CO AND HC EMISSIONS REDUCTION FROM SPARK IGNITION ENGINE BY CHEMICAL CATALYZER
Part I Preliminary Test Results

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تقليل انبعاثات أول أكسيد الكربون والهيدروكربون من محركات الاشعال بالشرارة بواسطة حفاز كيميائي

الخلاصة ـ يتم التحكم في الانبعاثات من محركات الاشعال بالشرارة التي تستخدم وقود الجازولين بواسطة نظام تم انتاجه وتصنيعه . هذا النظام يمكنه التحكم في هذه الانبعاثات للحد المسموح به دوليا . ويتم في هذا البحث عرض النتائج التي تم الحصول عليها باستخدام هذا النظام ومقارنتها بالنتائج على نفس المحرك التي تم الحصول عليها عند عدم استخدام النظام . وقد استخدمت في صناعة هذا النظام المعادن المتوافرة في السوق المصري مع الأخذ في الاعتبار التكاليف الاقتصادية . الأساس الذي يعمل عليه هذا المفاعل هو تفاعل أول أكسيد الكربون من مكونات غازات العادم مع أكسيد النحاس مع وجود أكسيد الزنك كحفاز للتفاعل في علبة كاتم الصوت . واتضح من النتائج التي تم الحصول عليها أن انخفاض ملموس تم الحصول عليه باستخدام هذا النظام لكلامن أول أكسيد الكربون والهيدروكربون المنبعثة من المحرك . ويزداد هذا الانخفاض في أول أكسيد الكربون عندما يكون في القيم القصوى له عند تشغيل المحرك (الاحمال الجزئية واستخدام المخلوط الغني) ، وصل هذا الانخفاض الى ٥٠٪ عندما كانت سرعة المحرك ١٢٥٠ لفة / د . وكذلك كان الانخفاض في الهيدروكربون كبيرا .

ABSTRACT

The exhaust emissions of gasoline fuelled engines will be controlled by a system that has been developed to a high technological level. The specific control system used will depend on the emission standards that will have to be met. Described in this paper are the design and development of a chemical catalyzer for reducing CO and HC emissions from spark ignition engine. The test set-up, procedures and the results obtained are presented and discussed. The material used for the catalytic is limited to the available in the market and its price. The basis on which the reactor will operate is that a chemical reaction will take place between CO presented in the exhaust gases and copper oxide in the muffler with the existence of zinc oxide as a catalyzer. The results obtained shows a significant reduction in CO and HC emitted from exhaust gases. The reduction of CO concentration varies with the amount of exhaust gases emitted from the engine. It increases in the case when CO concentration is in the high limit. The reduction is about 50% at engine speed of 1250 RPM. Dramatic reduction in HC emission is also obtained.

INTRODUCTION

Our discussions on spark ignition engines emissions formation and its control are presented[1-3]. Further reduction in emissions can be obtained with reactors in the exhaust system. These reactors include catalytic converters (for reducing NOx and oxidizing for CO and HC) and thermal reactors for CO and HC. Reviews of the current status of these devices have been published[4]. Catalytic converters and thermal reactors for HC and CO are now in use on automobiles in U.S.A and Japan. The catalytic converter for automobile use consist typically of an active catalytic material in a specially designed metal casing which directs the exhaust gas flow through the catalyst bed. The catalyst is usually made up of a small mass of active material such as noble metal or a combination of transition and non-transition metals, deposited on thermally stable support materials such as alumina. Fig.(1) indicates the temperature which must be attained in the catalyst bed to achieve effective removal of HC and CO[4]. The catalysts being considered for immediate in automobiles for HC and CO control include the noble metals Pl,Pd and Rh, either separately or in combination.

Oxidation of CO and HC after passage through the exhaust port can be enhanced with a thermal reactor. An enlarged exhaust manifold that bolts directly onto the cylinder head. Its

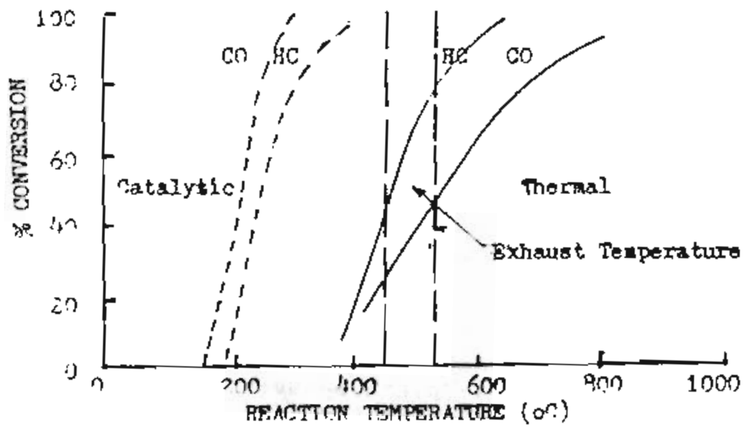

Fig.(1) Comparison of Catalytic Converter and Thermal Reactor for Oxidation of HC and CO Ref.(4)

function is to promote rapid mixing of the hot exhaust gases (with secondary air which is required with fuel-rich engine operation to produce a net oxidation atmosphere). A typical thermal reactor design is shown in Fig.(2). The temperature levels typically required for bulk gas oxidation of HC and CO in a thermal reactor are shown in Fig.(1). Note that they are considerably higher than those required for equivalent conversion in a catalytic converter, and that higher temperatures are required for CO oxidation than for HC oxidation. To achieve greater reduction, the reactor must be designed to reduce heat losses and increase residence time.

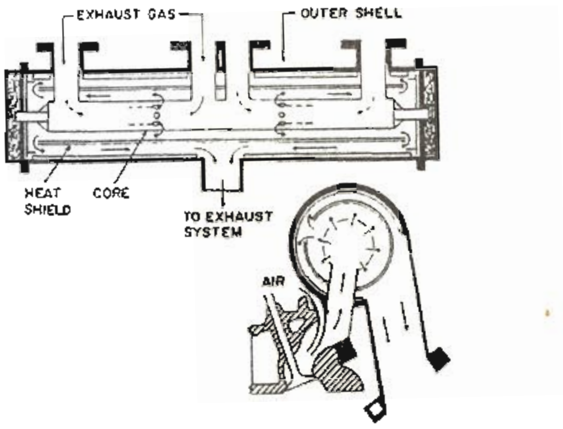

Fig.(2) Schematic of Thermal Reactor Design.

The principle of catalytic converter package is to control the emission levels of various pollutants by change the chemical characteristics of the exhaust gases. In contrast to thermal reactor, efficient catalytic oxidation can control CO and HC emission level almost completely at the temperature equivalent to normal exhaust gas temperature. Thus the fuel economy loss, necessary to increase the exhaust gas temperature, is avoided. Catalyst material, such as platinum or platinum and palladium are applied to ceramic support which has been treated with an aluminum oxide wash coat. This results in an extremely porous structure providing a large surface area to stimulate the combination of oxygen with HC and CO. The oxidation process converts most of these compounds to water vapor and carbon dioxide.

A practical limitation to reactor effectiveness with fuel-rich engine operation is mixing of secondary air and engine exhaust gases in the exhaust port and the reactor core. Combined experimental and analytical simulation studies of the mixing process[5], using stirred tank chemical reactor models have shown that the secondary air flow with a conventional air pump is effectively shut off by the exhaust blowdown process, and that virtually no oxidation occurs in the exhaust port because the air and exhaust gases are segregated. Mixing in the reactor itself is promoted by suitably arranging the reactor inlet and exit ports, and by using baffles. In systems with conventional secondary air pumps, maximum reduction in CO and HC occur with 10-20% excess air in the mixture. However, even with very high reactor core gas temperature, 100% HC and CO oxidation is not achieved due to incomplete mixing.

The objectives of the present work is to design, develop and testing of an exhaust emission control system for spark ignition engine. This control system will depend on the emission standards of HC and CO that will have to be met. The material used for the proposed catalytic is limited to the available in the market and its price. The basis on which the reactor will operate is that a chemical reaction will take place between the CO presented in the exhaust gases and copper oxide (CuO) in the muffler with the existence of zinc oxide (ZO) as a catalyzer.

2-EXPERIMENTAL SET-UP AND PROCEDURES

2.1-Engine Set-Up

The engine used in this experiments was a spark ignition, four stroke, four cylinder water cooled one of compression ratio 6.5 and bore and stroke of 80 and 120 mm. The ignition timing is set to 20 degree before top dead center. The engine was equipped with standard throttled carburetor and thermocouple to monitor the exhaust temperature. A needle valve was used to precisely control the fuel rate. Since the engine was operated at wide open throttle and different throttle positions in these tests, adjustment of this valve was the means for obtaining different air-fuel ratios.

Air flow rate to the engine was determined with the aid of an air box, calibrated orifice and inclined manometer. The power output of the engine was absorbed by a low voltage d.c swinging field dynamometer which capacity of absorbing the output from the engine and also use as a motor to drive the engine for starting and for determination of engine friction.

The HC and CO emissions were measured using Beckman Model 590 infrared analyzer. This instrument analyzes vehicle exhaust emissions for two components; carbon monoxide (CO) and hydrocarbons (HC). This model is a dual channel, non-dispersive infrared analyzer. Although physically an integrated system, functionally the analyzer constitutes two single beam filter photometers, one each for the CO and HC determinations. Each channel contains the following;

1-Hot element focused source that emits an essentially parallel beam of infrared energy.
2-Infrared band pass filter to isolate an optical absorption band that is characteristic of the measured component(CO&HC)
3-Continuous flow sample cell, sealed at the ends with replceable windows.
4-Focused black body themistor detector that receives only parallel rays. (The detectors for both channels are mounted in a single temperature controlled aluminum block)
5-Amplification circuitry with associated range selection and calibration controls.
6-Readout meter with dual scales covering low and high ranges.

2.2-Exhaust Muffler

The designed exhaust muffler had the same dimensions as that for the test engine as shown in Fig.(3).

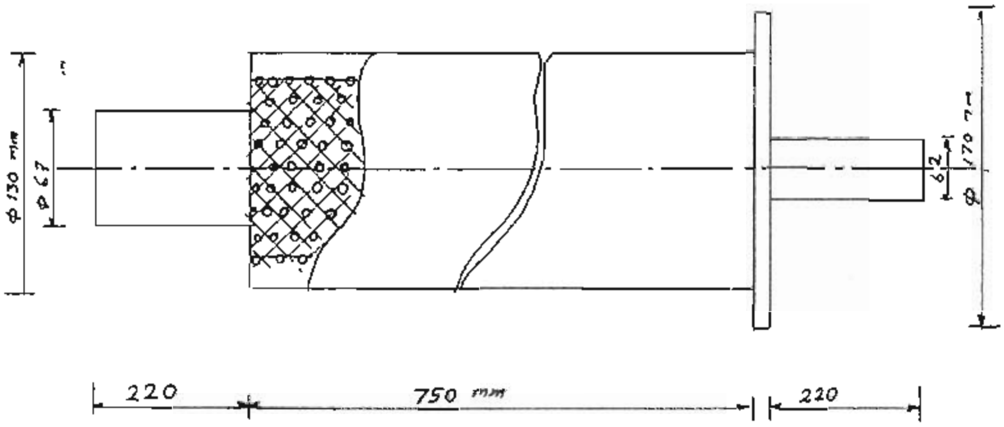

Fig.(3) Schematic of Catalytic and Muffler Assembly

It is constructed from three different sections, 67mm diameter, 220mm length pipe used as inlet tube, welded to the muffler with the dimension of 130mm diameter and 750mm length serves as a container for the catalytic elements. This muffler is flanged at its outlet side and bolted with four set screws to the flange of the outlet pipe with dimensions of 62mm diameter and 220mm length. By this design it can be install the catalytic elements and to vary the number of working elements in the test section. The pipes and muffler are all made from a 1mm thickness steel sheet. The inlet and outlet pipes each had been fastened with the muffler and be easy replaced with that of the test engine. This arrangement make possible the experiments to be carry out with and without the catalytic.

2.3-Catalytic Elements And Assembly

The catalytic elements is rolled as a cylinder 130mm. diameter and 120mm. length of 1mm steel sheet as shown in Fig.(4). It is contains ten radial blades, the catalytic material is placed inside a rolled steel wire nets. The catalytic material is prepared of copper and zinc oxides mixed together with the use of a local resin. By this method the catalyst was obtained in a form of grains, after they have been dried in the free air, the grains were placed in the steel wire nets and fitted in among the blades. This arrangements achieves a long path for the exhaust gases on the catalytic material and also helped as a damping effect of sound waves in the exhaust muffler and reduces the noise.

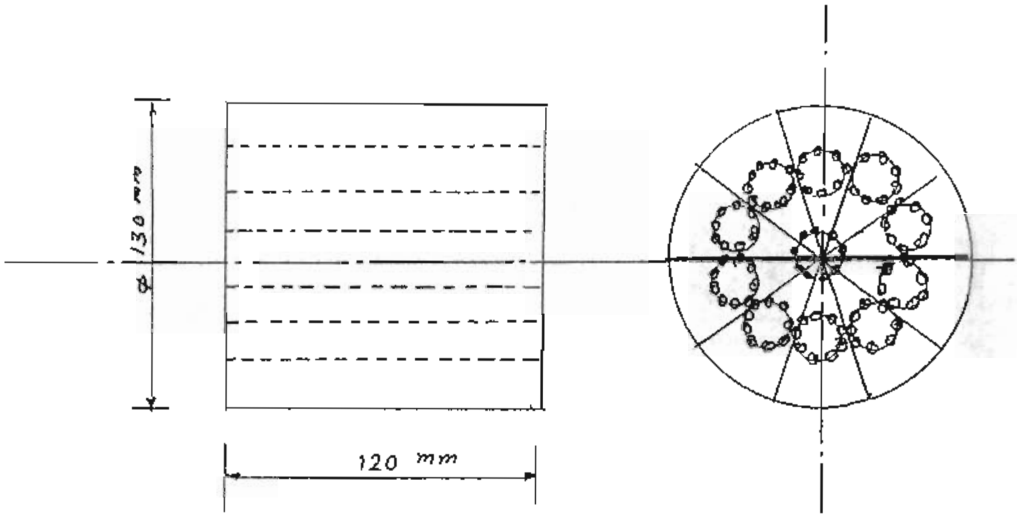

Fig.(4) Catalytic Element Assembly

The materials chosen for this reactor are limited to the available in the market and its price. The basis on which this reactor will operate is that a chemical reaction will take place between the carbon monoxide presented in exhaust gases and copper oxide in the muffler with the existence of zinc oxide as a catalyzer, the reaction equation will be;

$$CuO + CO \longrightarrow Cu + CO_2$$

Cyclic operation is possible via reoxidation.

3. RESULTS AND DISCUSSIONS

Series of experiments have been carried out with and without the catalyzer at different engine speed, engine loads and at a wide range of fuel-air ratios. Measurements of HC and CO emissions, engine torque, fuel and air consumptions and exhaust gas temperatures were made at a wide range of engine operating conditions. The results of tests were collected and displayed graphically as a group families of curves for each operation conditions. Some of the results obtained are presented and discussed now as in the following;

Figure(5) shows the measured percentage of CO and hydrocarbon (PPM HC) in the exhaust muffler with and without the catalyst as a function of engine speed. These relations are reached at full throttle opening and engine brake mean effective pressure (bmep) of 4.2 Kp/Cm.Cm. It is clear from this

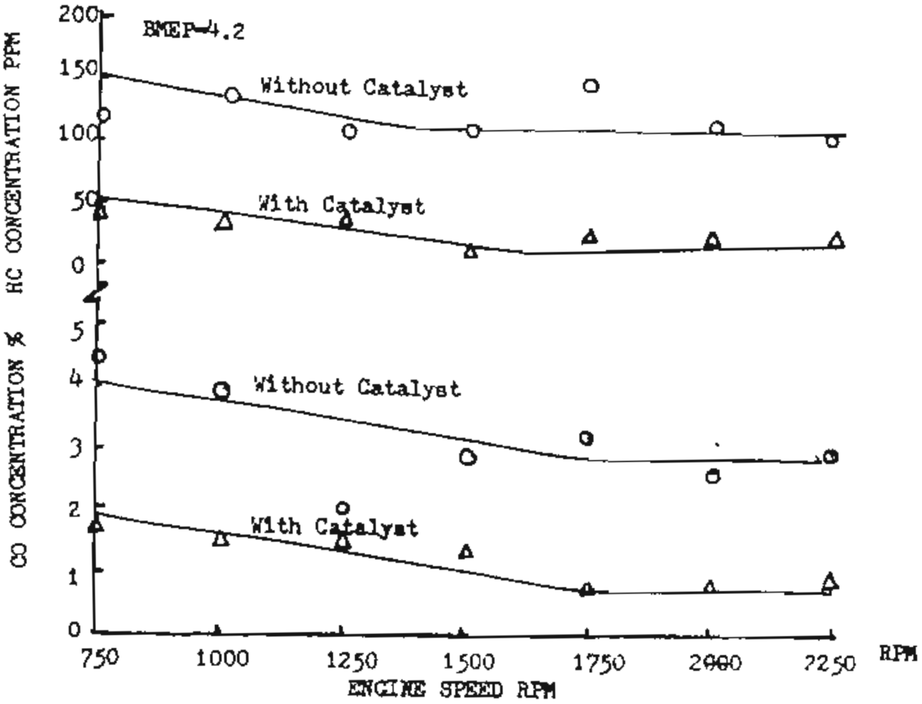

Fig.(5) Effect of Engine Speed on HC and CO Emissions

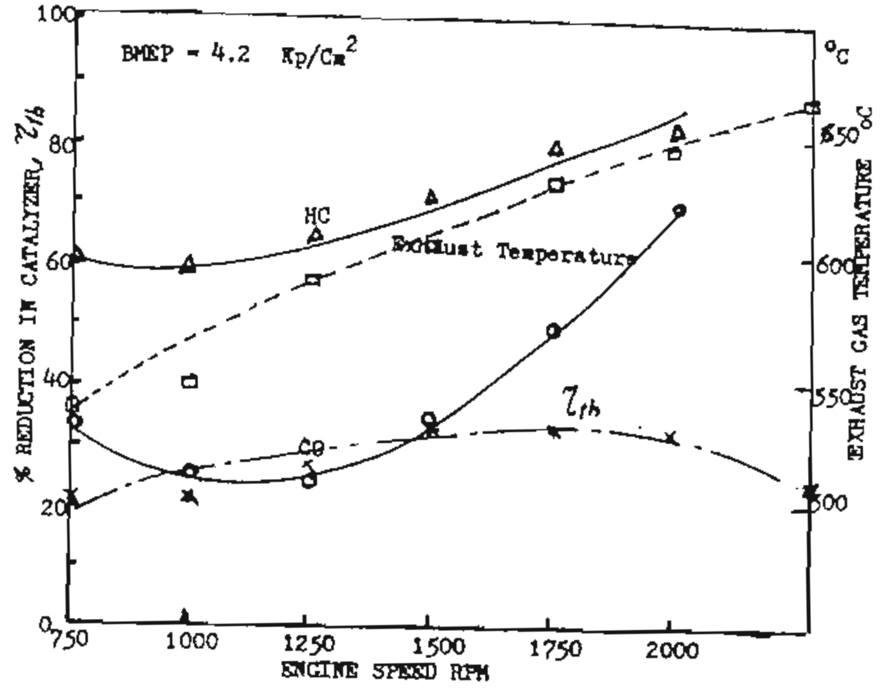

Fig.(6) Effect of Engine Speed on the %Reduction in Emissions figure that as the engine speed is increase the HC and CO emissions are decreases. It is also noticed that the use of catalyst will decrease engine emissions. The relative gains obtained when using the catalyst increases as engine speed increases. For example at engine speed of 1000 RPM the reduction in HC is about 60% and the reduction in CO is about 25%, while at an engine speed of 2000 RPM the reduction is about 80% in HC emission and about 70% in CO emission. This can be seen more clearly from the results presented in Fig.(6), which shows the percentage reduction in engine emissions when using the chemical catalyzer as a function of engine speed. The influence of engine speed on the HC and CO emissions can be explained as follows; As the engine speed is increased, the mixture turbulence is increased. The higher turbulence level will increase the burn rate and consequently reduce the unburned hydrocarbons as well as the percentage reduction in the catalyst. Also the good mixing and the higher combustion and exhaust gas temperature levels will tend to decrease CO and the percentage reduction in the catalyst.

Figures (7) and (8) show the effects of engine brake power (BHP) on HC and CO engine exhaust emissions and the percentage reduction when using the chemical catalyzer. The results presented in the figures are obtained at an engine speed of 2250 RPM and equivalence ratio of 1.1. It is clear from these results that as engine brake power increase CO and HC emissions are decrease. It is also clear that the use of the catalyst lead to further reduction in HC and CO emissions. The relative gains obtained when using the catalyst is noticed to be increase as the engine power increase. For example at engine power of 7.65 BHP, the reduction in HC is about 70% and the reduction in CO is about 57%, while at engine power of 22.95 BHP the reduction in HC emission is about 80% and the reduction in CO emission is about 65%. This can be seen clearly from the results presented in Fig.(8). This reduction in HC and CO as the engine power increases may be due to the following reasons; As the throttle opening is increased, the engine power is increased and the combustion temperature and exhaust gas temperature are increased. Also, the turbulence motion inside the combustion chamber increased, at the same time the combustion rate increases. These will tend to decrease CO formation and give a great chance to decrease the unburned HC.

Shown in Fig.(9) is the influence of equivalence ratio on HC and CO emissions with and without the catalyst at full throttle opening, variable load and at an engine speed of 2000 RPM. It is clear from this figure that the increase in equivalence ratio, results in increase in CO and HC emissions. This is due to the increase of fuel molecules in the mixture and deficiency of oxygen available to complete the combustion. The relative gains obtained when using the catalyst has been noticed to increase as the mixture becomes richer.

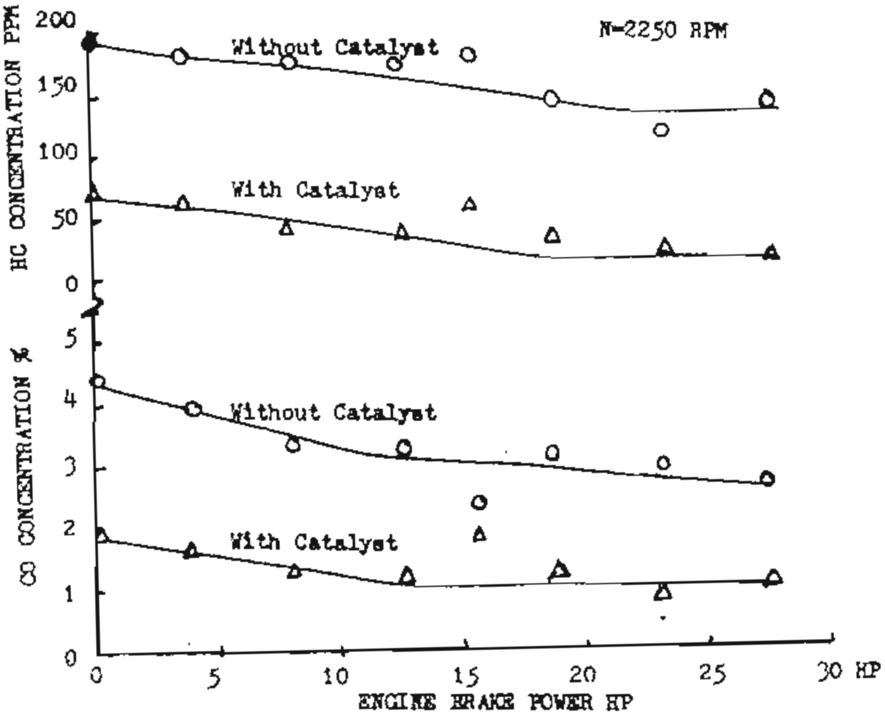

Fig.(7) Effect of Engine Load (BHP) on HC and CO Emissions

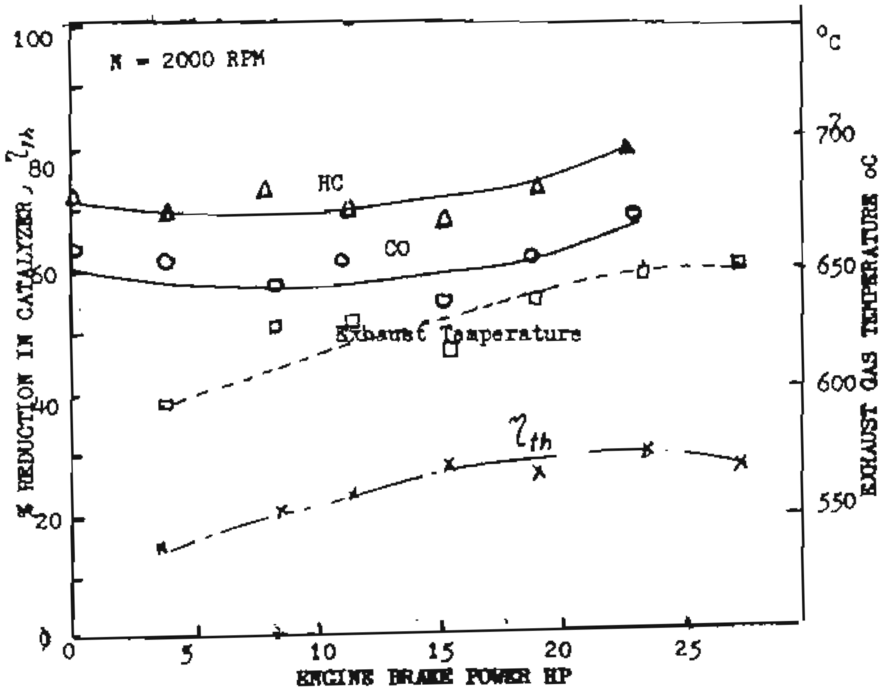

Fig.(8) Effect of Engine Load on the %Reduction in Emissions

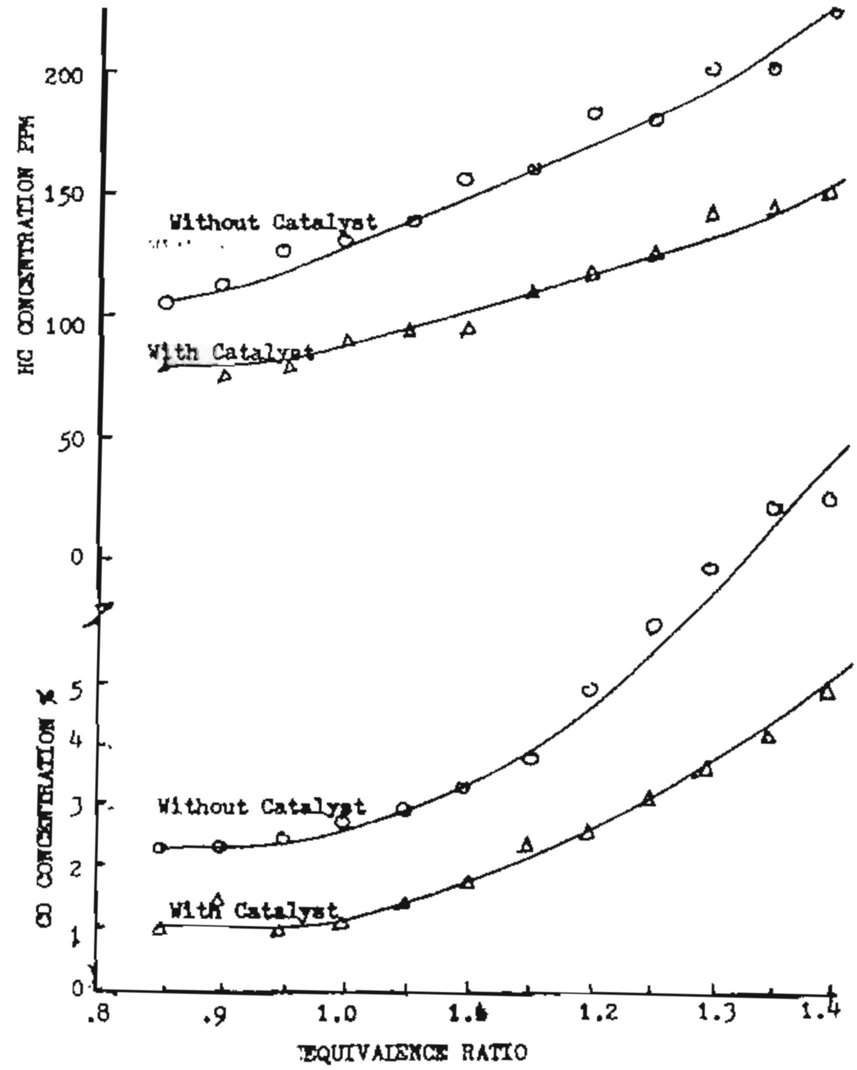

Fig.(9) Effect of Equivalence Ratio on HC and CO Emissions

CONCLUSIONS

From the experimental results reported in this paper it is well established that the engine operating parameters have a great effect on CO and HC emissions of spark ignition engine. The results also reveal that it is possible to produce a chemical catalyzer for reducing the CO and HC emitted from such engine. Studying of the experimental results reveal the following conclusions;

1-The use of chemical catalyzer in the exhaust muffler of the spark ignition engine results in decrease of the CO and HC emissions from spark ignition engine.
2-The catalyst material used was prepared of copper and zinc oxides mixed together to form grains placed in steel wire nets. This arrangement achieves a long path of the exhaust gases on the catalyst material and also make a damping effect of sound waves in the exhaust gases to reduce noise.
3-The maximum reduction in CO and HC emissions when using the catalyst are obtained at full load, higher engine speed and higher engine output.
4-The fraction of CO and HC reacted in the catalyzer increased with increasing engine speed and power due to the increase in the exhaust gas temperature.

NOMENCLATURE AND ABBREVIATION

BHP	Brake Horse Power	
bmep	Brake Mean Effective Pressure	Kp/Cm.Cm..
C	Degree Centigrade	
CO	Carbon Monoxide Concentration	%
HC	Unburned Hydrocarbon Concentration	PPM
PPM	Part Per Million	
RPM	Revolution Per Minute	
η_{th}	Thermal Efficiency	%

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