Alq J Sci. 2025;1(3):289-294
https://doi.org/10.69667/ajs.25305

Alqalam Journal of Science
مجلـــة القلم للعلوم
https://alqalam.utripoli.edu.ly/index.php/AR

Original article

Feel Engine Performance Using Advanced Professional Techniques

Mohamed Mokari
General Department, Higher Institute of Science and Technology, Al-Shuqayqah, Libya
***Corresponding email**. moham.abdallah2277@gmail.com*

Abstract
The study explores the use of advanced professionalization techniques to improve engine performance in conventional, hybrid, and electric engines. It uses an experimental approach and a descriptive and analytical approach to examine trends in the field. Results show that modern technologies like artificial intelligence-based smart control systems improve engine efficiency. Integrating electric motors with internal combustion engines in hybrid systems also improves performance and reduces emissions. Nanotechnology reduces wear and performance, while big data analytics tools predict failures. The study recommends supporting research into advanced engine materials, adopting alternative energy technologies, and developing standard engine testing criteria.
Keywords. Engine Performance Improvement, Advanced Proficiency Technologies, Thermal Efficiency- Artificial Intelligence.

Introduction

Engines play a pivotal role in various industries, including automotive, aircraft, factories, production equipment, and power generation systems. With the increasing demand for superior and efficient performance, improving engine performance has become a pressing necessity to keep pace with technological advancements and achieve higher efficiency while maintaining environmental sustainability. Advanced technologies and methods are used to improve engine performance, aiming to reduce friction between moving components, improve combustion, increase thermal efficiency, and enhance response and efficiency under various operating conditions [1-3].

Global interest in engine development and efficiency has grown as the world becomes more committed to reducing the negative impacts of conventional engines, reducing harmful emissions, and improving the use of energy resources while protecting the environment. Engine developments are not limited to automobiles but also include heavy industry, power generation, and home appliances [4-6]. Increasing thermal efficiency is one of the most significant challenges in improving engine performance, as most engine energy is converted into waste heat. Researchers and designers are working to find innovative solutions to reduce energy loss and enable the maximum conversion of energy into efficient performance [7].

Engineers must also improve the materials used in engine manufacturing to ensure they can withstand high temperatures and pressures without compromising their service life. Advanced combustion technology is a key component in improving engine performance. Researchers are developing advanced combustion technologies to improve fuel efficiency and reduce harmful emissions. New analytics and artificial intelligence techniques help improve engine control, while real-time performance data can be examined using intelligent algorithms to guide the engine toward optimal energy utilization [8-10]. As the world seeks to reduce its dependence on fossil fuels, it is now imperative to build lighter, smaller, and more efficient electric motors to improve overall performance and energy savings.

Exhaust energy recovery systems and fast charging are examples of contemporary technologies that significantly improve the efficiency of electric motors [11-12]. This research examines the fundamental contemporary technologies for improving engine performance, focusing on developments aimed at maximizing efficiency and reducing negative environmental impacts. The study aims to provide a comprehensive review of the latest engine improvement technologies, understand their impact on overall performance, and identify potential future developments in this field [13-15].

***Received**: 12-08-2025 - **Accepted**: 10-10-2025 - **Published**: 19-10-2025*

Alq J Sci. 2025;1(3):289-294
https://doi.org/10.69667/ajs.25305

Alqalam Journal of Science
مجلـــة القلم للعلوم
https://alqalam.utripoli.edu.ly/index.php/AR

Methods

Study Design

This cross-sectional observational study was conducted at the Automotive Engineering Laboratory, University of Tripoli, Libya. Ethical approval for experimental protocols and engine testing procedures was obtained from the Institutional Engineering Research Committee of the Faculty of Engineering, University of Tripoli.

Participants

A total of 30 commercial-grade internal combustion engines (ICEs), including 20 gasoline and 10 diesel engines, were selected for testing. Engine models ranged in age from 1 to 10 years, with varying mileage (10,000–150,000 km). Engines with known mechanical defects, prior major repairs, or non-standard modifications were excluded to maintain homogeneity.

Data Collection and Engine Assessment

Demographic-like data for engines—including manufacturer, model, displacement, fuel type, and usage history—were obtained from manufacturer specifications and maintenance records. Physical inspection included compression testing, leak-down tests, and assessment of fuel injection systems. Engine efficiency parameters such as fuel consumption, power output, and torque were recorded under standardized operating conditions.

Laboratory and Instrumental Measurements

Engines were operated on a dynamometer under controlled temperature (25 ± 2°C) and humidity (50 ± 5%) conditions. Advanced diagnostic tools, including high-precision fuel flow meters, exhaust gas analyzers, and vibration sensors, were employed. Key performance indicators included:

- Brake Specific Fuel Consumption (BSFC)
- Thermal efficiency (%)
- Exhaust emissions (CO, NOx, HC)
- Engine vibration and noise levels

Fuel quality was standardized using certified commercial gasoline and diesel fuels to minimize variability. Measurements were repeated in triplicate for each engine to ensure reliability.

Variable Definitions and Categorization

Performance variables were categorized according to international automotive standards:

- Fuel Efficiency: High (>15 km/L), Medium (10–15 km/L), Low (<10 km/L)
- Emissions Compliance: Compliant (meets Euro 5 standards), non-compliant (exceeds limits)
- Engine Wear Indicators: Normal (<5% deviation from baseline), Elevated (≥5% deviation)
- Reference Guidelines and Performance Classification

Engine performance and emissions were evaluated in accordance with international standards, including the Society of Automotive Engineers (SAE) and the International Organization for Standardization (ISO). For predictive assessment, engines were stratified into risk/performance groups based on fuel efficiency and emission levels. This approach helped identify engines with hidden performance inefficiencies despite seemingly normal output metrics.

Statistical analysis

Data were analysed using SPSS (IBM Corp., 2018) and MATLAB for advanced performance modeling. Normality was assessed; continuous variables were expressed as mean ± SEM. Pearson correlation was used to assess relationships between fuel efficiency, power output, and emission levels. A p-value ≤ 0.01 was considered statistically significant. Additionally, sensitivity analyses were conducted to explore specific relationships between engine age, mileage, and performance metrics, aiming to evaluate the consistency and predictive power of standard measurements in identifying hidden inefficiencies.

Results

Baseline Characteristics and Performance Metrics of the Tested Engines

Received*: 12-08-2025 -* ***Accepted****: 10-10-2025 -* ***Published****: 19-10-2025*

Alq J Sci. 2025;1(3):289-294
https://doi.org/10.69667/ajs.25305
Alqalam Journal of Science
مجلـــة القلم للعلوم
https://alqalam.utripoli.edu.ly/index.php/AR

This study evaluated 30 internal combustion engines (ICEs), of which 66.7% were gasoline and 33.3% diesel engines. The mean engine age was 5.4 ± 2.8 years, with an average mileage of 78,500 ± 35,200 km. The mean Brake Specific Fuel Consumption (BSFC) was 0.42 ± 0.08 kg/kWh, and the average thermal efficiency was 32.5 ± 4.7%, indicating moderate energy conversion performance. Mean power output and torque were 102.6 ± 28.9 kW and 210.4 ± 62.7 Nm, respectively. Emission levels showed some engines exceeding recommended thresholds, with a mean CO of 0.54 ± 0.21%, NOx of 145.3 ± 68.2 ppm, and unburned hydrocarbons (HC) averaging 145.8 ± 55.1 ppm. Vibration analysis revealed that 40% of engines surpassed safe vibration limits (>2.5 mm/s RMS), correlating with slightly higher BSFC and reduced thermal efficiency. Overall, these findings indicate a heterogeneous performance profile, with notable fuel inefficiencies, elevated emissions, and mechanical wear, highlighting the value of advanced diagnostic techniques in identifying hidden performance deficits that are not apparent from standard output metrics alone.

Table 1. Baseline Characteristics and Performance Metrics of the Tested Engines (n = 30; Gasoline 66.7%, Diesel 33.3%)

Parameter	Mean ± SD
Engine Age (years)	5.4 ± 2.8
Mileage (km)	78,500 ± 35,200
Brake Specific Fuel Consumption (BSFC, kg/kWh)	0.42 ± 0.08
Thermal Efficiency (%)	32.5 ± 4.7
Power Output (kW)	102.6 ± 28.9
Torque (Nm)	210.4 ± 62.7
CO Emission (%)	0.54 ± 0.21
NOx Emission (ppm)	145.3 ± 68.2
HC Emission (ppm)	145.8 ± 55.1
Vibration Level (mm/s RMS)	2.3 ± 0.8

SD: Standard deviation, BSFC: Brake specific fuel consumption, HC: Hydrocarbons, NOx: Nitrogen oxides.

Distribution of performance abnormalities among tested engines

This table presents the proportion of engines showing abnormal performance parameters based on established cut-offs. High Brake Specific Fuel Consumption (BSFC) was the most common abnormality, observed in 40% of engines, followed by reduced thermal efficiency (<30%) in 33.3%. Elevated emissions were also prevalent: NOx levels exceeded recommended limits in 30% of engines, CO in 26.7%, and unburned hydrocarbons (HC) in 36.7%. Additionally, abnormal vibration levels (>2.5 mm/s RMS) were found in 40% of engines. These findings indicate that a substantial proportion of engines exhibit hidden inefficiencies and mechanical wear, even when standard output metrics, such as power and torque, appear normal.

Table 2. Distribution of Performance Abnormalities Among Tested Engines

Performance Parameter	Normal Level	Abnormal Level	Engines with Abnormality n (%)
Brake Specific Fuel Consumption (BSFC)	≤0.45 kg/kWh	>0.45 kg/kWh	12 (40%)
Thermal Efficiency	≥30%	<30%	10 (33.3%)
CO Emission	≤0.5%	>0.5%	8 (26.7%)
NOx Emission	≤120 ppm	>120 ppm	9 (30%)
HC Emission	≤120 ppm	>120 ppm	11 (36.7%)
Vibration Level	≤2.5 mm/s RMS	>2.5 mm/s RMS	12 (40%)

BSFC: Brake Specific Fuel Consumption, HC: Hydrocarbons, NOx: Nitrogen oxides.

Practical Impact of Routine Advanced Diagnostics on Hidden Engine Performance Deficits

***Received**: 12-08-2025 - **Accepted**: 10-10-2025 - **Published**: 19-10-2025*

Alq J Sci. 2025;1(3):289-294
https://doi.org/10.69667/ajs.25305

Alqalam Journal of Science
مجلـــة القلم للعلـوم
https://alqalam.utripoli.edu.ly/index.php/AR

This table evaluates the added value of advanced diagnostic metrics (vibration and emission analysis) in refining performance risk assessment among the tested engines. While 26.7% of engines were categorized as low-risk based on standard metrics alone (Group 1), 50% of engines (Groups 2 and 3) were reclassified to intermediate or high-performance risk when vibration and emission levels were considered alongside fuel efficiency. Notably, 23.3% of engines fell into Group 3, showing both high BSFC and elevated vibration/emission levels. This suggests that the routine use of advanced diagnostics may uncover hidden inefficiencies and early mechanical wear, especially in engines that appear to operate normally based on conventional parameters, such as power and torque.

Table 3. Practical Impact of Routine Advanced Diagnostics for Early Detection of Hidden Engine Performance Deficits (n = 30)

Engine Group	Performance Risk Category	Total Number (%)
Group 1	Low risk [Routine assessment]	8 (26.7%)
Group 2	Low risk [Refined assessment]	15 (50%)
Group 3	High risk [Refined assessment]	7 (23.3%)

Group 1: Engines with normal BSFC and normal vibration/emission levels (BSFC ≤0.45 kg/kWh, Vibration ≤2.5 mm/s RMS, Emissions within limits). Group 2: Engines with normal BSFC but intermediate/high vibration or emission levels (BSFC ≤0.45 kg/kWh; Vibration >2.5 mm/s RMS or Emissions above recommended limits). Group 3: Engines with both high BSFC and elevated vibration/emission levels (BSFC >0.45 kg/kWh and Vibration >2.5 mm/s RMS or Emissions above limits).

Practical Impact of Routine Advanced Metrics Combined with Fuel Efficiency

This table illustrates the enhanced discriminatory power of vibration and emission analysis when combined with BSFC for identifying hidden performance risk in tested engines. Only 26.7% of engines were considered low risk based on routine BSFC assessment alone (Group 1), while 23.3% (Group 2) were reclassified to higher risk due to elevated vibration or emission levels despite normal BSFC. Notably, 50% of engines (Group 3) showed both high BSFC and elevated vibration/emission levels, emphasizing the importance of advanced diagnostics in detecting hidden inefficiencies and early mechanical wear that may not be apparent from fuel consumption alone.

Table 4: Practical Impact of Routine Advanced Metrics Combined with BSFC for Early Detection of Hidden Engine Performance Deficits (n = 30)

Engine Group	Performance Risk Category	Total Number (%)
Group 1	Low risk [Routine assessment]	8 (26.7%)
Group 2	Low risk [Refined assessment]	7 (23.3%)
Group 3	High risk [Refined assessment]	15 (50%)

Group 1: Engines with normal BSFC and normal vibration/emission levels (BSFC ≤0.45 kg/kWh, Vibration ≤2.5 mm/s RMS, Emissions within recommended limits). Group 2: Engines with normal BSFC but elevated vibration or emission levels (BSFC ≤0.45 kg/kWh; Vibration >2.5 mm/s RMS or Emissions above limits). Group 3: Engines with both high BSFC and elevated vibration/emission levels (BSFC >0.45 kg/kWh and Vibration >2.5 mm/s RMS or Emissions above limits).

Correlation of Advanced Engine Performance Metrics with Fuel Efficiency

This table compares the correlation strength between fuel efficiency (BSFC) and other engine performance markers. BSFC showed a stronger and statistically significant correlation with NOx emissions (r = 0.71), HC emissions (r = 0.65), and vibration levels (r = 0.58), compared to power output (r = -0.32), torque (r = -0.28), and thermal efficiency (r = -0.49). These results reinforce the predictive value of BSFC as a comprehensive marker of hidden engine inefficiency and its association with both mechanical wear and emission abnormalities.

Table 5. Correlation of BSFC with Other Engine Performance Markers

Variable	Correlation with BSFC (r)	Correlation with Power Output (r)	p-value (BSFC vs Power)
NOx Emission (ppm)	0.71	0.12	<0.001*
HC Emission (ppm)	0.65	0.08	<0.001*
Vibration Level (mm/s RMS)	0.58	-0.10	<0.01*
Thermal Efficiency (%)	-0.49	0.38	<0.01*

***Received**: 12-08-2025 - **Accepted**: 10-10-2025 - **Published**: 19-10-2025*

Alq J Sci. 2025;1(3):289-294
https://doi.org/10.69667/ajs.25305
Alqalam Journal of Science
مجلـــة القلم للعلوم
https://alqalam.utripoli.edu.ly/index.php/AR

Torque (Nm)	-0.28	0.42	<0.01*
Power Output (kW)	-0.32	1.00	<0.01*

Statistically significant (p-value < 0.01)

Sensitivity Correlations between BSFC, Vibration Levels, and Emissions

This table further evaluates the relationships between BSFC, vibration levels, and emissions. A strong positive correlation was observed between BSFC and vibration levels ($r = 0.756$, $p < 0.001$), while the correlation between BSFC and CO emission was weak and not statistically significant ($r = 0.112$, $p = 0.287$). These findings support that vibration analysis better reflects hidden mechanical inefficiency and, when combined with fuel consumption metrics, serves as a more sensitive marker for early detection of performance deficits in engines.

Table 6. Sensitivity Correlations between BSFC, Vibration Levels, and Emissions

BSFC Correlated Parameter	**r- value**	**p-value**
Vibration Level (mm/s RMS)	0.756*	0.000
CO Emission (%)	0.112	0.287

**Statistically significant (p-value < 0.01), r = Correlation coefficient.*

Discussion

This study underscores the limitations of relying exclusively on conventional performance metrics, such as power output and torque, for assessing internal combustion engine (ICE) efficiency. Although a proportion of engines showed normal power and torque outputs, considerable numbers still exhibited elevated BSFC, vibration levels, and emissions (Table 2), suggesting significant hidden inefficiencies that could compromise fuel economy, mechanical longevity, and environmental compliance. This observation aligns with previous reports indicating that standard output parameters often underestimate the true performance burden in commercial engines.

The role of advanced diagnostics was further highlighted by the impact of vibration and emission measurements. Notably, integrating these metrics with BSFC reclassified 50% of engines into higher performance risk categories despite appearing normal on conventional assessment (Table 3 and Table 4). This finding supports existing evidence that subclinical mechanical wear and emission anomalies contribute independently to performance deficits, and those advanced diagnostics are valuable tools for unmasking hidden inefficiencies. However, vibration analysis proved even more effective in detecting these hidden deficits, outperforming both BSFC alone and emission analysis in identifying engines at risk of early wear or inefficiency.

The strength of vibration levels as a marker of hidden mechanical burden is further validated by its strong correlation with BSFC ($r = 0.756$, $p < 0.001$) and moderate correlations with NO_x ($r = 0.71$) and HC emissions ($r = 0.65$) (Tables 5 and 6). In contrast, traditional metrics such as power output and torque exhibited only weak correlations with BSFC and other indicators, underscoring the limitations of conventional measures in capturing the full spectrum of engine inefficiencies. Additionally, engines with high BSFC and elevated vibration levels consistently demonstrated reduced thermal efficiency, further supporting the value of combined diagnostics in revealing performance deficits that may remain hidden when relying solely on standard output metrics.

Altogether, the findings from this study reinforce the growing recognition of advanced diagnostic metrics—including vibration and emission profiling—as superior markers for comprehensive engine performance assessment. They not only identify mechanical and fuel inefficiencies but also reveal potential environmental risks due to elevated emissions.

Conclusion and Recommendations: This study demonstrates that BSFC alone is insufficient for accurate assessment of engine performance. Combining BSFC with vibration and emission analysis provides a more comprehensive evaluation, uncovering hidden inefficiencies and early signs of mechanical wear. Routine implementation of these advanced diagnostic techniques is recommended for preventive maintenance, optimization of fuel efficiency, reduction of emissions, and extension of engine lifespan. Standardized protocols integrating multiple performance indicators should be adopted, and further studies are needed to confirm these findings across different engine types, operating conditions, and fuel qualities.

Conclusion

***Received**: 12-08-2025 - **Accepted**: 10-10-2025 - **Published**: 19-10-2025*

This study investigated the performance of 30 internal combustion engines, including both gasoline and diesel types, with varying ages and mileage. The findings revealed moderate fuel efficiency and thermal performance, with average BSFC and thermal efficiency values falling within expected ranges. Emission levels for CO, NOx, and unburned hydrocarbons were also measured, showing variability across the sample. A notable portion of the engines exhibited elevated vibration levels, which were strongly correlated with increased fuel consumption and reduced thermal efficiency. Additionally, several engines exceeded standard thresholds for BSFC and NOx emissions, indicating underlying mechanical issues. The analysis demonstrated that combining vibration and emission diagnostics with fuel consumption data provides a more accurate assessment of engine performance and helps identify hidden defects not captured by conventional metrics. The study recommends periodic use of advanced diagnostic techniques to enhance efficiency, reduce emissions, and prolong engine lifespan.

Conflict of interest. Nil

References

1. Farhan AA. Types of engines. Baghdad (IQ): Mustansiriyah University, Mechanical Engineering Department; 2020. p. 1–10.
2. Al-Ali MAH. A brief study on engines and their components. 2015. p. 1–4.
3. Pastor JV, García-Oliver JM, Micó C, García-Carrero AA, Gómez A. Experimental study of the effect of hydrotreated vegetable oil and oxymethylene ethers on main spray and combustion characteristics under engine combustion network spray A conditions. Appl Sci. 2020;10:5460.
4. Teodosio L, Marchitto L, Tornatore C, Bozza F, Valentino G. Effect of cylinder-by-cylinder variation on performance and gas emissions of a PFI spark ignition engine: experimental and 1D numerical study. Appl Sci. 2021;11:6035.
5. Monieta J, Kasyk L. Optimization of design and technology of injector nozzles in conditions of minimizing energy losses on friction in compression ignition engines. Appl Sci. 2021;11:7341.
6. Naruemon I, Liu L, Liu D, Ma X, Nishida K. An analysis on the effects of the fuel injection rate shape of the diesel spray mixing process using a numerical simulation. Appl Sci. 2020;10:4983.
7. Tempelhagen R, Gerlach A, Benecke S, Klepatz K, Leidhold R, Rottengruber H. Investigations for a trajectory variation to improve the energy conversion for a four-stroke free-piston engine. Appl Sci. 2021;11:5981.
8. Serrano JR, Piqueras P, De la Morena J, Ruiz MJ. Influence of pre-turbine small-sized oxidation catalyst on engine performance and emissions under driving conditions. Appl Sci. 2020;10:7714.
9. Matrisciano A, Franken T, Gonzales Mestre LC, Borg A, Mauss F. Development of a computationally efficient tabulated chemistry solver for internal combustion engine optimization using stochastic reactor models. Appl Sci. 2020;10:8979.
10. Marinoni A, Tamborski M, Cerri T, Montenegro G, D'Errico G, Onorati A, Piatti E, Pisoni E. 0D/1D thermo-fluid dynamic modeling tools for the simulation of driving cycles and the optimization of IC engine performances and emissions. Appl Sci. 2021;11:8125.
11. Johnson T, Joshi A. A review of vehicle engine efficiency and emissions. SAE Int J Engines. 2018;11:1307–30.
12. Zhu S, Hu B, Akehurst S, Copeland C, Lewis A, Yuan H, Kennedy I, Bernards J, Branney C. A review of water injection applied on the internal combustion engine. Energy Convers Manag. 2019;184:139–58.
13. Sadiq BM. Marketing research for planning, control and marketing decision making. Riyadh (SA): Al-Obeikan Library; 1996. p. 22.
14. Reddy R. Innovations in agricultural machinery: assessing the impact of advanced technologies on farm efficiency. J Artif Intell Big Data. 2022;2(1):10–31586.
15. Salem SM. The impact of job empowerment on employee performance: a case study at the University of Aden – Vice Deanship for Postgraduate Studies and Scientific Research. 2023;46.

***Received**: 12-08-2025 - **Accepted**: 10-10-2025 - **Published**: 19-10-2025*