Mansoura Bulletin Vol. 10, No. 2, December 1985 M. 1

EMISSION CHARACTERISTICS OF TORCH CHAMBER S.I.E BURNING HOMOGENEOUS LEAN MIXTURE

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ABSTRACT

This work is carried out to investigate the effect of connecting passage shape and flame initiation point on emission characteristics of torch chamber spark ignition engine burning homogeneous lean mixture. This engine has been developed to achieve lean combustion of homogeneous mixture. A torch chamber for turbulence generation is used to extend the effective lean misfire limit and to increase the flame propagation velocity. The experimental study shows that the engine emissions of NO, CO and HC, mean effective pressure and specific fuel consumption are strongly dependent on the connecting passage shape and ignition point location. In the present work, two different passage shape (cylinderical straight passage of 9 mm diameter and convergent-divergent nozzle with 9 mm throat diameter) and three ignition point location are used. The spark gap projection examined are 3.5, 8 and 13 mm electrode lengthes. The results show good fuel consumption and lower engine emissions of NO, CO and HC over the entire range of engine operation conditions when using convergent-divergent passage shape and the extended spark gap projection.

INTRODUCTION

At the time, the conventional spark Ignition engine confronted with two severe constraints stemming from the demands for, first, pollution control due to the concern over the environmental, and, then, fuel economy due to energy crisis. So far these demands were met primarily by peripheral engine system improvement [1,2]. It is well known that fuel economy and exhaust emissions such as NO, CO and HC can be improved when a lean mixture is adopted. Carburetor modification for better mixture formation improved the ignition system and adequate mixture flow during combustion these are effective in improving lean combustion. A non-homogeneous charge (stratified charge engine) combustion system has been investigated for leaner combustion to improve emissions and fuel economy [3,4]. For an automobile, however, a homogeneous lean combustion engine with carburetor seems more desirable. Since it is simpler in its configuration resulting lower production cost.

The torch chamber combustion system has been investigated as a means of controlling the combustion process in spark ignition engines [5,7]. Although, markedly different in configuration, the object of each torch chamber concept was to control the combustion process so as to permit higher compression ratios without detonation, extend the effective lean misfire limit and the use of special fuels with a gain in power or fuel economy. In such engine, a fresh mixture flows into the torch chamber through an connecting passage during the compression process resulting strong eddies of mixture within the torch chamber. A spark plug located in the torch chamber lgnits and produces a flame kernel there. This flame kernel propagates through the mixture in the torch chamber. As a result, an optimum jet flame is thrown into the mainchamber. This flame jet serves as an healthy lgnition source for the mixture in the mainchamber. The flame then propagates through the mainchamber mixture where in the bulk of the energy release occurs.

The torch chamber lgnition system has also been investigated as a means of controlling exhaust emissions from spark lgnition engines [8,9]. To have an effect on engine emissions without penalty in fuel economy, the objective of the torch chamber system design and optimization is the combustion of fuel - air mixture so lean that the resulting burning gas temperatures will not support NO_x formation while maintaining low CO and HC emissions. The objective of this study is to carry out the investigation of a torth chamber spark lgnition engine burnning homogeneous lean mixtures. Specifically, the study is to determine the effect of connecting passage shape and spark gap projection on engine exhaust emissions of NO, CO and HC's.

EXPERTMENTAL SETUP AND PROCEDURES

The experimental work is carried out at the Center of Research of Army Forces. The experimental setup is shown schematically in Fig. 1. The engine used is a modified Deutz-Disel engine. The engine is a four stroke, four cylinder, air cooled, overhead valves with a swirl prechamber. The engine specifications are shown in Table 1. The engine is modified to be a torch chamber spark ignition engine. The modifications have been involved are, a reduction of compression ratio from 17:1 to 9:1 by fitting spacers between engine crankcase and each liner. The intake manifold is modified to be fit with a conventional carburetor selected according to engine air

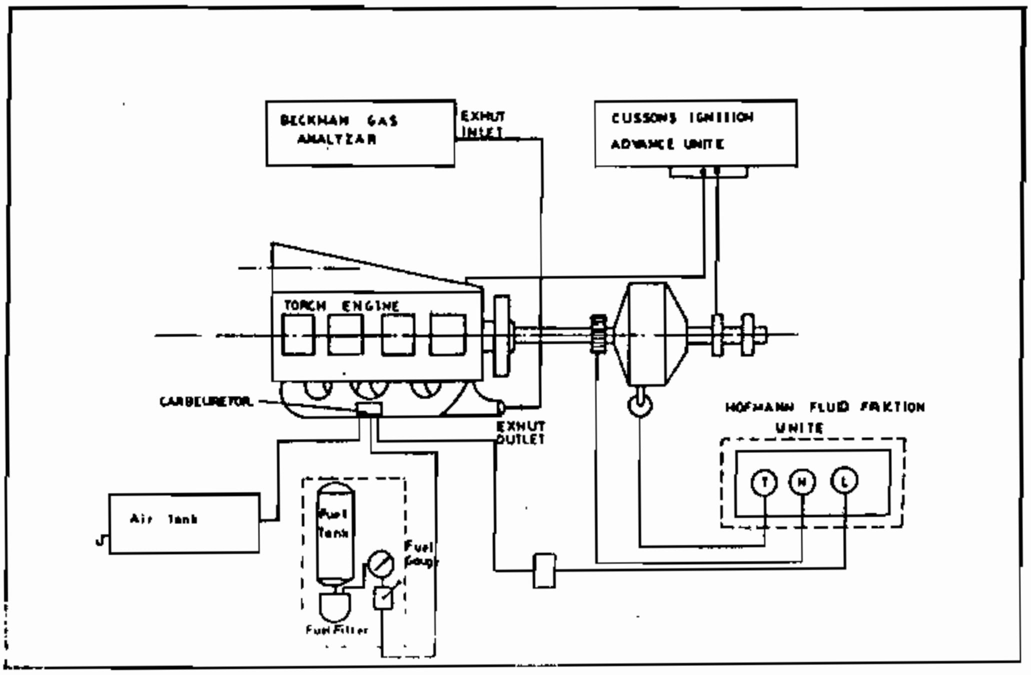


Fig. 1: Schematic Diagram of the Experimental Setup.

flow requirements at stream conditions. The carburetor used is modified to be fit with an adjustable needle valve as shown in Fig. 2. The engine is also fitted with a conventional ignition system and distributer.

The design situation for the engine cylinder head and the position of the spark plug is shown in Fig. 3. Two sets of cylinder heads equipped with two different passage shape have been used. The first set is originally fitted with a straight passage having a diameter of 9mm, 20mm length and 30° inclination to piston crown. The second set of cylinder

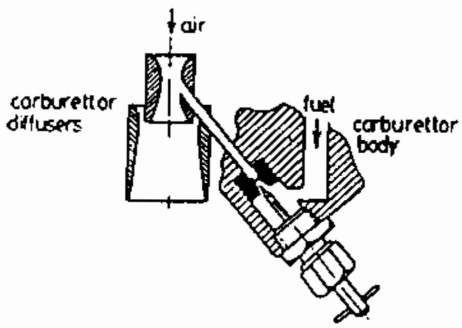


Fig.2. Mixture Strength Controlling Valve.

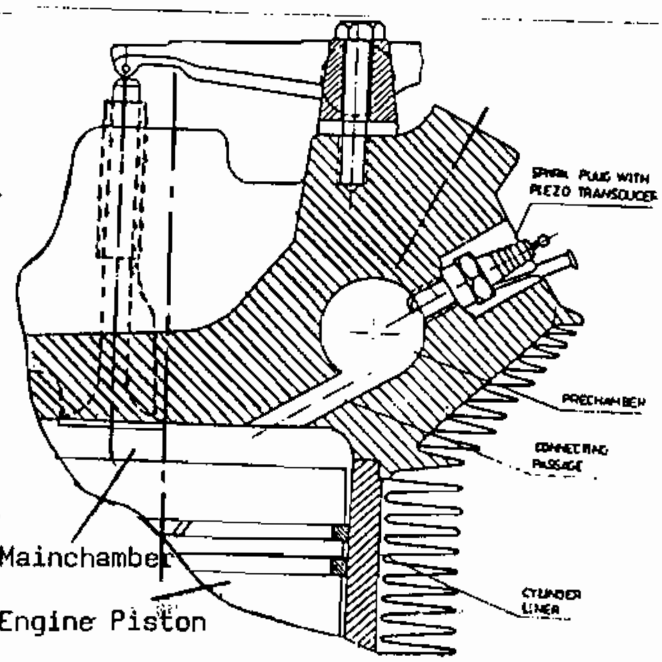


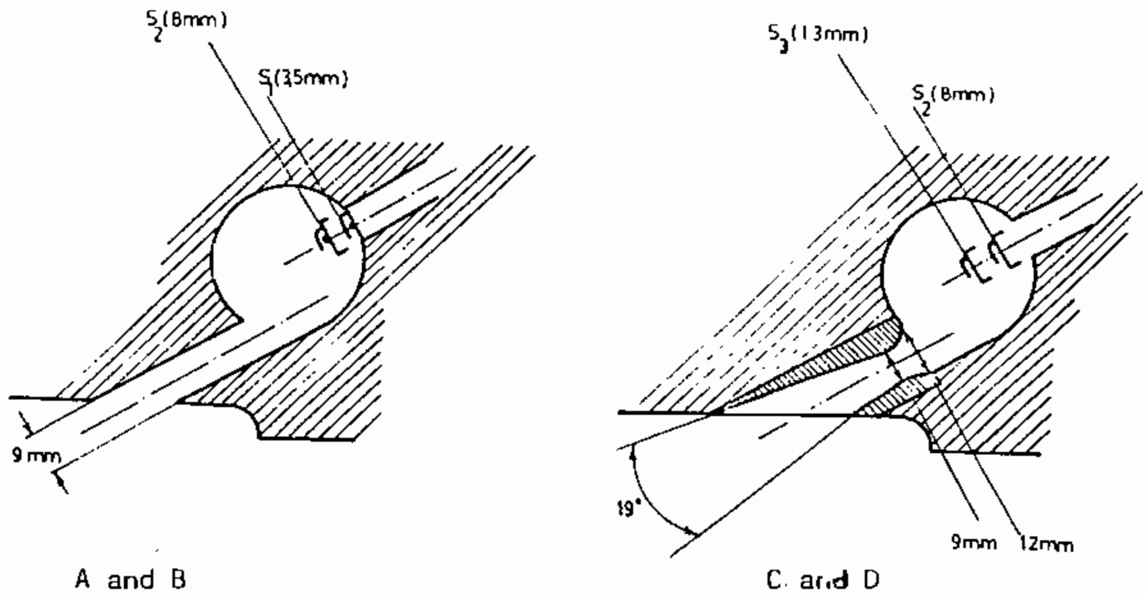
Fig. 3. The Torch Chamber Engine Cylinder Head.

Table 1: Engine Specifications

Engine bore (cm)			11.0
Engine stroke (cm)			14.0
Displacement volume (liter)			5.32
Connecting rod length (cm)			21.0
Compression ratio			9:1
Prechamber volume to total clearance volume ratio			17%
Connecting passage diameter (cm)			0.9
Value timing:	I.V.O	°BTDC	16
	I.V.C	°ABDC	40
	E.V.O	°BBDC	52
	E.V.C	°ATDC	16

head is fitted with a convergent-divergent nozzle with 9mm throat diameter and 19° divergence angle. In order to initiate the flame at different locations in the torch chamoer, spark plugs with three different electrode lengthes(3.5mm, 8mm and 13mm) are used. The four torch chamber configurations to be tested are shown in Fig. 4.

Engine tests are designed to investigate the effect of connecting passage shape and spark gap projection on the emissions characteristics and fuel economy of torch champer spark ignition engine.



Fig(4) PRECHAMBER ARRANGEMENTS TO BE TESTED

ARRANGEMENT A _ STRAIGHT CONNECTING PASSAGE WITH SPARK GAP LOCATION S_1
ARRANGEMENT B _ S_2
ARRANGEMENT C _ CONVERGANT DIVERGENT S_2
ARRANGEMENT D _ S_3

In order to cover the investigations, the engine has been run at different speed, throttle opening and different air-fuel ratios. The engine is loaded by an fluid friction dynamometer type Hofman-Bran-3t. The Ignition timing is indicated using a Cusson-P 4605 Ignition advance unit. The fuel flow is metered by a needle valve and is measured using volumetric type flow meter. The rate of air consumption is determined using an air box and orifice technique. Engine exhaust emissions of HC, CO and NO_x are measured by Beckman gas analyzers. To measure the CO emission a non-dispersive infrared analyzer model 864 is used. The HC emission is indicated using flame Ionization detector associated with sampling heated line, Beckman model 402. While the NO/NO_x emission is measured using Beckman model 951A. The Beckman analyzer model 7003 is used to monitor the Oxygen.

RESULTS AND DISCUSSIONS

The results of the experiments have been collected and displayed graphically as famillies of curves. All experiments are carried out with the torch chamber engine, at compression ratio of 9:1. Unless otherwise stated, the spark timing is always set st its maximum power value for the specific combination of torch chamber configuration and operating conditions being tested. For each combination A, B, C and D in Fig.4, engine emissions of NO, CO, and HC, b. s. f. c, b.m. e.p and exhaust gas temperature are recorded or determined for variable loads, fuel-air ratios and engine speeds keeping the other parameters constant.

Shown in Figs. 5 through 10, are a comparative curves of engine emissions of CO, NO and HC, b.m.e.p., b.s.f.c and the exhaust gas temperature at full load and fuel-air equivalence ratios of 1.1 and 0.8 as a function of engine speed. It is clear from these figures that the increase of the spark gap projection inside the prechamber gave a lower of CO, NO and HC engine emissions and an increase of the engine b.m. e.p and exhaust gas temperature (Comparing Combination A with B and C with D). It is also clear that the convergent-divergent connecting passage posses the same advantages over the straight one (Comparing Combination B with C). Combination D satisfies lower emissions of CO, NO and HC and higher b.m.e.p. allover engine speeds. Regarding the fuel economy, it has been found that the b.s.f.c decreases with increased gap projection and using the convergent-divergent connecting passage. Again, combination D which satifies lower CO, NO and HC emissions, higher b.m.e.p and higher exhaust gas temperature satifies also minimum b.s.f.c.

The relative gain obtained using combination D instead of combination A has been noticed to increase as the engine speed becomes higher. For example, at engine speed of 1200 rpm, the decrease in CO is 50%, the decrease in NO is 7.7%, the decrease in HC is 31.25% the decrease in b.s.f.c is 13.75% and the increase in b.m.e.p is 6.05%. This can be compared with 63.22%, 13.41%, 32.34%, 11.8% and 8.2% respectively at engine speed of 2200 rpm.

Studying the effects of connecting passage shape and the spark gap progections on engine emissions and fuel economy at various loads, the same results are confirmed as shown in Figs. 11 and 12. Shown in this figures are the emissions of CO, NO and HC, engine b. m.e.p and engine b.s.f.c of the engine fitted with combination A, B, C and D at various loads and an engine speed of 2000 rpm and a fuel-air equivalence ratio of 1.0. It can be seen from these figures that with the engine fitted with the combination C and D, a gain is obtained in engine emissions, b.m.e.p and b.s.f.c allover the load range. Similar results are confirmed at different engine speeds and various equivalence ratios.

Shown in Figs. 13 through 18, are the dependences of engine emissions, b.m.e.p, b.s.f.c and exhoust gas

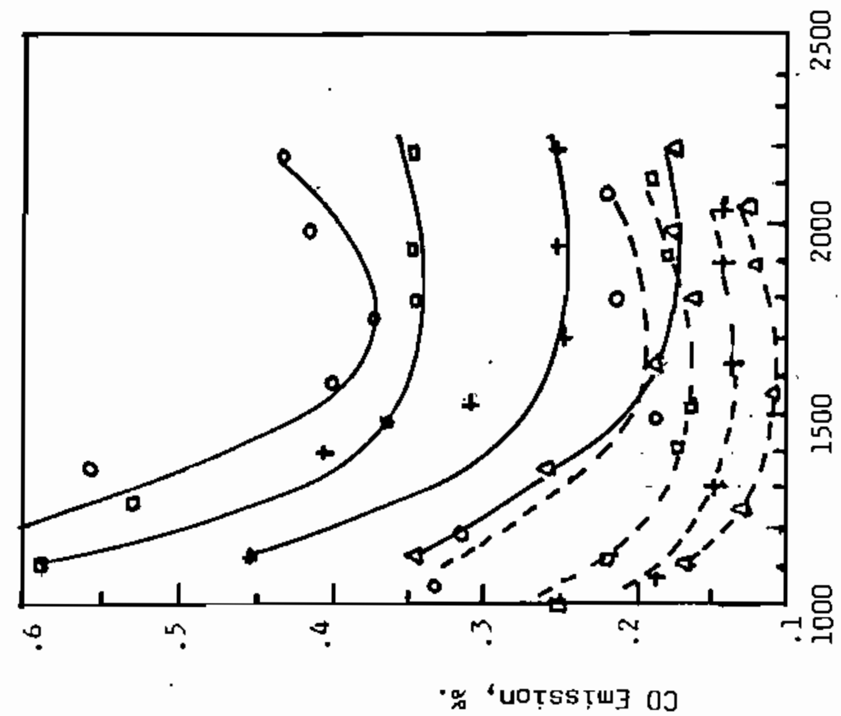


Fig. 5: CO Emission as a function of Engine speed at fullload.

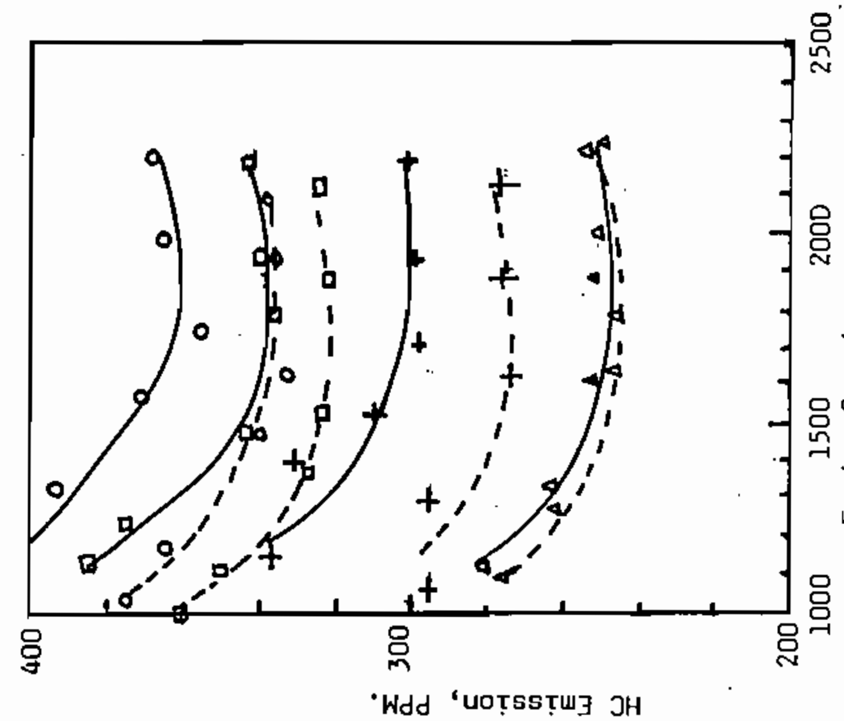


Fig.6: HC Emission as a function of Engine speed at fullload

—— Ø=1.1,... Ø=0.8,O Combination A, □ Combination B,+ Combination C,Δ Combination D.

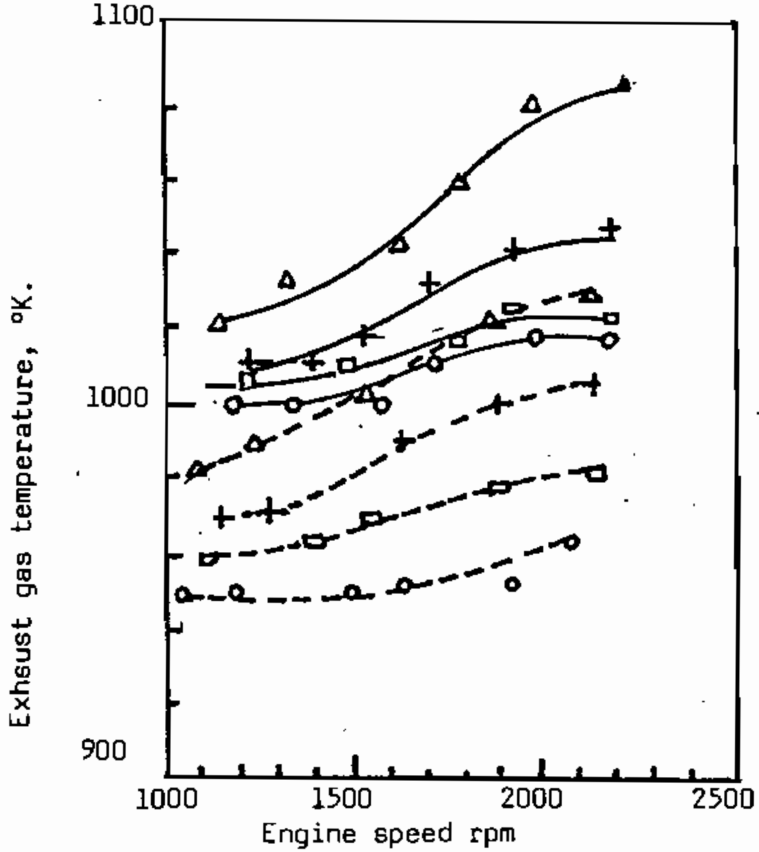


Fig. 7: Exhaust gas temperature as a function of engine speed at fullload.

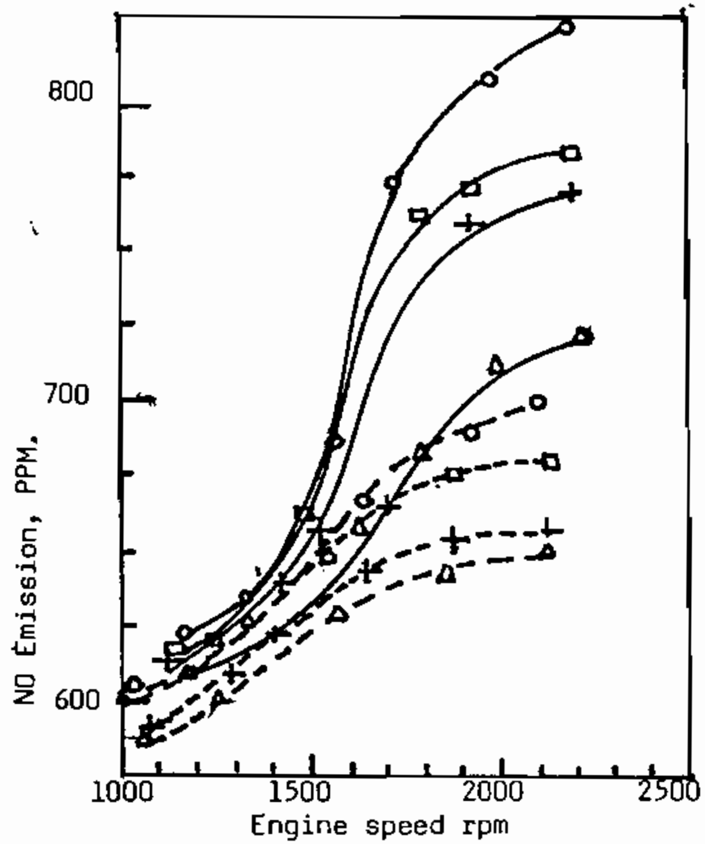


Fig. 8: NO Emission as a function of engine speed at fullload.

—— Ø=1.1,... Ø=0.8,0 Combination A, □ Combination B, + Combination C, Δ Combination D.

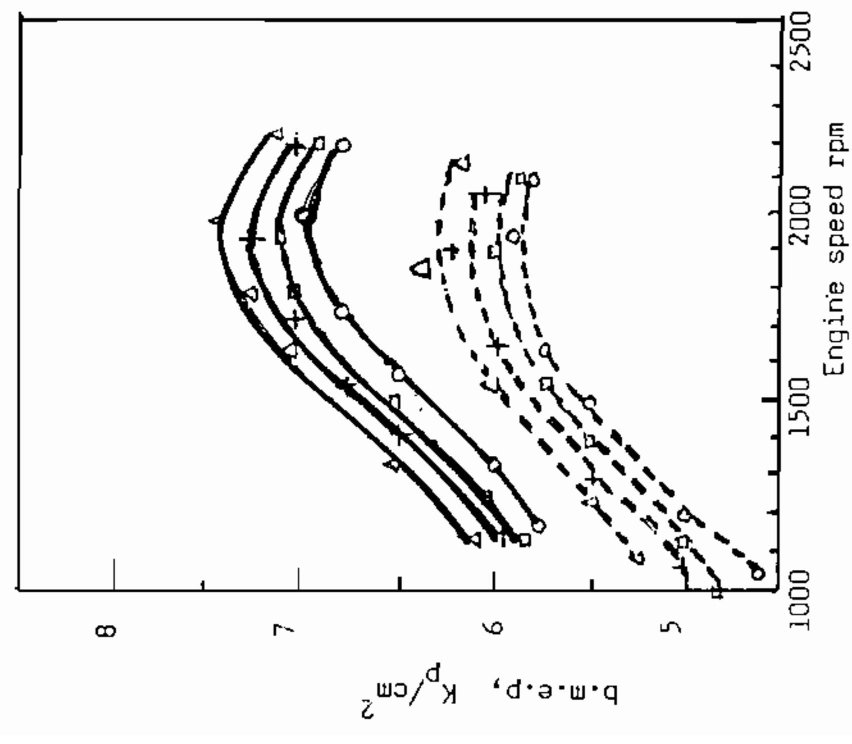


Fig. 9: Brake Mean effective pressure as a function of engine speed at fullload

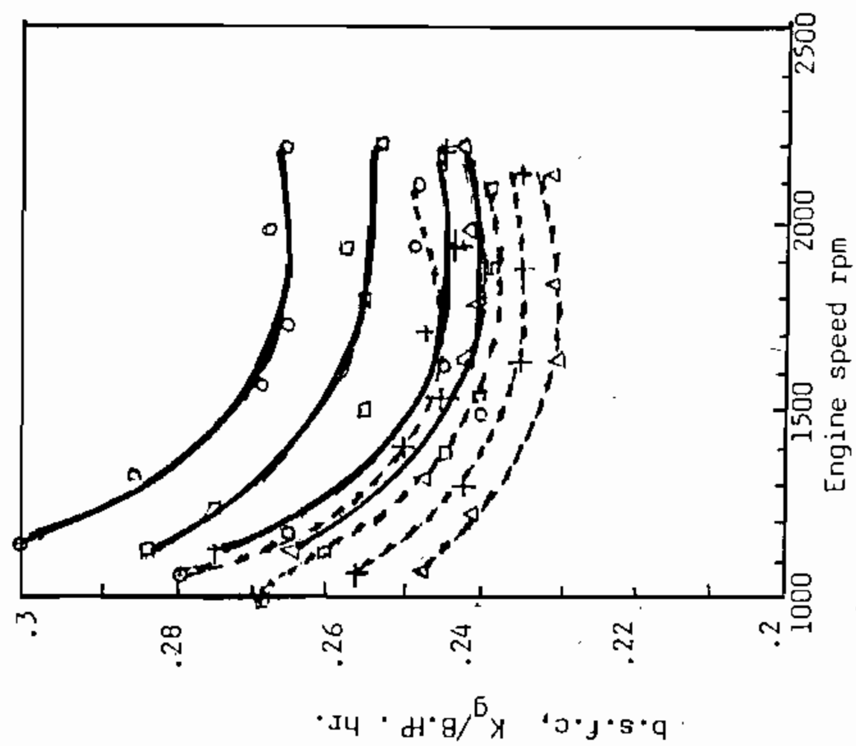


Fig. 10: Brake specific fuel consumption as a function of engine speed at fullload.

—— Ø=1.1,.... Ø=0.8,0 Combination A, □ Combination B, + Combination C, Δ Combination D.

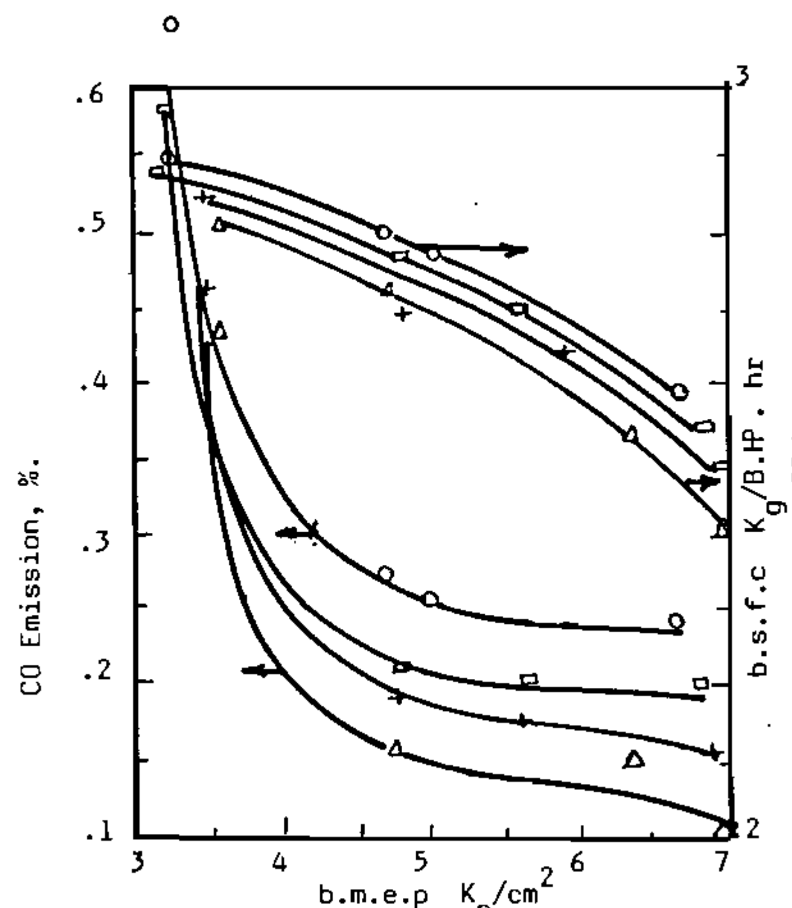


Fig. 11: The effect of engine load on CO emission and brack specific fuel consumption.

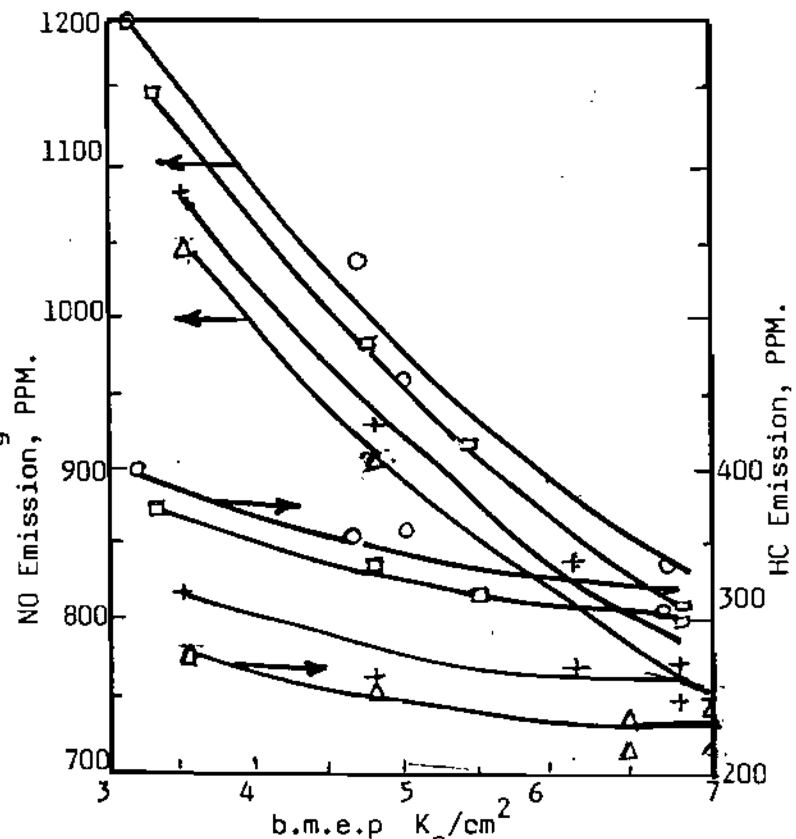


Fig. 12: The effect of engine load on NO and HC emissions.

Engine speed = 2000 rpm, Ø = 1.0 ○ Combination A, □ Combination B, + Combination C, △ Combination D.

temperture on spark gap projection, connecting passage shape and fuel-air equivalence retio at an engine speed of 2000 rpm for different engine loads namely 0.7 and full loads. It is clear from these figures that the engine emissions of CO, NO and HC, b.m.e.p and b.s.f.c are strongly enfluenced by the equivalence ratio. As the later goes to be leaner, the formers are decreased. During the engine tests, it has been found that the effective lean misfire limit (LML) goes to less leaner mixtures as the load decreased. It is also found that LML has been extended by extending the spark gop progection and a further extension has been gained using the convergent-divergent passage. It must bear in mind that this further extension led to decreased engine emissions and b.s.f.c as shown in Figs. 13 through 18. The leanest LML, $\emptyset=0.7$ ($\simeq 20:1$) air to fuel ratio) is obtained with the engine fitted with combinations C and D.

The results of the experiments described in this paper show that changes in the geometry of the connecting passage and location of the spark gap inside the prechamber can greatly affect the emissions and fuel economy of the torch chamber spark lgnition engine. The engine emissions and fuel economy are improved when using the convergent-divergent passage coupled with the extended spark gap projection. The emissions and fuel economy exhibited by the combination C and D can be contributed to the better performance and combustion characteristics and thecontrols of the fast pressure rise in the mainchamber when using the extended spark gap projection coupled with the convergent divergent passage (7). The better lgnition and combustion conditions in the torch chamber spark lgnition engine are proved by the delayed optimum lgnition point. As in the conventional spark lgnition engine, the exhaust gas emission of the torch chamber engine can be influenced by modifying the lgnition point. This applies to the quantity of CO, NO and HC. As long as the lgnition and combustion conditions are not essentially deterlorated retarded lgnition points tend to reduce the HC and CO emission as an increase of the expansion temperatures favour the post-combustion. The results also indicated that a very siqnificant reduction in NO formation is obtained due to the shortened exposure time at high temperature.

CONCLUSIONS

Studying of the experimental engine emissions and fuel economy curves reveals the following conclusions,

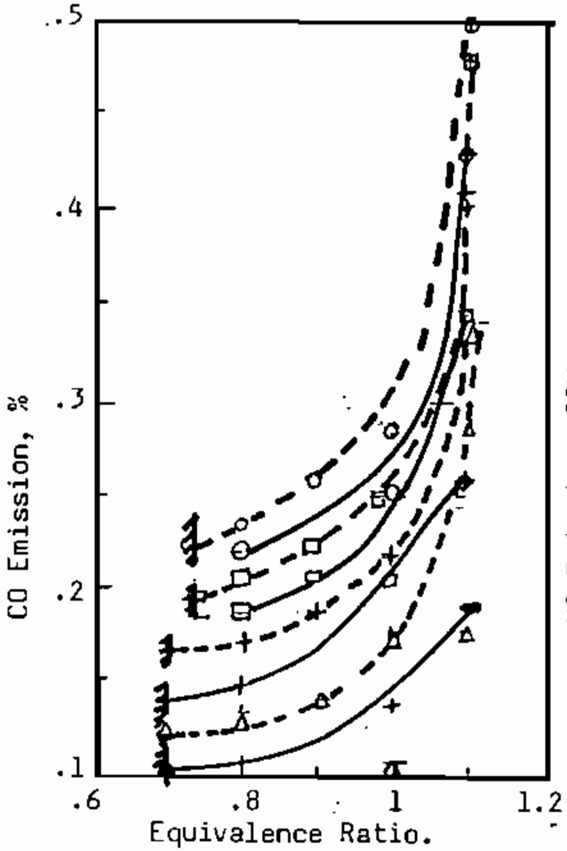


Fig.13: The effect of fuel-air equivalence ratio on CO emissions.

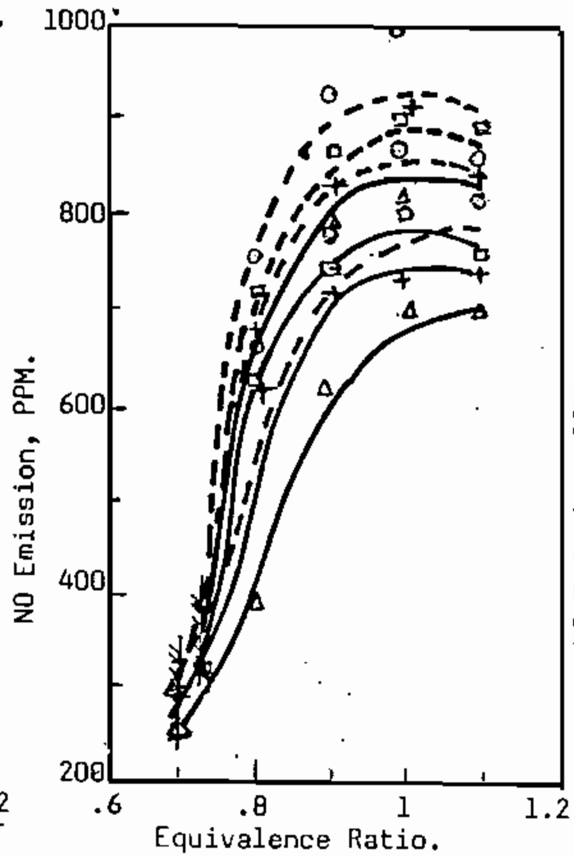


Fig.14: The effect of fuel-air equivalence rqtio on NO emissions.

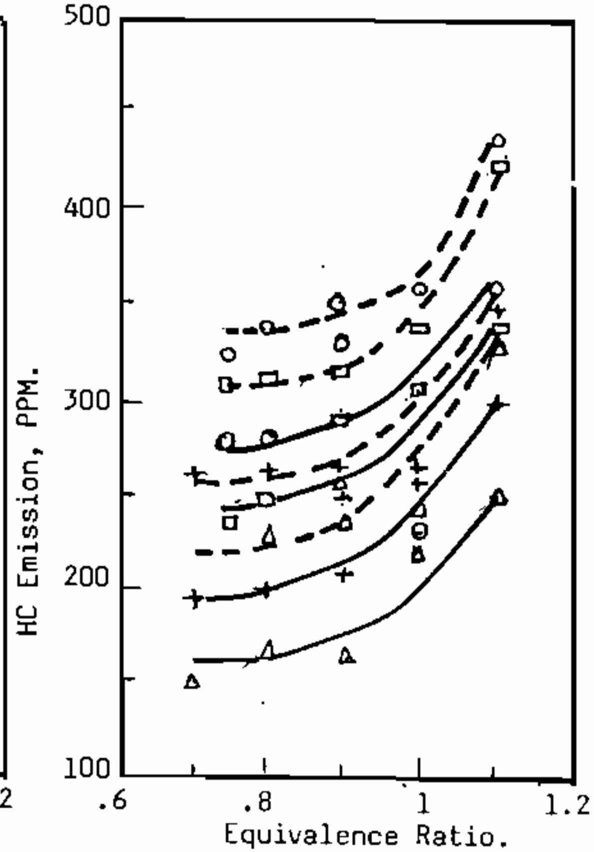


Fig.15: The effect of fuel-air equivalence rqtio on HC emission.

N=2000 rpm,... .7 throttle opening,—full-load. o Combination A, □ Combination B, + Combination C, Δ Combination D.

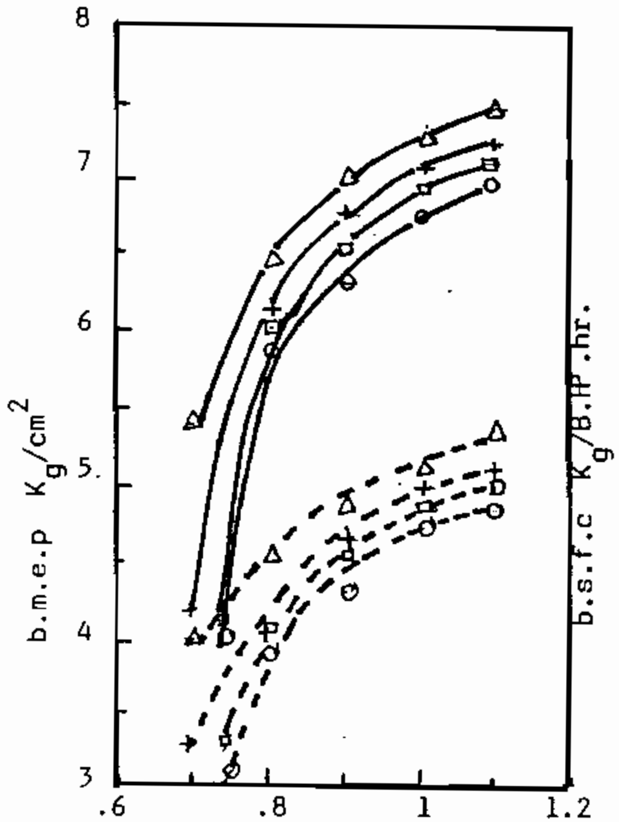


Fig.16: The effect of fuel-air equivalence ratio on engine b.m.e.p.

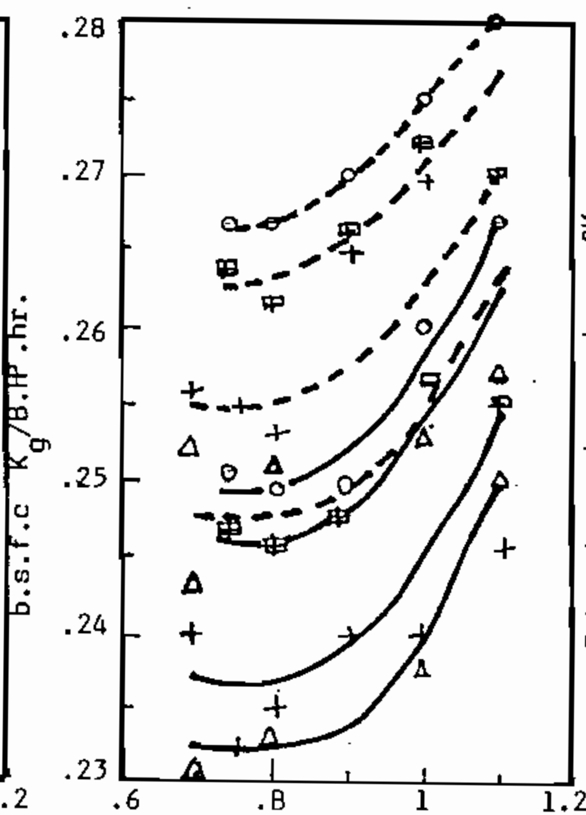


Fig.17: The effect of fuel-air equivalence ratio on engine b.s.f.c.

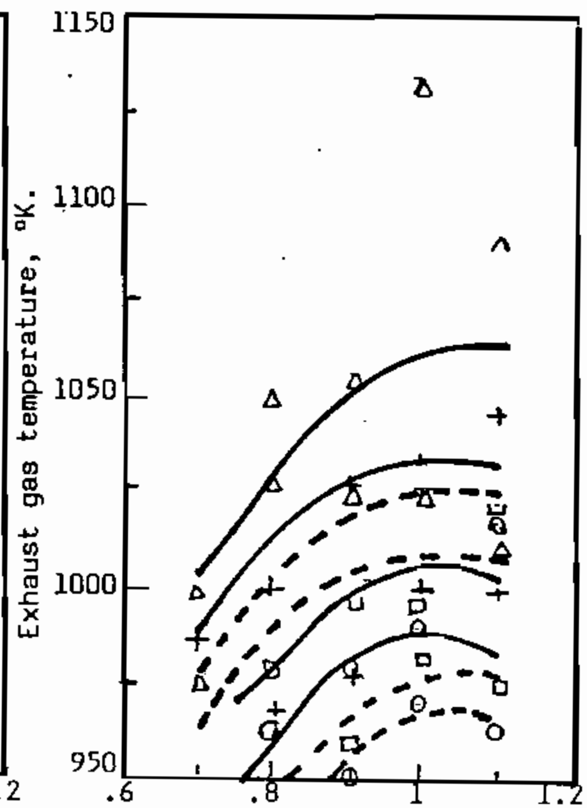


Fig.18: The effect of fuel-air Equivalence ratio on engine exhaust gas temperature.

N=2000 rpm,... .7 throttle opening,—full-load. o Combination A, □ Combination B, + Combination C, △ Combination D.

1- The torch chamber spark lgnition engine improves the combustion of the lean mixture.
2- Allover the range of fuel-air equivalence ratio examined, engine spead and engine load the engine emissions and fuel economy are improved when the convergent-divergent passage coupled together with the extended spark gap projection inside the prechamber.
3- At part load, the advantages are still gained with the convergent-divergent passage and the expanded spark gap projection.
4- The leanest misfire limit at Ø=0.7 (Air-fuel ratio ≃ 20:1) is achieved when using the convergent-divergent passage and extended spark gap projection.

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$\bar{c}/c_{\infty}$	$-\delta^{**} cy_o/\nu$	$x cy_o^2/c_{\infty}\nu$
1.0	0	0
0.9	0.105	0.024
0.8	0.223	0.098
0.7	0.357	0.228
0.6	0.511	0.424
0.5	0.693	0.696
0.4	0.916	1.059
0.35	1.050	1.281
0.3	1.204	1.514
0.25	1.386	1.829
0.2	1.609	2.172
0.15	1.895	2.564

Table (1) Results

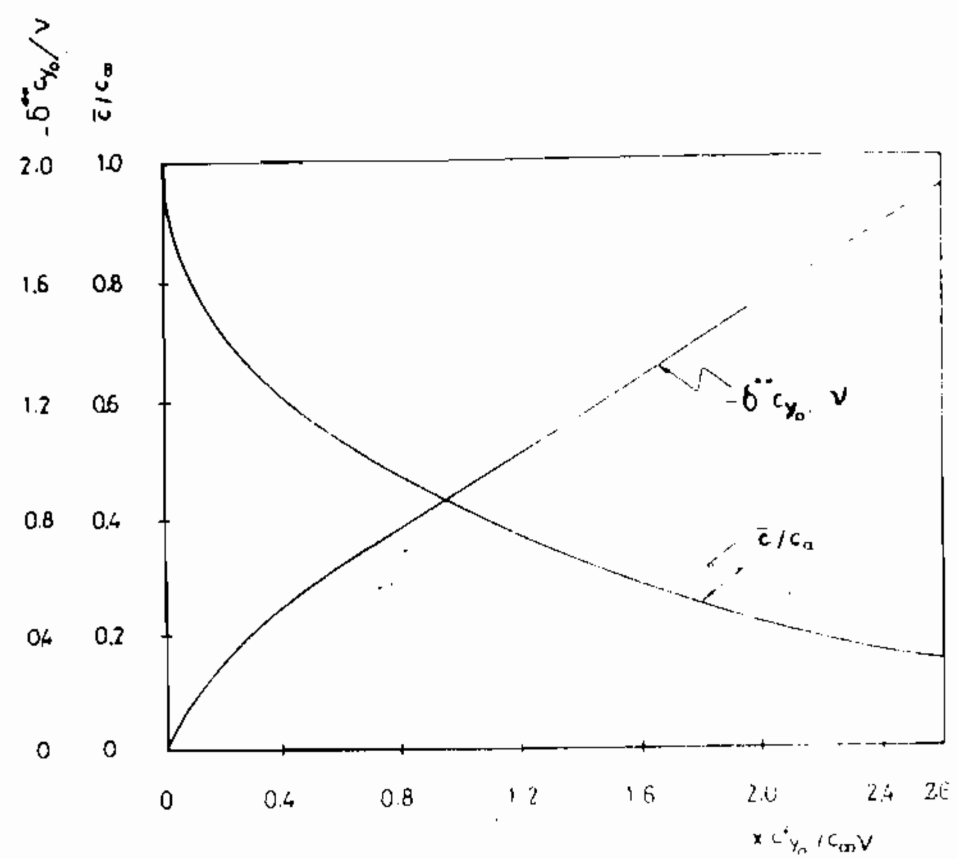

Fig.(1) Flow with varying velocity gradient and constant suction