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EXPERIMENTAL STUDY ON THE COMBUSTION AND EXHAUST EMISSIONS OF OTTO ENGINE FUEL WITH NAPHTHALENE-GASOLINE BLENDS

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ABSTRACT:- The growing demand of energy in transportations especially in small cars field leads to increase the contribution of this vital sector of modern life in the greenhouse effect and environment problems. Any enhancement in the thermal efficiency of the car's engines will reduce the amount of bad effects gases that released from gasoline engines exhausts. Rising Octane number and or enhance the combustion process result in increasing of engine output power. Naphthalene as mothballs, which is a commonly household used in exclusion of harmful insects, is probable additive to achieve that. The usage of Naphthalene needs to study its impacts on the performance of Otto cycle's engines and their exhaust gases. Blends of Naphthalene as additive and gasoline as base material have been prepared and examined. The study based on experimental tests and laboratory assays including; Octane number calculations, Fourier Transform Infrared Spectroscopy analysis (FTIR), Gas Chromatography Mass Spectrometry analysis (GCMS) and thermal performance tests and emissions analysis. Naphthalene had been approved as a good additive to rise the octane number and output power with some caveats. It should carefully control Naphthalene concentration to avoid the side effects of overdose and should not directly dissolved in the car fuel tank to prevent the formation of the deposits.
Keywords: Naphthalene, Gasoline engine, Additive, Octane number, Emission

INTRODUCTION

Global warming and the explosive growth in cars numbers force the researchers to find solutions to reduce fossil fuels harmful emissions. One of the suggested solutions, which is related to gasoline engines, is to boost the fuel Octane number because the original gasoline from oil refineries is naturally low Octane number. Actually, using high Octane number gasoline permit to get the maximum utilize of the energy from the used fuelas well as it prolong the engine life because it prevent the harmful mechanical problems due to knocking and preignitions problems

However, the essential and certified techniques to rise the Octane number are not environmentally friendly. Most of these methods involve conduct further chemical processes such as catalytic reforming process with what this means to disburse more energy, which are mostly comes from fossil sources. That is means more environmental damage with high production costs.

The other methods are in the field of adding additives to the gasoline to boost its Octane number. The problems in these methods are come from the additives themselves. Most of the reliable additives such as lead compounds are toxic chemicals with very bad effects on the human and organisms or on the whole environment. To avoid the side effects of using the conventional additives, new generation of materials, which are biochemical, have been proposedto replace the old groups. Ethanol, Methanol, Butanol and other bio additives have been tested, investigated and used as Octane booster over the past decade[1–3]. All of bio additives have high Octane number ranging from 110 to 130 RON[4,5], so when add it to the fuel; it lifts gasoline Octane number reasonable. However, because all of bio additives also have lower energy content than that of gasoline, it reduces the fuel power output and the thermal efficiency of the engine[6,7].It also damage engine parts by exposing them to erosions[8]. However, additives method are still a good choice if one could select a material that has high Octane number and high-energy content as well.

Indeed, gasoline is a composite mixture consists of hundreds of compounds of different boiling points and it produce from crude oil refinery. Four kind of active groups can be classified in gasoline compounds, Aromatic, Isoparaffin, paraffin and Naphthenes. All of these active groups share effective in giving the gasoline its Octane number[9].

Mendes et al. approved that some of these active groups like as Isoparaffin and Aromatic give gasoline high Octane number[10]. Existence of any compounds of these active group lead to some chemical processes like alkylation, reforming and isomerization, which in turn lead to increase the Octane number of the gasoline[10].Molecular structure play great role in tendency to ignition. Long chain compounds such as paraffin have high trend to self-ignition per contra short chain compounds like Isoparaffin have high resistance to self-explosion [9].

Naphthalene, sometimes-called Albocarbon, is an Aromatic compound with chemical structure $C_{10}H_8$. It is solid-state material with crystalline structure soluble in organic liquids and water. Naphthalene molecule can consider as double merged benzene rings[11]. There are two source of naphthalene, manufactured from coal tar or from oil refining. Look at the above; Naphthalene can be proposed to replace the bio additives. It is Aromatic with chemical components similar to gasoline and it low cost production that is mean high Octane number, a homogenous mixture with gasoline, low erosion effects, not low energy content and economically feasible.

Actually, Naphthalene is not new in the field of additives. Conversely, it is the oldest material that been used as Octane booster. Thenon-thoughtful usage of Naphthalene returns to twenties of the past century[12]. They used it in arbitrary amount without knowing how it works or how it effects the engines performance or engine parts. However, this usage was stopped after the increasing in the crude oil prices during World War 2, which leads to rise in Naphthalene prices because at that time, the oil was the only source of Naphthalene. Current work is try to inspect the possibility of using Naphthalene as Octane booster for gasoline fueled engines and its potential effects on the environment by systematic study and scientific investigation

EXPERIMENTAL AND MEASUREMENTS

In order to investigate the possible effects of using Naphthalene in gasoline engine fuel, four blends have been prepared. Blend Gis totally gasoline, N1, N2, N3 represent a mixture of gasoline as a base material plus Naphthalene in rate of 0.001, 0.004, 0.008 percentage respectively. They have been mixed directly by putting solid Naphthalene balls with specified amount in fixed quantity of gasoline and let it mix with time and shaking.To explore and fully understand all the effects and their causes, the procedure of the testing the blends was in four main stages.

Octane number calculations

The prepared mixtures have been tested by SHATOX™ Octane meter, which is showed in figure (1) to measure their RON, MON and AKI. The principles of the device is depended on comparative measurement of dielectric characteristics of the blend to the standard gasoline sample stored in the internal memory of its microprocessor. Due to its excessive sensitivity to change in dielectric properties, the device measurements considered very accurate instrument in Octane/Cetane measurements.

Fourier Transform Infrared Spectroscopy analysis (FTIR)

This method is uses to find the active groups of chemical compounds. It uses infrared radiation (IR) to pass through the blend and using detector to absorb the passers radiations and analyze them to find the spectrum. Every individual molecular structure has its own significant spectrum according to its ability to absorb and transmit of IR.

Gas Chromatography Mass Spectrometry analysis (GCMS)

This method consist of two parts, Gas Chromatography (GC), which is used capillary column under temperature regulator to separate blend to pure components through the difference between their boiling points. The second part is Mass Spectrometry, which is uses in identification and quantification of the different components according to the mass spectra.

Thermal performance tests and emissions analysis

After investigate the major specifications and calculate the required properties of the blends, they are ready now to study how and how much they will change the output power to find the total effects on the thermal performance of the engine. A test system product by PRODIT® ENGINEERING Company had been used to this purpose. The system consist of several parts which are the engine, hydraulic dynamometer, control board, fuel unit, air unitand control board unit, see figure (2). The first part is the four stroke with single cylinder gasoline fueled engine. The engine is coupled to the second part, which is the hydraulic dynamometer to measure the load torque. The torque applied to the dynamometer is detected by a strain gauge, which convert it to an electrical signal. The fuel unit supply the fuel to the engine from fuel tanks and it measures the fuel consumption by its integrated digital flow measurement system. The consumption is supplied and measured by the air unit, which consists of a damping chamber, suction hose, integrated and airflow digital gauge. It measure the airflow depending on the pressure difference induced by the flow in the suction hose. All the electrical signals come from dynamometer load cell, fuel flow meter, air flow meter, engine speed transducer and different point temperature sensors are conveying by electrical cables to the control board unit, which control all the system operation conditions including air throttle, engine speed, switch off, and switch on the engine.

The engine had been running on 3 rotational speed 1200, 1500 and 1800 r.p.m. at fixed weather condition to exclude any external influences. Different torque loads have been applied by the dynamometer ranged from 11 to 14 k N.m. In order to assure the stability in the results, after the first run the engine leaved to reach its stable temperature then the test proceed.

To calculate the heat rejected by exhaust gases and how adding Naphthalene will affect it and what the environmental effects that will comes after that, Exhaust gas calorimeter had been used. Itis consist of gas-water heat exchanger, water flow meter, and flow- rate regulation valve, temperature sensors to measure temperatures at different points and data control board, see figure (3). The gas-water heat exchanger is a shell and tube cross flow type used to transfer heat from hot gases to cold liquid like water. The calorimeter calculation is depend on estimate the rejected heat from the hot gases by knowing the difference between the input and output cooling water temperatures.

Analyzing the exhaust gases had been done using PROTECH FLUX® 2000-4 gas analyzer. The device uses IR to measure the concentration of Carbon Dioxide (CO_2), Carbon Monoxide (CO), Oxygen and Superfluity Hydrocarbons (SHC) in gases. The device warming up time is around 30 minutes with response time 15 seconds. It auto zeroing its reading in every new measurement to maintain its accuracy. With the integrated drainage system, the device throws away any condensate water during the measurement to prevent any possible damage due to water problems.

RESULTS AND DISCUSSIONS

The four blends have been prepared by directly mixing Gasoline with the specified concentration of Naphthalene and let the mixture at rest. It was observed that only the first blend (N1) had no undissolved Naphthalene, as for N2 and N3 blends, the free solid Naphthalene particles are easily observed in the mixture. The numbers of Octanes come from IFONA are showed in Table (1). There is no big rise in the values from blend G to blend N1. Moreover, increase the Naphthalene concentration in blend N2 seems fixing the Octane value or even give a negative effect in blend N3. To explain these behaviors, it should go to GCMS and FT-IR analysis to know what happen to the group of organic compounds of gasoline contents after adding the different proportions of Naphthalene.

Figure (4) presents GCMS results. It denotes to increment in Aromatics compounds in blend N1 such as toluene referring to the base mixture, blend G. Moreover, blend N1 shows raise in Olefins and Cyclic paraffin such Cyclopentane and 2,4,4-Trimethyl-2-pentene compare to other blends. Conversely, Paraffin compounds show lower rate in blend N1 than that of blend G.

Refer to blends N2 and N3, they show decreasing in the concentration of Olefin and Aromatic organic compounds and slight decreasing in Paraffin compounds rate. To the contrary, Isoparaffin compounds are in high concentrations in these blends compare to mixture G.

According to GCMs outcomes, the portion of Olefins and Cyclic paraffin in blend N1is about 85.23%, which is refer to a high MON number mixture as Mendes et al. [10] approved. The gained data shows also that blends N2 and N3 contain Aromatic compounds around 63.3 % and Olefins about 54.54%. These results match with the outcomes of Octane number analysis and they give the explanation as well. The low increment in Octane number might be emanated from the low solvability of Naphthalene. It can be noticed in figure (4) that the rate of dissolved Naphthalene is increased from blend N1 to N3. That is may consider the first cause of slight increasing in Octane number. The second reason may come from continuing growing of Isoparaffin compounds concentrations from mixture G to N3. If the overload and non-dissolved Naphthalene rate avoided, these adverse effects can be prevented. The existence of above-mentioned main compounds in the blends and their concentrations have been confirmed by the FT-IR analysis. It can identified C=C active group as Aromatic compounds, C-C and C-H as Aliphatic and C-H Aromatic.

Figure (5) demonstrates the relation between torque load and the engine rotational speed and its effect by naphthalene addition. It can be understood from the figure that the use of Naphthalene leads to a relatively slight increasing in the load that the engine can undergoes for the same rotational speed. Actually, there is no big effect of increasing Naphthalene concentration, whereas the effect of N3 blend is not too far from N2 blend effect as can be noticed from the figure. Furthermore, Naphthalene presence does not affect the optimal engine speed value required to endure the highest load torque.

The relation of brake power with the engine speed when fueled the engine by the four blend is presented in figure (6). The behaviors of the curves are confirm with the previous figure (5) result. It shows a slight enhancement on the brake power values due to adding Naphthalene to the gasoline without high change between the blends.

The changing of brake thermal efficiency according to increasing in Naphthalene concentration with different load torque is displayed in figure (7). Although the small impacts of Naphthalene adding on Octane number values and its slight effects on the brake power as it determined from previous figures but one can see the increment in the brake thermal efficiency is clear and continuous with going from N1 to N3. This is due to cumulative effects of these two factors In other words the slight increment of load with small rise of Octane number lead to considered growing of brake thermal efficiency. What asserts this is the big mounting of the efficiency for high torque load. Endorsement to this, figure (8) shows the specific fuel consumption with load torque and the effects of the blend on them. Owing to the cumulative effects coming from increasing of Naphthalene rate, S.F.C shows reducing in its values following the increasing in the Naphthalene concentrations. This decrement is very so significant for high torque load.

Recommending Naphthalene as fuel additive needs to investigate the changing in the engine exhaust emissions and whether this change is in positive trend or negative direction. Figure (9) plot superfluity hydrocarbons (SHC) against engine rotational speed for using the prepared blends as the engine fuel. The outcomes of this figure explained a good effect of Naphthalene in reducing the unburned hydrocarbons in the exhaust gases. It clearly show that

SHC is normally decrease according to increasing in the engine speed. Moreover, there will be further dropping of substantial values due to increasing in the Naphthalene rates.
Figure (10) consistent with the good result of SHC. This figure indicate the significant falling in CO_2 rates with increasing of Naphthalene concentrations. The deference between blends are in high values for low engine rotational speed especially between G, N1 and N2. For high speed, the difference seems to be small and similar.

Unlike the last two figures, figure (11) illustrates bad effect of using Naphthalene with gasoline. It clear that CO concentration goes up with increasing Naphthalene rate. This indicate that the combustion need more oxygen and the fuel to air ratio is a rich mixture. The variances are so clear between the blends.

Figure (12) explains the behavior of exhaust gas temperature with engine rotational speed for the engine under test with the four specified fuel blend. Temperature rising is obviously noticed subsequent the increasing in Naphthalene rate. Actually, the increment is unswervingly follow the increment of the additive.

Another evidence on the good effect of Naphthalene blend on the brake thermal efficiency is in figure (13), which show the relation between the volumetric efficiency with engine speed. The reduction in the volumetric efficiency value is so clear and it in the same rate for all Naphthalene blends (N1, N2 and N3). Actually, there were a shortage in Oxygen quantity in the combustion. This match with the results gained from the gas analyzer, which indicates that Oxygen concentration is zero in the exhaust gases for all studied cases.

The results of the exhaust gas calorimeter have been presented in figure (14). The rejected heat from exhaust is growing according to increasing in the additive. When compare between G and N3 blend, one can notice that the rejected heat is almost a little under doubled value. As faster as the engine go, as the difference decreases.

CONCLUSIONS

The changed in the gas emissions and thermal performance of gasoline engine fueled with mixture of gasoline plus Naphthalene have been studied. Different concentration of Naphthalene mixed with gasoline base have been combined. Various tests and experiments have been done to exam the different properties of the mixtures with how and how much they effects the power producing and the potential impacts on the environment. On Octane number values as merely, a very small enhancement had been approved after several tests on IFONA device. It confirmed that this improvement is not need to a high additive concentration contrariwise, more concentration leads to unfavorable effects on the other properties as have been verified. Another good effect of Naphthalene on gasoline engine is the slight augmentation on the heat production quantity from the fuel. GCMS and FTIR analysis refer that to increments of some compounds due to presence of Naphthalene. These compounds of increased concentrations have anability to liberate a high level of energy when burned. Overall, the improvements of using naphthalene as additive are combination effects, which come from small enhancement in liberated power and mild booster of Octane number, which in turn leads to increasing in the output power. In the environment side, Naphthalene is appears as a promise material to reduce the pollutions come from gasoline engines especially those related to remained hydrocarbons and CO_2 in the exhaust gases. Some increasing in CO concentration had been noticed and this due to lack of oxygen entering to the combustion chamber. In spite of that, according to the results, Naphthalene still can consider a good potential pollutions reducer. Generally, Naphthalene can be used to improve gasoline engine thermal performance and to reduce the harmful effects of exhaust gases but with proper calculation of the required concentration to avoid the inverse effects of overdue rates.

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Table (1): Octane number analysis data

	RON	MON	AKI
G	92.6	83	88
N1	93.2	83.9	88.5
N2	93.2	83.8	88.5
N3	92.6	83.5	88.1

Fig. (1): SHATOX™ Octane meter.

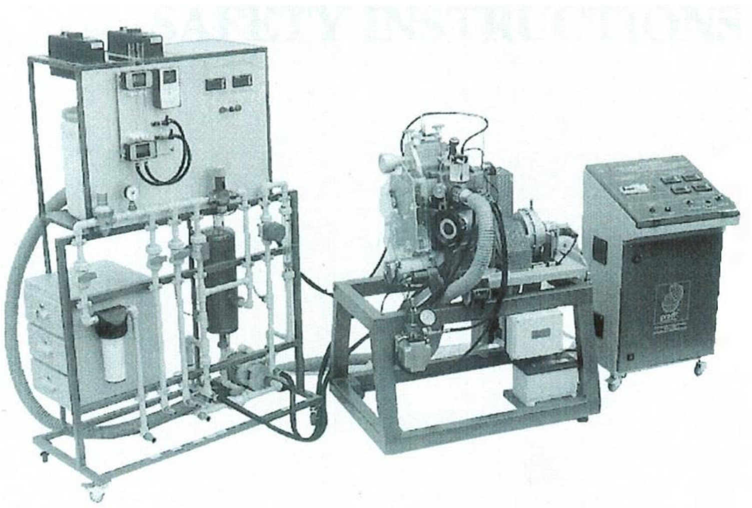

Fig. (2): The test system.

Fig. (3): The exhaust gas calorimeter unit.

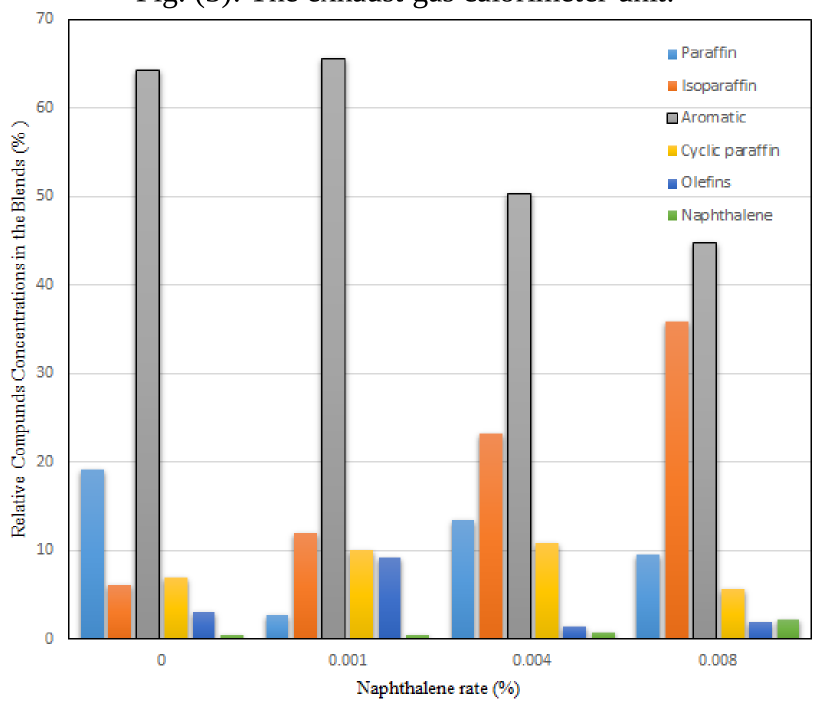

Fig. (4): The active groups concentrations in the blends.

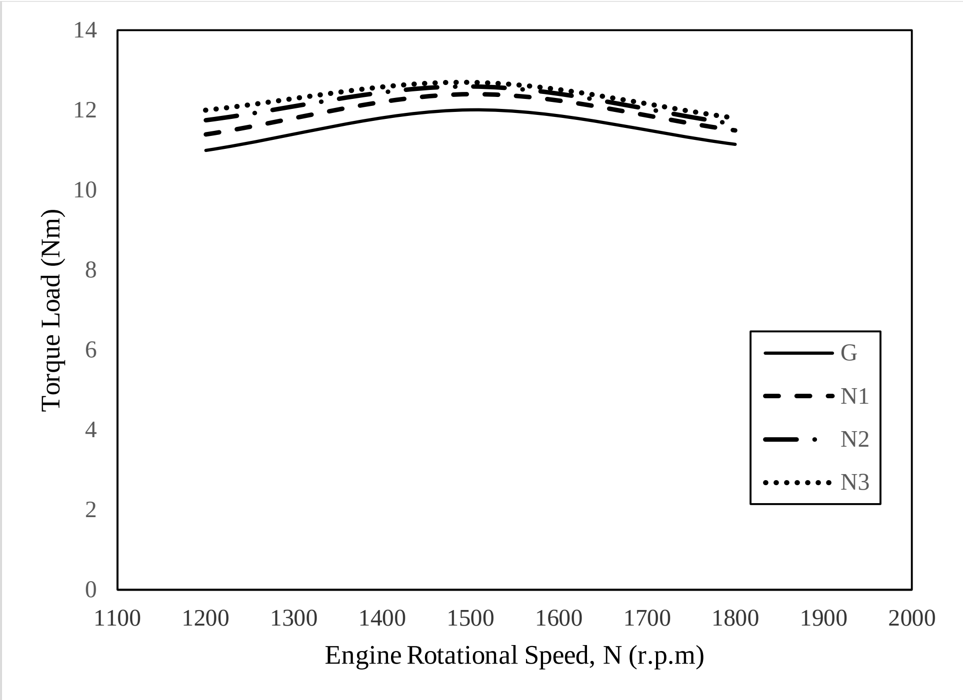

Fig. (5): Naphthalene concentration effects on the torque load at different engine rotational speed.

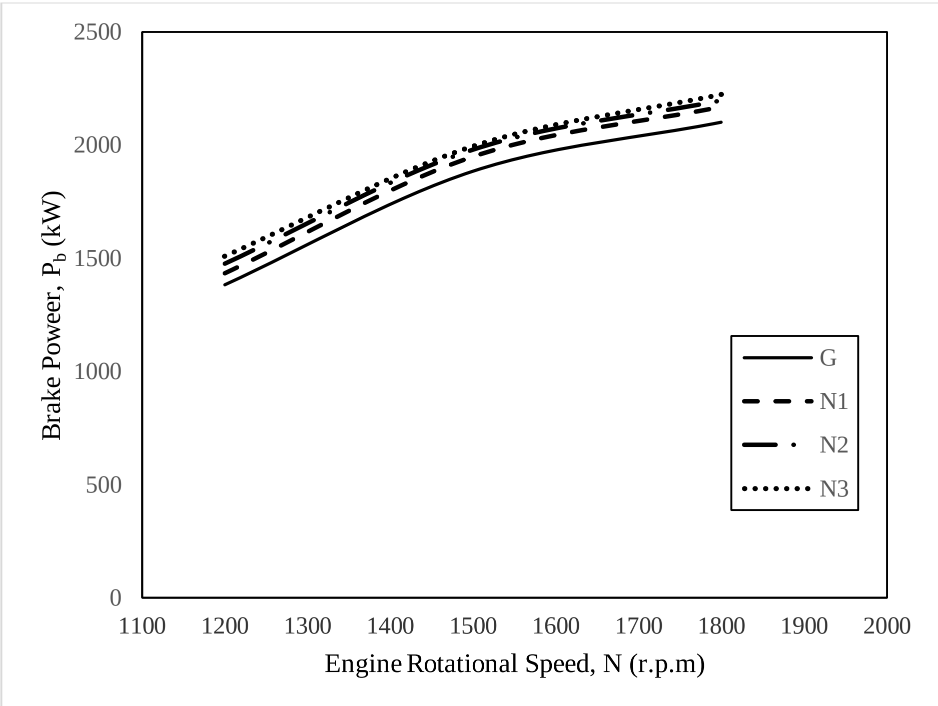

Fig. (6): Naphthalene concentration effects on the brake power at different engine rotational speed.

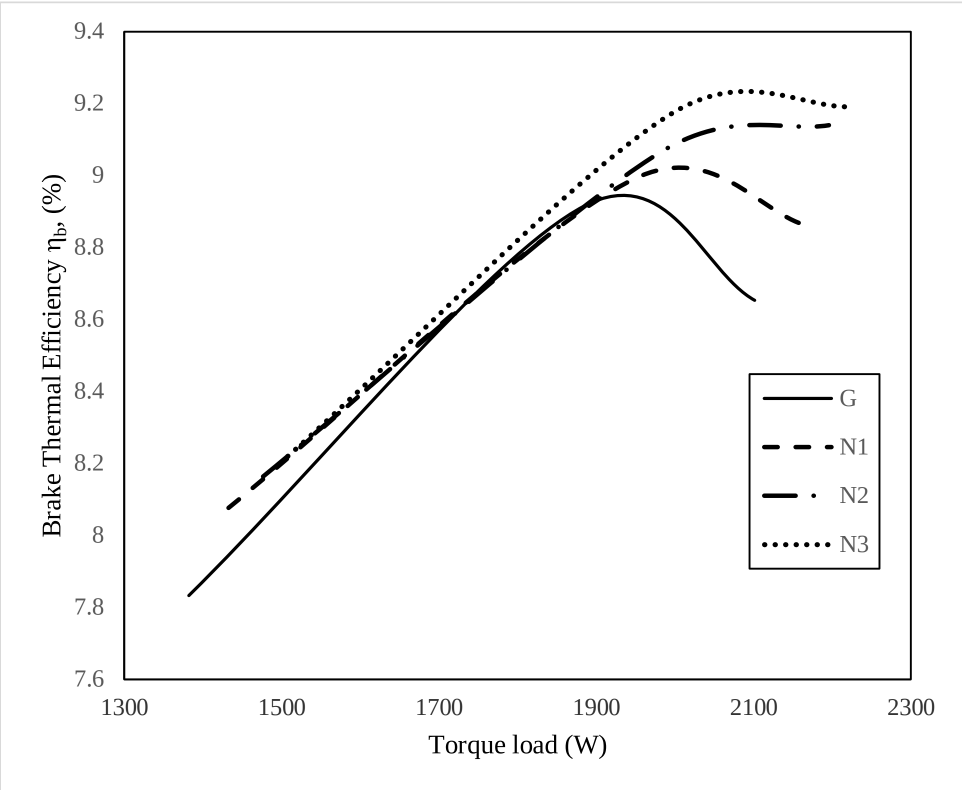

Fig. (7): Naphthalene concentration effects on the brake thermal efficiency with torque load.

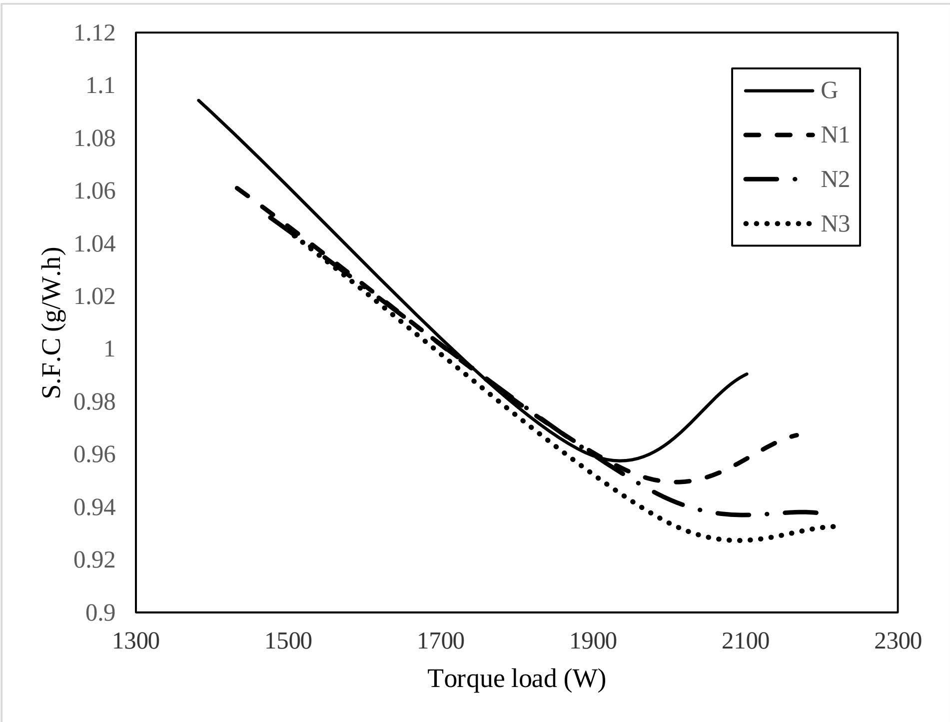

Fig. (8): Naphthalene concentration effects on the specific fuel consumption with torque load.

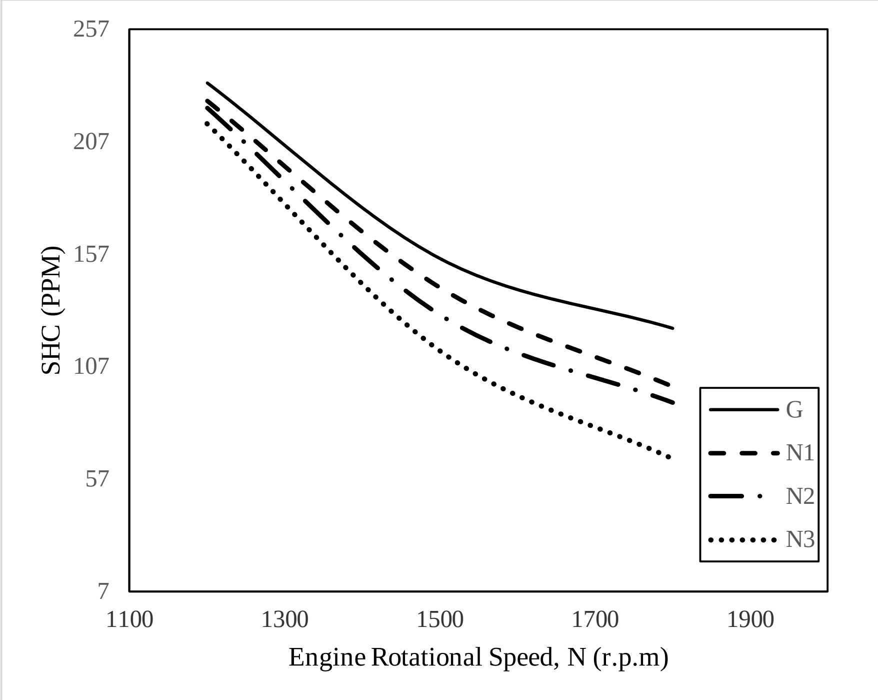

Fig. (9): Naphthalene concentration effects on the superfluity hydrocarbons at different engine rotational speed.

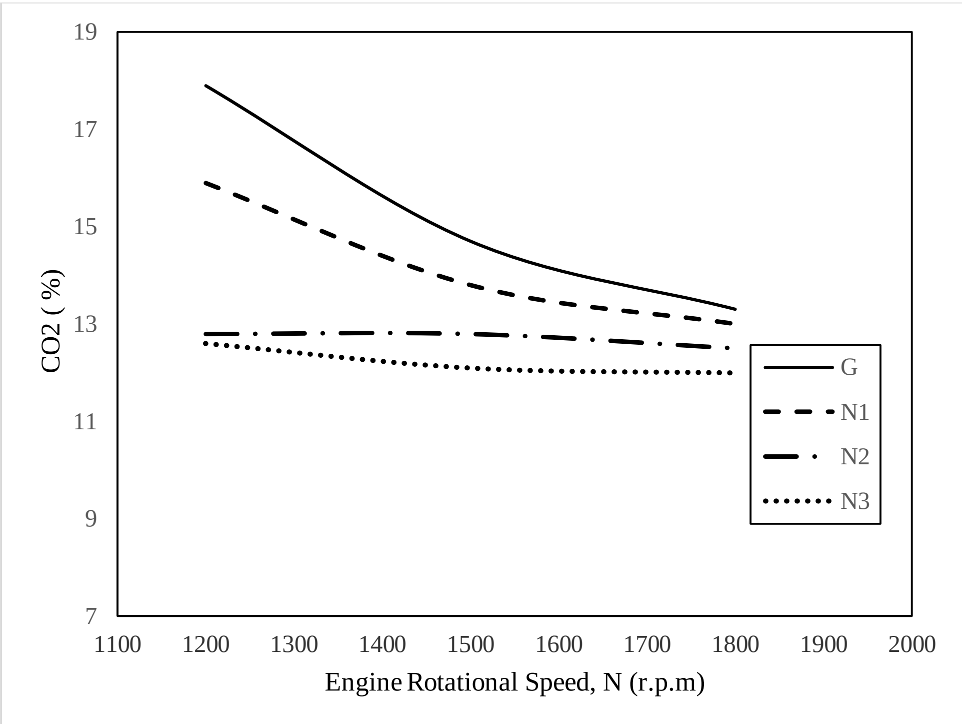

Fig. (10): Naphthalene concentration effects on CO_2 rates in the exhaust gases at different engine rotational speed.

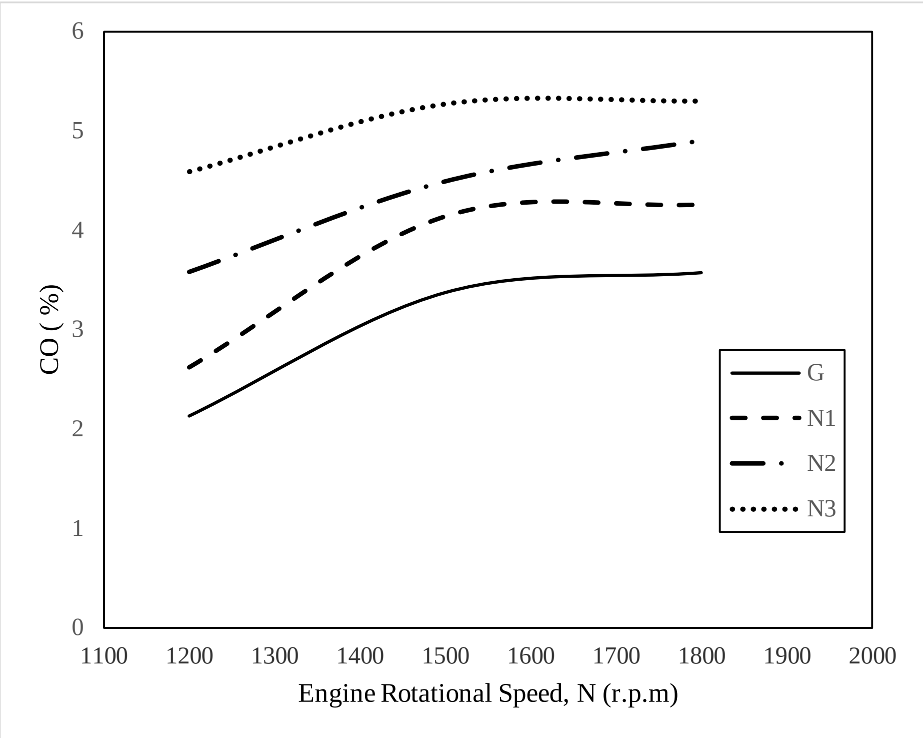

Fig. (11): Naphthalene concentration effects on CO rates in the exhaust gases at different engine rotational speed.

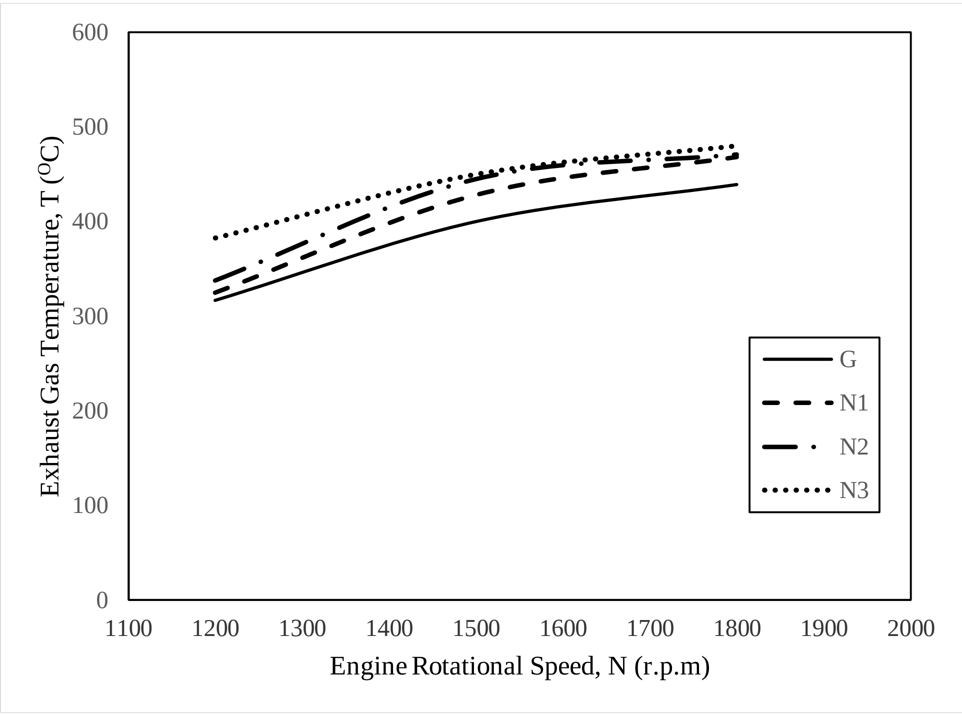

Fig. (12): Naphthalene concentration effects on exhaust gases temperature at different engine rotational speed.

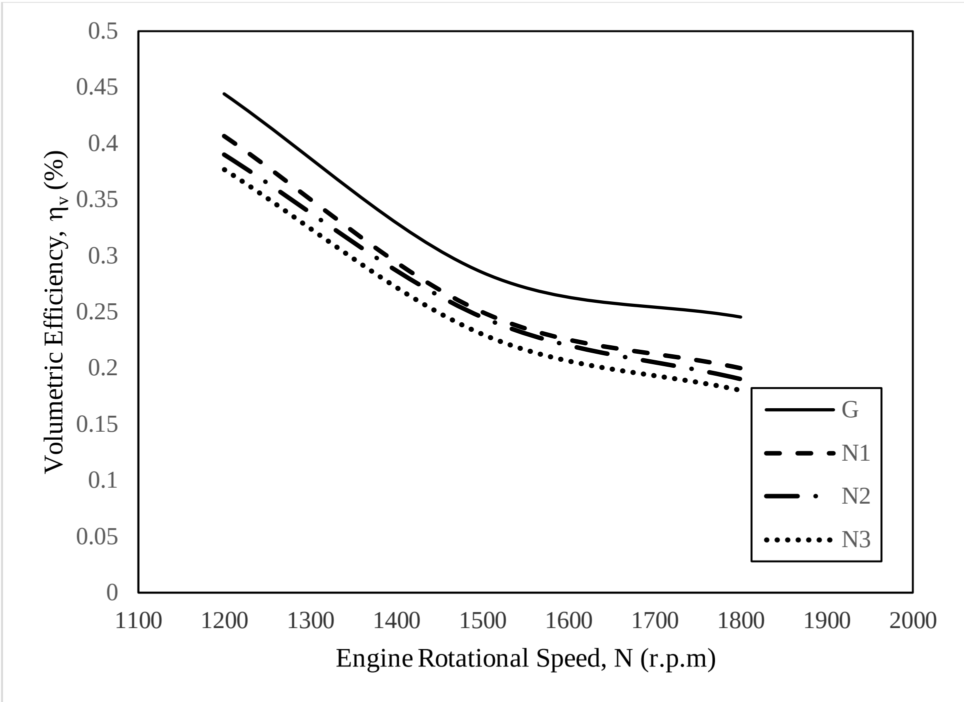

Fig. (13): Naphthalene concentration effects on volumetric efficiency at different engine rotational speed.

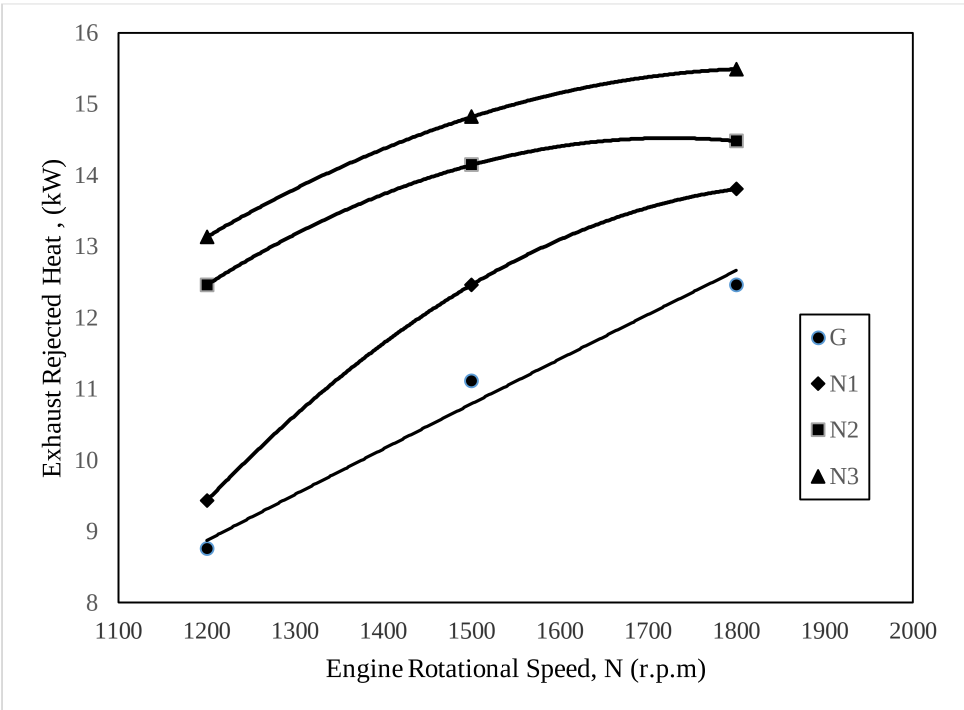

Fig. (14): Naphthalene concentration effects on exhaust rejected heat at different engine rotational speed.

دراسة تجريبية لاحتراق وغازات العادم لمحرك الاوتو المغذى بخلائط جازولين-نفتالين

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الخلاصة

الطلب المتزايد على الطاقة في المواصلات وخصوصاً في مجال السيارات الصغيرة يؤدي الى ازدياد مساهمة هذا القطاع الحيوي من الحياة المعاصرة في تأثير البيوت الزجاجية ومشاكل البيئة. أي تحسين في الكفاءة الحرارية لمحركات السيارات سوف تؤدي الى نقصان في التأثيرات السيئة للغازات التي تتحرر من عوادم محركات الجازولين. رفع العدد الأوكتاني مع او تحسين عملية الاحتراق ينتج زيادة في طاقة المحرك الناتجة. النفتالين على شكل كرات العث، الشائع الاستخدام منزلياً لأبعاد الحشرات الضارة هو مضاف محتمل لإنجاز هذه المهمة. استخدام النفتالين يحتاج الى دراسة تأثيراته على كفاءة محركات دورة اوتو وغازاتها العادمة. خلائط من النفتالين كمضاف والجازولين كمادة أساس تم تحضيرها واختبارها. الدراسة بنيت على اختبارات تجريبية وفحوصات مختبرية; حسابات العدد الأوكتاني و تحويلفورير للتحليل الطيفي بالأشعة الحمراء و التحليل اللوني مع تحليل الطيف الكتلي و اختبارات الأداء الحراري مع تحليل الغازات. تم اثبات ان النفتالين مادة مضافة جيدة لرفع العدد الاوكتاني والطاقة الخارجة مع بعض المحاذير. يجب السيطرة بدقة على تركيز النفتالين لتجنب التأثيرات الجانبية للجرعة الزائدة والاذابة يجب ان لا تكون مباشرة في خزان وقود السيارة لمنع تكون الرواسب.