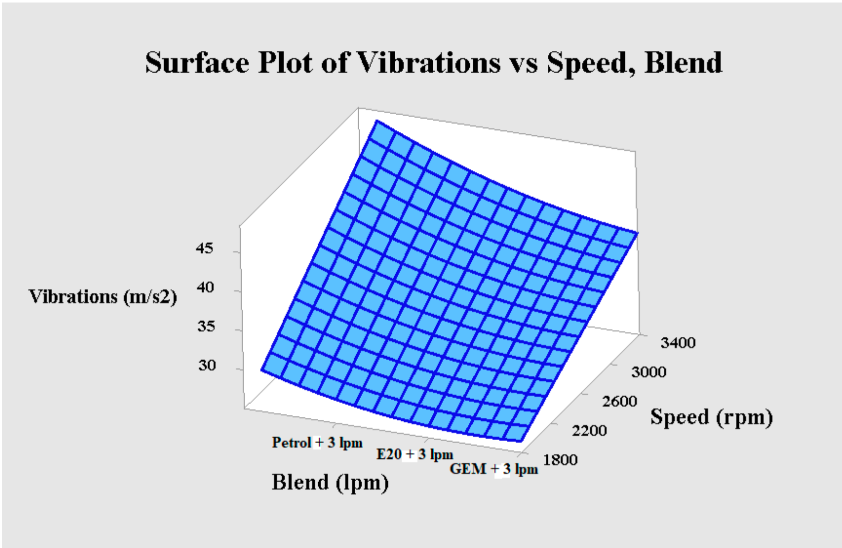

Figure 4. Deviation of vibrations with speed and blend.

Future Work: Hydrogen gas will be supplied at 3 lpm in future research work; the present article discusses a GEM blend with 3 lpm hydrogen, and the results obtained regarding its performance is very promising. The performance of the engine can be enhanced by supplying more hydrogen or increasing the hydrogen flow rates by 6, 9, 12 and 15 lpm.

4. Conclusions

Our experiment used a single-cylinder petrol engine operating in dual fuel mode at different speeds and a variety of blends, like pure petrol + 3 lpm hydrogen, E20 + 3 lpm hydrogen, and GEM + 3 lpm hydrogen at a constant load of 5 kg. An experimental investigation was conducted. Observations from experiments led to the following conclusions:

- We successfully connected a hydrogen cylinder to the port fuel injection spark ignition engine to modify it into dual fuel mode to run and conduct various tests.
- Brake thermal efficiency was enhanced with GEM + 3 lpm hydrogen (37.23%) when compared to the remaining two blends, E20 + 3 lpm hydrogen (36.54%) and pure petrol + 3 lpm hydrogen (33.67%).
- HC emissions also decreased with GEM + 3 lpm hydrogen (55 ppm) and attained the highest values for pure petrol + 3 lpm hydrogen (114 ppm) at 3400 rpm.
- Vibrations fell for GEM +3 lpm hydrogen (38.3826 m/s^2) when compared to those with pure petrol + 3 lpm hydrogen (43.1198 m/s^2).
- Ternary blends like GEM give a high amount of good and promising results from the tests conducted so far. When hydrogen 3 lpm was added, the results showed good agreement.

Author Contributions: S.C.: conceptualization and software; D.V.K.: data curation, review and editing; S.S.: writing original draft, conceptualization and visualization. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: No humans and animals are involved.

Data Availability Statement: No data available.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Subani, S.; Kumar, D.V. Combustion and Vibration Investigations of a Reactor-Based Dual Fuel CI Engine that Burns Hydrogen and Diesel. In *Intelligent Manufacturing Systems in Industry 4.0. IPDIMS 2022*; Lecture Notes in Mechanical Engineering; Deepak, B.B.V.L., Bahubalendruni, M.V.A.R., Parhi, D.R.K., Biswal, B.B., Eds.; Springer: Singapore, 2023. [CrossRef]
2. Sharif, S.K.; Nageswara Rao, B.; Jagadish, D. Comparative performance and emission studies of the CI engine with Nodularia Spumigena microalgae biodiesel versus different vegetable oil derived biodiesel. *SN Appl. Sci.* **2020**, *2*, 858. [CrossRef]
3. Brusstar, M.J.; Stuhldreher, M.; Swain, D.; Pidgeon, W.M. High efficiency and low emissions from a port-injected engine with neat alcohol fuels. In Proceedings of the SAE Powertrain & Fluid Systems Conference & Exhibition, San Diego, CA, USA, 21–24 October 2002. [CrossRef]
4. Bendu, H.; Deepak BB, V.L.; Murugan, S. Application of GRNN for the prediction of performance and exhaust emissions in HCCI engine using ethanol. *Energy Convers. Manag.* **2016**, *122*, 165–173. [CrossRef]
5. Farooq, S.k.; Kumar, D. Experimental Study on Performance, Emissions and Combustion Characteristics of PFI Spark Ignition Engine Fueled with E30 Equivalent Binary and Ternary GEM Blends. *Incas Bull.* **2020**, *12*, 101–112. [CrossRef]
6. Inbanaathan, P.V.; Balasubramanian, D.; Wae-Hayee, M.; Ravikumar, R.; Veza, I.; Yukesh, N.; Kalam, M.A.; Sonthalia, A.; Varuvel, E.G. Comprehensive study on using hydrogen-gasoline-ethanol blends as flexible fuels in an existing variable speed SI engine. *Int. J. Hydrogen Energy* **2023**, *48*, 39531–39552. [CrossRef]
7. Inbanaathan, P.V.; Balasubramanian, D.; Wae-Hayee, M.; Ravikumar, R.; Veza, I.; Yukesh, N.; Kalam, M.A.; Sonthalia, A.; Varuvel, E.G. A comparative study on effects of homogeneous or stratified hydrogen on combustion and emissions of a gasoline/hydrogen SI engine. *Int. J. Hydrogen Energy* **2019**, *44*, 39531–39552. [CrossRef]
8. Yilmaz, İ.; Taştan, M. Investigation of hydrogen addition to methanol-gasoline blends in an Sf I engine. *Int. J. Hydrogen Energy* **2018**, *43*, 20252–20261. [CrossRef]
9. Farooq, S.D. Vinay Kumar Optimization of Performance and Exhaust Emissions of a PFI SI Engine Operated with Iso-stoichiometric GEM Blends Using Response Surface Methodology. *Jordan J. Mech. Ind. Eng.* **2021**, *15*, 199–207.
10. Elfasakhany, A. Investigations on the effects of ethanol–methanol–gasoline blends in a spark-ignition engine: Performance and emissions analysis. *Eng. Sci. Technol. Int. J.* **2015**, *18*, 713–719. [CrossRef]
11. Bendu, H.; Deepak, B.B.V.L.; Murugan, S.J.A.E. Multi-objective optimization of ethanol fuelled HCCI engine performance using hybrid GRNN–PSO. *Appl. Energy* **2017**, *187*, 601–611. [CrossRef]
12. Selçuk, S. Environmental and enviro-economic effect analysis of hydrogen-methanol-gasoline addition into an SI engine. *Fuel* **2023**, *344*, 128124. [CrossRef]
13. Sharma, N.; Patel, C.; Tiwari, N.; Agarwal, A.K. Experimental investigations of noise and vibration characteristics of gasoline-methanol blend fuelled gasoline direct injection engine and their relationship with combustion characteristics. *Appl. Therm. Eng.* **2019**, *158*, 113754. [CrossRef]
14. Bharath, B.K.; Ams, V. Effect of ternary blends on the noise, vibration, and emission characteristics of an automotive spark ignition engine. *Energy Sources Part A Recover. Util Env. Eff.* **2020**, 1–22. [CrossRef]