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SWIRL MEASURING EQUIPMENT FOR DIRECT INJECTION DIESEL ENGINE

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ABSTRACT

Traditional swirl-measurement equipment that adopts a paddle wheel is manually operated to measure the swirl intensity generated from a helical port in an engine cylinder head. The conventional equipment was modified to operate automatically using a pneumatic cylinder to adjust the valve lift. The automatic swirl-measuring equipment was operated in either steady or quasi-steady flow conditions. The surge tank pressure was controlled automatically opening or closing a bypass valve, when the swirl flow was measured in a steady flow whereas, when the swirl flow was in a quasi-steady flow, the surge tank pressure varied naturally adapting to the valve lift in the conditions of closing the bypass valve. Photo sensor is used to measure the paddle speed and differential manometer is used to measure, the pressure at nozzle.

Keywords: Automation, Paddle Wheel Method, Quasi-Steady Flow, Steady Flow, Swirl Flow

1. INTRODUCTION

In order to postpone the energy crisis, one method is to employ the alternative fuels and another is to reducing the fuel consumption of internal combustion engine (ICE). In addition, the global warming effect is an important concern as well. However, the design of an internal combustion engine is a complex. To enhance the efficiency of an engine it is important to optimize thermal efficiency which is obtained at the highest possible compression ratio. But if the compression ratio is too high, there is a chance to have knock, which should be avoided. A solution for this problem is to promote rapid combustion to reduce the time available for the self-ignition to occur. To promote rapid combustion, sufficient large-scale turbulence (kinetic energy) is needed at the end of the compression stroke because it will result in a better mixing process of air and fuel and it will also enhance flame development. However, too much turbulence leads to excessive heat transfer from the gases to the cylinder walls and may create problems of flame propagation. The engine should run at low speeds, in order to have low mechanical losses but the combustion should be fast, enabling good combustion efficiency. Therefore high turbulence should be produced prior to combustion within the cylinder so swirl was induced by the inlet channel within the cylinder head. One of the most important factors that affect diesel engine performance is the rapid mixing of air and fuel in the combustion chamber. The important parameters affecting the air–fuel mixing of diesel engines include fuel injection pressure, injection timing, the architecture of the combustion chamber and the swirl intensity in the combustion chamber. The swirl flow, which induces the intake air to move in a tangential direction during the compression stroke is usually generated in the engine cylinder head. The highly pressurized injected fuel is deflected and dispersed in tangential flow in combustion chamber, which assists the air-fuel mixture in combustion chamber. The swirl flow in the combustion chamber remains an important influencing factor of the mixture formation process in the direct-injection diesel engines. The nature of the swirl flow in an operating engine is extremely difficult to determine instead, steady flow tests are often used to characterize the swirl. There are several swirl-measurements techniques used by manufacturers are the paddle wheel and impulse method. In the paddle wheel method, the swirl of a charge in a cylinder can find be by calculating the ratio of rotary speed of the paddle in a swirl measurement apparatus, to the engine speed as calculated by measuring the intake air flow rate. For the swirl measurement, the air is sucked by a blower through the port, over the valve lift with an adjustable stroke, past the cylinder liner and the surge tank and finally to a differential flow meter. The valve lift of the cylinder head is controlled automatically. In order to measure swirl in steady state the surge tank pressure is maintained constant by adjusting the bypass valve to either opened or closed. The swirl measuring equipment was modified by closing the bypass valve and controlling the valve lifts which allows quasi-steady flow condition.

1.1 Need Of Measurement Of Swirl:

Fuel droplets cannot be injected and distributed uniformly throughout the combustion space. If air within the cylinder were motionless then there will not be enough oxygen in the burning cone and burning of fuel would be either slow or totally fail. As it would be surrounded by its own products of combustion. Hence an orderly and controlled movement must be imparted to the air, so that a continuous flow of fresh air is brought to rate burning droplet and the products of combustion swept away. The rotational motion of fluid mass within the engine cylinder is called as “swirl”.

- One of the important factor affecting the air-fuel mixture is the swirl intensity inside the combustion chamber.
- Swirl affects the mixing and distribution of charge in the cylinder of diesel engine.
- Low values of swirl are desirable in racing engines.
- High values of swirl are desirable in applications concerned with efficiency and emissions.

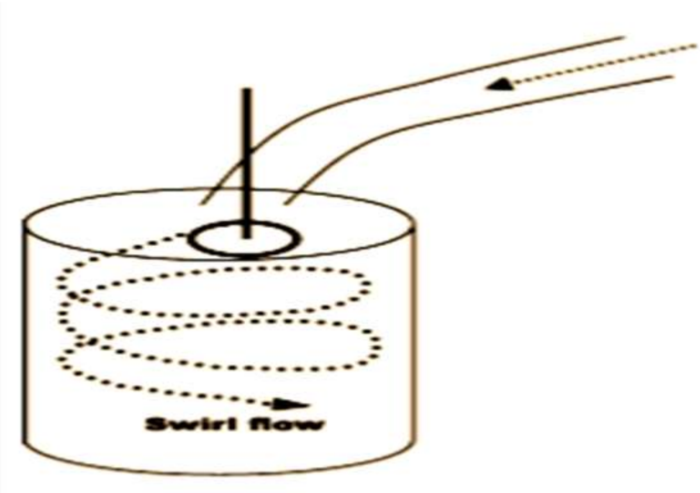

Fig.1: swirling motion in an engine cylinder

II. SWIRL MEASURING EQUIPMENT

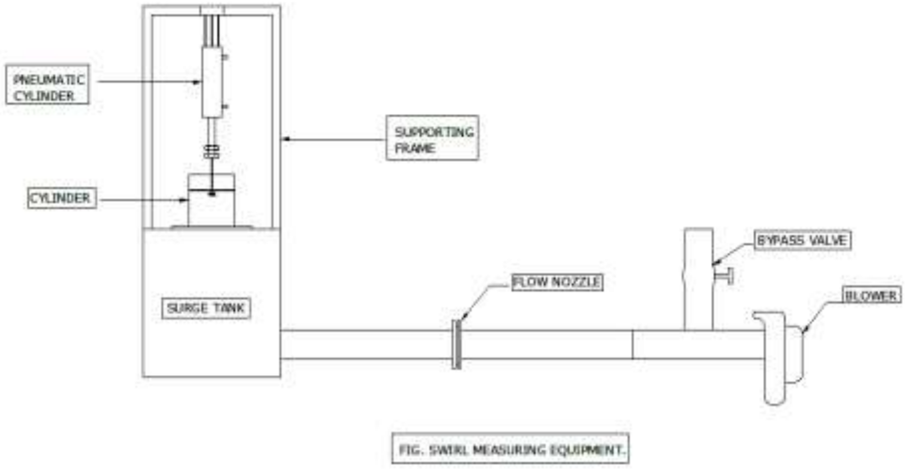

Fig.2: Block diagram of swirl measuring equipment experimental set up

2.1 Construction

The construction of swirl measuring equipment comprises of following parts:

- Surge tank :

The surge tank works as the vacuum creating tank in the swirl measuring equipment. The surge tank is structural member in equipment. The paddle wheel is mounted on the surge tank. The cylinder is also mounted on surface of surge tank. It is also connected to blower through pipe arrangement. The surge tank is used to create vacuum which is an essential requirement of the equipment.

- Cylinder and valve assembly:

The cylinder used in this experiment is Direct Injection Diesel Engine. The cylinder head is mounted on surge tank. The cylinder head consists of valve, actuating spring for the valve, cylinder of standard dimensions. These are one of the important parts in the equipment. The cylinder is made according to the large head engine dimensions.

- Paddle wheel:

The paddle wheel is mounted in the surge tank. The paddle wheel measures the intensity of air swirl. The paddle wheel is attached with sensor and counter for measuring the revolutions of paddle wheel. Paddle wheel is placed exactly below the cylinder head.

- Photo sensor and counter:

The photo sensor is a proximity switch which is kept near the paddle wheel for sensing the revolutions. The measured revolutions are displayed with the help of counter. The electrical input is given to the counter and displays the revolutions. The paddle wheel is equipped with a material which is used by the sensor to sense.

- Pipe assembly:

The one end of pipe is connected to the surge tank and other end is connected to the blower. The pipes are consists of flow nozzle in between them. There is arrangement for measuring the pressure difference before and after the orifice. Bypass valve is also connected with the pipe. The bypass valve is used to maintain constant pressure inside the surge tank.

- Blower:

The blower is connected with one end of the pipe. It creates vacuum inside the surge tank by sucking the air which is present inside of the Surge tank.

2.1 Working of Equipment

The swirl-measurement equipment developed in this study was traditional swirl-measurement equipment using several sensors for essential measurement of swirl. Two differential pressure manometers that measure the intake air flow rate and surge tank pressure, a photo sensor that counts the paddle revolutions, a spring that adjusts the valve lift, and manually operated bypass valve for adjusting surge tank pressure respectively in the traditional swirl-measurement equipment. For the measurement of the swirl ratio of the cylinder head, the Air is sucked by a blower through the port over a valve with an adjusted lift, past the cylinder liner and surge tank, and into the flow nozzle. The pressure drop is maintained uniformly at either 60mm H_2O or 40mm H_2O by controlling the bypass valve to be either opened or closed according to the position of the intake valve lift. A pulse pick-up transmits the paddle wheel rotation to an optical counter. The number of pulses for a given time interval are measured with counters, and the measurement provides the rotation speed ($N_{D)}$ of the paddle wheel. The pressure loss (ΔP) across the flow nozzle is measured with manometer. This procedure is repeated after adjusting the valve lift several times. The valve lift of the cylinder head is controlled by the spring. After the valve lift is adjusted to a large position, the bypass valve is controlled with the manually to obtain the target surge tank pressure. Therefore, the valve movement time interval between consecutive valve lifts cannot be constant when measuring the swirl in a steady flow. When the valve lift was increased continuously with a constant time interval with the bypass valve closed, the intake flow in the cylinder is in quasi-steady state. The valve lift in the quasi-steady flow is adjusted continuously. The spring that adjusts the valve lift. The reason why the spring is used to control the valve lift is due to its exact timing in controlling the interval between consecutive valve lifts. The observations required from the swirl measurement equipment were measured and recorded in a data, while the valve lift was adjusted continuously with a constant time interval. The surge tank pressures, the differential pressure at the flow nozzle are measured at each valve lift. The paddle rotating speed was calculated from cumulating the count of the photo sensor signals during a time interval of the adjustment between consecutive valve lifts.

III. FORMULAE USED

3.1 Mass Flow Rate

The intake air flow rate is measured using the flow nozzle. The pressure difference ΔP across the flow nozzle between the upstream and downstream is measured using the differential manometer in order to calculate the mass flow rate m˙ from :

$$m = C_d \times A \times \sqrt{2 \times \rho \times \Delta P} \quad (1)$$

Where,

m = mass flow rate (kg/s)

C_d = coefficient of discharge for flow nozzle = 0.95

A = area of flow nozzle (m^2)

ρ = density of air (kg/m^3)

ΔP = pressure difference (N/m^2)

The swirl estimates the rotation intensity of the cylinder charge, which is very important in the air–fuel mix in the combustion chamber. An equivalent engine speed N (rev/min) corresponding to the intake air flow rate measured with the flow nozzle is obtained by equating the axial flow velocity V_a to the mean piston speed V_m according to,

Axial flow velocity $(V_a) = \frac{m}{\rho A}$ (2)

Mean piston speed $(V_m) = \frac{SN}{30}$ (3)

Equivalent engine speed $(N) = \frac{30m}{\rho S A}$ (4)

3.2 Swirl Ratio

It is the ratio of rotation of paddle wheel placed inside the engine cylinder to the equivalent engine's speed.

$$\frac{Nd}{N} = \frac{Nd\rho A S}{m\ 30} \quad (5)$$

Where,

N_d =Speed of the paddle (rpm)

N = equivalent engine speed (rpm)

m= mass flow rate (kg/s)

A = area of piston (m^2)

S = engine stroke (mm)

3.3 Specifications of engine cylinder used for experiment

Engine model - R6126ZLCD

Type - 4 stroke, Direct Injection diesel engine

Bore - 135 mm

Stroke - 120 mm

Diameter of piston - 128 mm

3.4 Result Table for Steady state operation

SR NO.	VALVE LIFT (mm)	PADDLE WHEEL SPEED (RPM)	TANK PRESSURE (mm of water)	PRESSURE DIFFERENCE (ΔP in mm of water)	SWIRL NUMBER
1.	2	330	60	10	0.12
2.	4	600	60	20	0.16
3.	6	850	60	22	0.21
4.	8	952	60	24	0.23
5.	10	1012	60	18	0.28
6.	12	1210	60	16	0.36

The maximum swirl ratio is obtained at the maximum valve lift of the cylinder. The limit for the vertical displacement or movement of the valve is in between 2mm to 12 mm. Within this range the swirl ratio can be achieved at various valve lift. The swirl ratio is maximum at the valve lift of 12mm. The swirl ratio is dimensionless number and it is measured in terms of RPM.

IV. CONCLUSION

Swirl measuring equipment is easy to install and operate, resulting in low cost of ownership. Insertion of paddle wheel, lowers installation and maintenance cost. Equipment is developed to measure the swirl of an engine cylinder head. The equipment can be operated in either steady or quasi-steady flows. With the help of swirl number information, we can control the rate of combustion and emissions. With higher number of swirl, faster the combustion takes place, higher is the efficiency and lower the emissions. With the lower number of swirl, lower will be the rate of combustion, lower the efficiency and more will be emissions. We can adjust swirl number according to the application required and enhance the engine performance. For the future enhancement of the project automation is required. For the automation we can use PID controller transducers and stepped motors.

REFERENCES:

[1] Yuh-Yih Wu, Hsien-Chi Tsai, Manh-Cuong Nguyen, "Investigation of realizing SDI with high swirlcharge in a motorcycle engine" INTERNATIONAL JOURNAL OF ENERGY, Issue 2, Vol. 3, 2009

[2] K I Kim and C H Lee, "Development of a new swirl-measurement method for an engine cylinder head by automating the swirl-measuring process" Department of Automotive Engineering, Seoul National University of Technology, Proc. IMechE Vol. 223 Part D: J.

[3] Rajinder Kumar Son and Pranat Pal Dubey" Diesel engine air swirl measuements using AVL TEST RIG", International Journal Of Mechanical Engineering and Technology (IJMET), Volume 4, Issue 1, January-February (2013), pp. 79-91

[4] C. Crnojevic, F. Decool, P. Florent, "Swirl measurements in a motor cylinder" Experiments in Fluids 26 (1999) 542Ð548 (Springer-Verlag1999)

[5] M. L. Mathur and R. P. Sharma, Internal Combustion Engine(Dhanpat Rai Publications LTD. New Delhi)

[6] V. Ganesan, I.C. Engines(Tata McGraw-Hill publication LTD. New Delhi)