

Influence of Turbulence Generated Air Swirl on Performance and Emission of SI Engine

¹Mr. Smit K. Mistry, ²Mrs. Vandana Y. Gajjar,

¹ME Student, ²Assistant Professor

¹I.C Engine & Automobile

¹Shree S'ad Vidya Mandal Institute of Technology, Bharuch-392001, Gujarat, INDIA.

smit.mistry378@gmail.com

Abstract— Turbulence can be pictured as a random motion in three dimensions with vortices of varying size superimposed on one another, and randomly distributed within the flow. An experimental investigation was carried out to understand the effects on performance and exhaust emissions. For this research work, A Honda single cylinder, 4 stroke, air-cooled, having 2 Brake Horse Power, naturally aspirated engine was used. Swirling Device was fitted in intake system of engine. Two Intake system configurations were experimentally checked. The emissions, volumetric efficiency and brake thermal efficiency were also compared by using Swirling Device, with existing intake system. The specific fuel consumption (SFC), volumetric efficiency and exhaust gas emission decreased, whereas brake thermal efficiency (BTE) increase within the test. All experiments were conducted at different load conditions using an electric alternator generator and the exhaust analysis was carried out with the help of multi gas exhaust emission meter. Swirling Device in Existing intake System shows decrease in exhaust emission and fuel consumptions at different load conditions

Index Terms— Swirl, SI Engine, Intake System, Turbulence.

I. INTRODUCTION

The uses of automobiles are increasing day by day. Hence efficient petrol engines need encouragement in future since they consume less fuel and significantly reduce polluting gases like carbon monoxide and Unburned Hydrocarbons. Increasing petrol consumption causes large outflow of foreign exchange. Environmental problems have prompted developing countries like India to search for suitable environmental friendly efficient engines or to find methods to reduce emissions from existing engines.

Reductions in fuel consumption can be achieved by a variety of methods, including alternative fuel, Thermal Barrier Coating (TBC), Turbocharging, reducing friction losses using high grade lubricators. Significant improvements must also be made to the efficiency of the internal combustion I.C engine that powers nearly all the world's vehicle engines. One promising technology for improving IC engine efficiency is modification of intake system to create turbulence. Turbulence increases homogeneity of air-fuel mixture in all strata of combustion chamber.

II. LITERATURE SURVEY

The turbulent flow in a spark ignition engine plays an important role in determining its combustion characteristics and thermal efficiency. In order to analyze the combustion process, the turbulent flow and its turbulence intensity must be studied. To study the turbulent flow as varying various factors in a combustion chamber of a spark ignition engine, the L-head with or without squish area are selected. The turbulent as varying flow on the piston speed, inlet flow velocity, and squish velocity are measured by using hot wire anemometer. To examine the characteristics of turbulent flow, the ensemble averaged mean velocity, turbulence intensity, turbulence intensity decrease ratio, production rate of turbulence intensity, production coefficient of turbulence intensity are analyzed.

Anurag Mani Tripathi, Parth Panchal, Vidhyadhar Chaudhari^[7] studied combustion modeling of single cylinder four stroke spark ignition engine having compression ratio of 9.2 and displacement of 124.7 cc using computation fluid dynamics for predicting turbulent flame speed by using premixed combustion model. The methane gas is considered as a fuel in this study. Prediction of turbulent flame speed at different equivalence ratio and engine speed is carried out using FLUENT software. Turbulent flame speed has increased from 7.1053 m/sec to 8.0386 m/sec for equivalence ratio of 0.6 to 1.2. Hence it is concluded that turbulent flame speed increases with increase in equivalence ratio. Turbulent flame speed has increased from 7.1053 m/sec to 8.0386 m/sec for engine speed of 1500 rpm to 3000 rpm. Hence it is concluded that turbulent flame speed increases with increase in engine speed.

A.K.M. Mohiuddin^[9] studied swirl is the rotational flow of charge within the cylinder about its axis. The engine used in this investigation is a basic Double Overhead Camshaft (DOHC) which has a capacity of 1597 cc and installed with a total of 16 valves developed by Malaysian car manufacturer PROTON. The swirl adapter is placed inside the intake port of the Engine. The Adapter angle is set to 300 to force the charge to bounce off the wall of the port to create swirl. The objective of this paper is to find the effect of swirl on the engine and to compare it with the normal turbulence mixing process. The swirl effect analysis is done by using the GT-SUITE which has a standard swirl flow embedded in the software. The effect is simulated on the GT-SUITE and it is found that the swirl affects the engine in reducing the fuel consumption and increasing the volumetric efficiency. The experimental result shows that the effect of swirl increases the power as well as torque in the idle and cruising speed conditions in comparison

with normal turbulence. But it decreases rapidly in the acceleration speed. This happens due to the inability of the swirl adapter to generate swirl at higher wind flow velocity during the higher throttle opening condition. The Brake Specific Fuel Consumption is considerably lower at the lower speed but increases above the normal aspirated graph as the speed goes above 3500 rpm.

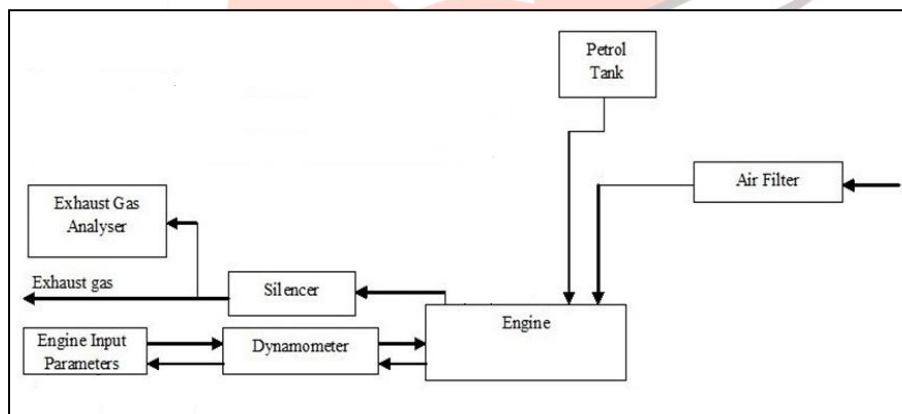
Kim J.S^[17] patented “Fluid Swirling Device” includes a pair of flat planar vanes securely mounted within a cylindrical housing. The vanes have a medial slit extending from the center to a longitudinal end of the vane. The vanes are interconnected at the slits so that they are in criss-cross positioning. The vanes are axially angled so that when positioned in an intake air duct the vanes impart a swirling motion to the air entering the engine providing more complete mixing of the air and fuel. These devices utilize vanes which are radially curved to attach both ends of the vanes to the same side of the cylindrical housing. However, the vane portions which are at the central area produce higher stresses at the attachment points due to the effects of leverage. In addition, the absence of a secure central connection and thereby lack of rigidity of the vanes at the central area results in deflection movement in response to the forces of the fluid flow. The movement of the vanes may adversely affect the fluid flow movement by setting up harmonics in the fluid.

Norbert G. Lyssy^[18] patented “Fixed Blade Turbulence Generator” is device and method for installing a device for improving the fuel/air mixture in internal combustion engines with or without a fuel injection system. An intermediate member operatively disposed between the engine intake manifold and the intake port comprises at least two helically twisted blades attached to the inner bore of an intake port opening in the intermediate member; these blades are angled in relation to the fuel/air flow path and twisted so as to impart a swirling to the fuel/air mixture. In fuel injected systems, the swirl is imparted to the air flow just prior to encountering the umbrella mist injected to the intake port by the fuel injector. The swirl mixing of the fuel/air improves engine performance, reduces pollutants, and increases gas mileage. Further, in fuel injection systems, the device reduces or eliminates the common occurrence of a burned intake valve caused by a clogged injector.

Kuang-Hsiung Lo and Su-Lin^[19] patented “Air Swirling Device”, which comprising a pipe member connected in between an air cleaner and an internal combustion engine. A plurality of swirl flow ducts spirally formed in the pipe member about an axis defined at a longitudinal center of the pipe member. A central flow duct axially formed in the pipe member and surrounded by the plurality of swirl flow ducts. Whereby upon suction by the engine, the inlet air flow will be swirled as guided by the plurality of swirl flow ducts to form a plurality of streams of swirling air flow to be combined with a central air flow through the central flow duct to form a forced-draft air flow to enter the engine. This swirling flow motion gives better mixing of air and fuel in combustion chamber.

Heru Prasanta Wijaya^[20] patented “The air-stirring blade” is provided that comprises a cylindrical body whose mid portion is provided with blade of such a construction that the inner side of the blade takes the form of stirred grooves with dip angle of about 10° to 80° or typically 30° with respect to vertical axis of the body. The outer side of the blade is of the same shape with the inner side thereof and there are four tangent lines between the blade and body forming a channel of cap-shaped cross section which is twisted along the body.

III. EXPERIMENTAL SETUP



The schematic diagram of experimental set up of 4-stroke SI engine is shown in Fig 1

Constant Speed Variable load engine testing method was used in experimental analysis. SI Engine was coupled with eddy dynamometer. There are various other measuring devices used in experimental analysis. Fluid-Expansion Temperature Measurement Devices, Techo meter, Multimeter, Air-Flow meter, Exhaust Gas Analyzer, etc were used to measure various parameters like temperature, engine speed (r.p.m), volt and current from dynamometer, Volume of intake air flow, exhaust emissions respectively.

Engine Specifications

No of cylinder	1
Engine Hp	2 BHP (1.49 KW)
Displacement	79.6 cc
Cooling	Air Cooled Engine
Bore & Stroke	48 mm x 44 mm
Compression Ratio	7:1

Experiments were done on various loads starting from no load to partial load and partial load to full load ranges. Constant engine speed was maintained during experiments. Speed of engine was maintained 2800.

IV. RESULT & DISCUSSION

Table I Result Table having Original Intake configuration

Sr. No.	Brake Power (kW)	Brake Thermal Effi. (%)	Indicated Thermal Effi. (%)	Vol. Effi. (%)
1	0.377	8.071	15.562	60.138
2	0.438	9.077	16.330	61.036
3	0.534	10.578	17.507	61.933
4	0.657	12.035	18.446	63.729
5	0.754	12.654	18.525	64.626
6	0.876	13.351	18.662	65.524
7	0.970	12.382	16.850	66.421
8	1.037	11.706	15.656	67.319

Table II Result Table having Swirling Device in Intake Manifold

Sr. No.	Brake Power (kW)	Brake Thermal Effi. (%)	Indicated Thermal Effi. (%)	Vol. Effi. (%)
1	0.377	8.560	14.915	59.241
2	0.438	9.428	15.455	59.241
3	0.534	11.171	17.025	60.138
4	0.657	13.066	18.610	61.036
5	0.754	14.189	19.456	62.831
6	0.876	15.290	20.177	63.729
7	0.970	13.698	17.652	64.626
8	1.037	13.177	16.734	64.626

As shown in above tables, following results were obtained from experimental analysis. Various graphs were plotted as given below at various brake power ranges.

GRAPHS

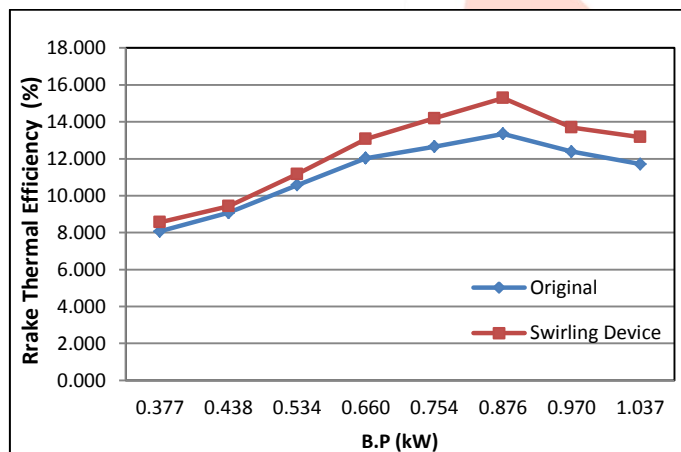


Fig 2 Brake Thermal efficiency VS Brake Power

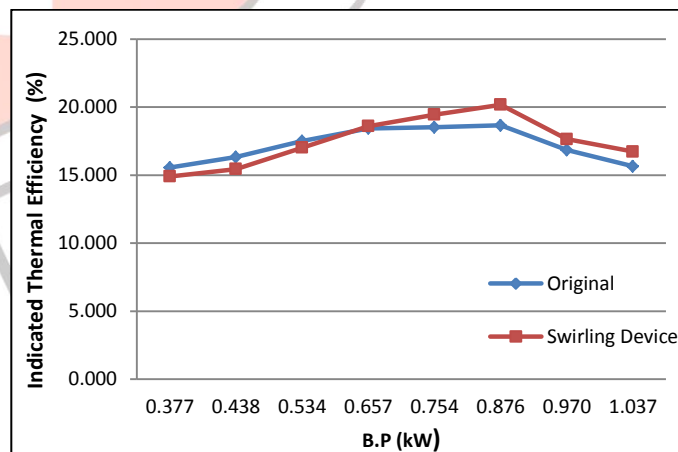


Fig 3 Indicated Thermal efficiency VS Brake Power

Fig 2 shows the relation between brake power and Brake Thermal Efficiency. As the brake power increases the Brake Thermal Efficiency also increases up to certain rated load and then decrease above that operating point. During the calculations and plotting graph Brake Thermal Efficiency on various loads was found higher while swirling device is attached in intake manifold of the system. Maximum increment in Brake Thermal Efficiency was found while operating engine in part load to full load range. Maximum percentage increase in Brake Thermal Efficiency obtained is 14.52 % at 0.876 kW brake power.

Fig 3 shows the relation between brake power and Indicated Thermal Efficiency. As the brake power increases the Indicated Thermal Efficiency also increases. During the calculations and plotting graph Indicated Thermal Efficiency on various loads was found lower and also higher while swirling device is attached in intake manifold of the system. Maximum increment in Indicated Thermal Efficiency was found while operating engine in part load to full load range. Maximum percentage increase in Indicated Thermal Efficiency obtained is 8.12 % at 0.876 kW brake power.

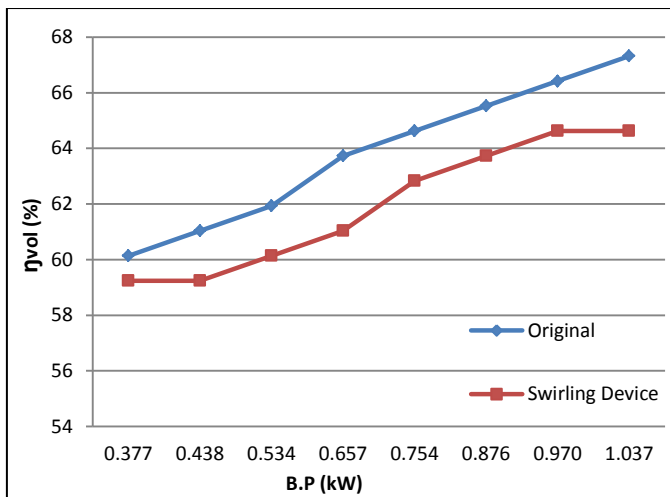


Fig 4 Volumetric efficiency versus Brake Power

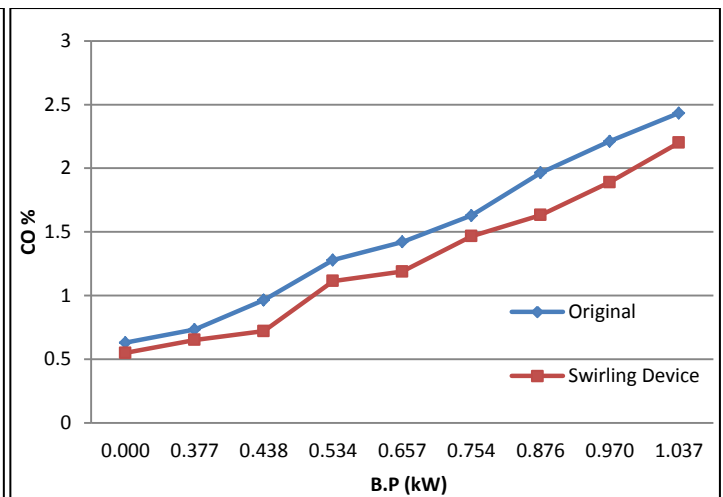


Fig 5 Carbon Monoxide versus Brake Power

Fig 4 shows the relation between brake power and Volumetric Efficiency. As the brake power increases the Volumetric Efficiency also increases. During the calculations and plotting graph Volumetric Efficiency on various loads was found lower while swirling device is attached in intake manifold of the system. Maximum reduction in Volumetric Efficiency was found while operating engine in part load to full load range. Maximum percentage decrease in Volumetric Efficiency obtained is 4.00 % at 1.037 kW brake power.

Fig 5 shows carbon monoxide emissions at different brake powers. As brake power increases carbon monoxide emissions also increase. Incompleteness of combustion is main reason for carbon monoxide emissions. While plotting graph, carbon monoxide emissions on various loads were found lower while swirling device is attached in intake manifold of the system. Maximum reduction in carbon monoxide emissions were found while operating engine in part load to full load range. Maximum percentage decrease in carbon monoxide emissions obtained is 16.90 % at 0.876 kW brake power.

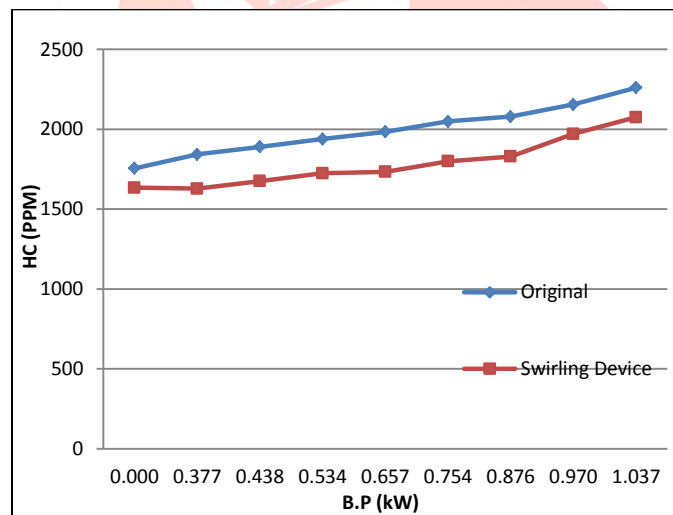


Fig 6 Unburned Hydrocarbons versus Brake Power

Fig 6 shows unburned hydrocarbon emissions at different brake powers. As brake power increases unburned hydrocarbon emissions also increase. Incompleteness of combustion is main reason for unburned hydrocarbon emissions. While plotting graph, unburned hydrocarbon emissions on various loads were found lower while swirling device is attached in intake manifold of the system. Maximum reduction in carbon monoxide emissions were found while operating engine in part load range. Maximum percentage decrease in unburned hydrocarbon emissions obtained is 12.01 % at 0.876 kW brake power.

V. CONCLUSION

An experimental study was conducted to evaluate various performance and emissions parameters of original configuration intake manifold and swirling device attached to intake manifold of engine. According to the results of experiments, Swirling device in intake manifold of engine has overall positive impact on performance and emission parameters. Maximum percentage decrease in Specific Fuel Consumption was 12.72 % at rated power with swirling device attached to intake manifold. Maximum percentage increase in Brake Thermal Efficiency was 14.52 % at rated power with swirling device attached to intake manifold. Maximum percentage increase in Indicated Thermal Efficiency obtained is 8.12 % at rated brake power with swirling device attached to intake manifold. Volumetric efficiency decrease, as there is obstruction to flow due to swirling device attached to intake manifold. But

maximum percentage decrease in Volumetric Efficiency obtained is 4.00 % at full brake power. Carbon monoxide and unburned hydrocarbon emissions are reduced in large amount. Maximum percentage decrease is 16.90 % and 12.01 % respectively. So, from above findings, it is concluded this Swirling Device improves performance and emission of SI engine.

ACKNOWLEDGMENT

The author would like to thank SVMIT Mechanical engineering department, Bharuch for their valuable input during course of investigation.

REFERENCES

- [1] C. Ramesh Kumar And G. Nagarajan “Investigation Of Flow During Intake Stroke Of A Single Cylinder Internal Combustion Engine” ARPN Journal of Engineering and Applied Sciences Vol. 7, February 2012, pp. 180-186
- [2] Sung Bin Han, Yon Jong Chung and Songyol Lee “Effect of Engine Variables on the Turbulent Flow of a Spark Ignition Engine” KSME Journal, Vol. 9, No.4, 1995 pp. 492-501
- [3] S. A. Sulaiman, S. H. M. Murad, I. Ibrahim And Z. A. Abdul Karim “Study Of Flow In Air-Intake System For A Single-Cylinder Go-Kart Engine” International Journal Of Automotive And Mechanical Engineering , Volume 1, Pp. 91-104, January-June 2010
- [4] Z. Barbouchi and J. Bessrouer “Turbulence study in the internal combustion engine” Journal of Engineering and Technology Research Vol.1 (9), pp. 194-202, December, 2009
- [5] Wendy H.K ,Kamaruzzaman Sopian, Zulkifli “ CFD Investigation of Fluid Flow and Turbulence Field Characteristics in a Four-Stroke Automotive Direct Injection Engine ” The Institution of Engineers, Malaysia (Vol. 69, No.1, March 2008
- [6] Stanislav Beroun, Pavel Brabec, Václav Dvořák “Compression Chamber Of An Si Engine With The Increasing Of The Turbulence” Research Centre of Engine and Automotive Engineering Liberec. 2006
- [7] Anurag Mani Tripathi, Parth Panchal, Vidhyadhar Chaudhari “ Turbulent Flame Speed Prediction For S.I. Engine Using Methane As Fuel” International Journal of Engineering Research and Applications Vol. 3(4), Jul-Aug 2013, pp.248-254
- [8] B.Murali Krishna and J.M.Mallikarjuna “Effect of Engine Speed on In-Cylinder Tumble Flows in a Motored Internal Combustion Engine” Journal of Applied Fluid Mechanics, Vol. 4, No. 1, pp. 1-14, 2011.
- [9] A.K.M.Mohiuddin “Investigation of the swirl effect on engine using designed swirl adapter” IIUM Engineering Journal, Special Issue, Mechanical Engineering, 2011 pp 197-205
- [10] Kihyung Lee, Choongsik Bae, Kernyong Kang “The effects of tumble and swirl flows on flame propagation in a four-valve S.I. engine” Applied Thermal Engineering 27 (2007) pp. 2122–2130
- [11] Kern Y. Kang And Je H. Baek “Turbulence Characteristics Of Tumble Flow In A Four-Valve Engine” Experimental Thermal And Fluid Science 18 (1998) Pp. 231-243
- [12] Turbulence Article - <http://www.sciencedaily.com/articles/t/turbulence.htm>
- [13] Internal Combustion Engines by R.K.Rajput Pg. No 201
- [14] Internal Combustion Engine Fundamentals by J.B.Heywood Pg No 307-339
- [15] Introduction To Internal Combustion Engines By Richard Stone Pg No 300-340
- [16] Engineering Fundamentals of the Internal Combustion Engine by Willard W. Pulkreback Pg No 206-213
- [17] Kim JS. Fluid swirling device, in United States Patent, USA Patent No-7,028,663 B1 2006
- [18] Lyssy NG. Fixed blade turbulence generator, United States Patent-US 4359997 B1, 1982
- [19] Kuang-hsiung Lo,Su-Lin, Air swirling device, United States Patent-US 20070169764 A1, 2007
- [20] Heru Prasanta Wijaya, Air-Stirring Blade For An Internal Combustion Engine, United States Patent No-US 6901907 B2, 2005