Development of Swirl Measurement Test Rig for Direct Injection Diesel Engine

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Abstract- *The rapid mixing of air fuel mixture is the important factor that affects the diesel engine performance. This mixing of air fuel assists by swirling flow of air in combustion chamber. In the paddle wheel method we are calculating swirl of a charge in a cylinder which is the ratio of rotary speed of the paddle wheel in a swirl measurement apparatus, to the engine speed as calculated by measuring the intake air flow rate. For the swirl measurement air is sucked by a blower through the port over a different valve lift and passes through cylinder which rotate paddle wheel. This rotation of paddle wheel is measured as rpm by using digital sensor meter. In order to measure swirl insteady state the surge tank pressure is maintained constant by adjusting the bypass valve. Digital pressure manometer is used to measure the pressure at venture.*

Keywords- Flow coefficient, Valve lift, Swirl ratio,Quasi-Steady Flow, Steady Flow

I. INTRODUCTION

Now days, the energy crisis becomes a major problem due to reduction of fuels.The global warming is the major issue due to emission of harmful exhaust gases from the vehicle exhaust. To optimize this energy crisis one need to focus on it. On the other hand there are many methods to take over this. One of the methods to reduce this energy crisis in fuels is to employ alternative fuel technology and another is to reduce the fuel consumption in engine. This can be achieved by complete burning of fuel in combustion chamber and which is obtained by swirl motion of air fuel mixture. The swirl is the rotation of air with fuel about cylinder axis and it is used in diesel engines to control air-fuel mixing. Several research studies related to swirl enhancement in IC engines reported that swirl facilitates mixing of air fuel mixture and increases the combustion rate[2-4]. The swirl flow in the combustion chamber is an important factor for the air fuel mixture formation 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. Thereare different techniques used to measure the swirl flow in cylinder[1]. Techniques like paddle wheel anemometer and torque meter are commonly used for steady state swirl measurement and also laser Doppler anemometry is used by many authors for study of in-cylinder bulk flow and turbulence structure [7].

II. EXPERIMENTAL SET UP

1. Construction

The construction of swirl measuring equipment includes of following parts:

A. Surge tank

The surge tank is essential equipment in test rig and it is used to create vacuum. The inlet of surge tank is connected to cylinder inlet and the outlet of surge tank is connected to blower through pipe assembly.The paddle wheel is attached before the inlet of surge tank and the cylinder is fixed on surface of surge tank.

B. Cylinder and valve assembly

These are the basic parts of the test rig. In this test rig the Direct Injection Diesel Engine cylinder is used. The cylinder head is fixed on cylinder liner. The cylinder head consists of valves, inlet port and valve actuating spring. The cylinder used is of standard dimensions. The cylinder liner dimensions are taken according to the engine head dimensions.

C. Paddle wheel

The paddle wheel is mounted on the cylindrical rod which is fixed on surge tank. This paddle wheel rotates when the air is sucked by blower and the RPM of paddle wheel is sensed by digital sensor. Paddle wheel is placed at distance of 1.2Dfrom the bottom surface of the cylinder head.

D. Pipe assembly

Pipe assembly is used to connect blower and surge tank. The one end of pipe is connected to the blower and other end is connected to the surge tank. The pipes are consists of venturimeter in between them. There is arrangement for measuring the pressure difference to calculate volume flow rate. Bypass valve is also attached with the pipe. The bypass valve is used to keep constant pressure inside the surge tank.

E. Blower

The blower is connected to surge tank with the help of pipe assembly. Blower is used to suck the air through inlet port of cylinder head and to maintain vacuum inside surge tank.

F. Digital RPM Sensor

Digital sensor is attached at bottom end of rod in which paddle wheel is fixed. The measured revolutions are displayed on screen as rpm. The paddle wheel is equipped with a cylindrical rod which is used by the sensor to sense.

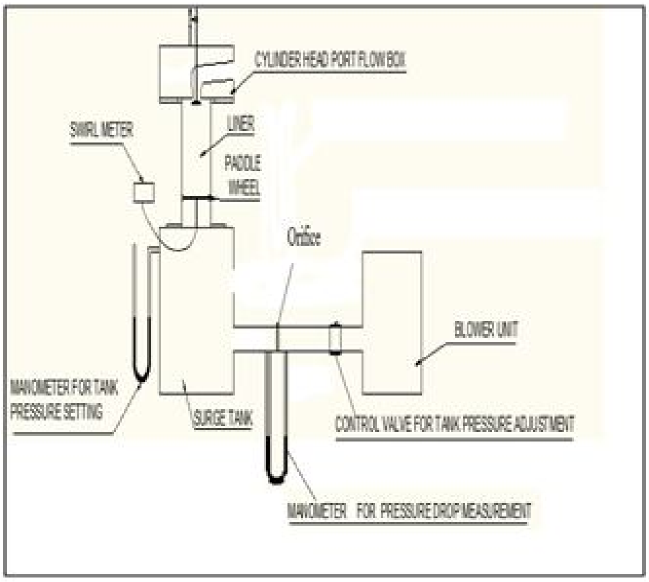

Fig.1 block diagram of swirl measuring experimental set up

2. WORKING OF TEST RIG

1. On the test rig mount the cylinder head liner plate which is used for assembling the cylinder head on test rig.
2. Put the cylinder head on that plate and fit the cylinder head on cylinder liner by C-clamp.
3. Rotate the spindle clockwise or anticlockwise to make it rest over valve such that valve spring comes under tension.
4. The valve was set at 1mm valve opening by giving a rotation to spindle.
5. Blower was started with control valve partially opened.
6. Maintain tank pressure drop 285 mm of WC. This pressure is maintained by adjusting blower speed.
7. Reading were taken for different valve lift and various reading were noted, namely, lift (L) in mm, Pressure difference at venturi and paddle wheel speed (Nd) in rpm.

Fig. 2Experimental setup used for experimentation

III.TECHNIQUE USED FOR MEASURING SWIRL

For measuring the rotation of the cylinder charge, a paddle wheel anemometer was developed and the method of measurement using the steady flow test. For the measurement of swirl air is sucked in by a test bed blower through the port and cylinder liner over the valve with adjustable lift. The pressure drop between the atmosphere and the tank is measured by u-tube manometer which is equal to the pressure loss in the inlet port and inlet valve as there is no pressure loss in cylinder liner. The rotation of the air sucked into the cylinder liner is measured by the paddle wheel speed which is sensed by digital sensor. The air sucked by blower passes through surge tank and finally through pipe assembly. To measure the volume flow rate the pressure difference is measured by digital pressure manometer at venturi. A paddle wheel is normally mounted at a distance equal to 1 to 1.75 times bore diameter. The length of paddle wheel was kept as 0.917 bore diameter whereas height of paddle wheel was 0.167bore diameter. The thickness of vanes was keep 1.5mm [5].

IV. MATHEMATICAL FORMULAE

1. Mass flow rate

The intake air flow rate is measured using the venturimeter. The pressure difference ΔP across the Venturi between the upstream and downstream is measured using the digital manometer. The mass flow rate m is

$$M_a = C_d * A * \sqrt{2 * \Delta P/\rho}$$

$$M_{th} = C_d * A_v * \sqrt{2 * g * h}$$

Where
M_a = actual mass flow rate (kg/s)
M_{th}= theoretical mass flow rate(kg/s)
C_d = coefficient of discharge for flow nozzle = 0.92
A = area of throat (m^2)
A_v= Valve seat area (m^2)
ρ = density of air (kg/m^3)
h= pressure difference at tank (N/m^2)
ΔP = pressure difference at Venturi
Axial flow velocity-Axial flow velocity is the flow velocity of air along the axis of cylinder. It depends on actual mass flow rate

$$V_a = \frac{m_a}{\rho A}$$

Equivalent engine speed – It is used as a measure ofrotational speedof a mechanical component of engine.

$$N = \frac{30 m_a}{\rho S A}$$

Mean piston speed –The mean piston speed is the average speed of the piston in a reciprocating engine. It is a function of strokeand RPM

$$V_m = \frac{S.N}{30}$$

3. Flow Coefficient (Cf)

Coefficient of discharge is (Flow Coefficient) the ratio of actual flow rate to theoretical discharge. It shows the relationship between the pressure drop across an orifice, valve or other assembly and the corresponding flow rate.

$$Cf = \frac{m_a}{m_{th}}$$

3. Swirl Ratio

It is a dimensionless parameter to quantify the rotational motion within the cylinder.It is defined in two different ways

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

$$\frac{N_d}{N} = \frac{N_d.\rho.S.A}{m.30}$$

Where,
N_d=Speed of the paddle (rpm)
N = equivalent engine speed (rpm)
S = engine stroke (mm)

4. Specifications of engine cylinder used in this experiment

Type - 4 stroke, Direct Injection diesel engine
Bore - 94 mm
Stroke - 120 mm
Compression ratio-16:1
Displacement – 4788 cc
Inner Valve Diameter – 35m

5. Result Table for Steady state operation

Table 1: Results for steady state operation

Sr. No.	Valve Lift (mm)	Paddle wheel rotation (rpm)	Pressure at venturi (Pa)	SwirlNumber	Flow coefficient
1	1	0	12	0	0.278
2	2	0	15	0	0.311
3	3	0	19	0	0.350
4	4	334	21	0.460	0.368
5	5	464	23	0.610	0.385
6	6	574	24	0.739	0.394
7	7	610	27	0.741	0.417
8	8	682	31	0.773	0.447
9	9	833	38	0.853	0.495
10	10	947	41	0.933	0.515
11	11	1027	47	0.945	0.551
12	12	1190	61	0.962	0.628
13	13	1294	65	1.013	0.648

V.CONCLUSION

The equipment used for measuring swirl of charge is easy to handle. It can be calculated in either steady or quasi static flow. Rate of combustion and emission can be controlled by varying the swirl no. of flow. For high rate of combustion we can increase the swirl no. which gives higher efficiency and lower the emission. For low combustion rate we can decrease swirl no. which gives lower efficiency and higher emission. With higher number of swirl, faster the combustion takes place, higher is the efficiency and lowers the emissions. With the lower number of swirl, lower will be the rate of combustion, lower the efficiency and more will be emissions.

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