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ABSTRACT

The work described in this thesis has been devoted to an experimental investigation of the effect of inlet air temperature on the performance of a four-stroke spark ignition engine when it is running on pure gasoline and its blends with ethanol at both full and part throttle. This was done by heating the inlet air to different temperatures and using gasoline and gasoline-ethanol blends with different percentages as fuel.

The test engine type is (FIAT 1500) with maximum power 55 k.W. at 5330 r.p.m., maximum torque 115 N.m. at 3330 r.p.m. and displacement volume 1481 c.c.

The experimental work consists of full throttle and part throttle tests. All tests were carried out without changing the static ignition advance. The setting of carburetor main jet needle has been tuned for maximum power with gasoline.

a. Full throttle Tests

The engine was tested for inlet air temperatures of 30, 35, 40, 45, 50 and 55°C For each inlet air temperature the engine was tested at full throttle using first gasoline then four different ethanol-gasoline blends of 4.89%, 9.79%, 15.3% and 21% by

weight. These tests were carried out to evaluate the brake power, brake torque, specific fuel consumption, volumetric efficiency, brake thermal efficiency, fuel-air equivalence ratio, exhaust gas temperature and the charge temperature at different inlet air temperatures. From the above findings the speed performance curves are obtained for different inlet air temperatures and fuel blends.

b. Part Throttle Tests

The engine was tested for inlet air temperatures of 30, 40 and 50°C. For each inlet air temperature the engine was tested at part throttle using first gasoline then ethanol-gasoline blend of 10%. These tests were carried out to evaluate the mean effective pressure and the specific fuel consumption. From the above findings the load performance curves are obtained for different inlet air temperatures with gasoline and 10% fuel blend.

From the speed and load performance curves which were obtained from full and part throttle tests final curves are obtained to describe the effect of inlet air temperature and ethanol ratio in the fuel blend on engine performance.

The principal findings could be summarized as follows:

a. When the engine runs at part throttle (low and medium loads) on pure gasoline or on ethanol-gasoline blend of 10% increasing inlet air temperature improves the brake thermal efficiency because increasing inlet air temperature in this case decreases compression work. The reduction in compression work is due to the reduction in the mass of working charge as a direct result of decreasing the amount of residual gases. This improvement in the thermal efficiency decreases with the increase of engine speed and engine load.

b. When the engine runs at part throttle (high load) and full throttle on pure gasoline or on any of its used blends with ethanol, its performance deteriorates with increasing inlet air temperature. The deterioration of the engine performance appears as a reduction in the brake thermal efficiency which is a direct result of the increase of the compression work. The increase in compression work is due to the increase of the mass of fuel vapour

c. When the engine runs at part throttle (low and high loads) and full throttle and for a given inlet air temperature the brake thermal efficiency improves with the increase of the ethanol ratio in the fuel blend. But when the engine runs at part throttle (medium load) no improvement in the thermal efficiency is observed. The improvement in the thermal efficiency is a direct result of compression work reduction. The reduction in compression work is due to the decreasing of the working charge temperature. The reduction in the working charge temperature is due to the cooling effect of the fuel blend which increases with the increase of ethanol ratio in the fuel blend. This reduction in compression work is not observed at medium part throttle because the fuel-air ratio is not high in this case.

ملخص البحث

يشتمل هذا البحث على دراسة عملية تفصيلية لتوضيح تأثير درجة حرارة الهواء الداخل على أداء محرك رباعى الأشواط يعمل بالشرارة عند تشغيله باستخدام الجازولين ومخلوط الجازولين والكحول الاثيلى كوقود عند الأحمال الكلية وكذا عند الأحمال الجزئية وذلك عند سرعات مختلفة وقد تم تنفيذ ذلك بتسخين الهواء الداخل للمحرك لدرجات حرارة مختلفة وباستخدام الجازولين ومخلوطه مع الكحول الاثيلى بنسب مختلفة كوقود مع تثبيت زاوية بدء الاشعال ووضع أبرة الفونية الرئيسية للمغذى وضبط المحرك لاعطاء اقصى قدرة باستخدام الجازولين.

عند اجراء تجارب الأحمال الكلية تم اختبار المحرك عند درجات حرارة للهواء الداخل تبلغ ٣٠، ٣٥، ٤٠ ، ٤٥، ٥٠ ، ٥٥°م باستخدام الجازولين ومخلوط الكحول الاثيلى مع الجازولين بنسب٤،٨٩%، ٩،٧٩%، ١٥،٣% ، ٢١% فى المخلوط واثناء الاختبارتم قياس القدرة الفرمليه وعزم الدوران ومعدل استهلاك الوقود والكفاءة الحجمية والكفاءة الحرارية ونسبة الوقود للهواء ودرجة حرارة غازات العادم وكذلك درجة حرارة شحنة الهواء والوقود فى مجمع السحب ثم استخدمت هذه البيانات فى رسم منحنيات الأداء عند السرعات المختلفة لكل درجة حرارة هواء ولكل نوع من انواع الوقود.

عند اجراء تجارب الأحمال الجزئية تم اختبار المحرك عند درجات حرارة للهواء الداخل تبلغ ٣٠، ٤٠ ، ٥٠°م باستخدام الجازولين ومخلوط الكحول الاثيلى معه بنسبة ١٠% فى المخلوط واثناء الاختبار تم قياس معدل استهلاك الوقود ومتوسط الضغط المؤثر واستخدمت البيانات المقاسة فى رسم منحنيات الأداء عند الأحمال المختلفة لكل درجة حرارة ولكل نوع من انواع الوقود.

من المنحنيات السابق ذكرها تم رسم المنحنيات التى توضح تاثير كل من درجة حرارة الهواء الداخل للمحرك وكذلك نسبة الكحول الاثيلى فى الوقود المستخدم على اداء المحرك ومنها تم استخلاص النتائج الرئيسية الاتية :-

١ـ زيادة درجة حرارة الهواء الداخل تؤدى الى تحسن اداء المحرك فى حالة ادارته عند احمال منخفضة ومتوسطة باستخدام الجازولين ومخلوط الكحول الاثيلى مع الجازولين بنسبة ١٠٪ هذا التحسن فى اداء المحرك يظهر فى صورة زيادة الكفاءة الحرارية كنتيجة لنقص الشغل المستهلك فى شوط الانضغاط بسبب نقص كتلة الشحنة الناتج عن نقص كمية الغازات المتبقية وهذا التحسن فى الكفاءة الحرارية يقل مع زيادة سرعة المحرك وزيادة الحمل.

٢ـ عند ادارة المحرك عند حمل عالى او كامل فان زيادة درجة حرارة الهواء الداخل لها تاثير ضار على اداء المحرك وذلك عند استخدام الجازولين او مخلوطه مع الكحول الاثيلى كوقود هذا التاثير الضار يتضح فى انخفاض الكفاءة الحرارية كنتيجة لزيادة الشغل المستهلك فى شوط الانضغاط بسبب زيادة كمية البخار بالشحنة.

٣ـ زيادة نسبة الكحول الاثيلى فى الوقود المستخدم مع ثبات درجة حرارة الهواء الداخل عند قيمة معينة يؤدى الى تحسن اداء المحرك فى صورة زيادة الكفاءة الحرارية وذلك عند ادارة المحرك عند احمال جزئية منخفضة وعالية وعند الحمل الكامل اما عند الاحمال المتوسطة فلم يلاحظ اى تحسن فى الاداء والتحسن السابق يتضح فى زيادة الكفاءة الحرارية نتيجة لنقص الشغل المستهلك فى شوط الانضغاط بسبب نقص درجة حرارة الشحنة الناتج عن الحرارة الكامنة العالية للوقود المستخدم وهذا التحسن لايتضح عند ادارة المحرك عند احمال متوسطة بسبب نقص نسبة الوقود للهواء فى هذه الحالة.

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A_j	Cross-sectional area of fuel jet	m^2
BP	Brake power	kW
C_a	Coefficient of discharge of carburettor throat	-
C_f	Coefficient of discharge of fuel jet	-
F	Fuel-air ratio	-
F_{st}	stoichiometric fuel-air ratio	-
g_b	Brake specific fuel consumption	g/kWh
LHV	Lower heating value	kJ/kg
q_b	Brake specific heat consumption	MJ/kWh
M_a	Mass air consumption per second	kg/s
N	Engine speed	r.p.m.
P_b	Brake mean effective pressure	bar
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T_{ex}	Exhaust gas temperature	$^{\circ}C$
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T_m	Charge temperature in the intake manifold	$^{\circ}C$
V_d	Cylinder displacement volume	m^3

Greek Symbols

ΔT	Drop in the charge temperature in the intake manifold
$\acute{\Delta} T$	Rise in the charge temperature in the cylinder
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η_v	Volumetric efficiency
λ	Ethanol ratio in the fuel blend by weight
ρ_f	Fuel density
ρ_i	Inlet air density
Φ	Equivalence fuel-air ratio

DAR ALMANDUMAH

دار المنظومة

الرواد في قواعد المعلومات العربية

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AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

THE EFFECT OF THE INLET AIR TEMPERATURE ON THE PERFORMANCE OF SPARK IGNITION ENGINES USING GASOLINE-ETHANOL BLENDS AS FUEL

Thesis

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Mechanical Engineering

By

HASSAN IBRAHIM IBRAHIM

B.Sc. (1970) Mechanical Engineering

Military Technical College

1991

SUPERVISORS

Prof. Dr. Adel A. El-Ehwany

Prof of Heat Engines

Faculty of Engineering

Ain Shams University

Dr. Mohamed H. Gabr

Asst. Prof. of Mech. Engg.

Faculty of Engineering

Ain Shams University

EXAMINERS

Prof. Dr. Abdel Fatah Ibrahim

Prof. of Mech. Engineering

Alexandria University

Prof. Dr. Mahmoud Mostafa Ghoniem

Emirt Prof. of Mech. Engineering

Ain Shams University

Prof. Dr. Adel Abdel Malek El-Ehwany

Prof. of Heat Engines

Ain Shams University

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CHAPTER 1

INTRODUCTION

Methyl and ethyl alcoholsare currently of considerable interest for use in automobiles as alternatives to petroleum based fuels. The main reason for advocating alcohol as a fuel is that it can be manufactured from farm products or waste materials while gasoline is a natural resource which is being rapidly depleted. Ethyl alcohol manufacture from renewable biomass is technically well developed. Also methyl alcohol can be produced from natural gas and coal. Alcohols are therefore the most attractive alternative vehicle fuels economically and politically for the near future.

The technology required for utilization of methyl and ethyl alcohol is very similar to that of gasoline. Consequently storage facilities and handling procedures as well as service stations and vehicle parts need suffer little change. Both types of alcohol have the advantage of good antiknock characteristics, but for economic reasons they are not used as a fuel in the present time. To make use of the advantage of good antiknock characteristics and to decrease the effect of economic reasons, a blend of both types of alcohol or one of them with gasoline can be used.

In Egypt ethyl alcohol is produced as a byproduct of sugar industry ie it will be easy to use ethanol-gasoline blend. Using ethanol-gasoline blend as a fuel solves partially the problem of air pollution with lead compounds because it could be possible to reduce the amount of TEL used to improve the fuel knock characteristics.

The aim of this work is to study the effect of inlet air temperature on the performance of four-stroke spark ignition engines using ethanol-gasoline blends with different percentages as a fuel.

It is known [1] and [2] that increasing inlet air temperature has a harmful effect on the performance of four-stroke spark ignition engines when running on pure gasoline. This harmful effect appears as reduction in engine air capacity and engine power. It appears also as an increase of fuel-air ratio which increases the amount of incomplete combustion products and a decrease in engine thermal efficiency.

To my knowledge there is no available information about the effect of inlet air temperature on the performance of spark-ignition engine when it is running on ethanol-gasoline blends. As the latent heat of vaporization of ethanol is much greater than that of gasoline some changes in the effect of inlet air temperature on engine performance are expected.

CHAPTER 2

REVIEW OF PREVIOUS WORK

The material of this chapter includes a review of the previous work carried out on the following :

1- The effect of alcohol (methanol or ethanol) addition to gasoline.

2- The effect of using alcohol gasoline blend on the spark ignition engine performance.

3- The effect of inlet air temperature and the charge temperature on the spark ignition engine performance.

1- The Effect of Alcohol (Methanol or Ethanol) Addition to Gasoline:

Campbell [3] and Menrad [4] studied the properties of methanol and ethanol and the effect of their addition to gasoline on the quality of the blend and found the following:

* The energy available from combustion of alcohol-gasoline blend is less than from gasoline.

* The higher specific gravities of these alcohols cause an increase in the specific gravity of the blend when they are added to gasoline.

* The addition of alcohol to gasoline increases the Reid vapour pressure and distillation characteristics of the blend ie increases the volatility of the blend. Increasing the blend volatility may increase vapour lock problems.

* When the alcohol-gasoline blends are metered through carburettors calibrated for gasoline surplus air is supplied ie air-fuel ratios increase and the mixtures become weaker.

* The higher heat of vaporization of alcohol could cause starting problems for engines working on its blend with gasoline.

Thompson [5] found that the reported high octane number for alcohol is due to two different properties :

i- An inherent high antiknock value.

ii- The cooling effect on the air-fuel mixture because of the high heat of vaporization.

The second property probably accounts for the large variations in measured octane number. The change in octane number due to adding alcohol to gasoline can vary greatly due to differences in the percentage added, the quality and type of gasoline basestock and the lead level of the gasoline.

2- The Effect of Using Alcohol Gasoline Blends on the Spark Ignition Engine Performance

Hilliard [6] presented theoretical considerations and relevant calculations which show that alcohol fuels can improve volumetric efficiencies of spark ignition engines provided the evaporation is adiabatic.

Karpov [7] and Bernhardt [8] found that the excellent octane rating of methanol provides the possibility to increase compression ratio of spark ignition engines up to 14 and this improves the fuel consumption and the thermal efficiency.

Bernhardt [8] observed that when using pure methanol as a fuel in spark ignition engines and due to its high heat of vaporization the intake air and thus the methanol-air mixture is cooled. This leads to a rise in effective engine power. The methanol engine had about 10% higher output than the gasoline engine (with maximum power spark timing). Methanol also produces a considerably higher brake thermal efficiency for the same compression ratio. This is due principally to the greater volumetric efficiency which results from the high density of methanol-air mixture.

Heinrich [9] carried out a group of experiments on (methanol gas spark ignition engine). This engine is equipped with a methanol vaporizer and a gas mixer. The compression ratio of this engine is 11.5. In the upper load range of this engine load control works in the same way as in the diesel engine, in that the amount of fuel is varied whilst the quantity of air remains constant (quality control). In the case of the medium and lower load ranges, load control works in the same way as in spark ignition engines by throttling the lean air-methanol vapour mixture, as a whole the mixture composition remaining constant (quantity control).

As opposed to the conventional spark ignition engine, the methanol gas engine shows very low fuel consumption figures because of the energy recovered by vaporizing the methanol and because of the lean operation resulting from the quality-quantity control system. The lower heating value of methanol vapour is around 6% higher than that of liquid methanol ie approximately 6% of the lower heating value is won from waste energy, contributing to an improvement of overall efficiency.

The effects of using ethanol and/or methanol with unleaded gasoline fuel on exhaust emissions (CO, HC and CHO) have been experimentally investigated by Bata [10] and [11] and Kampen [12]. The production of (CO) was reduced by about 40:50% at equivalence ratio on the lean side near stoichiometry.

The effect of the kind of alcohol (ethanol and/or methanol) on the production of (CO) was insignificant under the same conditions, but methanol generally produced less (CO). Also the production of (CO) decreases as the percent of alcohol increases in the blend.

The effect of alcohol type on (HC) was insignificant but the unburned hydrocarbons were slightly increased due to the increase in the vapour pressure. The minimum production of (CH) was at the lean side ($\Phi = 0.85$). For aldehyde the emission was increased in the range of 60:100% due to the lower maximum combustion temperature and also with the increase of alcohol in the blend. Aldehyde is an eye irritant. More research is required to control aldehyde production before an extensive use of alcohol.

Bernhardt [8] studied the exhaust emission characteristics of a methanol fueled engine and he noticed the following:

* A significant reduction in oxides of nitrogen emissions results from the use of methanol.
* The carbon monoxide emissions are about the same with either methanol or gasoline. However near stoichiometric and up to 10% lean mixtures (CO) emissions are reduced when ethanol is used.

* Emissions of hydrocarbons are significantly lower with methanol than with gasoline.

Winnington [13] studied the effect of using gasohol (gasoline-ethanol blend) as a fuel on the performance of spark ignition engines. A series of tests were carried out to study the performance of car engines, tuned to run on gasoline, but running on gasohol. The test programme also included road tests and fuel properties analysis.

i. Gasohol blends and the road programme:

The two blends chosen for this series of tests were blend A (15% ethanol, 41% premium and 44% regular) and blend B (20% ethanol, 54% premium and 26% regular). These percentages were designed to give the blend the same octane rating as premium gasoline, 93 octane.

An extensive programme of road tests was carried out. The routes chosen were such that almost all possible conditions of altitude and temperature in Kenya were simulated. The results of road tests show an increase in power when going uphill or starting off from a stop position and no vapour-lock is observed.

ii. Laboratory test programme:

The tests were carried out in two series. In the first series, a single-cylinder, variable compression, Ricardo test engine was run at various compression ratios between and including 8:1 and 12:1. The carburettor fuel-air ratio was adjusted to yield maximum power on premium. The engine performance was noted on premium, regular and the two gasohol blends and checked over the full range of operating speeds and throttle settings for each compression ratio tested. In the second series of tests a Peugeot 504 GR engine was mounted on a static test rig and coupled to a fluid dynamometer. Again the engine performance was tested over the full speed range and throttle settings.

The main test series on the Ricardo and Peugeot engine showed only small differences in engine performance when gasohol was substituted for premium petrol. Trends shown by blend A were slightly less pronounced than with blend B. Also at low engine speeds and high compression ratios, there was more reduction in power with premium than with the blends.

The Ricardo engine over the test range of 8:1 to 10:1 compression ratios, showed an average drop in power compared to premium of 2.5% on blend A and 7.5% on blend B. The specific fuel consumption of gasohol showed an increase compared to premium of around 0.5% and 4% on blend A and B respectively. The Peugeot engine on the whole, appeared to be less affected than the Ricardo engine by the substitution of gasohol for premium. The power was down overall by around 1% on blend A and 2.5% on blend B and the specific fuel consumption was up by about 0.5% and 1% respectively for blend A and blend B.

The reason for this variation in results is that, in the Ricardo tests, the fuel flow through the carburettor was reduced by 3.1% for blend A and 5.6% for blend B when compared with premium. However, this was not the case for the Peugeot engine which showed only very small changes in fuel flow about 0.5% when the blends were substituted for premium. The most likely explanation of this phenomenon is that while the blends have only slight differences in density compared to premium, there is a greater difference in viscosity. A standard carburettor on the Peugeot uses metering orifice to control the flow rate of the fuel. The flow through this orifice is turbulent and largely unaffected by viscosity. The carburetion on the Ricardo engine, however, is controlled by a needle valve in which the fuel flows through an annulus. This flow will tend to be laminar and so is more affected by the fuel viscosity.

The bulk of the main test sequence was done with the carburetion set around the mixture strength which gave maximum power output on premium, the effect on different carburettor setting was also studied for a compression ratio of 9:1, half-throttle at 3000 rpm on the Ricardo engine. The results of this study are shown in Fig. 2.1. From the figure it can be seen that a different carburettor setting is required to obtain optimal performance for either maximum power or minimum specific fuel consumption for each fuel. Hence any single setting, if the engine is to run on a variety of fuels, must be a compromise. Significantly, the jet setting for maximum power on premium is perhaps the best "set point", because at that setting blend A is operating at its best "fuel economy point" and the best economy point for blend B is not far off it. A similar carburetion study was done on the Peugeot engine. This was done by running the engine at 4000 rpm, full throttle, using a range of nine different main-jets. The power output and the specific fuel consumption were found to be virtually the same for each of the fuels.

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By

HASSAN IBRAHIM IBRAHIM

B.Sc. (1970) Mechanical Engineering
Military Technical College

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كلية الهندسة
قسم هندسة الطاقه والسيارات

تأثيــر درجة حرارة الهواء الداخل على اداء محــرك اشعال بالشــرارة يستخدم خليــط من الكحــول الايثيلي مع البنزيــن

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ا د . عادل عبد الملك الاهــوانى
استاذ الآلات الحراريه
كلية الهندسه - جامعة عين شمس

د . محمــد حلمــى جبــر
استاذ مساعد
كلية الهندسه - جامعة عين شمس

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