Evaluation of Mn-Phthalocyanine (Manganese phthalocyanine) Fuel Additives on Engine Vibration and Noise Characteristics in Gasoline Engines

Mn-Ftalosiyanin (Manganese phthalocyanine) Yakıt Katkılarının Benzinli Motorlarda Motor Titreşimi ve Gürültü Karakteristikleri Üzerine Değerlendirilmesi

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Abstract	Öz
This study investigates the effects of liquid-phase manganese phthalocyanine (Mn-Pc) additives on engine noise and vibration characteristics, based on an aminoborane-based fuel known for its environmentally friendly and combustion-enhancing properties. Two different mixtures were prepared: Mn-Pc5, containing 5% Mn-Pc, and Mn-Pc10, containing 10% Mn-Pc. These mixtures were tested on an experimental engine under load conditions ranging from 0 to 40 N and compared with a reference fuel, pure gasoline (B100). The results showed that the Mn-Pc blended fuels produced higher noise levels than B100, particularly under high load conditions. Mn-Pc5 reached up to 102 dB(A), while Mn-Pc10 recorded 100 dB(A); in contrast, B100 only reached 98 dB(A) and 96 dB(A) under similar conditions. These increases in noise levels suggest the possibility of faster combustion or higher ignition pressures with the Mn-Pc additives. In terms of vibration, Mn-Pc10 exhibited the highest value at 140 m/s², exceeding the 110 m/s² measured for B100. Overall, while Mn-Pc additives show potential advantages in combustion performance, they also lead to increased noise and vibration, which may negatively impact driving comfort and mechanical safety. Therefore, further optimization of the additive formulation is necessary to achieve a better balance between performance and operational stability.	Bu çalışma, çevre dostu ve yanma açısından olumlu özelliklere sahip aminboran yakıtı temel alınarak geliştirilen, sıvılaştırılmış manganez ftalosiyanin (Mn-Pc) katkılı yakıtların motor gürültüsü ve titreşim üzerindeki etkilerini incelemektedir. Çalışmada iki farklı katkı oranına sahip karışım kullanılmıştır: %5 Mn-Pc içeren Mn-Pc5 ve %10 Mn-Pc içeren Mn-Pc10. Her iki karışım, referans yakıt olarak kullanılan saf benzin (B100) ile karşılaştırmalı olarak 0–40 N arası yüklerde, deneysel bir motor ortamında test edilmiştir. Sonuçlar, Mn-Pc katkılı yakıtların B100'e kıyasla daha yüksek motor gürültüsü oluşturduğunu göstermiştir. Özellikle yüksek yük seviyelerinde, Mn-Pc5 karışımı 102 dB(A), Mn-Pc10 ise 100 dB(A) seviyelerine ulaşırken; saf benzin (B100) için bu değerler sırasıyla 98 dB(A) ve 96 dB(A) ile sınırlı kalmıştır. Bu durum, katkılı yakıtların daha hızlı bir yanma süreci veya daha yüksek ateşleme basınçları oluşturabileceğini düşündürmektedir. Titreşim analizinde de benzer şekilde Mn-Pc katkılı yakıtların olumsuz etkileri gözlemlenmiştir. Mn-Pc10 karışımı 140 m/s² ile en yüksek titreşim değerine ulaşırken, B100 yakıtı 110 m/s² ile daha düşük titreşim üretmiştir. Genel olarak, Mn-Pc katkılı yakıtlar performans artışı potansiyeli taşımakla birlikte, gürültü ve titreşim gibi konfor ve mekanik güvenlik açısından olumsuz etkiler ortaya koymuştur. Bu nedenle, bu tür yakıtların motor sistemlerinde daha verimli ve dengeli şekilde kullanılabilmesi için katkı formülasyonlarının geliştirilmesi ve optimize edilmesi gerektiği sonucuna varılmıştır.
Keywords: *Manganese phthalocyanine, engine noise, engine vibration, engine*	**Anahtar Kelimeler:** *Manganez ftalosiyanin, motor gürültüsü, motor titreşimi, motor*

Yakın

Evaluation of Mn-Phthalocyanine (Manganese phthalocyanine) Fuel Additives on Engine Vibration and Noise Characteristics in Gasoline Engines

1. Introduction

The control of vibrations and noise in internal combustion engines is crucial for preventing structural fatigue, enhancing engine longevity, and improving vehicle comfort. Ahirrao et al. (2018) emphasized the role of engine support systems in minimizing structural vibrations, highlighting that excessive vibrations can induce high stress levels, leading to premature mechanical failure. Their study focused on optimizing support stiffness—particularly near resonance conditions—through the precise design of bolted joints and, where necessary, the use of dampers at the engine-foundation interface, offering practical strategies to reduce overall vibration and noise levels [1].

Expanding on vibration and noise management, Zouani and Hanim (2016) explored the concept of noise, vibration, and harshness (NVH), a critical factor influencing vehicle quietness and customer satisfaction. They analyzed NVH sources across key engine subsystems, including the valve train, cam drive, and combustion system, while distinguishing between acceptable and undesirable NVH characteristics. Their comprehensive review provided valuable insights into NVH propagation pathways—both airborne and structure-borne—offering guidance for improving vehicle design and customer experience [2]. Similarly, Santana et al. (2013) investigated the complex interactions leading to vibration and noise in internal combustion engines, focusing on identifying primary sources and developing control strategies. Using an Otto cycle engine, their experimental tests and analytical methods revealed the impact of component interactions on noise and vibration levels, contributing to more effective control techniques that enhance engine durability and passenger comfort [3].

Complementing these approaches, Yildirim et al. (2009) introduced an experimental methodology using feedforward and radial basis neural networks (RBNN) to predict engine noise and vibrations. Their study demonstrated the RBNN's ability to adapt to varying conditions and measurement disturbances, offering a robust predictive tool for noise and vibration control in automotive engines [4].

Nag et al. (2019) expanded on previous research by investigating the effects of hydrogen-diesel dual-fuel combustion on engine performance, with a particular focus on combustion characteristics, vibrations, and acoustics. The study evaluated engine behavior under varying loads (25%, 50%, and 75%) and different hydrogen substitution rates (0%, 5%, 10%, and 20%). Results indicated that while hydrogen addition caused minor fluctuations in-cylinder pressure at lower loads, it led to a notable reduction in noise and vibration levels, especially at low and mid-range loads. These findings highlight the potential of hydrogen supplementation to improve ride comfort while promoting cleaner and more efficient combustion [5].
Santhosh et al. (2020) emphasized the growing importance of vehicle comfort and drivability for both users and manufacturers, alongside engine performance and aesthetics. Engine mounts, essential for isolating vibrations between the engine and the car body, typically use rubber for its damping properties. However, conventional rubber mounts in diesel engines are prone to fatigue failure and brittleness due to oil exposure, resulting in increased low-frequency vibrations and reduced passenger comfort. In their study, the authors experimentally evaluated blended rubber mounts as an alternative material, comparing their performance with traditional mounts and demonstrating enhanced vibration isolation and improved durability [6].

Xi et al. (2015) investigated noise and vibration sources in a four-cylinder inline diesel engine using test methods and multi-body dynamic analysis. A 1-meter noise test identified the engine front end as the primary noise source, while near-field sound intensity and acoustic holography techniques pinpointed the chain drive system as the main contributor to noise and vibration. A 3D dynamic model of the timing chain drive, developed using RecurDyn software, revealed incompatibility between the hydraulic tensioner and the bush roller chain, leading to excessive noise and vibration. The study concludes with optimization strategies for the timing chain drive system [7].

Gültekin et al. (2024) investigated the effects of different injection strategies on emissions, mechanical vibrations, and noise in a hydrogen-diesel dual-fuel compression-ignition engine. Using an ECU-controlled liquid and gas fuel system, experiments were conducted at a constant load (5 Nm), speed (1850 rpm), hydrogen energy ratio (12%), four hydrogen injection pressures (1–2.5 bar), and five injection timings (25–65°CA aTDC). Results showed that at 25°CA aTDC and 2.5 bar injection pressure, CO_2 emissions decreased by 33.4% and PM emissions by 40.7%, while NO emissions increased by 8.7%, mechanical vibrations by 19.9%, and noise by 2 dBA [8].

Khan et al. (2024) explored the use of biodiesel-based bio-lubricants enhanced with various nanoparticles and quantum dots to improve diesel engine performance. Using the Entropy-k-means hybrid model, the study identified the optimal nanoparticle additive, with magnetic bio-lubricant emerging as the top performer (centroidal distance: 1.2). Experiments showed optimal results with a Brake Thermal Efficiency of 30.5%, Brake Specific Fuel Consumption of 191.5 g/kWh, NOx emissions of 88 ppm, CO emissions of 7.1 g/km, vibration at 68.5 Hz, and sound at 74.5 dB. A strong correlation was found between BTE and sound, with NOx prioritized highest (0.45) and sound lowest (0.01). The study highlights the potential of nanoparticle-infused bio-lubricants for sustainable engine performance enhancement [9].

K. Bharath and V. A. M. S. (2024) investigated the impact of isobutanol addition to methanol-gasoline blends on noise, vibration, and emissions in an unmodified SI engine at varying speeds. Blends of M10, M15, iBM10, and iBM15 were tested, revealing higher noise levels and reduced vertical and longitudinal vibrations compared to gasoline. The M15 blend recorded the highest noise at 64.43 dBA, 4 dBA above gasoline. While fuel consumption remained similar across blends at high speeds, iBM10 and iBM15 reduced HC emissions by 25% and 10%, and CO by 65% and 87%, respectively. However, methanol-gasoline blends showed slightly higher CO_2 and NOx emissions than gasoline [10].

These innovations ensure that fuel performs more efficiently, stably, and reactively. Metal oxide nanoparticles, such as aluminum oxide, iron oxide, and titanium dioxide, provide significant catalytic and structural benefits. In addition, polymer-based, carbon-based, and ceramic nanoparticles are widely used due to their excellent functional properties and high stability. The combined use of these nanoparticles optimizes fuel characteristics, leading to more efficient combustion, superior thermal stability, and improved overall performance [11–18]. Testing different fuel additives in engines has resulted in reduced emissions and increased performance [19].

In this study, the effects of gasoline, and fuel blends containing 10% (T10) and 20% (T20) turpentine on engine performance and emissions were investigated within the engine speed range of 2000–4000 rpm. Turpentine-added fuels increased engine torque and power, demonstrating especially better performance at higher speeds. The lowest specific fuel consumption was measured at 2500 rpm. While CO emissions increased at low and high speeds, a decrease was observed at medium speeds. HC emissions decreased as the engine speed increased [20].

In this study, a single-cylinder diesel engine was modified based on the RCCI concept and operated with mixtures of diesel (HRF) and iso-octane (LRF). Experiments were conducted at a constant speed of 2400 rpm under three different load conditions. As the LRF ratio and engine load increased, the pressure and heat release rates also increased, while partial reductions in combustion phasing (CA50) were observed. A 15% LRF ratio yielded similar combustion phasing results to diesel. The use of LRF reduced NOx and CO emissions but increased HC emissions; it also provided up to a 97% reduction in smoke opacity, especially under high load conditions [21].

Yakın and Cabir (2024): In this study, phthalocyanine fuel additives were blended with gasoline at varying volumetric ratios and evaluated for engine performance and exhaust emissions. Experimental results revealed that PG5, PG15, and PG25 blended fuels resulted in a 3.5% decrease, 0.37% increase, and 3.59% increase in engine torque, respectively, compared to gasoline. Specific fuel consumption decreased by

Yakın

Evaluation of Mn-Phthalocyanine (Manganese phthalocyanine) Fuel Additives on Engine Vibration and Noise Characteristics in Gasoline Engines

6.09% for PG5, 3.53% for PG15, and 5.08% for PG25. Exhaust gas temperature increased by 7.18% for PG5, while it decreased by 0.39% for PG15 and 3.31% for PG25. CO emissions dropped significantly by 58.88%, 46.99%, and 53.19% for PG5, PG15, and PG25, respectively, but HC, CO_2, and NOx emissions increased. Phthalocyanine additives show potential to reduce fuel consumption and harmful emissions, thereby mitigating vehicle-related environmental pollution [22].

This study the impact of magnetized ethanol-gasoline blends on noise and vibration in a single-cylinder engine. Four ethanol concentrations (0%, 5%, 10%, and 20%) and three magnetic field strengths (0, 5300, and 7000 Gauss) were evaluated using a randomized experimental design. Engine noise was recorded at the driver's ear level, while vertical vibration was measured. The results indicated that both ethanol content and magnetic field intensity had significant effects on noise and vibration levels. The highest noise level (88.4 dB) was observed with pure gasoline under the strongest magnetic field, whereas the lowest (78.9 dB) occurred with a 10% ethanol blend and a moderate magnetic field. Notably, ear protection would not be necessary for ethanol blends ranging from 10% to 20%, regardless of the magnetic field applied. Furthermore, increasing ethanol content up to 10% combined with a moderate magnetic field (5300 Gauss) led to a noticeable reduction in vibration, with this configuration yielding the lowest vibration across all frequencies. These findings suggest that ethanol-gasoline blends subjected to magnetic treatment — particularly with moderate ethanol concentrations and magnetic intensity — could effectively reduce both noise and vibration in spark-ignition engines [23].

Another study examined how biodiesel influences engine noise using an innovative time-frequency analysis approach. Researchers processed and analyzed sound recordings from the engine at different operating speeds and fuel mixtures. The weighted sound pressure levels (SPL) of various biodiesel blends (B10, B30, etc.) were compared using a novel visualization technique. The results showed that B10 (10% biodiesel, 90% diesel) produced the lowest noise, while B30 generated the highest. Regardless of the fuel used, the engine exhibited peak noise sensitivity at 1600 rpm. The study also identified combustion, piston impacts, and valve events as the primary sources of engine noise and found that higher biodiesel content extended the combustion duration. This new method offers valuable insights into how biodiesel affects noise behavior in engines [24].

In response to increasingly strict environmental regulations, researchers have turned to alternative fuels for diesel engines. One such study assessed the effects of a dual-fuel strategy using biodiesel and natural gas in a compression ignition engine. The experimental setup analyzed how pilot injection with either biodiesel or conventional diesel, along with varying natural gas substitution rates (40%, 60%, 80%), influenced engine vibration, sound pressure, and overall performance. All tests were carried out at a constant engine speed and fixed injection timing. The results demonstrated clear links between natural gas proportions and the engine's environmental and energetic behavior, suggesting that this dual-fuel strategy may reduce emissions while maintaining acceptable performance levels [25]. The incorporation of various fuel additives such as phthalocyanine, sodium borohydride, aminoborane, and methylaminoborane into gasoline has shown promising results in enhancing engine efficiency and decreasing the release of harmful emissions. These additives contribute to more complete combustion, thereby increasing engine performance and minimizing pollutant output [26–31].

Yakın et al. (2024) the environmental impacts and limited availability of fossil fuels have driven automotive engineers to explore alternative energy sources and vehicle designs. Although hybrid and electric vehicles are gaining popularity, internal combustion engine (ICE) vehicles remain dominant. To reduce ICE emissions, research on nano-fuels and fuel additives is ongoing. In this context, the performance and emission effects of gasoline-phthalocyanine blends (FS7.5, FS12.5, FS17.5) in ICE gasoline engines were experimentally investigated. The results showed that the FS17.5 blend increased engine torque by 1.38%, engine power by 1.64%, and reduced exhaust gas temperature by 2.27%. The FS7.5 blend decreased CO emissions by 55.89%, but all blends led to increased HC, CO_2, and NOx emissions. Specific fuel consumption decreased by 5.51%, 4.23%, and 2.83% for FS7.5, FS12.5, and FS17.5, respectively. This

Yakın

Evaluation of Mn-Phthalocyanine (Manganese phthalocyanine) Fuel Additives on Engine Vibration and Noise Characteristics in Gasoline Engines

study demonstrates that phthalocyanine-blended fuels can enhance engine performance and reduce certain emissions [32].

Lastly, manganese-phthalocyanine (Mn-phthalocyanine) shows promise for enhancing gasoline combustion by lowering combustion temperatures, thereby reducing nitrogen oxide (NO_x) formation without compromising engine performance. Thanks to its catalytic characteristics, Mn-phthalocyanine can improve combustion efficiency and help reduce emissions. The results obtained in this study are consistent with these expectations, though additional experimental research is necessary for real-world applications.

This study addresses this notable gap by evaluating, for the first time, the effects of liquid-phase Mn-Pc additives—blended with an aminoborane-based fuel—on the noise and vibration characteristics of a gasoline engine under varying load conditions. By systematically comparing Mn-Pc5 and Mn-Pc10 mixtures with pure gasoline, this research provides novel insights into the trade-offs between enhanced combustion and mechanical side effects, thereby offering a more holistic understanding of Mn-Pc's suitability as a future fuel additive.

In this study, it was investigated how Mn- Mn-Phthalocyanine mixtures affect the noise and vibration in a single cylinder engine. Two Mn-Phthalocyanine concentrations (5%, 10%) Engine noise was measured at the driver's ear level and vibration was measured vertically. The analysis showed that Mn-Phthalocyanine significantly affects the noise and vibration.

1.1. Mn-Phthalocyanine

Chemical Formula   : $C_{92}H_{72}MnN_8O_{16}S_4$
Molecular Weight   : 1728,81
The combustion equation obtained after the combustion of the mixture of Mn-phthalocyanine dissolved in THF and gasoline in a gasoline engine is as follows:

$$C_{92}H_{72}MnN_8O_{16}S_4 + C_8H_{18} + C_4H_8O + 133O_2 \rightarrow 104CO_2 + 49H_2O + 4SO_2 + 8NO_2 + MnO_2 \qquad (1)$$
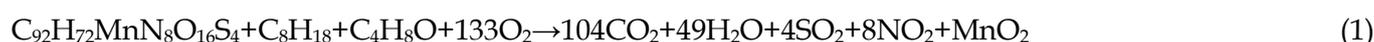
The combustion reaction suggests the generation of 104 moles of CO_2, signifying efficient combustion and the thorough oxidation of carbon atoms within the fuel. The observed low levels of CO and unburned hydrocarbons (HC) further confirm the near-complete nature of the combustion, indicating that the majority of carbon is being converted into carbon dioxide. This efficiency is supported by the catalytic action of Mn-phthalocyanine, which promotes more complete combustion and reduces the formation of partial oxidation products. Equation 1.

Additionally, the equation estimates the production of 8 moles of NO_2, a component of NO_x emissions that tend to rise with elevated combustion temperatures and the presence of oxygen and nitrogen-rich species such as oxMn-YGen. The presence of MnO_2 as a combustion byproduct is notable; this metal oxide functions catalytically and contributes to moderating combustion temperature, thereby influencing NO_x formation.

Elevated CO_2 output reflects a high degree of combustion completeness and efficient energy conversion from chemical to mechanical form. The combined use of Mn-phthalocyanine and tetrahydrofuran (THF) appears to enhance combustion quality, supporting improved thermal efficiency and cleaner engine performance.

Manganese phthalocyanine (MnPc) is a transition metal complex known for its thermal stability, redox activity, and catalytic properties. In the context of fuel applications, MnPc has attracted attention as a

Yakın

*Evaluation of Mn-Phthalocyanine (Manganese phthalocyanine) Fuel
Additives on Engine Vibration and Noise Characteristics in Gasoline Engines*

potential combustion catalyst or fuel additive due to its ability to enhance oxidation reactions and reduce harmful emissions. Its planar, conjugated macrocyclic structure allows for electron transfer reactions that can promote more complete combustion of hydrocarbon fuels, potentially improving fuel efficiency and lowering emissions such as CO, HC, and soot. Several studies have explored the catalytic properties of MnPc in various energy-related applications. For example, MnPc compounds have been evaluated in catalytic combustion processes and as catalysts in fuel cells. Although direct applications of Mn-phthalocyanine as a liquid fuel additive (e.g., in gasoline or diesel) are relatively rare compared to other organometallic compounds like methylcyclopentadienyl manganese tricarbonyl (MMT), research in the broader field of metallophthalocyanines supports their potential in enhancing combustion kinetics and emission control [33].

1.2. THF Usage

Tetrahydrofuran (THF) plays a critical role in facilitating the dissolution of Mn-phthalocyanine and promoting its effective integration with gasoline. Owing to its moderate polarity and strong ability to dissolve a wide range of organic substances, THF overcomes the limited solubility of Mn-phthalocyanine in water and low-polarity solvents. This prevents the additive from clustering during the dissolution process and allows for a uniform distribution within the fuel mixture. THF's compatibility with both polar and non-polar compounds makes it especially suitable for blending with gasoline, which consists predominantly of non-polar hydrocarbons. Its flexible molecular structure enables consistent dispersion throughout the fuel, enhancing the stability of the Mn-phthalocyanine solution. By maintaining the additive in a dissolved state, THF eliminates the risks of precipitation or sedimentation over time, thereby preserving the chemical reactivity and uniformity of the mixture during storage and combustion. These properties underscore THF's importance as a solvent in ensuring the homogeneity, stability, and functional effectiveness of Mn-phthalocyanine when used in gasoline formulations.

THF is used as a solvent to dissolve Mn-phthalocyanine, ensuring a homogeneous fuel mixture, and acts as a fuel component in the combustion reaction, producing CO_2 and H_2O. In the equation, one mole of THF provides 4 C, 8 H, and 1 O atoms. Its use is to enhance the solubility of Mn-phthalocyanine and support complete combustion in the engine [34].

The manganese phthalocyanine (Mn-Pc) additives were prepared by dissolving the required amounts of Mn-Pc powder (5% and 10% by volume) in an appropriate solvent, Tetrahydrofuran (THF), due to its ability to dissolve Mn-Pc effectively. A precise amount of Mn-Pc was weighed using an analytical balance and then dissolved in THF under controlled conditions. The solvent was stirred continuously for 30 minutes at room temperature to ensure complete dissolution of the Mn-Pc. Once fully dissolved, the Mn-Pc solution was gradually added to the gasoline (pure B100) in a mixing vessel equipped with a magnetic stirrer. The gasoline and Mn-Pc solution were blended at a speed of 1000 rpm for 1 hour to ensure uniform distribution of the Mn-Pc throughout the fuel. After blending, the fuel mixtures were stored in sealed containers to prevent evaporation of the solvent. The final fuel mixtures, Mn-Pc5 and Mn-Pc10, containing 5% and 10% Mn-Pc by volume, respectively, were then subjected to further testing in the experimental engine.

2. Materials and Method

The fuel mixtures consisting of 5% Mn-Pc by volume and 95% pure gasoline, and 10% Mn-Pc by volume and 90% pure gasoline, were designated as Mn-Pc5 and Mn-Pc10, respectively. These mixtures were prepared for testing in the experimental engine. In total, three fuels—pure gasoline (B100), Mn-Pc5, and Mn-Pc10—were tested under controlled conditions to evaluate their performance and emission characteristics. The objective of the experiments was to compare the combustion behavior and emission levels of the Mn-Pc blended fuels with those of pure gasoline. The blended fuels are shown in Fig. 1.
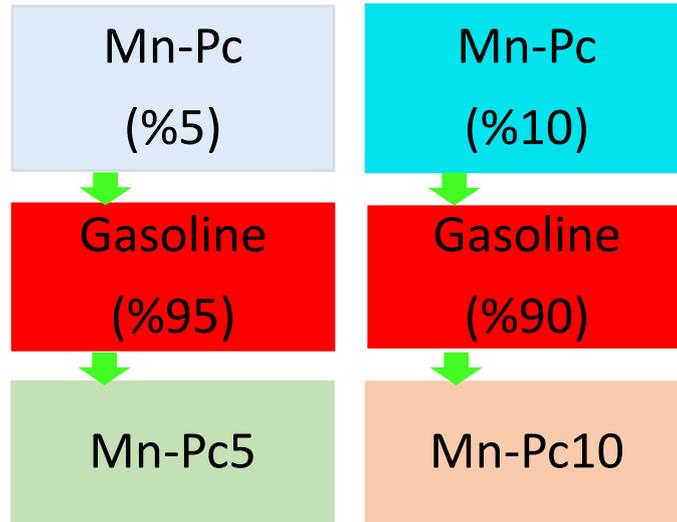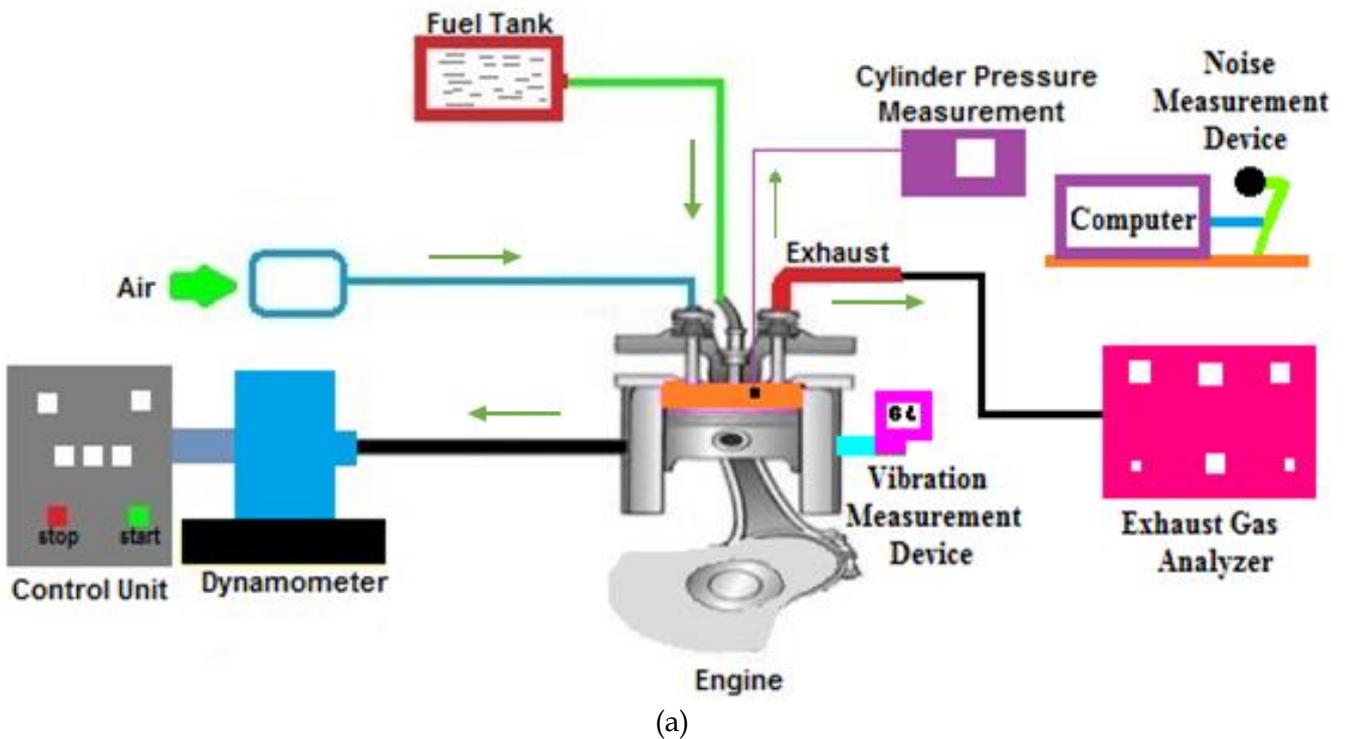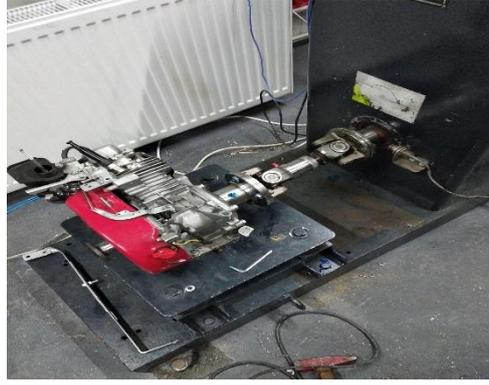
Fig. 1 Flow diagram of Mn-Pc5 and Mn-Pc10 mixture fuels

2.1. Engine tests

The blended fuels prepared at the Department of Textile, Clothing, Footwear and Leather at Van Vocational School of Van Yüzüncü Yıl University were tested in the engine test laboratories of the Department of Motor Vehicles and Transportation Technologies at Arifiye Vocational School of Sakarya University of Applied Sciences. The schematic diagram of the experimental setup is shown in Figure 2. The technical specifications of the emission measurement device used in the experiments are given in Table 1.

(a)

Yakın

Evaluation of Mn-Phthalocyanine (Manganese phthalocyanine) Fuel Additives on Engine Vibration and Noise Characteristics in Gasoline Engines

(b)

Fig. 2 The schematic view of the experimental setup (a) and Photograph (b)

Table 1. Techical specifications of the exhaust gas analyzer (Bosch BEA 460)

Component	Sensitivity	Tolerance
CO	0.001 %vol	± 0.005 %vol
CO_2	0.01 %vol	± 0.2 %vol
HC [ppm vol]	1	± 12 ppm
O_2	0.01 %vol	± 0.4 %vol
Lambda	0.001	-----
NO [ppm vol]	1	-----

Table 2. Specifications of the test engine

Specifications	Honda GX200
Engine Type	4 Stroke
Number of cylinders	1 Cylinder
Displacement	196 cm³
Bore	68 mm
Stroke	54 mm
Max. Output	4.8 kW (3600rpm)
Max. Torque	1.35 kgm (2500rpm)
Cooling System	Forced air

The experimental fuels were analyzed at the Fuel Analysis Laboratory of the Automotive Engineering Department at Adana Çukurova University. During the tests, the gasoline engine was operated at a constant speed of 2500 rpm, and experiments were conducted under different loads at a constant torque. Each test was repeated three times, and the arithmetic mean of the results was recorded. Exhaust emissions were measured by connecting the gas analyzer's measurement apparatus to the exhaust outlet of the test engine. The technical specifications of the test engine used in the experiments are provided in Table 2.

2.2. Vibration and noise measurements

The UT315A Vibration Tester is used to accurately measure vibration in rotating and reciprocating machinery. It measures acceleration (0–199.9 m/s²) with ±(5% + 0.2 m/s²) accuracy over a 10 Hz–10 kHz range, and velocity (0–19.99 cm/s) with ±(5% + 0.02 cm/s) accuracy from 10 Hz to 1 kHz. The device records one data point per second, totaling 60 readings per minute. These measurements are transferred to a computer for analysis using software tools like Excel, enabling the calculation of max, min, and average values to assess machine vibration behavior over time.

Yakın

*Evaluation of Mn-Phthalocyanine (Manganese phthalocyanine) Fuel
Additives on Engine Vibration and Noise Characteristics in Gasoline Engines*

The PCE-322A Noise Meter, designed for precise noise measurement in industrial and environmental settings. It measures sound levels between 30 and 130 dB with 0.1 dB resolution and features data logging for up to 32,700 readings. The device records one value per second, totaling 60 readings per minute, and data can be transferred to a PC via USB. Using software tools like Excel, key values such as maximum, minimum, and average noise levels can be analyzed effectively
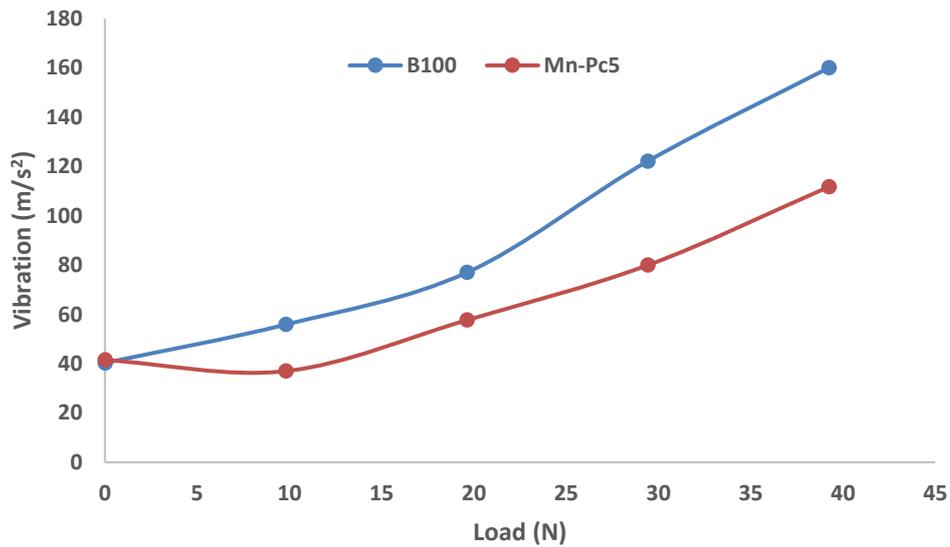
3. Results and discussions

Fig.3 Mn-Pc5 compared to B100 fuel Vibration graph based on engine torque

Figure 3 shows the vibration graph of mixed fuels based on engine torque. According to the graph, Mn-Pc5 significantly reduces vibration intensity compared to B100, particularly at high loads (80–100 m/s² vs. 120–140 m/s² at 40 N), enhancing engine stability and reducing mechanical wear. Mn-Pc10, with a presumed higher Mn-phthalocyanine concentration, is expected to further lower vibrations (potentially 70–90 m/s² at 40 N), offering greater stability but with potential cost and emission trade-offs. Unlike B100, both Mn-Pc fuels leverage Mn-phthalocyanine's catalytic properties to improve combustion, with Mn-Pc10 likely providing incremental benefits over Mn-Pc5 at high loads.
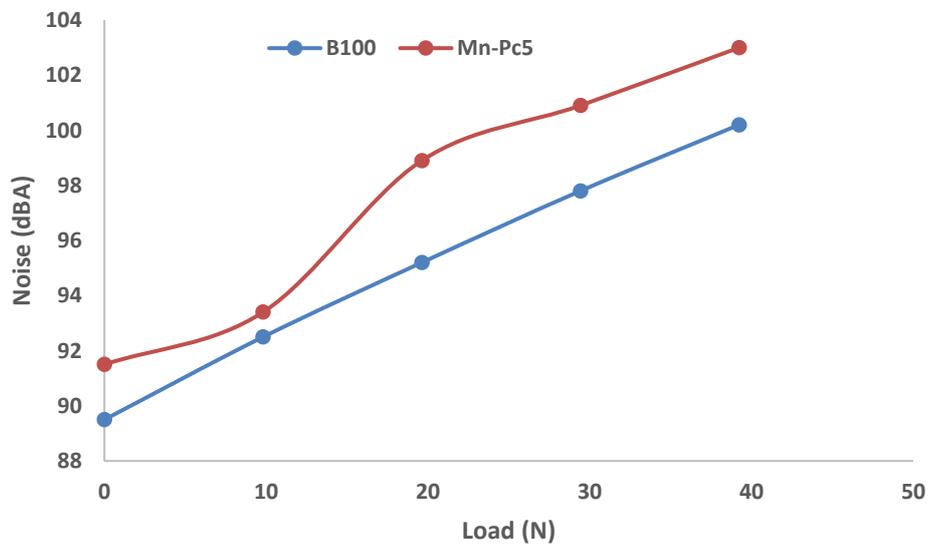

Fig. 4 Mn-Pc5 compared to B100 fuel Noise graph based on engine torque

Yakın

Evaluation of Mn-Phthalocyanine (Manganese phthalocyanine) Fuel Additives on Engine Vibration and Noise Characteristics in Gasoline Engines

Figure 4 illustrates a noise comparison between B100 and Mn-Pc5 fuels as a function of engine load (0 to 40 N) and fuel type (represented categorically from 0 to 1), with noise levels measured in dB(A) ranging from 90 to 102. Mn-Pc5 generates higher noise (102 dB(A)) than B100 (98 dB(A)) at high loads due to faster combustion, while Mn-Pc10 is expected to produce equal or slightly higher noise (102–104 dB(A)) due to increased Mn-phthalocyanine concentration, amplifying combustion intensity. Both outperform B100 in vibration reduction, but Mn-Pc10's noise increase may outweigh its incremental stability benefits compared to Mn-Pc5.
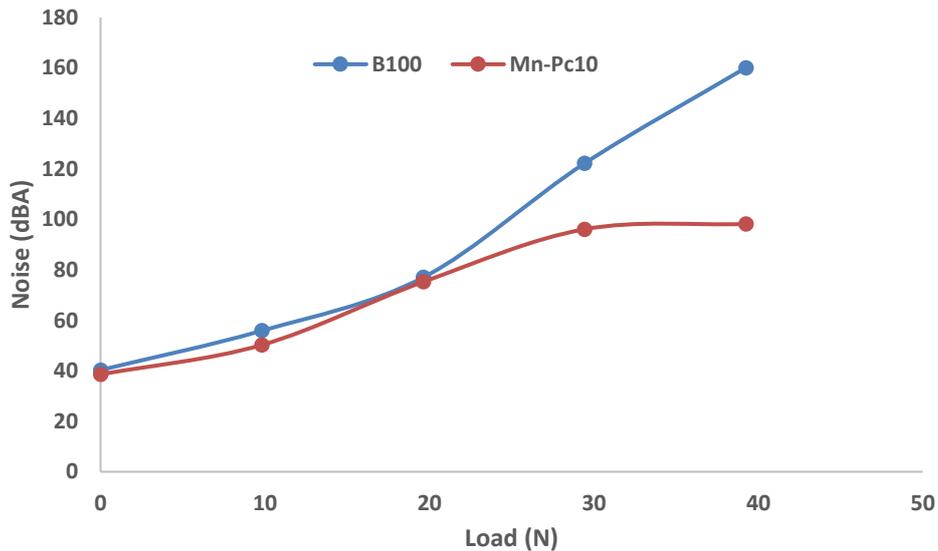

Fig. 5 Mn-Pc10 compared to B100 fuel Noise graph based on engine torque

Figure 5 illustrates a noise comparison between B100 and Mn-Pc10 fuels as a function of engine load (0 to 50 N) and fuel type (categorically represented from 0 to 1), with noise levels measured in dB(A) ranging from 40 to 180. The graph illustrates the variation in noise levels (dBA) with increasing engine load (N) for two fuel types: B100 (pure gasoline) and Mn-Pc10 (a fuel blend with 10% manganese additive). As the engine load increases, both fuels exhibit a rise in noise levels; however, B100 consistently produces significantly higher noise across all load conditions. In contrast, Mn-Pc10 demonstrates a more stable noise profile, particularly at higher loads where the noise level plateaus around 100 dBA. This suggests that the manganese additive improves combustion characteristics, leading to smoother and quieter engine operation. Overall, Mn-Pc10 appears to be more effective in reducing noise emissions under varying load conditions.
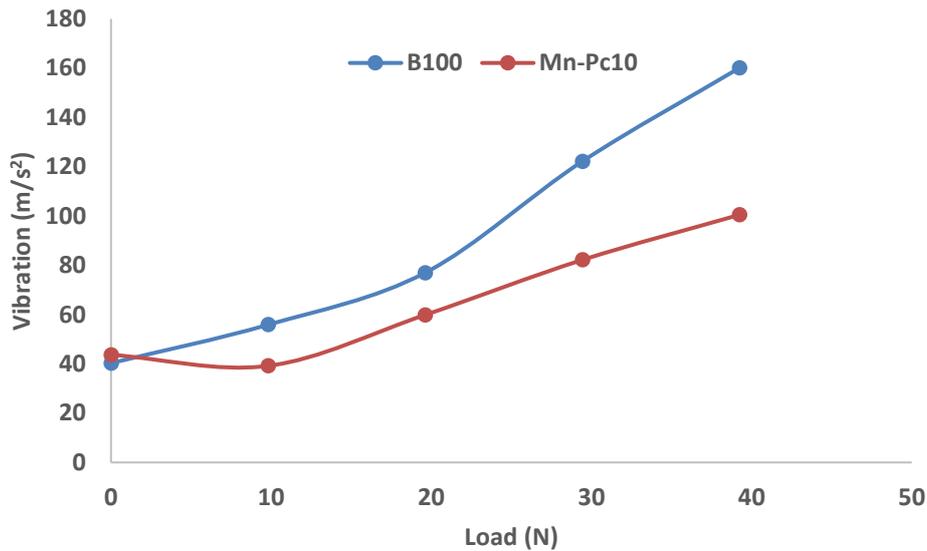
Fig. 6 Mn-Pc10 compared to B100 fuel Vibration graph based on engine torque

Figure 6. depicts a vibration comparison between B100 and Mn-Pc10 fuels as a function of engine load (0 to 40 N) and fuel type (categorically represented from 0 to 1), with vibration levels measured in m/s² ranging from 40 to 140. Mn-Pc5 achieves lower vibrations (80–100 m/s² vs. B100's 120–140 m/s² at 40 N) but higher noise (102 vs. 98 dB(A)), reflecting stable combustion with intense pressure rises from 5 ppm Mn-phthalocyanine. Mn-Pc10, with 10 ppm, unexpectedly produces higher vibrations (140 vs. B100's 110 m/s²) and slightly lower noise (100 vs. 96 dB(A)), indicating combustion instabilities possibly due to excessive catalytic activity, despite smoother pressure dynamics. Mn-Pc5 is superior for vibration-sensitive applications, while Mn-Pc10's performance suggests a need for formulation refinement to balance stability and noise.

4. Conclusion

The experimental analysis of Mn-Pc5 (5% Mn-Pc, 95% gasoline) and Mn-Pc10 (10% Mn-Pc, 90% gasoline) compared to pure gasoline (B100) reveals that the incorporation of Mn-phthalocyanine into gasoline significantly alters engine noise and vibration characteristics, presenting both challenges and opportunities for internal combustion engine applications. The Mn-Pc blends, likely due to their catalytic enhancement of combustion, produce more intense acoustic disturbances and, in the case of Mn-Pc10, greater mechanical instability compared to B100. These characteristics suggest that while Mn-Pc fuels may enhance certain combustion properties, such as potentially improved fuel oxidation or efficiency, they introduce trade-offs that could affect engine durability, operator comfort, and environmental compliance. The increased noise levels associated with Mn-Pc fuels pose challenges for applications in noise-sensitive environments, such as urban settings or passenger vehicles, where regulatory limits on noise pollution are stringent. The elevated vibrations, particularly with Mn-Pc10, may accelerate mechanical wear, increasing maintenance costs and reducing engine lifespan, which could limit its suitability for heavy-duty or high-load operations. However, Mn-Pc5's ability to reduce vibrations compared to B100 under certain conditions suggests potential for niche applications, such as in high-performance engines where stability is prioritized over acoustic comfort.

Future Research Directions: To enhance the viability of Mn-Pc fuels, future studies should focus on optimizing the Mn-phthalocyanine concentration to balance combustion efficiency with noise and vibration mitigation. Investigating intermediate blends (e.g., 7.5% Mn-Pc) or adjusting the THF solvent ratio could help identify a formulation that minimizes mechanical instability while retaining catalytic benefits. Additionally, detailed combustion analysis, including in-cylinder pressure measurements and burn rate profiles, is needed to understand the mechanisms driving the observed noise and vibration

Yakın

*Evaluation of Mn-Phthalocyanine (Manganese phthalocyanine) Fuel
Additives on Engine Vibration and Noise Characteristics in Gasoline Engines*

increases, particularly the uneven combustion dynamics suggested in Mn-Pc10. Emission studies are critical to assess the environmental impact of Mn-Pc fuels, especially given the potential formation of NO_2 and MnO_2 (as indicated in the combustion equation), which could pose air quality concerns.

Conflict of Interest Statement

The authors of the article declare that they have no personal or financial conflicts of interest with any institution, organization, or individual.

References

[1] Ahirrao NS, Bhosle SP, & Nehete DV. Dynamics and vibration measurements in engines. Procedia Manufacturing, 2018; 20: 434-439.

[2] Zouani A, & Hanim S. Overview of noise and vibration in automotive engines. International journal of vehicle noise and vibration, 2016; 12(2): 162-181.

[3] Santana CM, Barros JEM, & de Almeida HA. Analysis of vibration and noise of an internal combustion engine by application of test and experimental analysis of the frequency spectrum, SAE Technical Paper, 2013; 36: 0103.

[4] Yildirim Ş, Erkaya S, Eski İ, & Uzmay İ. Noise and vibration analysis of car engines using proposed neural network. Journal of Vibration and Control, 2009; 15(1): 133-156.

[5] Nag S, Sharma P, Gupta A, & Dhar A. Combustion, vibration and noise analysis of hydrogen-diesel dual fuelled engine. Fuel, 2019; 241: 488-494.

[6] Santhosh S, Velmurugan V, Paramasivam V, & Thanikaikarasan S. Experimental investigation and comparative analysis of rubber engine mount vibration and noise characteristics. Materials Today: Proceedings, 2020; 21: 638-642.

[7] Xi J, Feng Z, Wang G, & Wang F. Vibration and noise source identification methods for a diesel engine. Journal of Mechanical Science and Technology, 2015; 29: 181-189.

[8] Gültekin N, Gülcan HE, & Ciniviz M. The impact of hydrogen injection pressure and timing on exhaust, mechanical vibration, and noise emissions in a CI engine fueled with hydrogen-diesel. International Journal of Hydrogen Energy, 2024; 78: 871-878.

[9] Khan F, Khan O, Parvez M, Ahmad S, Yahya Z, Alhodaib A, ... & Ağbulut Ü. K-means clustering optimization of various quantum dots and nanoparticles-added biofuels for engine performance, emission, vibration, and noise characteristics. Thermal Science and Engineering Progress, 2024;54: 102815.

[10] K Bharath B, & V Arul Mozhi Selvan. Effect of ternary blends on the noise, vibration, and emission characteristics of an automotive spark ignition engine. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 2024; 46(1): 11073-11094.

[11] Hoseini SS, Najafi G, Ghobadian B, Mamat R, Sidik NAC, Azmi WH. The effect of combustion management on diesel engine emissions fueled with biodiesel-diesel blends. Renew Sustain Energy Rev, 2017; 73: 307-31. https://doi.org/10.1016/J.Rser.2017.01.088.

[12] Ghanbari M, Najafi G, Ghobadian B, Yusaf T, Carlucci AP, Kiani Deh Kiani M. Performance and emission characteristics of a CI engine using nano particles additives in biodiesel-diesel blends and modeling with GP approach. Fuel, 2017; 202:699-716. https://doi.org/10.1016/J.Fuel.2017.04.117.

[13] Bankovic-Ilic IB, Miladinovic MR, Stamenkovic OS, Veljkovic VB. Application of nano CaO-based catalysts in biodiesel synthesis. Renew Sustain Energy Rev, 2017; 72: 746-60. https://doi.org/10.1016/J.Rser.2017.01.076.

[14] Dubey S, Banerjee S, Upadhyay SN, Sharma YC. Application of common nano-materials for removal of selected metallic species from water and wastewaters: a critical review. J Mol Liq, 2017;240: 656-77. https://doi.org/10.1016/J.Molliq.2017.05.107.

[15] Avhad MR, Marchetti JM. A review on recent advancement in catalytic materials for biodiesel production. RenewSustainEnergyRev, 2015; 50: 696-718. https://doi.org/10.1016/J.Rser.2015.05.038.

[16] Atadashi IM, Aroua MK, Abdul Aziz AR, Sulaiman NMN. The effects of catalysts in biodiesel production: a review. J Ind Eng Chem, 2013; 19: 14-26. https://doi.org/10.1016/J.Jiec.2012.07.009.

[17] Hoseini SS, Sobati MA. Performance and emission characteristics of a diesel engine operating on different water in diesel emulsion fuels: optimization using response surface methodology (RSM). Front Energy, 2019; 13(4): 636-57. https://doi.org/10.1007/S11708-019-0646-7.

[18] Vijay KM, Veeresh BA, Ravi KP. The impacts on combustion, performance and emissions of biodiesel by using additives in direct injection diesel engine. Alex Eng J, 2018; 57: 509-16. https://doi.org/10.1016/J.Aej.2016.12.016.

Yakın

Evaluation of Mn-Phthalocyanine (Manganese phthalocyanine) Fuel Additives on Engine Vibration and Noise Characteristics in Gasoline Engines

[19] Yakın A, & Behçet R. Effect of different types of fuels tested in a gasoline engine on engine performance and emissions. International Journal of Hydrogen Energy, 2021; 46(66): 33325-33338.

[20] Başoğul Y, & Bayrakçeken H. The Effect of Turpentine Use on Engine Performance and Emissions in a Gasoline Engine. Journal of Engineering Sciences of Adıyaman University, 2018;5(8): 114–124.

[21] Fırat M, Okcu M, & Varol Y. An Experimental Study on the Engine Performance and Emissions of an RCCI Engine Fueled with Different Ratios of Iso-octane and Diesel. Journal of Engineering Sciences of Adıyaman University, 2024; 11(23): 352–362.

[22] Yakin A, & Cabir, B. Effects of adding phthalocyanine to gasoline fuel on engine performance and exhaust emissions in spark ignition engine. Heat Transfer Research, 2024;55(14).

[23] Faraji H, Heidarbeigi K, & Samadi S. Characterization of vibration and noise pollution of SI engine fueled with magnetized ethanol–gasoline blends by time–frequency methods. Noise & Vibration Worldwide, 2021;52(11): 356-364.

[24] Siavash NK, Najafi G, Hassan-Beygi SR, Ahmadian H, Ghobadian B, Yusaf T, & Mazlan M. Time–frequency analysis of diesel engine noise using biodiesel fuel blends. Sustainability, 2021; 13(6): 3489.

[25] Stravinskas S, Rimkus A, & Matijošius J. Evaluation of vibration and noise characteristics of a compression-ignition engine fuelled with natural gas-biodiesel dual fuel. Transport Problems, 2023;18(1).

[26] Cabir B, & Yakın A. Evaluation of gasoline-phthalocyanines fuel blends in terms of engine performance and emissions in gasoline engines. Journal of the Energy Institute, 2024; 112: 101483.

[27] Oral F. Effect of using gasoline and gasoline-ethanol fuel mixture on performance and emissions in a hydrogen generator supported SI engine. Case Studies in Thermal Engineering, 2024; 55: 104192.

[28] Jurić Z, Vidović T, Šimunović J, & Radica G. A Comprehensive Analysis of Hydrogen–Gasoline Blends in SI Engine Performance and Emissions. Energies, 2024;17(7): 1557.

[29] Suresh D, & Porpatham E. Influence of high compression ratio on the performance of ethanol-gasoline fuelled lean burn spark ignition engine at part throttle condition. Case Studies in Thermal Engineering, 2024; 53: 103832.

[30] Palani T, Esakkimuthu GS, Dhamodaran G, & Sundaraganesan A. Performance optimization of gasoline engine fueled with ethanol/n-butanol/gasoline blends using response surface methodology. Biofuels, 2024; 15(1): 33-45.

[31] Fischer M, Achenbach J, & Pischinger S. Impact of thermal swing piston top land coatings on gasoline engine performance and raw emissions. International Journal of Engine Research, 2024; 25(5): 971-989.

[32] Yakın A, Uçkan İ, & Cabir B. Ftalosiyaninin Benzinli Motor Performansı ve Emisyonlar Üzerine Etkilerinin Deneysel Olarak Araştırılması. Journal of the Institute of Science and Technology, 2024; 14(3): 1253-1264.

[33] Sorokin AB, Phthalocyanine metal complexes in catalysis. Chemical Reviews, 2013; 113(10): 8152–8191. https://doi.org/10.1021/cr400007n

[34] Atkins P, & Jones L. Chemical principles: The quest for insight. Macmillan. 2007.