"Improvement in Performance and Reduction in Emission of Single Cylinder 4- Stroke SI Engine with Implementation of Swirl Adapter in Intake Manifold"

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ABSTRACT

Alcohol fuel have been used as a fuel for engine since 19th century. Among all available alcohols ethanol is known as most suitable renewable, bio-based and ecofriendly blend for gasoline engine. Ethanol can be manufactured from variable sources such as corn, maize, sugarcane and other bio waste material.
Adding ethanol to petrol in various percentages, such E2, E5, E10, E15 E20 and so on can reduces carbon monoxide emissions from the petrol and improves engine performance. It has evidence with various research work. In this investigation Solidworks Software designed and 3D Print manufactured Swirl Adapter is used along with ethanol blended gasoline to reduce exhaust emissions along with increasing engine performance.
Keywords: *Ethanol Blending, 3D Printing, Swirl Adapter*

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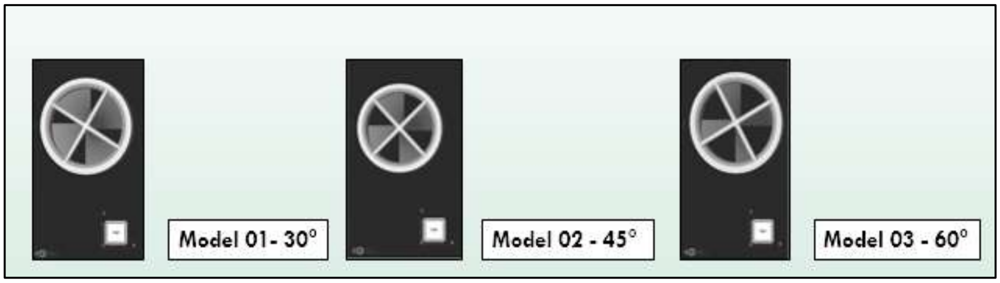
1 Introduction

Ethanol is a common by-product that comes from agricultural feedstock like corn, hemp, potato, etc. It can be used as a bio-fuel in Flexi-fuel vehicles. Ethanol is greener than gasoline because the corn and crop plantations absorb carbon dioxide from the atmosphere as they grow. While the fuel still releases CO2 when you burn it, the net increase is comparatively lower. However, ethanol is less efficient as a fuel. It has a lower energy content than energy-rich gasoline and diesel. As we know now a day's Gasoline fuel or crude oil is limited hence some alternate should obtained and by adding the ethanol into petrol (Gasoline) it provide good alternate fuel. Ethanol is not only renewable fuel but also colourless liquid with mild characteristics odors; ethanol can be produce from sugarcane, agricultural residues, woody bio-mass or waste. However, the simple process of chemically derived from ethylene or ethane. Ethanol is easily mixed other fuel like petrol or diesel and also it can be used as transportation fuel even in its original form. In the world now-a-days everyone looking forward for ethanol as not only renewable fuel but also it reduces carbon-monoxide (co) in the air and automatically it helps to reduces global warming.
But blending of ethanol with gasoline is found useful than using it alone as a fuel. Ethanol Blending Program (EBP) is launched in 2003 on pilot basis. The aim of EBP is to promote the use of alternative and environmental friendly fuels. Currently, only 10% of ethanol blend is permissible in India. However, in 2019, it only reached 5.6%. The statement issued by the ministry states "It [E20] will help in reducing emissions of carbon dioxide, hydrocarbons, etc. It will also help reduce the oil import bill, thereby saving foreign exchange and boosting energy security." The ministry said the vehicle manufacturer would define the percentage of ethanol in the blend for its vehicles.

Swirl is usually defined as organized rotation of the charge about the cylinder axis. Swirl is created by bringing the intake flow into the cylinder with an initial angular momentum. While some decay in swirl due to friction occurs during the engine cycle, intake generated swirl usually persists through the compression, combustion, and expansion process.
In engine design with bowl-in-piston combustion chambers, the rotation motion set up during intake is substantially modified during compression. Swirl is used in diesels and some stratified-charge engine concepts to promote more rapid mixing between the inducted air charge and the injected fuel. Swirl is also used to speed up the combustion process in spark-ignition engines. In two-stroke engines, it is used to improve scavenging. In some designs of pre-chamber engines, organized rotation about the pre-chamber axis is also called swirl. In the engine where swirl within the pre-combustion chamber is important, the flow into the pre-chamber during the compression process creates the rotating flow.

2. Basic



Definitions:

2.1 Swirl

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2.2 Swirl Production

There are actually two general ways of producing swirl during the induction process. Firstly, the flow is discharged into the cylinder tangentially towards the cylinder wall, where it is deflected sideways and downward in a swirling motion. In the other one, the swirl is largely generated within the inlet port: the flow is forced to rotate about the valve axis before it enters the cylinder. The former type of motion is achieved by forcing the flow distribution around the circumference of the inlet valve to be non-uniform, so that the inlet flow has a substantial net angular momentum about the cylinder axis. The directed port and the deflector wall port are two common ways of achieving this result. The directed port brings the flow toward the valve opening in the desired tangential direction. Its passage is straight, which due to other cylinder head requirements restricts the flow area and results in a relatively low discharge coefficient. The deflector wall port uses the inner side wall to force the flow preferentially through the outer periphery of the valve opening in a tangential direction. Since only one wall is used to obtain a directional effect, the port areas are less restrictive. Flow rotation about the cylinder axis can also be generated by masking off or shrouding part of the peripheral inlet valve open area. A mask or shroud is often used on the valve in research engines as changes can readily be made. In production engines, the added cost and weight, problems of distortion, the need to prevent valve rotation, and reduced volumetric efficiency make masking the valve an unattractive approach. The more practical alternative of building a mask on the cylinder head around part of the inlet valve periphery is used in production of spark-ignition engines to generate swirl. It can easily be incorporated in the cylinder head casting process.

2.3 Swirl Adapter

The swirl adapter is practically placed inside the intake port of the Test Engine Model. The number of helical guide vanes is 4 and angle of helix is set to 30 degree, 45 degree and 60 degree to force the air fuel mixture to the wall of the port to create swirl. The outside diameter is set to match inside surface area of the intake manifold. The adapter is easy to fit and can be removed after testing on Engine Test Setup. The movement of the swirl adapter is locked by the surface of the cylinder head so that it does not go into the combustion chamber. The design of the adapter is shown in Fig. 01 and specification are shown in table no. 01

Fig. No. 01

Model Name	**Swirl Adapter**
Software	Solidworks - 2016 x64 bit version
Specification	Diameter 45 mm
	Depth - 25 mm
	No. of Helix – 4 No's
	Helix Angle – 30,45 & 60 degree
	Material – Polylactic acid(PLA)

Table No. 01

3. Methodology:

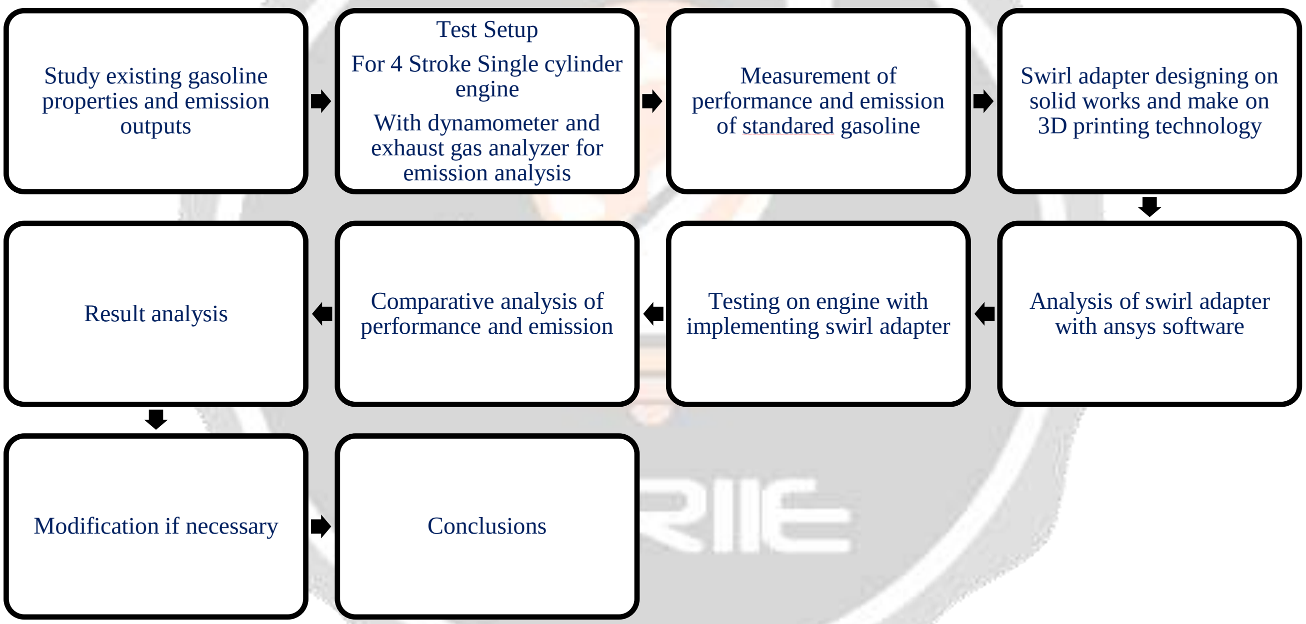


Table No 02

4. Test Setup:

The specification of the experimental test engine is presented in the Table No 02. The engine is shown in the figure 03. The tests began with starting the normal engine without inserting the 60 degree helical swirl adapter in the intake manifold operating with standard E5 blended gasoline fuel. After the gasoline engine attains the standard rpm (ranging 1200-1800) and the engine working temperature, no load, 5kg load and 10 kg was applied by regulating the load regulator. After the gasoline engine attained the working temperature at this load, the necessary engine and emission data were recorded.

After carrying out the experiments without swirl adapter, 60 degree helical swirl adapter are inserted in the inlet manifold and engine is operated with this implement. After the gasoline engine attains the standard rpm (ranging 1200-1800) and the engine working temperature, no load, 5kg load and 10 kg was applied by regulating the load regulator. After the gasoline engine attained the working temperature at this load, the necessary engine and emission data were recorded.

Now we got two test results – one is without swirl adapter and another result is with implementing swirl adapter. This both test results data were analyzed and conclude.

Fig No. 03

Product	Research Engine test setup 1 cylinder, 4 stroke, Multifuel VCR with open ECU for petrol mode (Computerized)
Engine	Type 1 cylinder, 4 stroke, water cooled, stroke 110 mm, bore 87.5 mm. Capacity 661 cc. Petrol mode: Power 3.5 KW @ 1500 rpm, Speed range 1200-1800 rpm, CR range 6:1-10:1
Software	"Enginesoft" Engine performance analysis software

Table No. 03

5. Results and Discussion

This segment presents the effect of swirl on gasoline engine operating with standard E5 (5% of Ethanol + 95% of gasoline) blend. For presentation of the test results the standard data were represented as graphs, with and without swirl adapter respectively.

5.1 Performance Parameters

IP, BP & FP

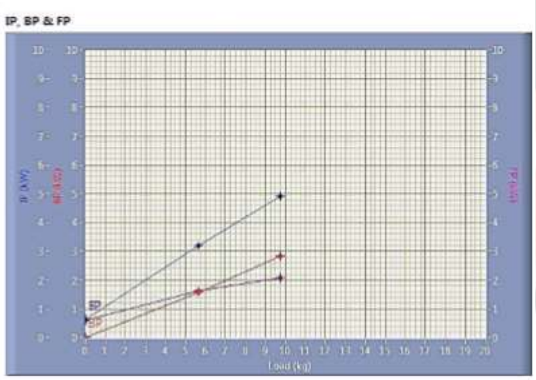
The graphs of IP, BP, & FP against applied loads, test graph without swirl adapter are plotted in graph no 01 and graph with swirl adapter models are plotted in graph no 02. It can be seen that BP goes on decreasing with application of swirl adapter when engine speed is increased from 1200 to 1800 rpm under 5kg and 10kg load. The most possible reason for reduction in brake power is increase in load on test engine. No significant change in indicated power shown. A slightly decrease in frictional power due to decrease in break power.

IMEP, BMEP & FMEP

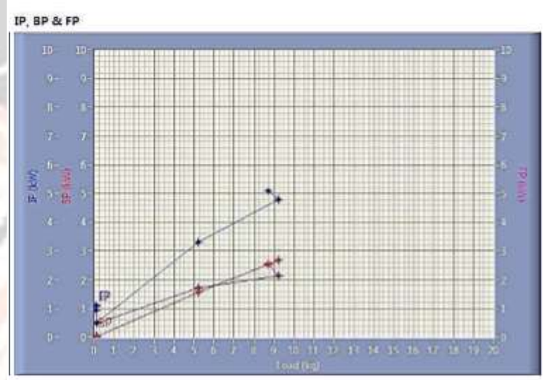
The graphs of IMEP, BMEP, & FMEP against applied loads, test graph without swirl adapter are plotted in graph no 03 and graph with swirl adapter models are plotted in graph no 04. It can be seen that the variation of BMEP for both test is a function of the engine speed. It can be seen that the BMEP increases in an almost linear function when engine speed increase to 1200 to 1800 rpm. Also higher IMEP is seen in swirl adapter application, also it remains same under loads 5 kg and 10 kg. BMEP increases consistently in all loads. It was observed that FMEP is higher under no load and remains same in 5 kg and 10 kg loads.

Torque, Mechanical & Volumetric efficiency

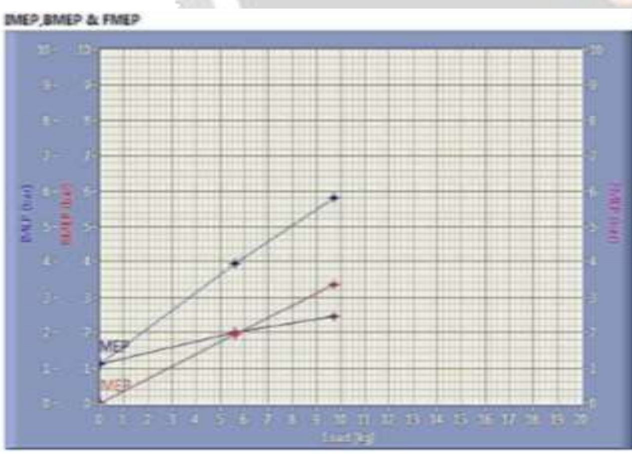
The graphs of Torque, Mechanical & Volumetric efficiency against applied loads, test graph without swirl adapter are plotted in graph no 05 and graph with swirl adapter models are plotted in graph no 06. The effects of the swirl on engine torque between 1200 to 1800 rpm engine speed are shown in above fig. at compression ratio of 10:1. More rapid homogenous charge induction is a possible reason for more complete combustion, thereby average increasing the torque. At full load condition where the mixture is a little rich, thereby increasing the power and hence increased mechanical efficiency.



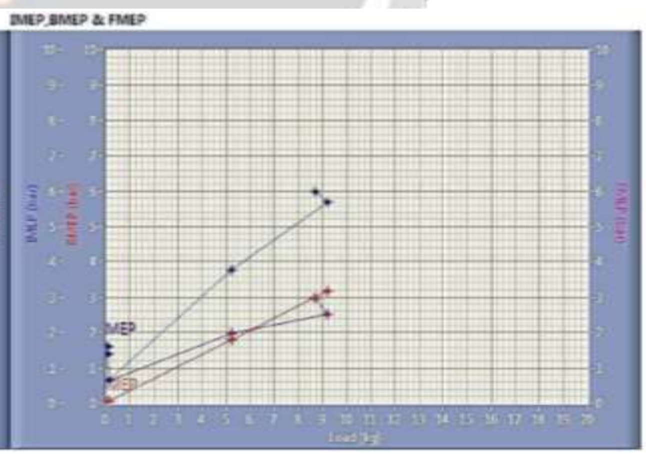
Graph NO. 01



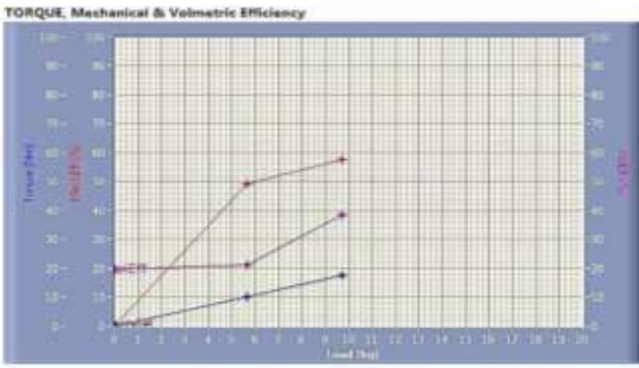
Graph NO. 02



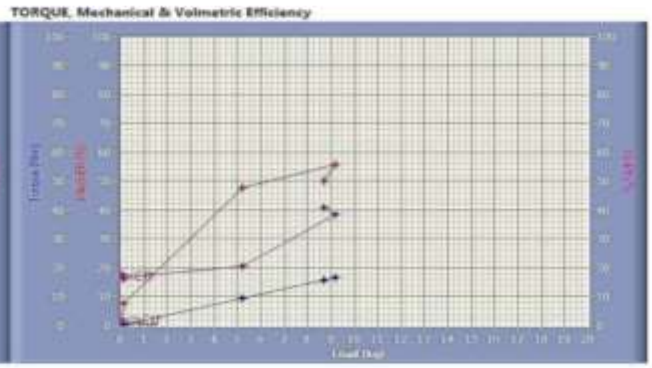
Graph NO. 03



Graph NO. 04



Graph NO. 05



Graph NO. 06

5.2 Emission Parameters:

This segment presents the effect on emission came out from engine test setup. Automotive exhaust gas analyzer is used for collecting data. And the specifications (Table no.04) and test results are shown in the tabulated form in table no. 05. It has been observed that 11.11 % reduction in HC, 17.85 % reduction in CO and 07.00 % reduction in CO_2.

Specification of Analyzer:

Product	NHA406EN Automotive Exhaust Gas Analyzer
Mode	Auto
Detects	HC/CO/CO2/NOx
Worm up time	10 min
Power supply	AC220V 50Hz

Table No. 04

Observation Table:

Sr. No	Parameter	Without swirl adapter	With swirl adapter
1	HC (ppm)	1400	**1260**
2	CO (%)	3.3	**2.9**
3	CO2 (%)	2.8	**2.7**

Table No. 05

6. Conclusions:

Experiments for performance & emission characteristics are conducted on a single cylinder, 4-stroke, SI engine at a compression ratio of 10. The following conclusions are drawn based on the engine operating on E5 blends with implementing Swirl Adapter device. All parameters are compared at no load, 5 kg load and 10 kg load with SI engine test bench.

Performance Conclusions:

i. It can be seen that BP goes on decreasing with application of swirl adapter when engine speed is increased from 1200 to 1800 rpm under 5kg and 10kg load.

ii. It can be seen that the variation of BMEP for both test is a function of the engine speed and BMEP increases in an almost linear function when engine speed increase to 1200 to 1800 rpm.

iii. Higher IMEP is seen in swirl adapter application, also it remains same under loads 5 kg and 10 kg. It was observed that FMEP is higher under no load and remains same in 5 kg and 10 kg loads.

iv. At full load condition where the mixture is a little rich, thereby increasing the power and hence increased mechanical efficiency.

Emission Conclusions:

i. A significant reduction (11.11%) of in HC emission was observed as result of leaning effect and additional fuel oxygen caused by the ethanol addition.

ii. The significant reduction is observed in carbon monoxide about 17.85 % because of improved combustion quality due more homogenous mixture and organized charge intake.

It was found that slight reduction in CO_2 emissions about 7% was observed as a result of the additional oxygen inducted.

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