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AN EXPERIMENTAL INVESTIGATION OF THE INFLUNCE OF HIGHER OCTANE NUMBER THAN ENGINE REQUIREMENT ON ENGINE PERFORMANCE AND EMISSIONS

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ABSTRACT

In this study, the effect of using higher-octane gasoline than that of engine requirement on performance and exhaust emission was experimentally studied. The test engine chosen has fuel systems with carburetor because 40% of the vehicle population in Turkey have carburetor. The engine required 91-RON (Research Octane Number) gasoline was tested using 95-RON and 91-RON. Results show that using higher octane ratings than requirement on engine not only decreases engine performance but also increases exhaust emissions.

Key Words: Spark ignition engine, Gasoline fuel, Research octane number,
Specific fuel consumption and exhaust emission

MOTORUN İHTİYACINDAN YÜKSEK OKTANLI BENZİN KULLANIMININ MOTOR PERFORMANSI VE EMİSYONLAR ÜZERİNE ETKİSİNİN DENEYSEL İNCELENMESİ

ÖZET

Bu çalışmada, motorun ihtiyacından yüksek oktanlı benzin kullanımının performans ve emisyonlar üzerine etkisi deneysel olarak incelenmiştir. Türkiye'de araç popülasyonun % 40'ını karbüratörlü taşıtların oluşturması nedeniyle test motoru olarak karbüratörlü bir motor seçilmiştir. 91 oktanlı benzine ihtiyaç duyan test motoru 91-RON ve 95-RON benzin kullanarak test edilmiştir. Sonuçlar, motorun ihtiyacından daha yüksek oktanlı benzin kullanımının sadece performansı düşürmediğini aynı zamanda egzoz emisyonlarını artırdığını ortaya koymaktadır.

Anahtar Kelimeler: Buji ile ateşlemeli motor, Benzin yakıtı, Araştırma oktan sayısı,
Özgül yakıt tüketimi ve egzoz emisyonları

1. INTRODUCTION

In the research studies on SI engine fuels, the aim is to improve the fuel properties, to decrease the engine fuel consumption, to augmented engine power and to diminish the unwanted exhaust emissions. Considerable progress has been made in unfolding of the spark ignition engine over its more than 100-year history, particularly in recent years. Examples [1, 2] include the adaptation of SI engines to three-way catalysts, advancing engine design and improving fuel properties. Additionally, in recent years, researchers [3, 4] have interested in octane number since exhaust emissions from automobiles and engine performance are known to have a very close relationship to gasoline quality (octane number). Therefore In this study, engine performance and exhaust emissions were investigated using gasoline powered SI engine with two different octane number gasoline.

Gasoline is main fuel for the SI internal combustion engine. Increasing fuel efficiency, changing its attributes and progressing features are the major research areas in the automotive industry. The octane number of gasoline is one of the most important measures of the fuel quality. First of all, it would be the best discussions [5, 6, 7, and 8] about the octane number of gasoline since the octane number of a gasoline is a measure of its resistance to detonation. The octane number of an engine is determined according to the engine design and compression ratio. Weather, driving condition, and mechanical conditions of the engine are some examples that will be able to effect this requirement. For instance, combustion-chamber deposits decrease volumetric efficiency, which boost octane requirement and probability detonation. Diminished cooling efficiency, problems in fuel systems, ignition troubles and failure of emission controls can also change octane requirements [9, 10].

In practice, it is believed that the higher octane rating makes engine better in performance. This attracts people to use higher-octane gasoline in their engines. Although it has been explained that using correct gasoline is the best for the engine, people still prefer to use higher-octane gasoline. Using excessive higher octane rating gasoline on the engine makes longer ignition delay and shorter speed of the flame. However, to reach maximum combustion pressure, it is essential to have longer time. This leads the maximum pressure to increase engine output power. If the less-octane gasoline is used, the flash point will be less than normal-octane gasoline. The time, which is spent between ignitions and starting to burn of mixture, will be very short. These causes diminish effective power [11].

In a university research [12] the effect of gasoline octane number on the engine performance was studied. In that work, three different octane ratings of 91, 95 and 97-RON (Research octane number) were investigated in three engine models that all required 95 RON. The Toyota Corolla engine models were 5A-FE, 4A-FE and 7A-FE with engine displacements of 1.5, 1.6 and 1.8 lt respectively. Test runs were conducted at two throttle settings of 50% WOT (Wide Open Throttle) and 100% WOT and with a range of engine speeds. It was reported that at a given throttle position engine power insignificantly changes with octane number for all tested engines.

Sudsanguan and Chanchaowna [10] were investigated the effect of gasoline octane number on effective power and fuel economy. In that research, the engine required 91-RON was tested with 91-RON and 95-RON. Results showed that the average fuel consumption using 95-RON is higher than that of 91-RON. Moreover, it was seen in this paper that using higher-octane rating gasoline than engine requirement wasn't augmented effective power.

A paper in proceedings [13] clearly reported that octane number is effective on exhaust emissions. In this work, two different octane gasoline fuels, which with 91 and 93 octane number were conducted in a four-cylinder and four-stroke SI engine. The results demonstrated that than the octane number was increased 91 to 93, CO emissions boosted nearly 5 percent.

The additives used to increase octane number have also effect on emissions. For instance, the study [14] confirms that the tetra alkyl lead in gasoline is very important parameter influencing the content of exhaust emissions. However, there are only few studies in the literature about the effect of higher octane rating on the gasoline engines with carburetted fuel system. Therefore, in the current study, the effect of higher-octane gasoline on performance and exhaust emission was studied using a carburetted gasoline engine.

2. EXPERIMENTAL FACILITIES

The engine used in the tests was a Fiat DKS 1.6 (lt) originally requires gasoline fuel with 91-RON. Details of the engine specification are shown in Table 1. Fuels tested were commercial grades with 91 and 95-RON. Details of gasoline compositions and properties are given in Table 2.

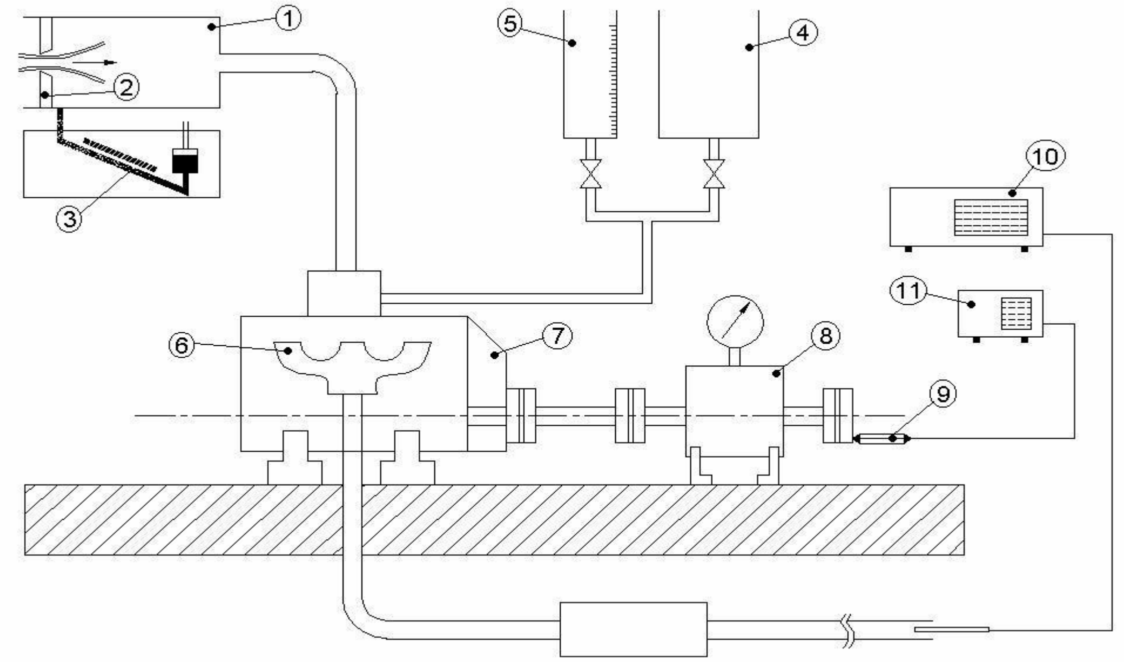
Table 1. The Technical Specifications Of The Fiat DKS Engine [15].

Engine type	131 A 1016
Cylinder number	4
Cylinder bore	84 mm
Stroke	71.5 mm
Total cylinder volume	1600 cc
Compression ratio	8:1
Maximum torque	117.2 Nm at 3400 rpm
Maximum power	58.88 kW
Engine octane requirement	91 RON

Table 2. Properties Of The Fuels Used In The Tests [16].

Research octane number	**91**	**95**
Density at 15 °C, kg/lt	0.738	0.745
Reid vapour pressure, kPa	59.34	60.03
Boiling temperature, °C	198.9	209
Lower heating value, kJ/kg	43932	43304
Tetra alkyl lead as gPb/lt	0.10	0.36

Pressure change in the intake manifold was determined by inclined manometer. Engine load was measured by using a dynamometer. Exhaust gas pollutants such as CO, CO_2, HC, were measured by an exhaust gas analyser (Bilsa 320). Fuel consumption was quantified by combined container method and air ratio was determined by orifice-meter. The experimental apparatus are shown in Figure1.



1. Air tank 2. Orifice 3. Inclined manometer 4. Fuel tank
5. Measurement container 6. Exhaust manifold 7. Test engine 8. Dynamometer
9. Exhaust gas analyser 10. Tachometer sensor 11. Tachometer

Figure 1. Engine Laboratory Set Up

3. THEORETICAL ANALYSIS

3.1. Mass Flow Rate of Air

After each experimental run, raw data from the instruments were recorded. By using the raw data, mass flow rate of air and Reynolds numbers were calculated. The mass flow rate was measured by means of an orifice plate. The operating principle of orifice plates is based on the relationship between the velocity and pressure of a flowing fluid. When a restriction, such as small diameter orifice plate, is inserted in a stream, fluid velocity must increase when passing through it. A proportional drop in pressure based on Bernoulli's equation accompanies the rise in velocity.

The mass flow rate through the intake pipe was calculated by using the following expression given by a standard [17].

$$\dot{m} = C.\varepsilon.\frac{\pi.d^2}{4}.\left(\frac{2.\rho_a.\Delta P}{1-\Phi^4}\right) \tag{1}$$

where ε is the expansion factor, which can be assumed as unity under our experimental conditions, d is the orifice plate diameter, Φ is the ratio of the diameter of the orifice plate to the diameter of the intake pipe, ρ_a is the density of air, ΔP is the pressure drop across the orifice plate, and C is the charge coefficient expressed according to a standard [17] as;

$$C = 0{,}5959 + 0{,}0312\Phi^{2{,}1} + 0{,}1840\Phi^8 + 0.039\Phi^4(1-\Phi^4)^{-1} - 0.01584\Phi^3 + 91.71\Phi^{2.5}\,\mathrm{Re}_p^{-1.5} \tag{2}$$

The Reynolds number, Re_p, in the pipe is then calculated as:

$$\mathrm{Re}_p = \frac{4.\dot{m}}{\pi.\mu.D_p} \tag{3}$$

Where μ is the viscosity of air, D_p is the pipe diameter.

3.2. Fuel Mass Flow Rate

Fuel mass flow rate was measured by means of scaled container, which depends on time shown in the equation below.

$$\dot{m}f = \frac{\rho_f.V_f}{t} \tag{4}$$

Where ρ_f is the density (kg/lt) of fuel, V_f is the volume (lt) of consumed fuel; t is fuel consumption period as second.

3.3. Specific Fuel Consumption Rate

Specific fuel consumption related to effective power and fuel mass rate is as shown in the equation below:

$$bsfc = 3.6\times10^6\,\frac{\dot{m}f}{Pe} \tag{5}$$

Where $\dot{m}f$ fuel mass flow rate and Pe is is effective power, which is directly obtained from the dynamometer.

For instance, if the fuel flow rate is $9.25\text{x}10^{-4}$ kg/s and effective power is 9.215 kW at 40 Nm constant load and 2200 rpm, the brake specific fuel consumption is found as follows;

$$bsfc = 3.6\times10^6\,\frac{9.25\times10^{-4}}{9.215} = 362g/kW-h$$

The uncertainty associated with the mass flow rate was affected by all of the parameters in the experiments, such as pressure drop across the orifice plate, the calculations of all factors and coefficients and the thermal properties of the working fluid. The maximum value of the uncertainty in the mass flow rate was found to be as ± 2% for laminar flows.

4. TEST PROCEDURE

All test runs were conducted on the test-bench. The combination of all performance tests included engine setting at two constant loads (20 and 40 Nm), engine speeds 1000-2400 rpm with 200-rpm intervals. In each test run, the engine speed and amount of the load kept constant after the adjustment, because the values to be taken later were dependent on them. The values at the working point, oil temperature, brake specific fuel consumption, mass flow rate of air, engine speed, torque and exhaust gas pollutants such as CO, CO_2 and HC were taken at every point. Each test process was repeated at three times. The values given in this study are the average of these three test results. Before each experiment, the engine was regulated according catalogue values. All data were collected after the engine stabilized.

5. RESULTS AND DISCUSSIONS

To compare bsfc and emissions, the engine was operated with 91 and 95-RON gasoline, the engine was tested at two fixed loads (20 and 40 Nm) and speeds were varied from 1000 to 2400 rpm. Effective power various revolutions for two different loads (20 and 40 Nm) are shown in figure 2.

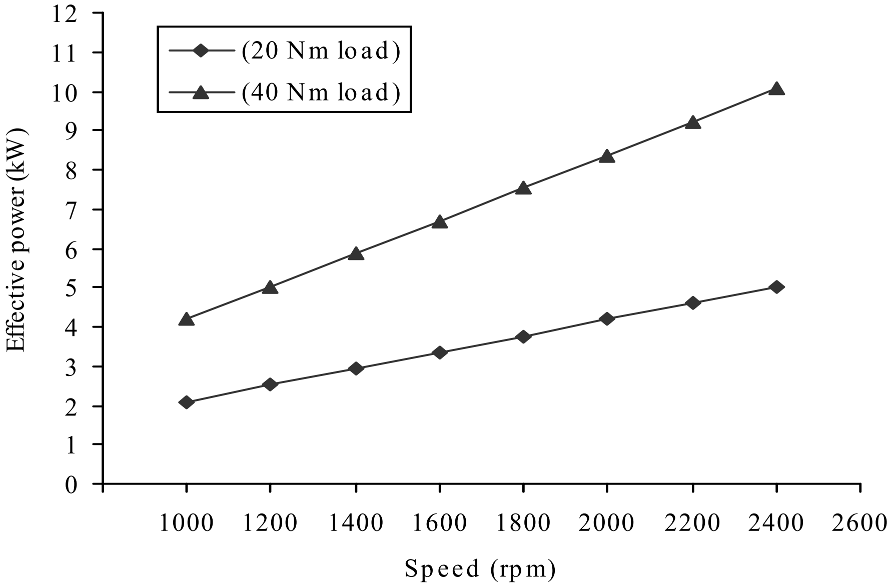


Figure 2. Relationship Between Effective Power And Engine Speeds At 20 And 40 Nm Loads

Test results at various speeds are shown in Figure 3. Minimum bsfc was observed 354 g/kW-h for 91-RON gasoline and 374 g/kW-h for 95-RON gasoline at 40 Nm constant load and 1800 rpm. It can be seen that the trend of bsfc using 91-RON is slightly lower and average bsfc using 91-RON is 5.6% better than that of 95-RON. Starting at the minimum bsfc point, increasing or decreasing speed at constant load increased bsfc due to primarily to the reducing engine volumetric efficiency. If excessive higher octane rating gasoline on the engine is used, the ignition delay will be longer and the speed of the flame will be shorter. These cause the reduction of the maximum pressure and the engine output power. Therefore, fuel consumption per output power will increase. The obtained test results confirmed this statement.

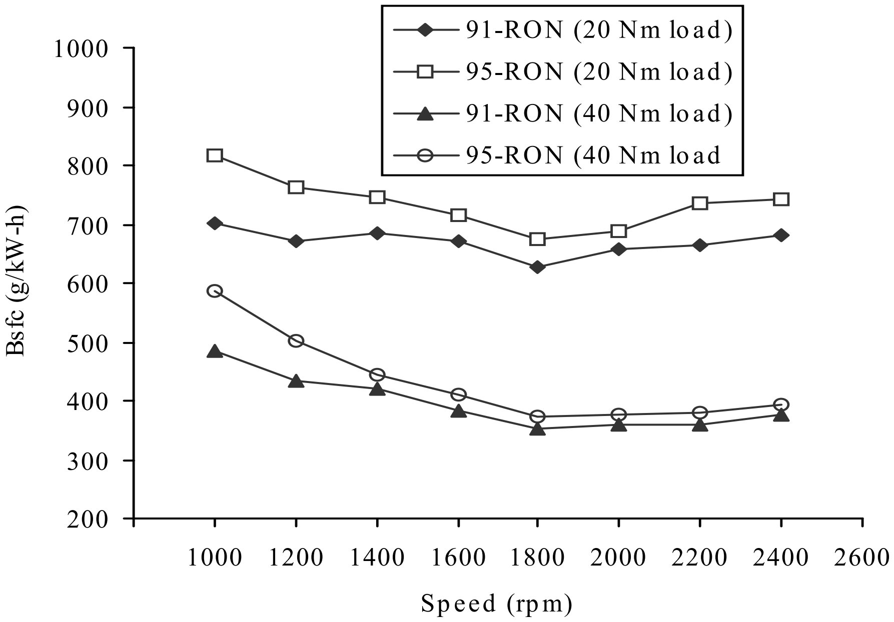


Figure 3. Relationship Between Bsfc And Engine Speeds At 20 And 40 Nm Loads.

The most important emission from IC engines is carbon monoxide (CO). Since SI engines often operate close to stoichiometric at part load and fuel rich at full load, CO emissions may be significant and must be controlled. The level of CO emission in the exhaust of an IC engine varies as a consequence of the fuel/air equivalence ratio. For fuel-rich mixtures, CO concentration in the exhaust increases with increasing equivalence ratio, i.e., as the amount of excess fuel increases. For fuel-lean mixtures, CO concentrations in the exhaust vary little with equivalence ratio [9, 18].

CO emission results were presented in Figure 4. The results indicate that CO values of 91- RON gasoline were approximately 5.7% lower than 95-RON gasoline. This is probably resulting of the tetra alkyl, which is one of the most important parameters in formation exhaust emissions. It is shown in Table 2, the amount of tetra alkyl is less by 0.26 gPb/l in 91-RON gasoline compared with 95-RON gasoline. Minimum CO was found 0.54% with 91-RON gasoline and 0.59% with 95-RON gasoline at maximum constant load and speed (40 Nm load and 2400 rpm). The values of CO in all working conditions decreased with increasing rpm. This is reason of improving combustion process. Increase in load could probably augment volumetric efficiency, boosting of turbulence in combustion chamber hence ensure more homogenous mixture and better combustion.

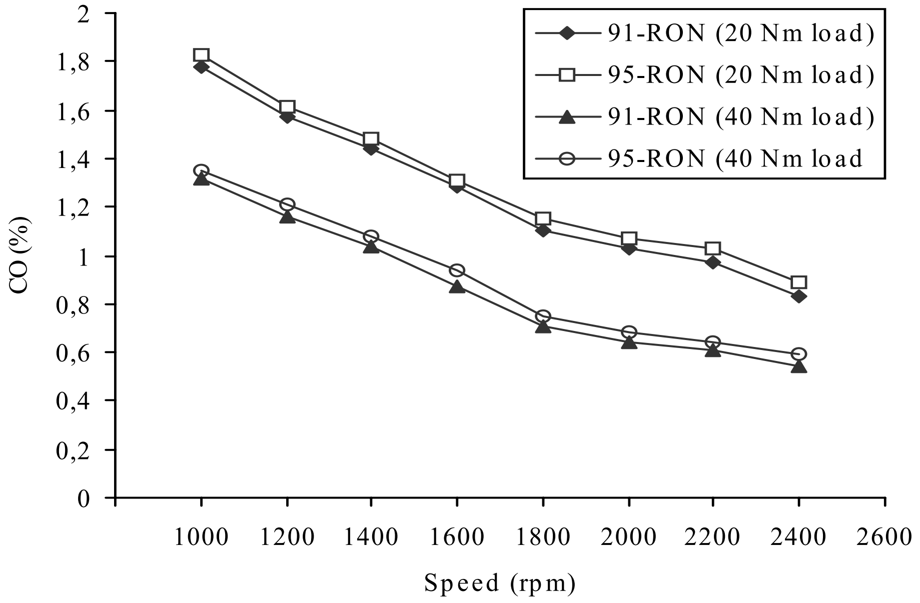


Figure 4. CO Emission Various With Revolution At 20 And 40 Nm Loads

Unburned hydrocarbon (HC) in the exhaust of an IC engine is another of the emissions, which must be controlled. These emissions have several different sources. Most of the HC results as a consequence of an unburned, fuel-air mixture. Another source is the lubricating engine oil and a final source of HC in IC engines is incomplete combustion [9, 18, and 19].

One of the most important variables, which affect HC emissions in the exhaust, is fuel/air equivalence ratio. With a cold engine, fuel vaporization is slow, and the fuel flow is increased to provide an easily combustible fuel-rich mixture in the cylinder during engine warm up. In this process, HC emissions are higher. At part-load and warm engine conditions, the engine produces lower HC emissions because of the leaner mixtures. Engine speed and spark timing are also important since they affect not only the quality of combustion but also the combustion process. As a consequence of a short combustion process, e.g. in the use of high-speed engines the amount of unburned HC will increase [19].

HC emission various with engine speed for two constant loads are shown in Figure 5. HC concentrations increased moderately with increasing speed and load that was in the same trend with CO. The experimental results indicate that HC values of 91-RON gasoline were 3.4% lower than 95-RON gasoline. Probably this is because the amount of tetra alkyl leads less 91-RON gasoline compared with 95-RON gasoline. As it expected, minimum HC was observed 112 ppm with 91-RON gasoline and 119 with 95-RON gasoline at maximum constant load and speed (40 Nm load and 2400 rpm).

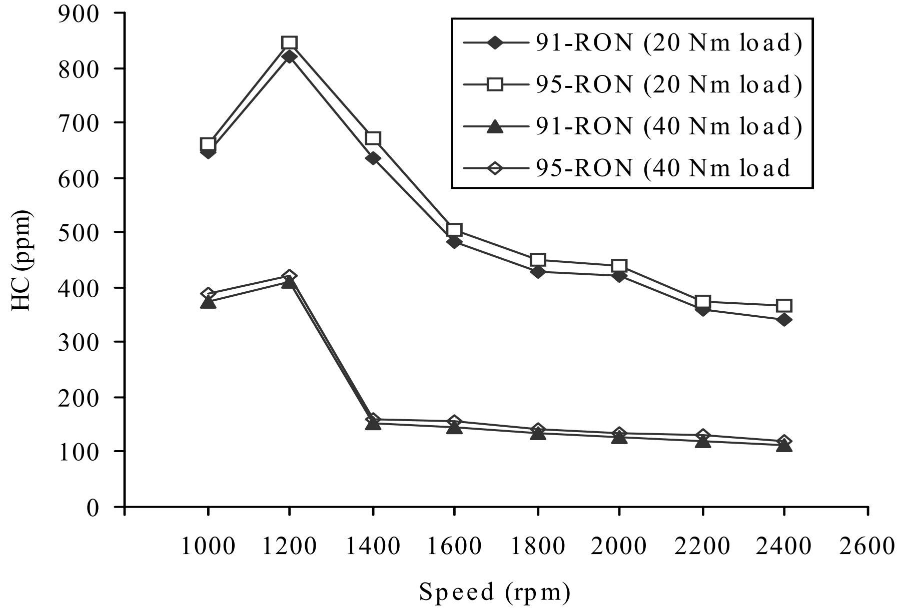


Figure 5. HC Emissions With Revolution At 20 And 40 Nm Loads

From the above test results bsfc and emissions, all confirm that lower-octane gasoline produces slightly better fuel economy and less exhaust emissions.

6. CONCLUSIONS

The effect of using higher-octane gasoline than engine requirement on fuel economy and exhaust emissions was studied. 91-RON gasoline and 95-RON gasoline were tested using the engine required 91-RON gasoline.

When the engine was tested at two constant load position and different speeds, results show that 91-RON gasoline produced approximately 5.6% lower bsfc than 95-RON.

From the point of exhaust emission, 91-RON gasoline caused 5.7% CO and 3.4% HC lower than 95 octane gasoline. The chemical components resulting from combustion of tetra alkyl lead in gasoline may cause higher emissions. In order to reduce exhaust emissions, it is necessary to diminish amount of tetra alkyl lead in gasoline. Therefore, using correct gasoline in the engine requirement is more advantageous than higher-octane gasoline under all operating conditions.

Nomenclature

$\dot{m}$ = Mass flows rate, kg/s
$\dot{m}_f$ = Fuel mass flow rate. kg/s
d = Diameter of the orifice plate, m
D_p = Diameter of PVC pipe, m
Re_p = Reynoulds number in the PVC pipe
ε = Expansion factor
Φ = Orifice plate diameter ratio, d/Dp
ρ_a = Air density, kg/m^3
ρ_f = Fuel density, kg/m^3
Pe = Effective power, kW
μ = Dynamic viscosity
ΔP = Pressure drop across the orifice plate, Pa
V_f = Volume of consumed fuel, m^3

t = Fuel consumption period

Abbrevations

RON = Research octane number
WOT = Wide open throttle
CO = Carbon monoxide
HC = Hydrocarbons
ppm = Particulate per million
rpm = Revolution per minute
bsfc = Specific fuel consumption, g/kW-h

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