

RESEARCH ARTICLE

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SYNERGISTIC PERFORMANCE AND EMISSION OPTIMISATION OF A TWO-STROKE SI ENGINE USING MG-PSZ THERMAL BARRIER COATED PISTON WITH ETHANOL–BUTANOL BLENDS THROUGH ANN–NSGA-II–TOPSIS APPROACH

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ABSTRACT

This paper reaches an assessment of the performance and emission traits of a two-stroke spark-ignition engine that is run with gasoline, E20, and B20 fuel under normal and Mg-PSZ-coated piston set ups. The characterization of fuels through GC and FTIR-generated stable mixtures and effective incorporation of the oxygenated functional groups. E20 in uncoated form enhanced brake thermal efficiency (BTE) by about 4-6 % than gasoline, and lowered HC and CO by 8-12 and 10-15 % respectively. Mg-PSZ coating increased the BTE by 5-8 percent and decreased the total fuel consumption by 3-6 percent at all loads. Coated conditions resulted in a further reduction of HC and CO emissions of 10-18%. ANN modeling resulted in R2 values in excess of 0.92 and NSGA-II-TOPSIS optimization established a coated high-load case with an overall 9-12% improvement in the performance-emission which shows high level of synergy between oxygenated fuels and thermal barrier coating.



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I. INTRODUCTION

The tribological and thermal conditions in two-stroke engines are worse than those in four-stroke engines, and piston components of the former face increased stresses of wear and lubrication. Besides acting as a mechanism of imparting the forces of combustion to the crankshaft, the piston in a two-stroke engine manages the timing of intake and exhaust ports as well. This dual action coupled with the constant sliding movement, high combustion temperatures, intermittent lubrication and exposure to combustion residues speed up the process of wear, scuffing and seizure of piston skirt. Such degradation processes affect the engine durability, efficiency, and performance in terms of emissions. In solving these problems, high performance piston surface finishes have become a significant technology in the internal combustion engine. Pistons work in severe thermal gradient and dynamic mechanical loads. Alloyed aluminum without coating is highly prone to adhesive wear and thermal fatigue (especially in the piston). Thermal barrier coating (TBCs) have thus come under extensive research study to enhance the life of the piston and efficiency during combustion [1-4] These coatings inhibit heat transfer between the combustion chamber and the piston substrate and thus increase thermal retention as well as overall engine efficiency.

The use of ceramic-based coating especially partially stabilized zirconia (PSZ) has been of interest because of low thermal conductivity, high melting point, and stability to the chemical environment [5-7]. In the case of piston crowns, PSZ-based finishes minimize cooling losses and retain heated in-cylinder temperatures and result in favorable combustion properties. Furthermore, skirt coatings that contain solid lubricants are used to reduce the friction and scuffing during the boundary lubrication conditions. In parallel with the improvements in coating, biofuels with oxygen groups, like ethanol and n-butanol mixtures have been actively researched as being a viable alternative to gasoline. Octane rating is enhanced by ethanol blends and carbon monoxide and hydrocarbon emissions are reduced by ethanol blends in spark-ignition engines [8-10]. Equally, n-butanol blends have the benefits of high energy density and compatibility with fuel compared to ethanol [11-13]. These fuels have shown great promise with regard to enhancing the combustion efficiency and reducing engine-out emissions [14] [15]. Nevertheless, alcohol-gasoline mixtures can raise the frictional wear occurrence and a little change of fuel consumption nature in the two-stroke engines because of the variations in the lubricity and vaporization conduct [16].

This provides a room to combine sophisticated ceramic coating with oxygenated fuels in a synergistic way. Specifically, Magnesium-Stabilized Zirconia (Mg-PSZ) coatings have been demonstrated to perform better as thermal insulation and an increase in the thermal efficiency of the brakes under the operation of alcohol-blended fuel [17]. Moreover, the use of ceramic-based coatings, including Al_2O_3 and TiO_2 , has shown enhanced wear resistance of coated engine parts when using ethanol-based fuels [16]. Although there has been significant development in the field of coating technology and biofuels research, little has been done relating to the integration of the two in two-stroke engines under extreme tribological conditions. Additionally, predictive and multi-objective decision making tools are needed in order to optimize the trade-off between the brake thermal efficiency, reduction of emissions, and fuel consumption. Thus, the current research analyzes the synergy of the functioning of Mg-PSZ coated pistons using E20 and B20 mixtures in a two-stroke spark igniting engine. Artificial Neural Network (ANN) model predicting the performance and emission characteristics is created and multi-objective optimization is performed with the help of the Non-dominated Sorting Genetic Algorithm II (NSGA-II). The Technique of Order of Preference by Similarity to Ideal Solution (TOPSIS) is the method that allows identifying the most appropriate compromise solution between efficiency, emissions and fuel economy when determining the optimal operating condition.

II. THEORETICAL REFERENCE

II.1 SUBTITLE

II.1.1 Preparation of Fuel Blends

Analytical grade ethanol and n-butanol were purchased against certified local chemical suppliers, and commercial gasoline was purchased at a local petrol station. Table 1 shows the physicochemical properties of pure petrol, ethanol and butanol. The fuel blends were made in three different configurations, i.e. pure petrol (100%), petrol-ethanol blend (E20: 80% petrol + 20% ethanol) [18], and petrol-butanol blend (B20: 80% petrol + 20% n-butanol) [19-22]. The choice of 20 percent alcohol content was informed by the previous experiments that showed better combustion characteristics and reduction of emissions without any substantial engine adjustments [18-22]. A magnetic stirrer was used to stir the mixture in 20 minutes to mix it homogeneously. The ready blends of E20 and B20 were put in the capped 100 mL glass containers at room temperature to avoid absorption of moisture and phase separation. In order to motivate fuel stability implementation, especially in ethanol-gasoline engine, stability test was made following the steps that are reported in two-stroke SI engines [23]. It was established that properties of blended fuels were in line with ASTM standards. The properties measured are summarized in Table 2.

Table 1: Properties of Pure Petrol, Ethanol, and Butanol.

S. No	Parameter	Pure Petrol	Butanol	Ethanol
1	Chemical Formula	Complex mixture	$\text{C}_4\text{H}_9\text{OH}$	$\text{C}_2\text{H}_5\text{OH}$
2	Density (kg/m^3)	753	810	790
3	Calorific Value (MJ/kg)	49.2	33.3	26.8
4	Viscosity ($\text{mPa}\cdot\text{s}$)	0.4–0.8	2.57	1.08
5	Octane Number	96.3	98.3	98.8

Source: Author, (2026).

Table 2: Properties of E20 and B20 Blends.

S. No	Parameter	E20	B20
1	Density (kg/m^3)	0.7541	0.810
2	Fire Point ($^{\circ}\text{C}$)	30.0	36.5
3	Calorific Value (MJ/kg)	32.43	33.3
4	Octane Number	87.7	88.7

Source: Author, (2026).

II.1.2 Thermal Barrier Coating (Mg-PSZ)

Magnesia-partially stabilized zirconia (Mg-PSZ) was the thermal barrier coating material selected because of its desirable mechanical strength, low thermal conductivity, and high fracture toughness [24] [25]. Mg-PSZ is commonly explored in the area of thermal barrier coating (TBC) systems used in the internal combustion engines [26]. The substrate was made of aluminum alloy which is a typical product in the spark ignition engines. Before the deposition of the ceramic topcoat, a bond coat layer (e.g. MCrAlY or NiAl) could be used to increase adhesion and oxidation resistance [27].

It was coated with Mg-PSZ ceramic top coat [28] of the approximate thickness of 100 μm by the plasma spraying method [29] [30] Fig. 1 and Fig. 2 are the schematic representation of the plasma spraying set up and the coating process.

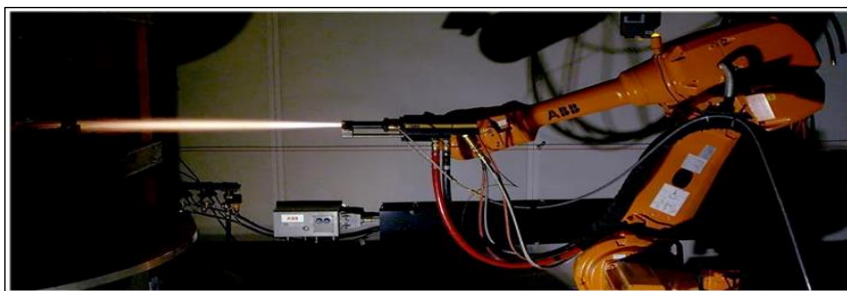


Figure 1: Mg-PSz spraying on the piston surface by using the plasma spray method.
Source: Authors, (2026).

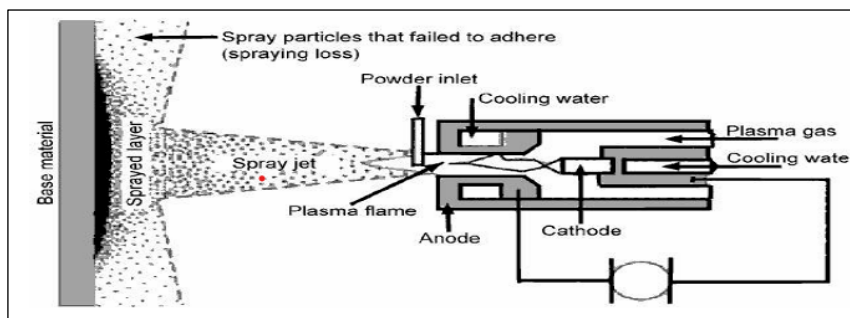


Figure 2: Schematic layout of the Plasma Spray method.
Source: Authors, (2026).

Figure 3 shows a comparison of normal piston and Mg-PSZ coated piston. The coating enhances thermal insulation of the piston crown and as such, minimizes the amount of heat passed on to the piston substrate and the lubricating oil.



Fig (a): normal piston.



Fig (b): Mg-PSZ-coated piston.

Figure 3: Piston Comparison for normal and coated piston.
Source: Authors, (2026).

The thermophysical and mechanical properties of Mg-PSZ are listed in Table 3.

Table 3: Properties of Mg-PSZ.

Property	Value
Density	$5.6 \times 10^3 \text{ kg/m}^3$
Modulus of Elasticity	350 GPa
Flexural Strength	545 MPa
Compressive Strength	1700 MPa
Fracture Toughness	$6 \text{ MPa} \cdot \text{m}^{1/2}$
Hardness	1100 HV
Thermal Expansion	$10 \times 10^{-6} \text{ }^\circ\text{C}^{-1}$
Thermal Conductivity	$2.5 \text{ W/m} \cdot \text{K}$
Specific Heat Capacity	$400 \text{ J/kg} \cdot \text{K}$
Maximum Working Temperature	1000 $^\circ\text{C}$
Dielectric Strength	6 kV/mm

Source: Authors, (2026).

III. CHARACTERISATION OF FUEL BLENDS

Gas Chromatography (GC)

Gas Chromatography (GC) was utilized in order to establish the compositional distribution of volatile elements in the E20 and B20 mixes. GC is a separation of compounds in contact with a carrier gas phase and a stationary phase in a capillary column according to their partition between the carrier gas phase and the stationary phase. It is a common approach to the characterization of fuels, as well as to the determination of alcohol levels in gasoline mixtures [31-33] The GC analysis in the research was done to verify the uniformity of the blend and to ascertain the alcohol content in the prepared samples. Fourier Transform Infrared (FTIR) Spectroscopy. Fourier Transform Infrared (FTIR) was used to determine functional groups and determine the chemical interactions in the blended fuels [34-36] FTIR is a technique that works by identifying vibrational exchanges of bonded molecules in the presence of the infrared radiation. The method employs the use of a Michelson interferometer and the interferogram obtained is transformed into an absorption spectrum by means of Fourier transformation. FTIR has found extensive use in the characterization of gasoline-ethanol blends and stability of fuels [37] [38] Experimental Setup:



Figure 4: Experimental setup.

Source: Authors, (2026).

It is evident in Figure. 4 that the investigation is conducted by acquiring an experimental set up of a two-stroke air-cooled single cylinder spark ignition with an electrically loaded eddy current dynamometer. Table 4 and 5 contain the specifications of the base engine and the generator.

Table 4: Engine Specifications.

Item	Specifications
BHP	3HP
Speed	3000 RPM
No of Cylinders	1
Bore	57mm
Stroke	57mm
Compression Ratio	7.4:1

Source: Authors, (2026).

Table 5: Generator Specifications.

Item	Specifications
Power	3kW
Speed	3000 RPM
Type	Compound Wound

Source: Authors, (2026).

At no load condition, when the engine is started by standard piston, pure petrol, ethanol, and butanol, then, observe the time when fuel is consumed, and the current and voltage can be measured on the panel board. Monitor the exhausts with a gas analyzer. Subsequently, the loading of the different loads will be put into consideration and the same followed. Replacement of the new piston i.e. the piston covered with Mg-PSZ and the test procedure will be again repeated. The observance of all the parameters will give a comparative result analysis between the normal piston and the piston coating as well as gasoline blends.

IV. METHODOLOGY

The general approach to the research is a combination of experimental research, modeling based on data and multi-objective optimization. The entire Design of Experiments (DOE) was a fully factorial design that was used in order to systematically assess the effect of piston configuration, fuel blend and engine load on performance and emission properties. Artificial Neural Network (ANN) model was developed on the experimental dataset and it acted as a surrogate model to continue prediction. The trained ANN model was then integrated with the Non-dominated Sorting Genetic Algorithm II (NSGA-II) to use as the multi-objective optimizer. The Technique of Order of Preference by Similarity to Ideal Solution (TOPSIS) was employed in ranking the Pareto-optimal solutions to find the best operating condition.

Table 6 contains the parameters of the experimental design, such as the levels of the factors and the sum of all the test combinations. Table 7 shows the input and output variables that were involved in ANN modeling and optimization and Table 8 and Table 9 show the detailed ANN architecture and training parameters and multi-objective optimization parameters used in NSGA-II and TOPSIS, respectively. All these tables provide transparency, reproducibility, and methodological clarity to the framework of ANN-NSGA-II-TOPSIS employed in the current study.

Table 6: Experimental Design Matrix (DOE Structure).

Factor	Type	Levels	Description
Piston Type	Categorical	2	Base piston, Mg-PSZ coated piston
Fuel Blend	Categorical	3	Gasoline, E20, B20
Engine Load	Continuous	5	0%, 25%, 50%, 75%, 100%
Total Runs	—	30	2 × 3 × 5 Full factorial design

Source: Authors, (2026).

Table 7: Input and Output Variables Used for ANN Modeling.

Category	Variable	Symbol	Unit
Input	Piston Type	P	—
Input	Fuel Blend	F	—
Input	Engine Load	L	%
Output	Brake Thermal Efficiency	BTE	%
Output	Mechanical Efficiency	η_{mech}	%
Output	Hydrocarbon Emission	HC	ppm
Output	Carbon Monoxide	CO	%

Source: Authors, (2026).

Table 8: ANN Model Configuration.

Parameter	Specification
Model Type	Feedforward Artificial Neural Network
Hidden Layers	2
Activation Function	ReLU / Sigmoid
Training Algorithm	Backpropagation
Performance Metrics	R ² , RMSE
Data Preprocessing	Normalization, Encoding

Source: Authors, (2026).

Table 9: Multi-Objective Optimization Configuration.

Component	Description
Algorithm	NSGA-II
Objectives	Maximize BTE, Maximize η_{mech} , Minimize HC, Minimize CO
Population Size	Defined per iteration
Generations	Iterative convergence
Decision Method	TOPSIS Ranking
Final Output	Optimal operating condition

Source: Authors, (2026).

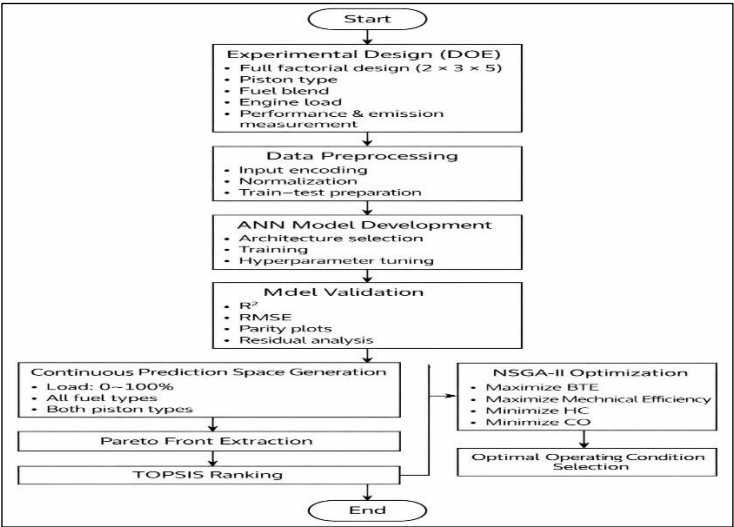


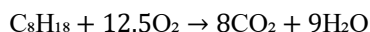
Figure 5: Integrated ANN-NSGA-II-TOPSIS optimization framework for coated two-stroke engine analysis.
Source: Authors, (2026).

The combined approach taken by the current study is shown in Figure 5. A experiment in the form of a full factorial ($2 \times 3 \times 5$) was carried out taking into account the piston type, fuel mix, and engine load. The performance and emission data obtained were pre-processed by normalization and encoding and then an Artificial Neural Network (ANN) model was trained. The validation of the model was done through R2, RMSE, parity plot and residual analysis. An ANN that was trained was then applied to produce a continuous prediction space, and this facilitated multi-objective optimization via NSGA-II. TOPSIS was used to obtain pareto-optimal solutions and rank them to identify which operating condition is most balanced yielding the highest efficiency and minimum emissions.

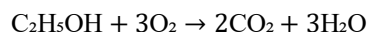
V. RESULTS AND DISCUSSIONS

Baseline Engine Performance and Fuel Characterisation Performance of the Engine

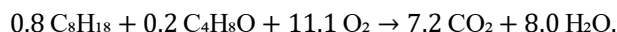
The experimental results obtained from the test rig are presented to compare the performance of pure petrol, E20, and B20 blends under conventional and Mg-PSZ-coated piston configurations. During combustion, petrol hydrocarbons oxidize according to:



Similarly, ethanol undergoes complete oxidation as:



The presence of the hydroxyl group ($-\text{OH}$) in ethanol contributes additional oxygen, promoting more complete combustion of hydrocarbon fractions. Although ethanol improves octane rating and combustion completeness, its lower calorific value slightly reduces the overall energy content of the blend. Similarly, the idealized combustion of the petrol–butanol blend can be represented as:



The oxygenated structure enhances oxidation but marginally lowers energy density compared to neat petrol.

Gas Chromatographic Analysis

The gas chromatograms of pure petrol, E20, and B20 blends are shown in Fig. 6. Pure petrol presents several peaks which are related to light hydrocarbons and aromatic fractions. The E20 mixture has another sharp peak at about 0.8 min which is attributed to ethanol meaning that it is more volatile. The B20 mixture exhibits a different peak of 1.3 min that is associated with butanol which is less volatile when compared to ethanol. The total hydrocarbon profile is still to a great extent the same, which proves that there is no significant change in the base fuel composition and that it was blended successfully.

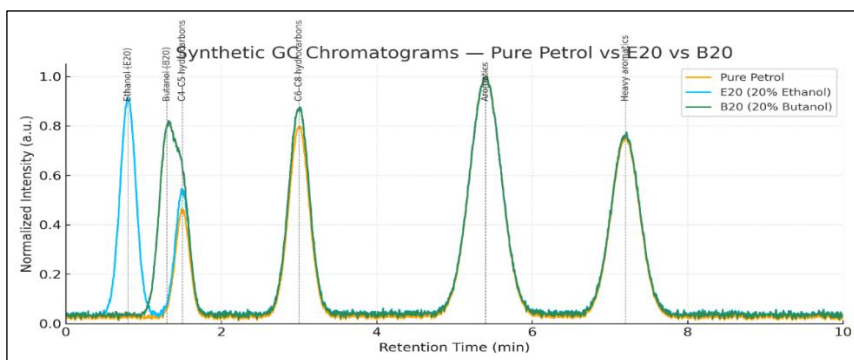


Figure 6: Gas Chromatography test for Pure petrol, E20 and B20.
Source: Authors, (2026).

FTIR Spectroscopic Analysis

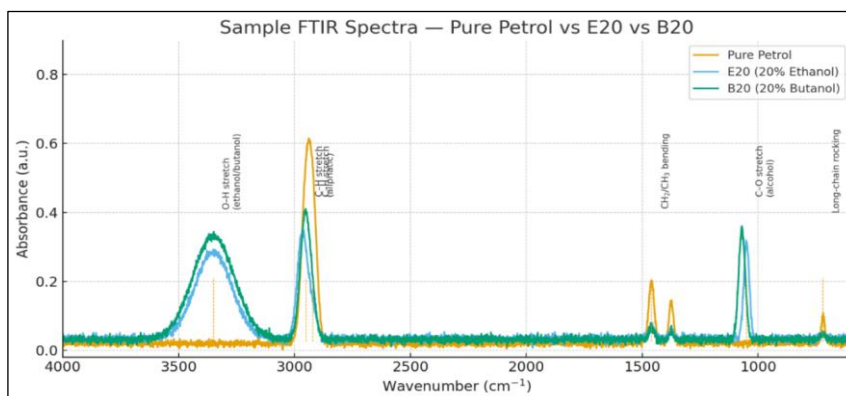


Figure 7: FTIR test for Pure petrol, E20 and B20.
Source: Authors, (2026).

The FTIR spectra of pure petrol, E20, and B20 in the 4000-600 cm^{-1} range are presented in Fig. 7. The pure petrol has typical characteristic C-H aliphatic stretching bands (2950-2925 cm^{-1}). The presence of ethanol is indicated by the E20 blend which has a broad O-H stretch at 3350 cm^{-1} and a C-O peak at 1040 cm^{-1} . In the same way, O-H absorption at 3350 cm^{-1} and C-O stretch at 1070 cm^{-1} are observed in B20. The formation of oxygenated functional groups affirms the successful incorporation of alcohols and the retention of the predominant hydrocarbon backbone.

Load vs Brake Power

Figure. 8 (a) indicates that all fuels have a positive relationship between the brake power and the load when uncoated. At full load gasoline gives the highest brake power as the calorific value of gasoline is higher. E20 is better than B20 in medium and high loads as the enrichment of oxygen increases the combustion efficiency.

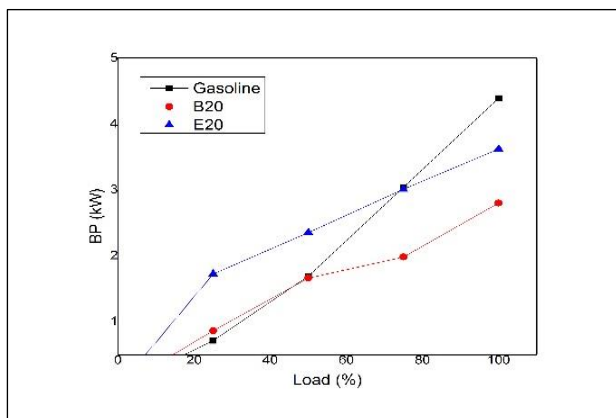


Figure (a): For Un-Coated piston.

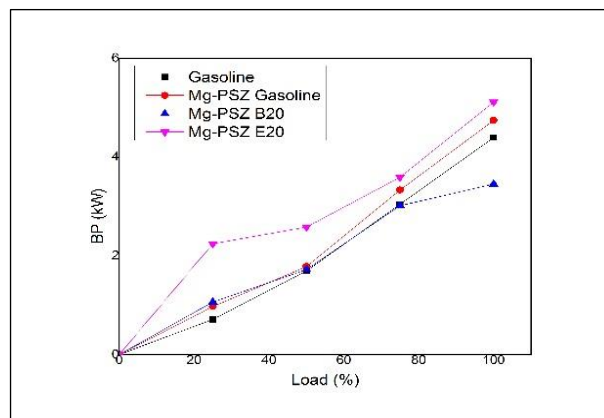


Figure (b): For Mg-PSZ-coated piston.

Figure 8: Load Vs Brake Power.

Source: Authors, (2026).

In Mg-PSZ-coated conditions (Fig. 7(b)) there is an improvement of brake power with all fuels. The coating minimizes the heat losses and raises the in-cylinder temperatures. Mg-PSZ + E20 gives the maximum brake power and B20 is also relatively lesser because of its low heating value.

Load vs Total Fuel Consumption (TFC)

Figure. 8 (a) shows that all fuels in the uncoated engine have a positive correlation between load and TFC. Gasoline is the lowest in TFC whereas B20 is the most consumed owing to lesser energy density.

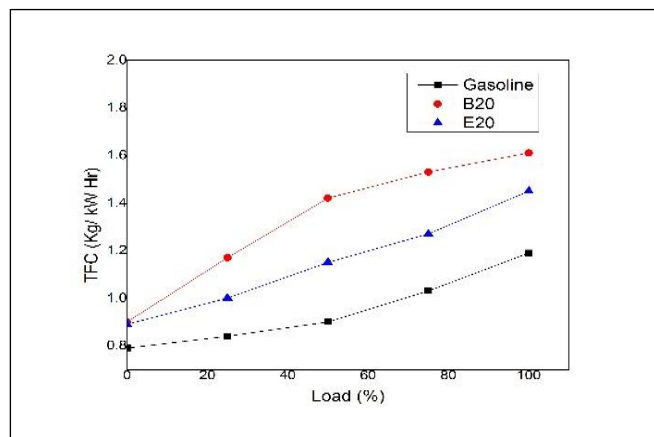


Figure (a): For Uncoated piston.

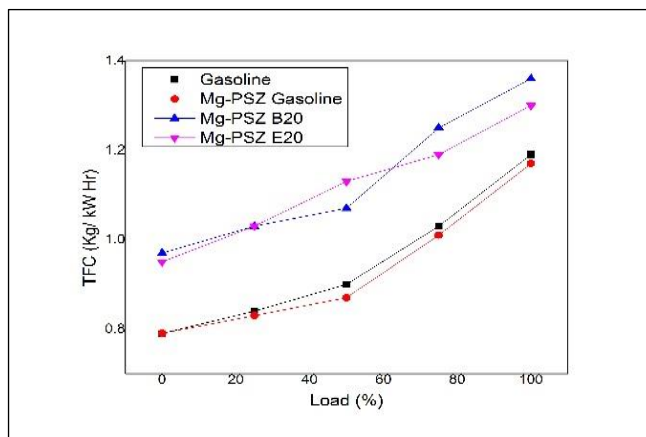


Figure (b): For Mg-PSZ piston.

Figure 9: Load Vs Total Fuel Consumption.

Source: Authors, (2026).

When coated with Mg-PSZ (Fig. 9(b)) TFC reduces at all conditions of load. An increase in thermal retention will also increase the efficiency of combustion and the use of fuel. Even though the oxygenated blends burn a little bit more fuel compared to gasoline, the coating counteracts this disparity.

Load vs Brake Thermal Efficiency (BTE)

Figure. 10 (a) indicates that E20 has a better BTE than gasoline and B20 in the uncoated engine owing to the improved combustion that is enhanced by oxygen. B20 has a little less efficiency.

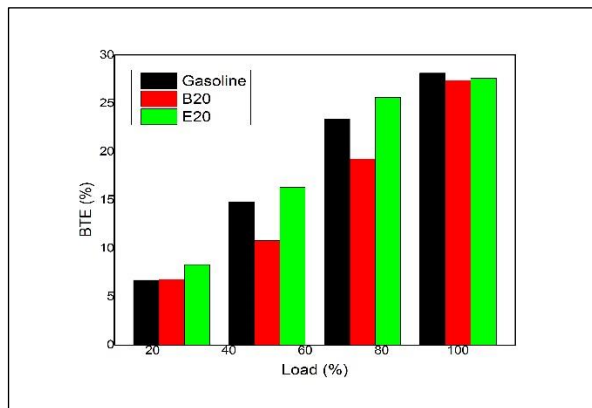


Figure (a): For Un coated piston.

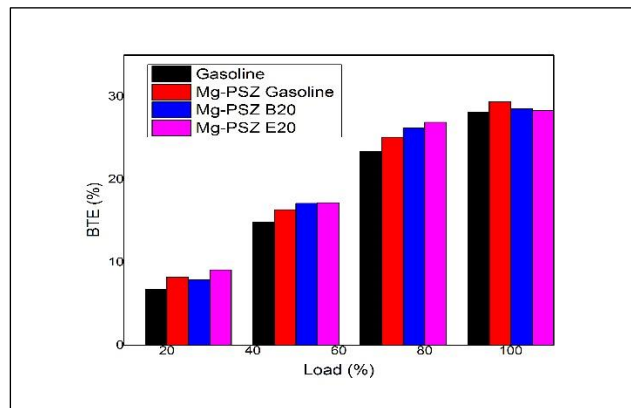


Figure (b): For Mg-PSZ-coated piston.

Figure 10: Load Vs η BTH.

Source: Authors, (2026).

Under Mg-PSZ coating (Fig. 9(b)) there is an increase of BTE of all fuels because of the reduced heat rejection. The coated E20 blend is most efficient when full loaded, which portrays the synergistic influence of oxygenated fuel and thermal insulation.

Load vs Hydrocarbon (HC) Emissions

Fig. 11 (a) indicates that the emissions of the gasoline are greater under the uncoated conditions. E20 and B20 lower HC because they enhance oxidation of fuel bound oxygen.

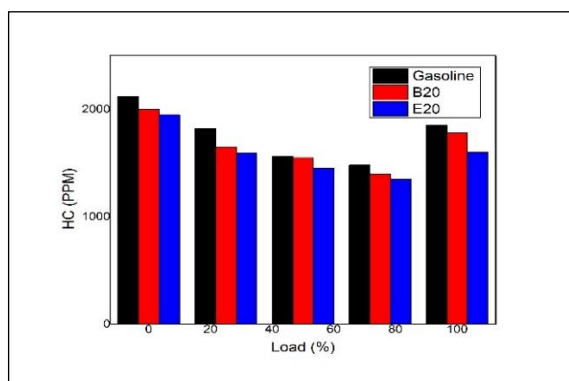


Figure (a): For Uncoated Piston.

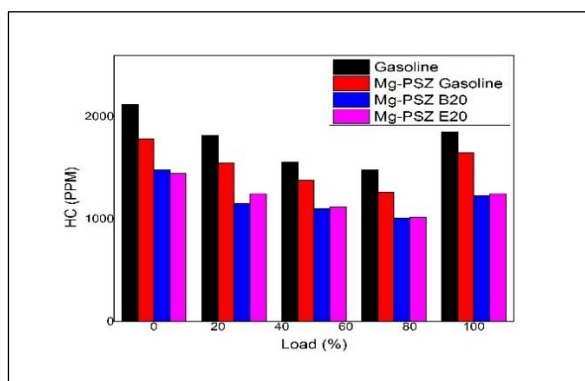


Figure (b): For Mg- PSZ coated piston.

Figure 11: Load Vs HC.

Source: Authors, (2026).

Using Mg-PSZ coating (Fig. 10 (b)), the carbon monoxide emissions drop even further in all fuels due to high combustion temperature and better burning of the unburned hydrocarbons. The lowest HC emissions are recorded by Mg-PSZ + E20.

Load vs Carbon Monoxide (CO) Emissions

Figure. 12 (a) indicates that gasoline results in the best CO emissions in the uncoated conditions. Oxidated blends decrease the formation of CO as a result of better oxidation.

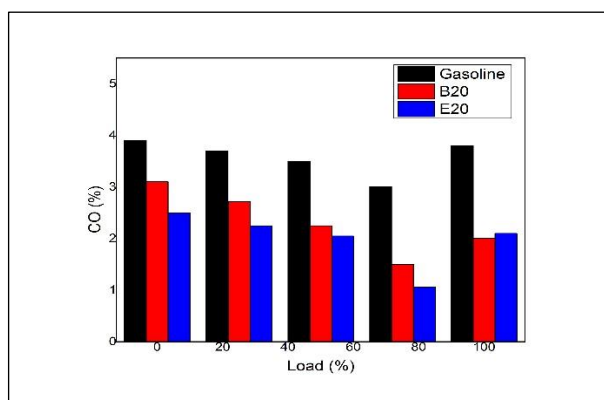


Figure (a): Uncoated Piston.

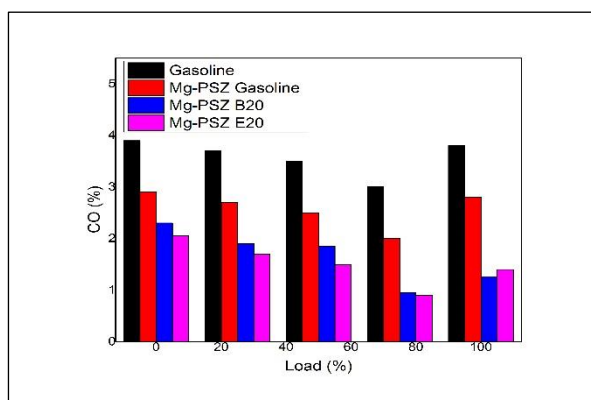


Figure (b): Mg- PSZ Coated piston.

Figure 12: Load Vs CO.

Source: Authors, (2026).

Emission of CO is reduced by a very large percentage with Mg-PSZ coating (Fig. 12 (b)) in all fuels since the better thermal insulation increases the oxidation rate of the CO to produce CO₂. The E20 and B20 blends with coating have the lowest CO emissions.

Multi-Objective Optimization and Decision Analysis

ANN Model Validation

An Artificial Neural Network (ANN) was created to estimate the brake thermal efficiency (BTE), mechanical, hydrocarbon (HC), and carbon monoxide (CO) emissions as a function of piston type, fuel blend, and engine load. The coefficient of determination (R^2) and root mean square error (RMSE) were used to determine model performance. Table 10. Statistical performance parameters of the ANN model in predicting engine performance and emission parameters.

Table 10: Performance Metrics of the Developed ANN Model.

Output Parameter	R^2	RMSE
Brake Thermal Efficiency (BTE)	0.9996	0.2014
Mechanical Efficiency	0.9999	0.2548
Hydrocarbon Emission (HC)	0.9988	9.8408
Carbon Monoxide Emission (CO)	0.9209	0.2292

Source: Authors, (2026).

NSGA-II Pareto Optimisation

The ANN model has been validated and incorporated into the Non-dominated Sorting Genetic Algorithm II (NSGA-II) to undertake multi-objective optimization. The goals were outlined to be:

- Maximize BTE
- Maximize mechanical efficiency
- Minimize HC emissions
- Minimize CO emissions

NSGA-II produced a Pareto front that reflected the efficiency / emission properties trade off. The Pareto solutions depict how difficult it is to maximize thermal efficiency and minimize exhaust emissions.

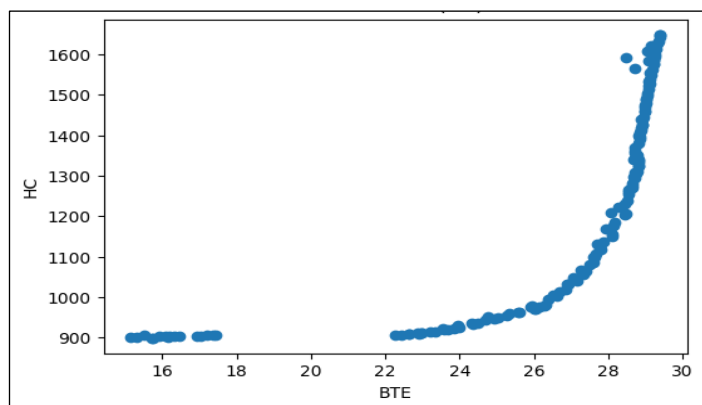


Figure 13 (a): 2D Pareto front plots.
Source: Authors, (2026).

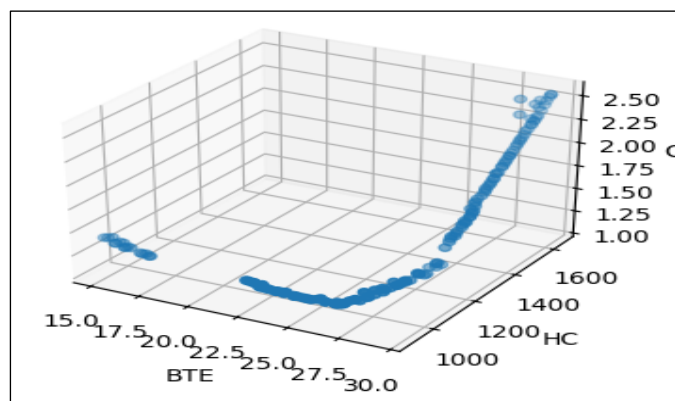


Figure 13: (b): 3D Pareto surface.
Source: Authors, (2026).

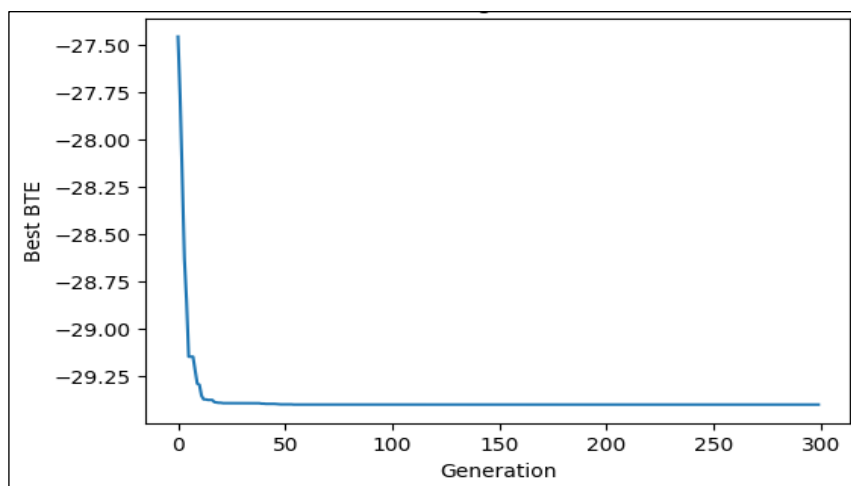


Figure 14: Convergence curve.
Source: Authors, (2026).

The Pareto analysis validates the fact that regions of greater efficiency are associated with the modest rise in the emissions levels, and a decision-making approach should be employed to find a compromise. Figures 13 and 14 show the results of the multi-objective optimization achieved with the help of the NSGA-II algorithm. Figure 13 shows the Pareto front, where the parameters of efficiency (BTE and mechanical efficiency) and the emissions (HC and CO) are maximized and minimized respectively. The allocation of non-dominated solutions proves that the conflict between performance enhancement and reduction of emissions is natural, which means that the changes in thermal efficiency can result in insignificant changes in the formation of pollutants. The convergence behaviour of the optimization process is depicted by figure 16 whereby the value of the objectives decreases with the increase in the generations, which proves that the algorithm converges to a consistent state and is able to accurately identify the optimal solution region.

TOPSIS-Based Optimal Solution Selection

In order to check the most balanced operating point, Technique of Order of Preference by Similarity to Ideal Solution (TOPSIS) was used on the Pareto-optimal set. Closeness coefficient was calculated on individual solutions and they were ranked according to the proximity of the solutions to the ideal point.

The solution arrived at is the best and it is:

- Piston type: 1 (Mg-PSZ coated)
- Fuel blend: 1.96 (approximately E20–B20 range)
- Load: 84.55%
- Closeness coefficient: 0.8156

The findings show that a coated piston that is running at and around high load with an oxygen blended fuel mixture is the one that provides the most appropriate compromise in terms of efficiency improvement and emissions reduction.

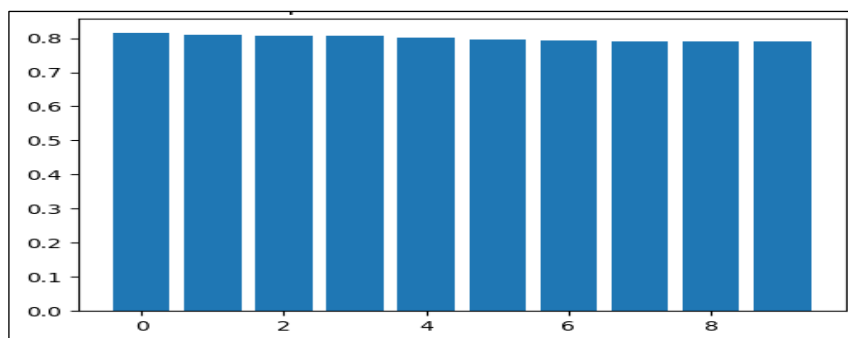


Figure 15: Closeness coefficient ranking bar chart.

Source: Authors, (2026).

The TOPSIS ranking of closeness coefficients of the Pareto-optimal solutions in NSGA-II are provided in Figure 15. The closeness coefficient is the relative closeness of each solution to the optimal point, i.e., the situation where maximum efficiency and minimum emissions are both attained. The greater the value of coefficient, the higher the overall performance-emission balance. The best solution has the closest value (0.8156), which proves its superiority with the candidate solutions. The ranking trend indicates a progressive trade-off behaviour, which confirms the usefulness of TOPSIS in making the most balanced operating condition among the Pareto frontier.

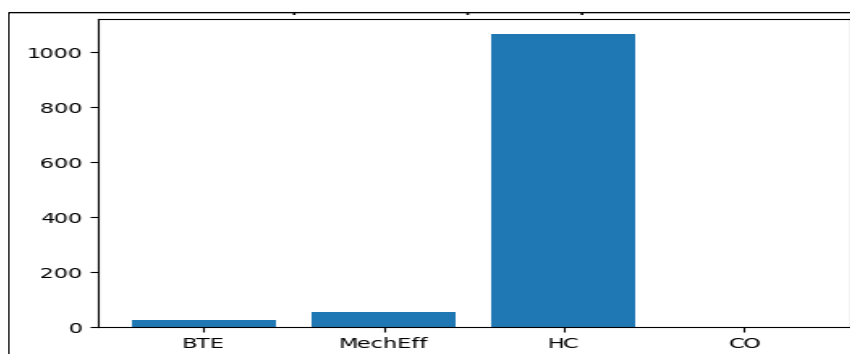


Figure 16: Radar comparison of baseline vs optimized condition.

Source: Authors, (2026).

Figure 16 has compared the experimental condition at the baseline with TOPSIS-optimized operating point of BTE, mechanical efficiency, HC, and CO emissions. The optimized result, which can be associated with the Mg-PSZ coated piston at high loads and oxygenated mixture, depicts a better thermal efficiency and lower emissions levels compared to the baseline one. The concurrent improvement of the efficiency parameters and the reduction of the pollutants formation is pointed out in the comparative visualization. This supports the usefulness of the combined ANN-NSGA-II-TOPSIS model to determine a balanced and performance-effective operating range.

VI. CONCLUSION

The current experiment was a controlled systematic assessment of the performing capabilities of a two-stroke spark-ignition engine and the overall emission characteristics of oxygenated fuel blends (E20 and B20) with Mg-PSZ thermal barrier coating. The results of the fuel characterization by the use of GC and FTIR confirmed the successful blending of the hydrocarbon backbone with the introduction of oxygenated functional groups successfully. The outcomes of the experiment showed that E20 enhanced brake thermal efficiency (BTE) by about 4-6 % over gasoline under uncoated conditions since it enhanced oxygen- assisted combustion. The greatest changes were however realized when Mg-PSZ coating was utilized. This coated configuration increased BTE by 5-8 %, decreased total fuel consumption by 3-6 percent and had massive reductions in emissions, including 12-18 percent lower hydrocarbon (HC) emission and 15-20 % lower carbon monoxide (CO) emission compared to the uncoated gasoline baseline. Out of all the combinations that have been tested, the Mg-PSZ-coated piston with E20 showed the best overall performance-emission balance, especially at the higher load conditions. ANN modeling exhibited a high predictive performance ($R^2 = 0.92-0.999$), with the combined NSGA-II-TOPSIS optimization model establishing an optimum high-load coated operating condition with a closeness coefficient of 0.8156, which proved the existence of a strong trade-off between efficiency increase and emission decrease.

VII. AUTHOR'S CONTRIBUTION

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