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Efficiency Enhancement of 2-Stroke SI Engine by Increasing Compression Ratio

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Abstract: Historically two stroke engine petrol engines find wide applications in construction of two wheelers worldwide, however due to stringent environmental laws enforced universally; these engines are fading in numbers. In spite of the tight norms, internationally these engines are still used in agriculture, gensets etc. Several designs of variable compression ratio two stroke engines are commercially available for analysis purpose. In this project, attempt is made to increase the existing compression ratio of a used two-stroke single cylinder air cooled petrol engine by minor engine modifications, and to study its performance at a fixed speed. The original cylinder head is removed and a suitable mechanical arrangement is incorporated in its place, making it practically feasible to vary the compression ratio and then test the engine. The results have shown a considerable improvement in the engine efficiency and also reduction in the value of specific fuel consumption. Besides, an attempt is made for testing the same engine with duel fuels and gasohol, by mixing petrol with alcohol (Ethanol) in different proportions. The results indicate that the engine efficiency got slightly reduced but the exhaust from the engine contained lesser percentage of harmful gases. Internal combustion engines develop varying brake power depending on the compression ratio, while the other parameters held constant. For compression ignition engines, the compression ratio is ought to be above certain value for the ignition to take place. The spark ignition engines can be operated with lower compression ratios also. The ignition being controlled by the spark strength and advance. The effect of compression ratio on the power output of the engine is main concern in the present study.

I. INTRODUCTION

Efficiency is very important in any equipment, particularly automobiles and the world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based carbon resources. Alcohol fuels particularly ethanol can be produced by fermentation of bio mass crops, mainly sugar cane, wheat and wood. Usage of alcohols and liquefied petroleum gas as a fuel for spark ignition engines has some advantage to compare the gasoline. The engine thermal efficiency can be improved with increasing of compression ratio. This can be achieved by replacing the actual cylinder cover with an adjustable piston and one more cylinder. By adjusting the adjustable piston the clearance volume can be changed as a result the compression ratio. And one more method is blending gasoline with alcohol (ethanol). Because, Alcohol burns with lower flame temperatures and luminosity owing to decreasing the peak temperature inside the cylinder and hence the heat losses are lower.

II. ENGINE SPECIFICATION

Engine type	:	two stroke, air cooled, petrol driven, spark ignition
No. of cylindes	:	one
Bore	:	57 mm
Stroke	:	57 mm
Displacement	:	145.45 cc
Compression ratio (variable)	:	6.1 to 11.1
Maximum power	:	4.632kw (6.3hp)
Rated speed	:	5200 r.p.m
Ignition timing t.d.c	:	spark advance of 22^0 +/- 1 before

Petrol-oil mixture	:	3% self mixing 2t oil
Length of piston (stationary)	:	175 mm
Diameter of piston (stationary)	:	57.10 mm
Length of threaded part	:	80 mm
Type of thread	:	metric 60 ^{0}
Pitch of thread	:	6 mm
Length of rectangular wedge	:	16.30 mm
Breadth of rectangular wedge	:	5.70 mm
Depth of rectangular wedge	:	5.70 mm
Length of studs	:	310 mm
Diameter of studs	:	8mm

A. Principle of Operation of Varying Compression Ratio Arrangement

The compression ratio of an engine is inversely proportional to its clearance volume as is evident from its definition. Hence, the variation in compression ratio is brought about by varying the clearance volume in the engine cylinder. This is effected by the use of an additional piston cylinder arrangement. The cylinder head of the engine is removed and an auxiliary cylinder (know as stationary piston as it does not move during the engine operation) which now acts as the cylinder head can be moved towards or away from the IDC of the engine cylinder in order to decrease or increase the clearance volume respectively thus varying the compression ratio.

II. FABRICATION OF THE TEST RIG

A. The stationary piston is extended in length by welding a hollow aluminum casting to it. Threads are cut on the casting after matching which facilitates precise translator motion of the stationary piston when moved with the help of a nut. The hollowness (air gap) of the casting helps in better cooling of the new mechanism.
B. A rectangular wedge is cut at the face of the stationary piston to accommodate the spark plug.
C. Auxiliary piston-cylinder arrangement was mounted on the original cylinder by means of studs.
D. A hole is drilled at the appropriate position in the auxiliary cylinder to fix the spark plug.
E. The surface profile of the stationary piston is machined so as to match the profile of the moving piston in order to avoid intervention during close tolerance operations (during the inward movement of the stationary piston for higher compression ratios).
F. An additional groove to accommodate a third piston ring is cut on the stationary piston to prevent compression leakage caused due to high compression ratios.
G. A lock plate is provided at the outer end of the above said arrangement which is secured with the help of bolts. This is necessary to withstand the high cylinder pressures.

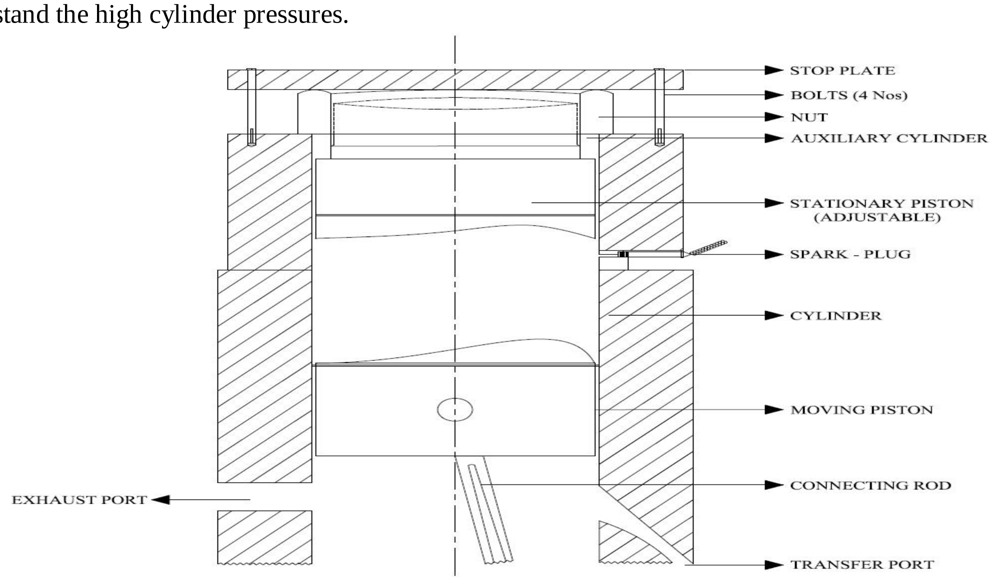

Fig: 1 fabricated engine with variable compression ratio:

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III. EVALUATION OF PERFORMANCE OF THE ENGINE

Conventional liquid hydrocarbon fuels such as petroleum and diesel fuels have remained almost entirely unchallenged since the motor vehicles were invented. This is largely due to their high energy densities and convenient handling methods. However, their source is finite, resources are not uniformly distributed and their increased usage contributes to a variety of local and regional air pollution. Several alternative fuels have been used in motor vehicles due to their prospect of reduced levels of combustion related exhaust emissions and benefits such as better fuel consumption and ensuring the diversity of fuel by employing non-conventional feed stocks. Nevertheless, very few alternative fuels have been commercially exploited owing to their high costs and enormous infrastructure requirements for the production, distribution and refueling aspects, ethanol being one such fuel.

Ethanol can be used as a fuel by itself or otherwise blended with petrol in varying amounts. Though various proportions of petrol-ethanol are possible fuel mixtures, this study limits itself to the use of ethanol as:

Blending agent: Blend of 90% petrol with 10% alcohol commonly termed as Gasohol.

Dual Fuel: Equal proportions of both petrol and ethanol.

The properties of the two fuels are comparable as seen from the table

	GASOHOL	DUAL FUEL
Specific Calorific Value (KJ/Kg)	43,900	26,700
Octane number (RON/MON)	91/80	109/98
Latent heat of vaporization (KJ/Kg)	376-502	903
Ignition temperature (C)	220	420
Stoichiometric A/F ratio	14.5	9
Specific gravity	0.725	0.796
Maximum compression ratio without knock	8 to 10:1	Over 15:1

Ethanol makes an excellent motor fuel with its octane number exceeding that of petrol. It also has a lower vapour pressure than petrol which results in lower evaporative emissions. It is non-toxic and has a lower flammability in air than petrol, which reduces the number and severity of vehicle fires.

IV. RESULTS

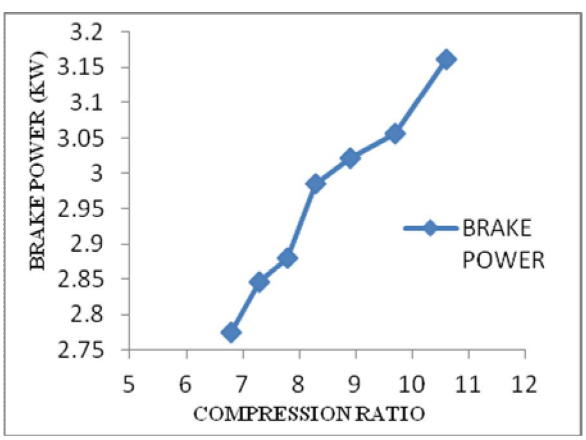


Fig: 2 brake power v_s compression ratio
Fuel: 100 % petrol
Speed: 3500rpm@full load

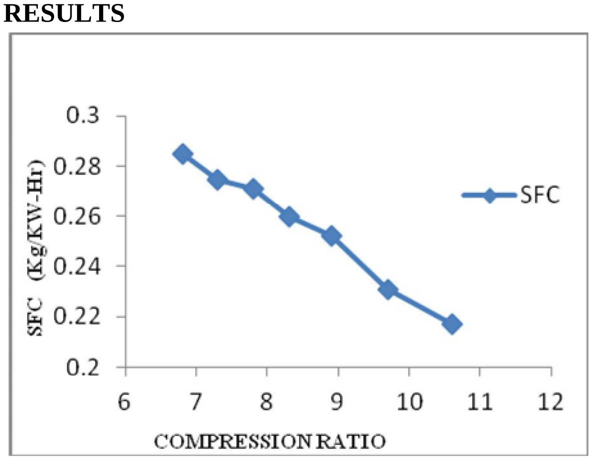
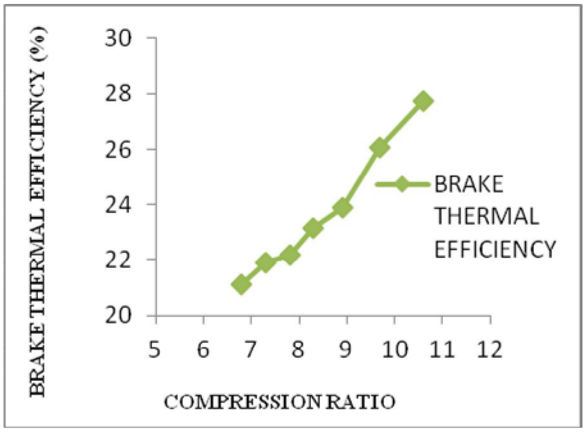


fig: 3 sfc v_s compression ratio
fuel: 100% petrol
speed:3500@full load



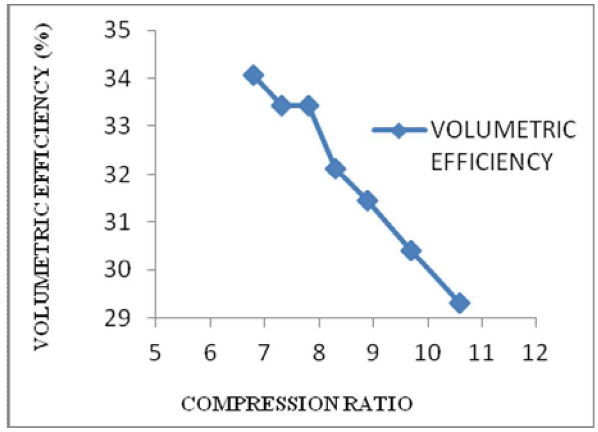


Fig: 4 brake thermal efficiency v_s compression ratio

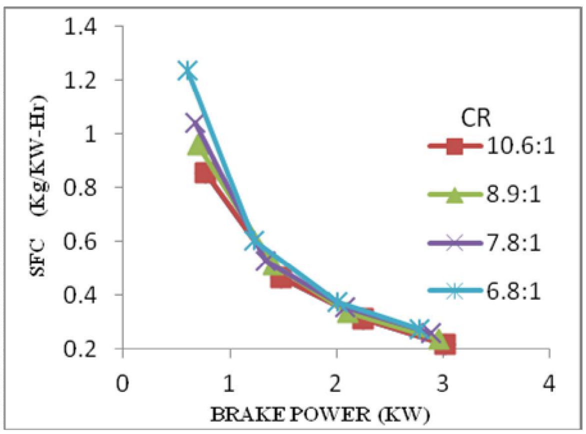
Fuel: 100% petrol

Speed: 3500rpm@full load

fig: 5 volumetric efficiency vs compression ratio

fuel: 100% petrol

speed: 3500rpm@full load



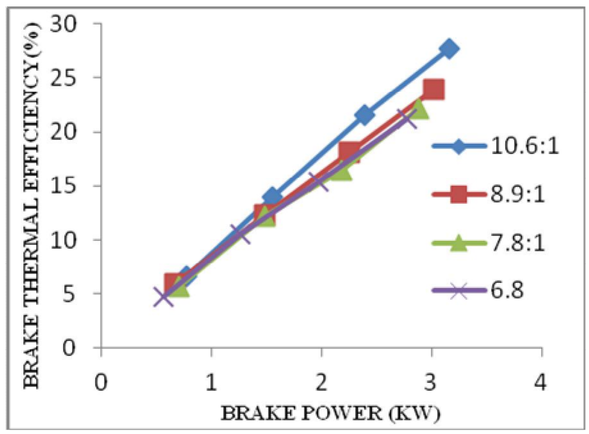


Fig: 6 SFC V_S BRAKE POWER

FUEL: 100% PETROL

SPEED: 3500RPM

Fig: 7 BRAKE THERMAL EFFICIENCY V_S BRAKE POWER

FUEL: 100% PETROL @ SPEED: 3500 RPM

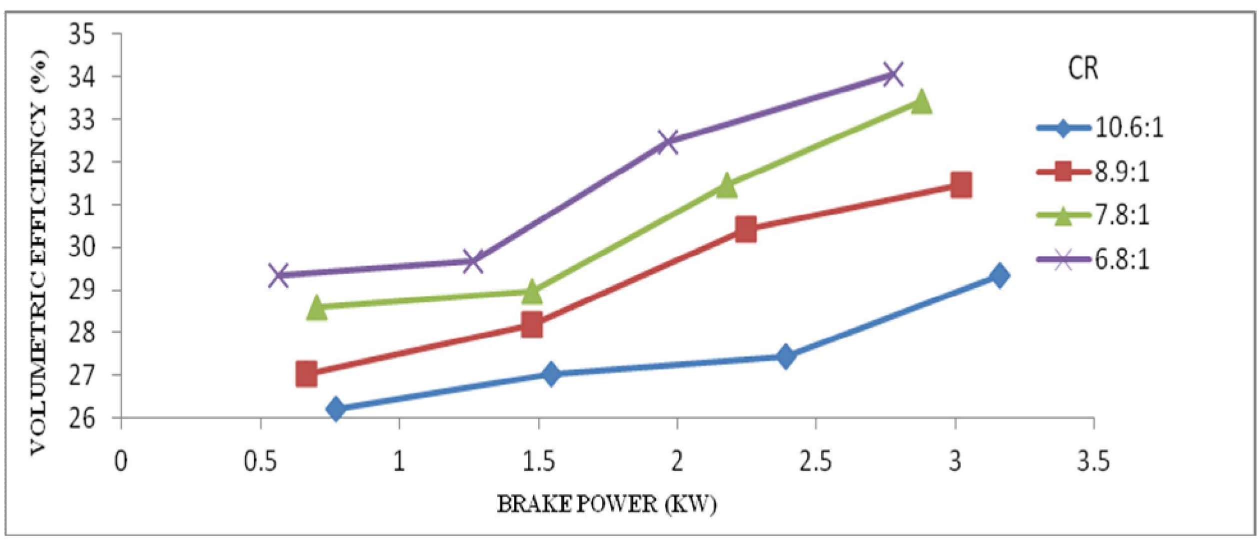


Fig: 8 volumetric efficiency vs brake power; fuel: 100 % petrol; speed: 3500rpm

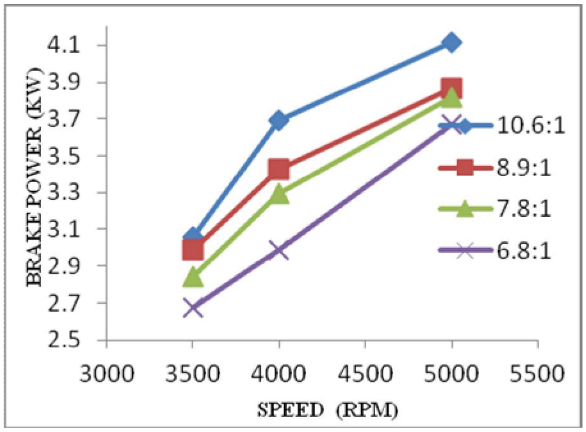


fig:9 brake power v_s speed
fuel: 100% petrol @full load

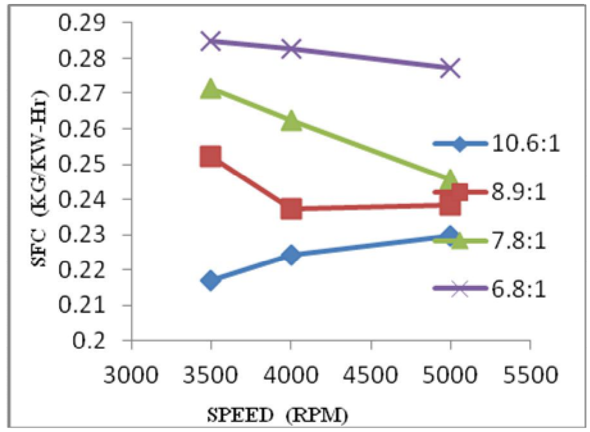


fig:10 sfc v_s speed
fuel: 100% petrol @full load

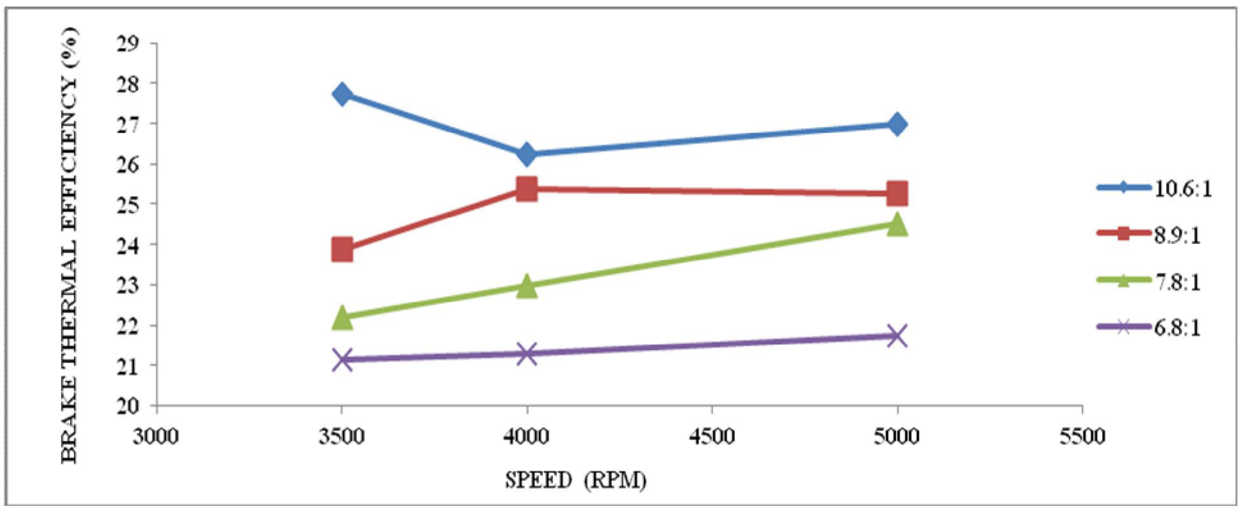


Fig: 11brake Thermal Efficiency V_s Speed: Fuel: 100% Petrol@ Full Load

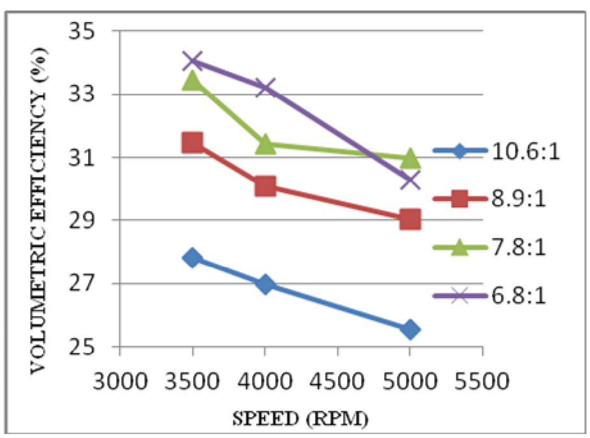


Fig: 12 volumetric efficiency v_s speed
fuel: 100% petrol@ full load

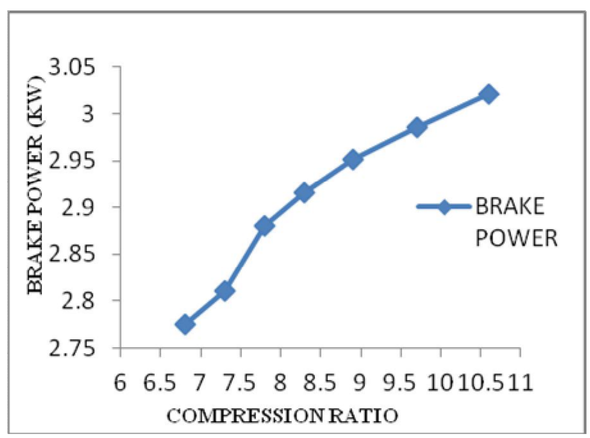


fig: 13 brake power v_s
compression ratio: fuel: gasohol
speed: 3500 rpm@full load

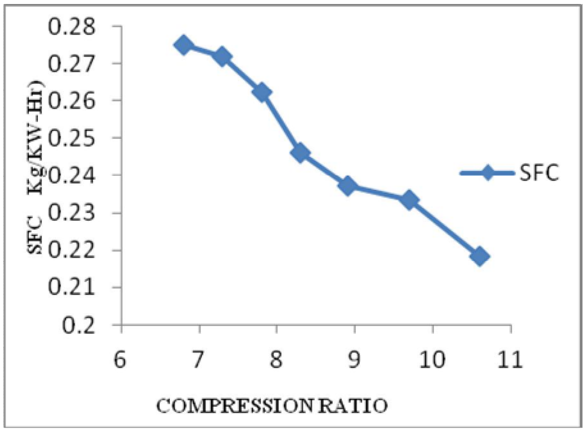


Fig: 14 specific fuel consumption
V_s compression ratio
Fuel: gasohol
Speed: 3500 rpm@full load

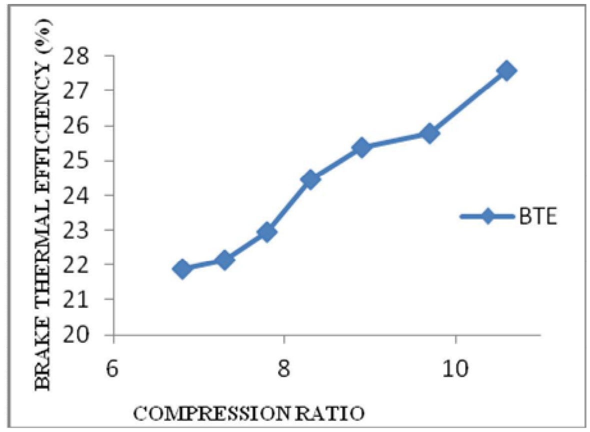


fig: 15 brake thermal efficiency
v_s compression ratio
fuel::gasohol
speed: 3500 rpm@full load

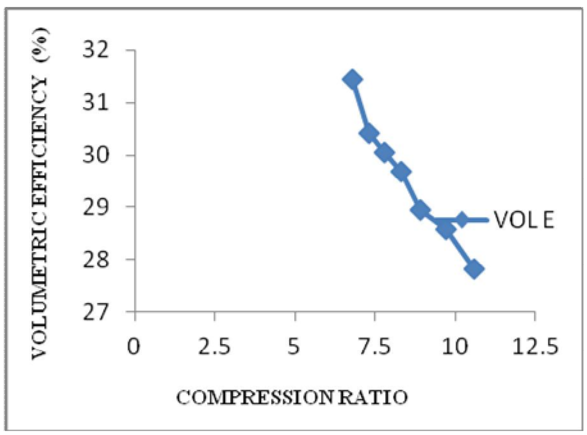


fig: 16 volumetric efficiency vs
compression ratio
fuel: gasohol; speed: 3500 rpm

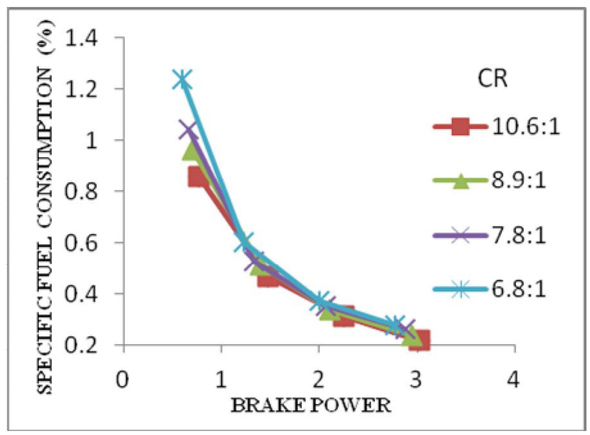


fig 17 specific fuel consumption v_s
brake power
fuel: gasohol speed; 3500 rpm @FULL LOAD

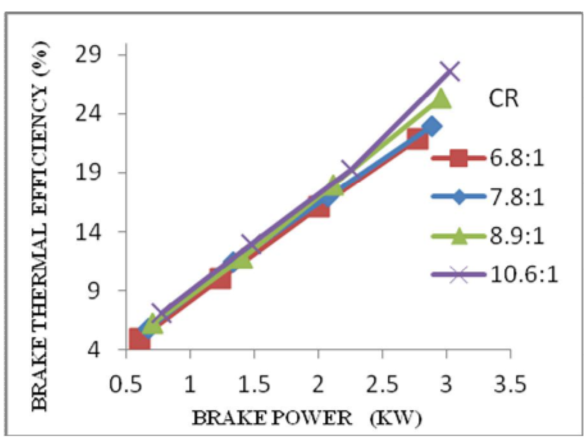


Fig: 18 BRAKE THERMAL EFFICIENCY VS
BRAKE POWER: FUEL: GASOHOL
SPEED: 3500 RPM

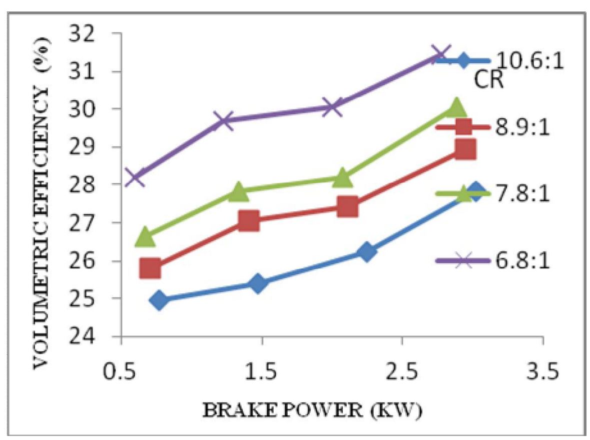


Fig: 19 VOLUMERIC EFFICIENCY V_S
BRAKE POWER: FUEL: GASOHOL
SPEED; 3500 RPM

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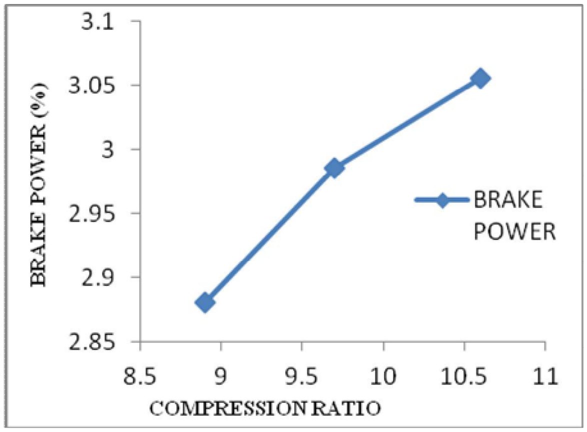

Fig: 20 brake power vs compression ratio
Speed: 3500@ full load

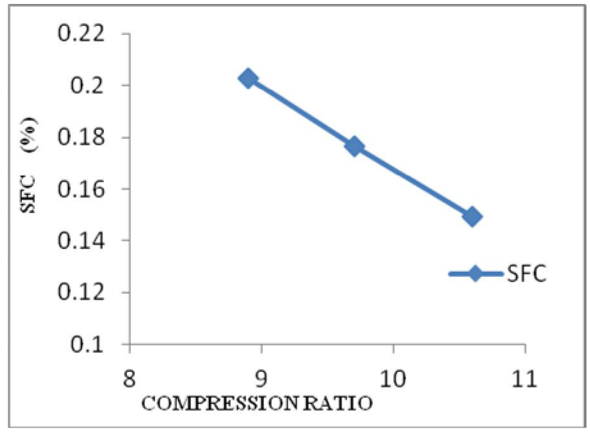

fig: 21 specific fuel consumption v_s fuel: dual fuel
compression ratio: fuel: dual fuel
SPEED: 3500@ FULL LOAD

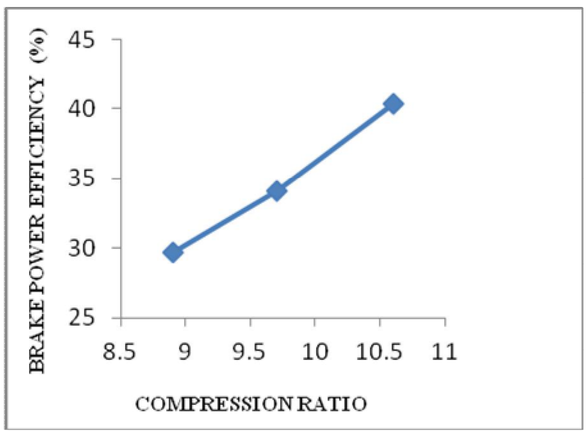

Fig: 22 BRAKE THERMAL EFFICIENCY
V_S COMPRESSION RATIO
FUEL: DUAL FUEL; SPPED:3500@FULL LOAD

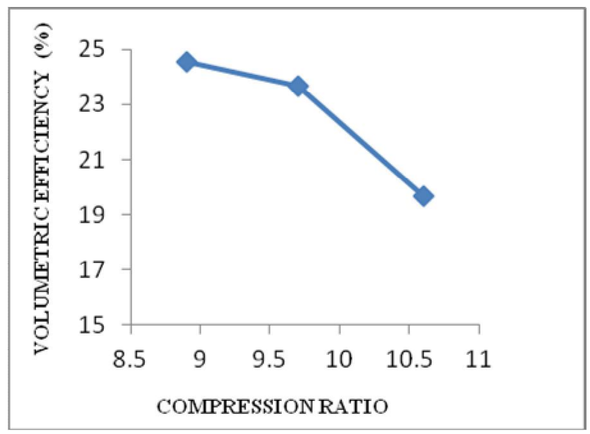

Fig: 23 VOLUMETRIC EFFICIENCY
V_S COMPRESSION RATIO
FUEL: DUAL FUEL; SPPED:3500@FULL LOAD

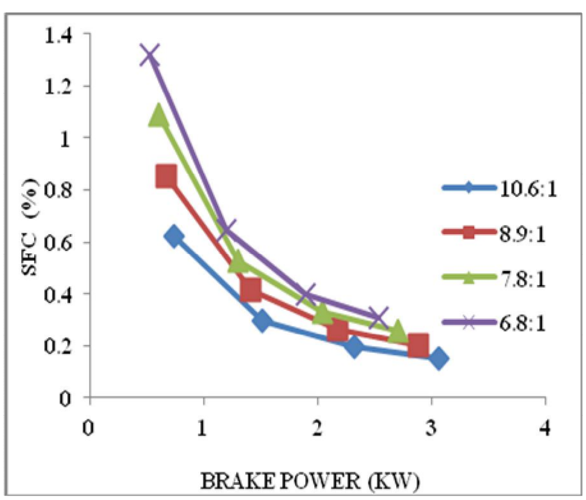

Fig: 24 SPECIFIC FUEL CONSUMPTION V_s
BRAKE POWER
FUEL: DUAL FUEL @SPEED: 3500 RPM

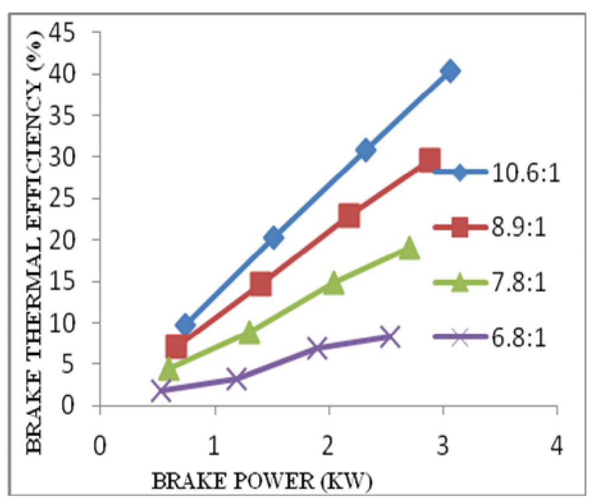

Fig:25 BRAKE THERMAL EFFICIENCYV_S
BRAKE POWER
FUEL: DUAL FUE; SPEED: 3500 RPM

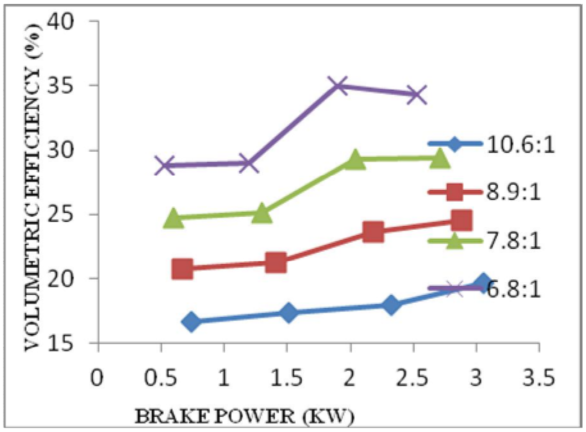

Fig: 26 VOLUMETRIC EFFICIENCY V_S
BRAKE POWER; FUEL: DUAL FUEL
SPEED: 3500 RPM

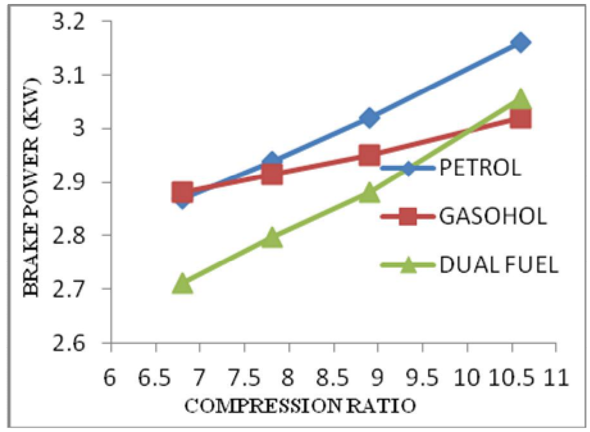

Fig: 27 BRAKE POWER V_S
COMPRESSION RATIO
SPEED:3500@FULL LOAD

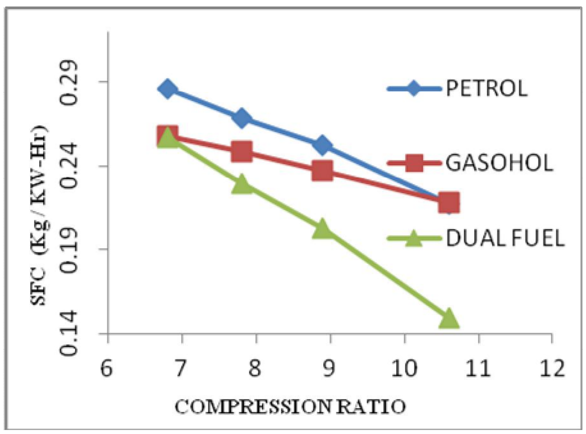

Fig: 28 SPECIFIC FUEL CONSUMPTION V_S
COMPRESSION RATIO
SPEED:3500@FULL LOAD

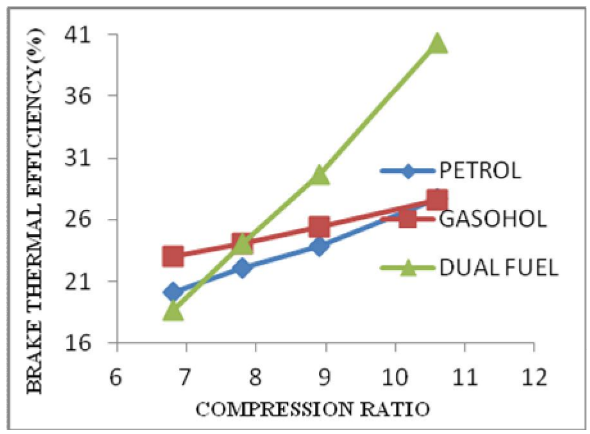

Fig: 29 BRAKE THERMAL EFFICIENCY V_S
COMPRESSION RATIO
SPEED:3500@FULL LOAD

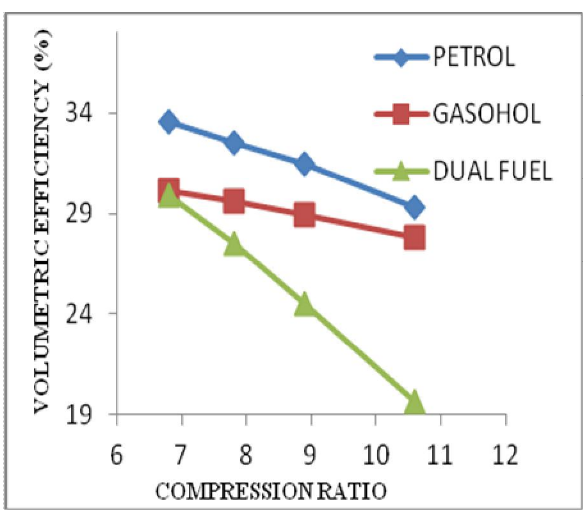

Fig: 30 VOLUMETRIC EFFICIENCY V_S
COMPRESSION RATIO
SPEED:3500@FULL LOAD

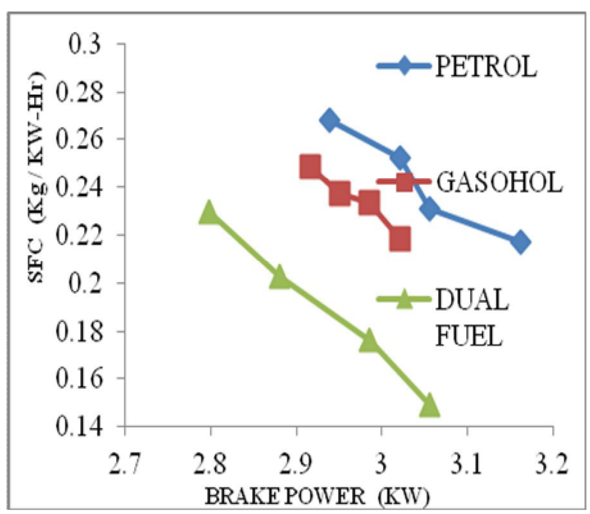

Fig: 31 SPECIFIC FUEL CONSUMPTION V_S
BRAKE POWER
SPEED: 3500 RPM @FULL LOAD

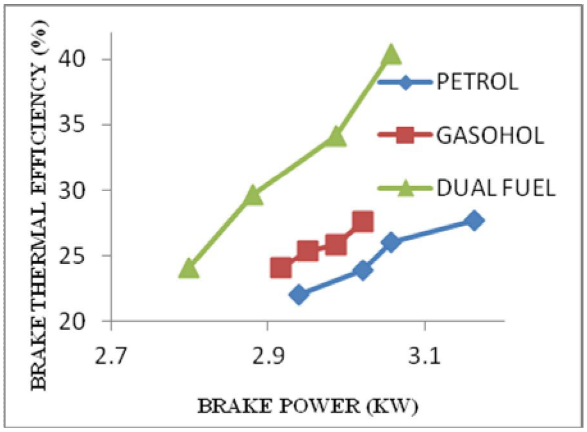

Fig: 32 BRAKE THERMAL EFFICIENCY V_S
BRAKE POWER
SPEED: 3500 RPM @FULL LOAD

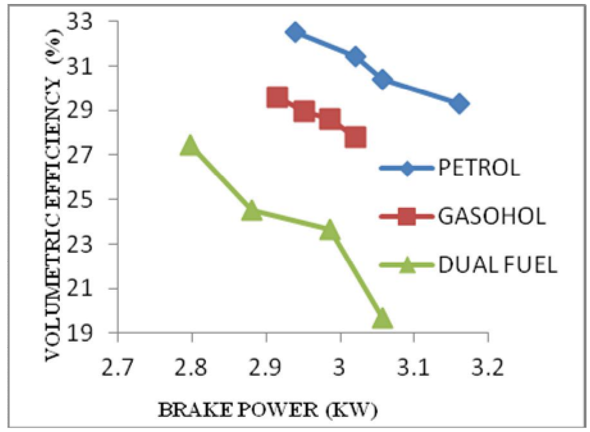

Fig: 33 VOLUMETRIC EFFICIENCY V_S
BRAKE POWER
SPEED: 3500 RPM @FULL LOAD

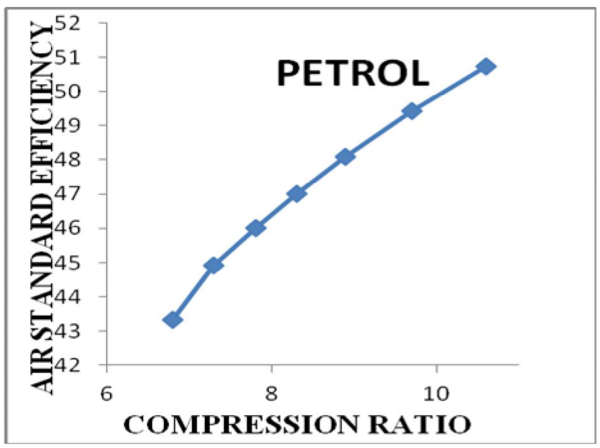

Fig: 34 AIR STANDARD EFFICIENCY V_S
COMPRESSION RATIO
FUEL: 100 % PETROL & SPEED: 3500RPM

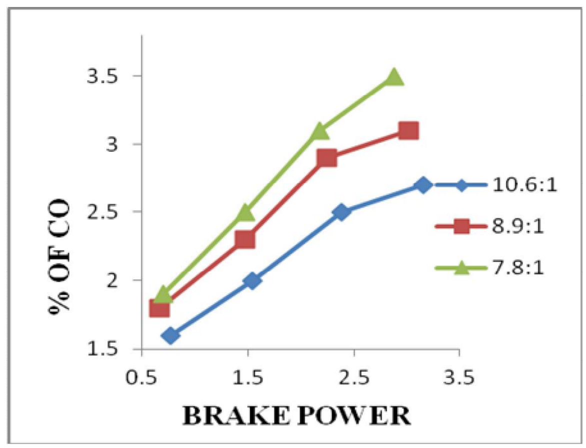

Fig: 35 % OF CARBON MONOXIDE V_S
BRAKE POWER
FUEL: 100 % PETROL;SPEED: 3500RPM

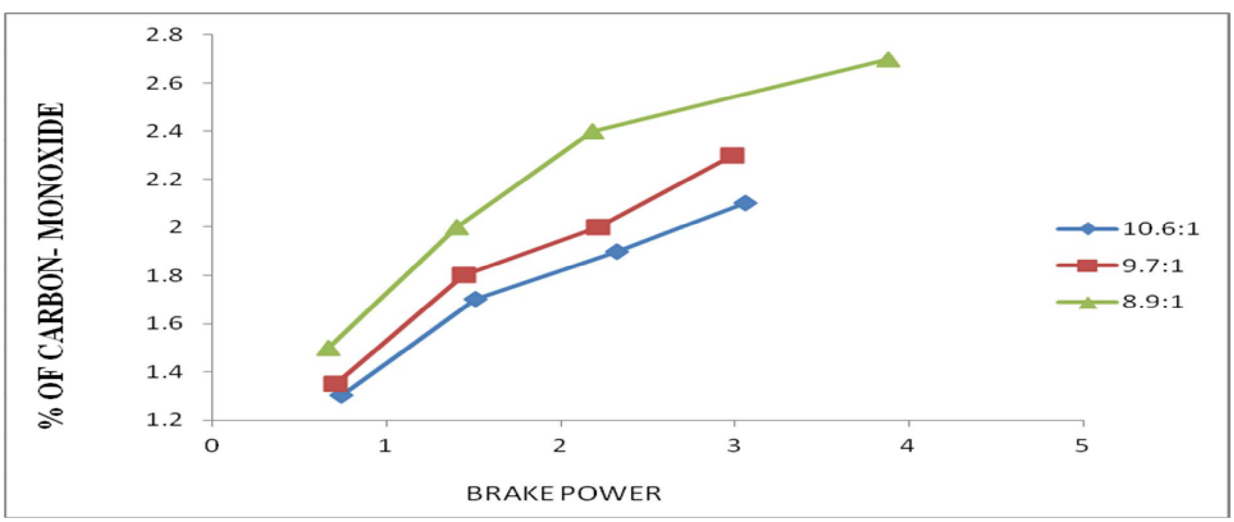

Fig: 36 Carbon Monoxide V_s Brake Power; Fuel: Dual Fuel@Speed:3500rpm

V. RESULTS & DISCUSSIONS

A. *The Following Results Were Obtained When The Above Said Engine is Tested on All The Three Fuel Compression*

1) Fig 2,13,20,27 shows that as the compression ratio is increased for the above mentioned engine, the output Brake Power increases. This may be due to the increase in compression pressures and higher temperatures resulting out of higher compression ratios which causes higher flame speeds, as well as higher rates of chemical reactions.
2) Fig 3,14,21,28 reveals that S.F.C. decreases with the increase in the compression ratio which may be due to the fact that the density of the charge increases with the compression ratio. This leads to more efficient combustion improving the fuel consumption characteristics.
3) Fig. 4,15,22,29 depicts that the Brake thermal efficiency increases with the increase in the compression Ratio which is because of the reason that high compression ratio results in increased temperature and pressures produced, together with the reduction in the quantity of residuals, which results in higher brake power output with lesser fuel consumption. Therefore the brake thermal efficiency of the modified engine was found increasing.
4) Fig. 5,16,23,30 shows that there is a considerable reduction in the volumetric efficiency with increase in the compression ratio. Since volumetric efficiency of an engine is limited by the maximum amount of air that can be taken during the suction stroke because only a certain amount of fuel can be burnt effectively with this quantity of air. Thus, the volumetric efficiency is an indication of the breathing ability of the engine. The cylinder pressures increase with the compression ratio and the expansion of the exhaust gases occupies a greater portion of the piston displacement thus reducing the space for incoming charge. In addition, these exhaust products tend to raise the temperature of the fresh charge reducing its density and effectively reducing the volumetric efficiency.
5) The air standard efficiency of the engine increases with the compression ratio (Ref. Fig.34) as there is more scope for expansion work, i.e. enables a large expansion ratio for the process.
6) In Fig. 31, which is a comparative figure, it is observed that for different compression ratios in the range 6.8: I to 10.6:1 when 10% Alcohol (Ethanol) is mixed with petrol (gasohol), the S.F.C. decreases, with the increase in the value of B.P. this trend is similar to the behaviour of the Engine with 100% petrol as fuel, as observed from Fig. 2. This indicates usage of gasohol as alternate fuel.
7) Fig. 32 which is a comparative figure, shows that the Brake thermal efficiency increases with increase in B.P. which is evident from its definition. For higher compression ratios higher values of brake thermal efficiency are achieved as discussed earlier (Point 3). The mild knocking observed in petrol at higher compression ratios (9.7:1 & 10.6:1) is due to the octane number limitations of the fuel. Because of this limitation, we can increase the compression ratio up to 9.0:1 without much difficulty. Hence, the variable compression ratio engine can be effectively used to find the highest useful compression ratio (H.U.C.R.) of various fuels.
8) Fig. 33 reveals that with the increase in the value of B.P., volumetric efficiency decreases and it is also observed that for higher values of B.P. the volumetric efficiency decrease is more predominate in the case of higher compression ratios. This may be due to the reasons discussed above in point 4.
9) Fig. 27 & 28 the variation of B.P. & SFC Vs compression ratio are plotted using dual fuel (50% petrol + 50% Alcohol i.e. Ethanol). The trend is the same as obtained in the above discussed figures, except the fact that the highest value of B.P. achieved in this case is slightly less than the highest value obtained when the fuel used was 100% petrol. It is also observed that S.F.C for 50% alcohol mixture is less than that of values obtained with 100% petrol as fuel. Despite the use of ethanol, which has anti-knock capability, the engine showed some mild knocking when tested at high compression ratio (values higher than 10: 1) with gasohol and dual fuels. This mild knocking could be attributed to the factors such as combustion chamber design, location and positioning of spark plug and octane number of petrol used in the testing.
10) At an operating compression ratio of 8.9:1, it can be observed that

A switch over from petrol to gasohol leads to 5% reduction in the specific fuel consumption whereas a switch over from petrol to dual-fuel leads to a 30% reduction in specific fuel consumption.

A switch over from petrol to gasohol reduces the power output by 3% whereas a switch over from petrol to dual-fuel reduces the power output by 5%.

(Ref. Fig. 27 & 28)

11) Fig. 35 & 36 shows that as the value of B.P. is increased for this modified engine, the percentage of carbon monoxide emissions increases but Fig. 36 shows that lesser carbon monoxide is emitted when dual fuels are used.

VI. CONCLUSIONS

A. Obtaining higher compression ratios by the above mentioned modifications of the cylinder head could be the most effective means of improving the efficiency of the engine and conserving the heat energy produced by the combustion of the fuel.

B. Moreover the reduction in the value of S.F.C with the increase in compression ratio indicates that the fuel efficiency of the engine is enhanced..

C. The maximum values of compression ratio in two-stroke spark ignition engines are restricted to the necessity of ensuring normal fuel combustion without detonation of self-ignition. However, at compression ratios above 10: 1, the risk of pre-ignition poses a serious threat to the extent that even in the absence of detonation, there is little value from the point of view of fuel economy in using high octane number fuels.

D. With the usage of alternative fuels becoming imperative, ethanol & methanol have evolved as a primary choice owing to their combustion friendly properties, availability, low cost and ease of handling. This performance analysis gives a clear indication of its capacity to supplement the existing conventional fuels to a great extent. Their expanded use as an automotive fuel can replace oil (imported), aid the agricultural economy by creating a stable market for its farm feed stocks and improve air quality by reduced emissions.

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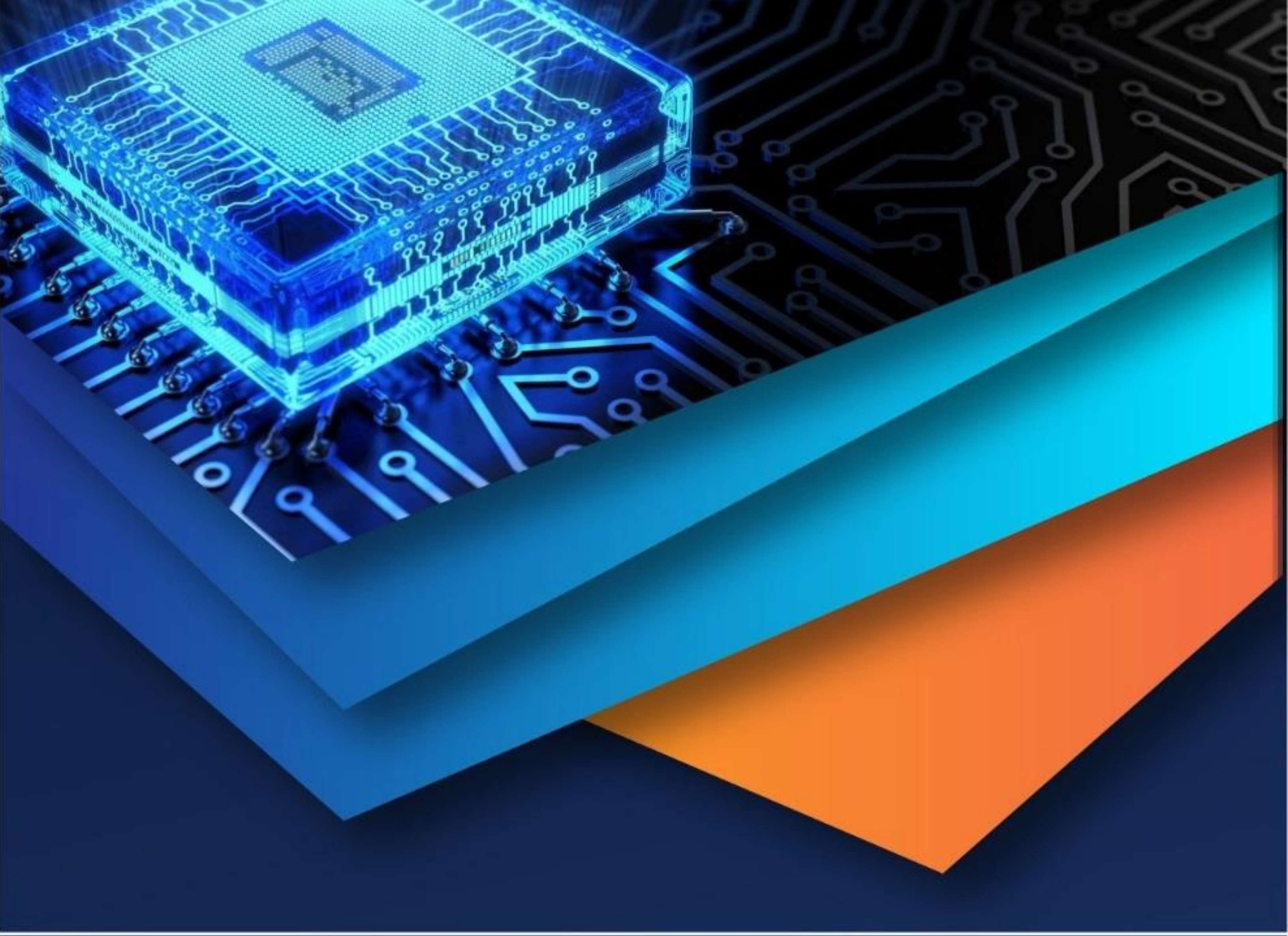

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