

Cold Flow Simulation for an IC Engine with Different Lengths of Connecting Rod

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Abstract: During the combustion period of an internal combustion engine, rotating flow or swirl can considerably increase the intensity of turbulence of the air-fuel mixture. This, in turn, can lead to increase in thermal efficiency. By varying the connecting rod length, swirl can be varied. Meaningful curves for swirl ratio are obtained by running cold flow simulations in ANSYS FLUENT for different connecting rod lengths and for different engine speeds (high and low). Dynamic air motion is visualized and velocity magnitude is plotted for the different crank angle from 0° to 720° for the ANSYS IC Engine module. Finally, swirl ratios obtained for different lengths of connecting rods for an engine speed are compared.

Keywords: ANSYS FLUENT, Cold Flow Simulation, Connecting rod length, Swirl

I. Introduction

There is a huge need for developing eco-friendly and economically feasible automobiles and simultaneously meet the demands for high performance. This requires constant innovation and new engine conceptions in order to keep up with the growing demands of the 21st century. The development of fuel-air mixture in the cylinder affects the performance, efficiency and emission formation of SI engines. To improve combustion, performance, and efficiency of the engine, the fluid flow dynamics play a vital role in the air-fuel mixture formation. The air motion inside the cylinder is affected mainly by manifold design, inlet and exhaust valve profile and combustion chamber setup. Due to high velocities involved, all flows into, out of and within cylinders are turbulent. Because of turbulence, there is a rise in combustion rates, increased heat transfer, evaporation and mixing. The turbulence throughout the combustion cycle considerably depends on the airflow (rotating) in the cylinder (Swirl and Tumble). Thus increase in turbulence (as a function of swirl) may lead to a decrease in the burning period and an increase in the thermal efficiency. Swirl (rotational motion about an axis parallel to the axis of the cylinder) and tumble (rotational motion about an axis perpendicular to the cylinder axis) escalate flame propagation speed, reduce cyclical variations, and expand the lean limit, though excessive rotational motion can have harmful effects on the flow resistance of the induction system and on heat transfer and efficiency. [1-3].

The aforementioned problems are difficult to solve by the experimental techniques due to the severe conditions inside an IC Engine (High Temperature and Pressure). Alternatively, computer simulations (Computational Fluid Dynamics, CFD) enable us to carry out iterative parameter studies with well-defined boundary conditions to test various configurations. Examination of common fluid flow patterns from CFD simulations, namely, swirl and tumble motion typical of automotive engines, and their variation with the length of connecting rod is done. The results of the analysis are used to inspect the homogeneousness of the air-fuel mixture structure for improved combustion process and enhanced engine performance. IC engine module of the ANSYS is used to carry out the simulations. Mean effective pressure is directly proportional to the swirl ratio induced, thus higher the swirl ratio better is the combustion [4-5].

The following are the objectives of the paper

- 1) To study the air motion inside the cylinder for different lengths of connecting rod at two different RPMs.
- 2) To compare the swirl ratio for the above air motion study.

II. Methodology

2.1 Cold Flow Analysis

In cold flow analysis, the engine is modeled without taking into consideration the chemical reactions occurring in the combustion stage. Only the airflow inside the engine is modeled and configured. The objective is to capture the air movement by studying the interface of constantly varying geometry with the dynamics of the fluid during the intake process. This enables us to determine the characteristics of airflow (swirl and tumble) in the cylinder as the intake and exhaust valve open and close at their specified time intervals.

High turbulence intensity aids rapid flame propagation. It also helps in better combustion during the power stroke. A homogeneous and high turbulent airflow is very critical to maintain correct fuel/air ratio.

2.2 Geometry

Finite Element analysis was used to determine the characteristics of the IC Engine. The model was imported into Finite Element preprocessing tool ANSYS MESH for the meshing analysis. The model was then imported into Finite Element solver tool ANSYS FLUENT for post-processing the results.

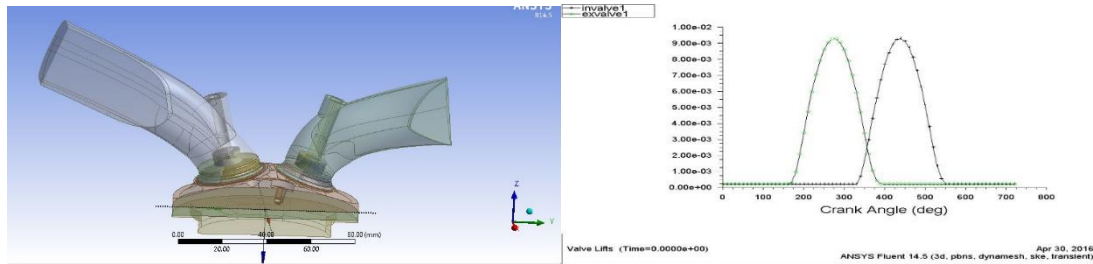


Fig 1.The geometry of the engine Fig 2.Valve Lift Profile in the engine used

2.3 Meshing

Meshing is done using the decomposed geometry (Each part of the geometry is well defined). IC Engine meshing tool helps in minimizing the effort required to generate a mesh for the IC Engine solver. Nameselections are created in the decomposed file, which are used to identify different zones. This helps in creating essential mesh controls. Decomposition partitions a volume into further smaller volumes. These are then meshed individually. Dynamic meshing is used as the combustion chamber expands and compresses with change in crank angle.

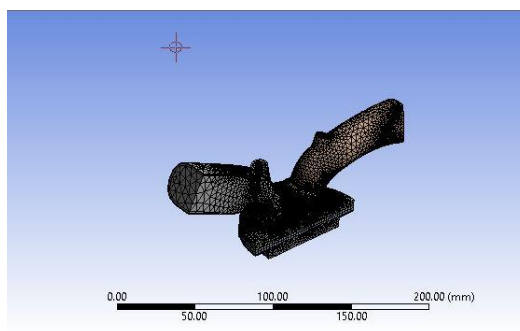


Fig 3.Meshed Geometry

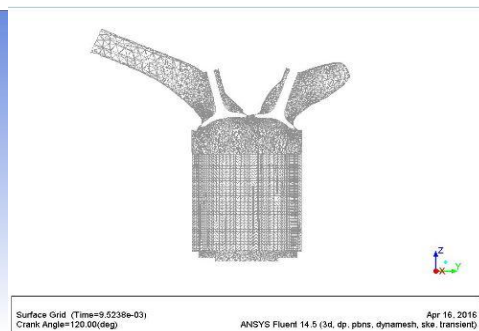


Fig 4. Dynamic Meshing

2.4 Simulation

Simulation is carried out using parameter valve lift. Dynamic motion is visualized and velocity magnitude is plotted for crank angle starting from 0° to 720°. All the necessary inputs required to simulate the engine were input and the simulation was carried out. Result revealed the swirl and tumble regions of fluid and piston layer. Swirl, X-axis tumble, Y-axis tumble and moment of inertia were written in a running directory in text file [6-7].

There is a small range of connecting rod to crank radius ratios, as the rod angle should not encourage excessive friction as it decreases the thermal efficiency. The optimum ratio lies between 1.4 and 2.2. The crank radius chosen for the given engine is 48mm. The simulation was carried out for four different connecting rod lengths over two engine speeds- low speed (2100 rpm) and high speed (5000 rpm). The connecting rod lengths taken were 150 mm, 170 mm, 180 mm, and 200 mm. Four cases of connecting rod lengths were evaluated over each engine speed keeping the crank radius constant [8].

The engine specifications used are given below in the table.

Table 1.Specifications of the engine used

S.No.	Parts	Dimensions
1.	Connecting Rod Lengths	a) 150 mm b) 170 mm c) 180 mm d) 200 mm
2.	Engine Speed	a) 2100 rpm (low speed) b) 5000 rpm (high speed)
3.	Crank radius	48mm
4.	Valve lift	0.2 Mm

- a. Simulation of every time step consisted of 1° crank angle and thus 720 time steps were set for the calculation to simulate one complete cycle of IC engine.
- b. Swirl ratios were plotted by visualizing dynamic motion starting from crank angle 0° to 720°
- c. The simulation results are plotted as a graph between swirl ratio and crank angle.

III. Results And Discussions

Fig 5 shows the variation of exhaust velocities for connecting rod lengths of 150mm, 170mm, 180mm & 200mm at 2100 rpm and 5000 rpm. Fig 5.a shows maximum exhaust velocity for a given connecting rod length at 2100 rpm. Maximum exhaust velocity decreases as the connecting rod length is increased. The values of maximum exhaust velocity for a given connecting rod length at 2100 rpm have been tabulated in Table 2. Fig 5.b shows maximum exhaust velocity for a given connecting rod length at 5000 rpm. The maximum exhaust velocity does not vary much for a given connecting rod length as in the above case. The values of maximum exhaust velocity for a given connecting rod length at 5000 rpm have been tabulated in Table 3.

Table 2. Comparison of Exhaust velocities at 2100 rpm

Connecting Rod Length (mm)	Crank Angle (degrees)	Maximum Exhaust Velocity (m/s)
150	268	180
170	268	165
180	296.50	150
200	300	128

Table 3. Comparison of Exhaust velocities at 5000 rpm

Connecting Rod Length (mm)	Crank Angle (degrees)	Maximum Exhaust Velocity (m/s)
150	320	375
170	320	373
180	320	375
200	320	371

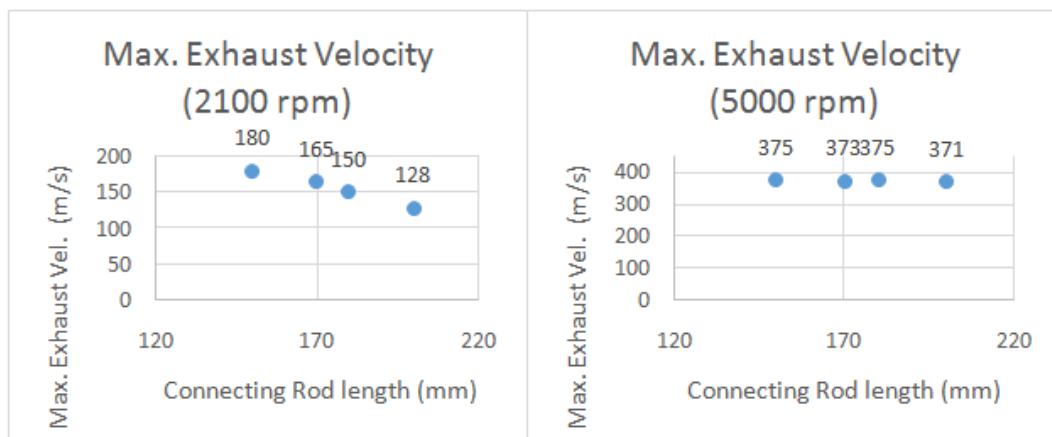


Fig 5 Variation of Exhaust Velocities for connecting rod lengths of 150mm, 170mm, 180mm & 200mm at a) 2100 rpm b) 5000 rpm

Fig 6 gives a comparison between the different swirl ratios obtained for connecting rod lengths of 150mm, 170mm, 180mm & 200mm at 2100 rpm and 5000 rpm. Fig 6.a shows considerable variation in swirl ratio for change in the length of connecting rod length from 150mm to 200mm at 2100rpm. Fig 6.b shows no such degree of variation in swirl ratio for change in connecting rod length from 150mm to 200mm at 5000rpm as in the above case.

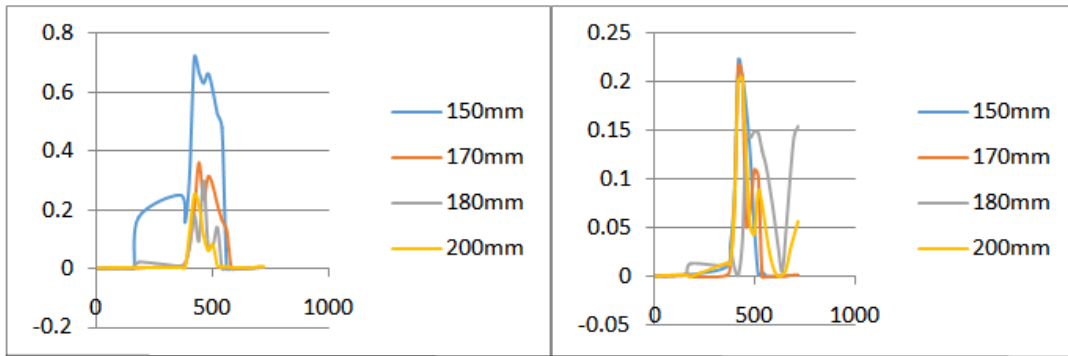


Fig 6 Comparison between different swirl ratios at a) 2100 rpm b) 5000 rpm

Fig 7 shows the velocity contours for connecting rod lengths of 150mm, 170mm, 180mm & 200mm when the exhaust velocity is maximum at 2100 rpm and at corresponding crank angles. In **Fig 7.a** for 150 mm connecting rod length, the maximum exhaust velocity obtained is 180m/s at a crank angle of 268°. In **Fig 7.b**, for 170 mm connecting rod length, the maximum exhaust velocity obtained is 165m/s at a crank angle of 268°. In **Fig 7.c** for 180 mm connecting rod length, the maximum exhaust velocity obtained is 150m/s at a crank angle of 296.5°. In **Fig 7.d**, For 200 mm connecting rod length, the maximum exhaust velocity obtained is 128m/s at crank angle of 300°.

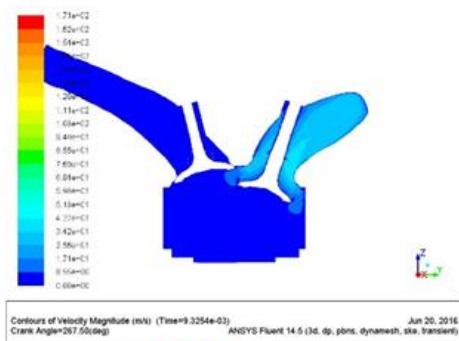


Fig 7.a

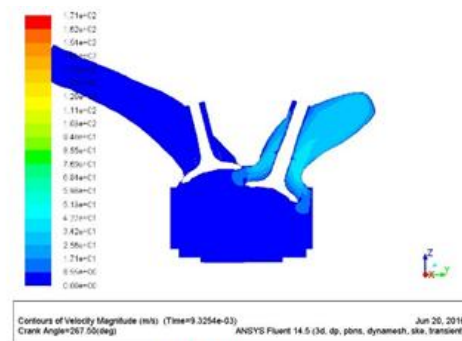


Fig 7.b

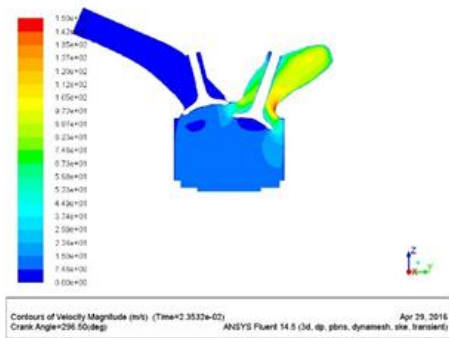


Fig 7.c

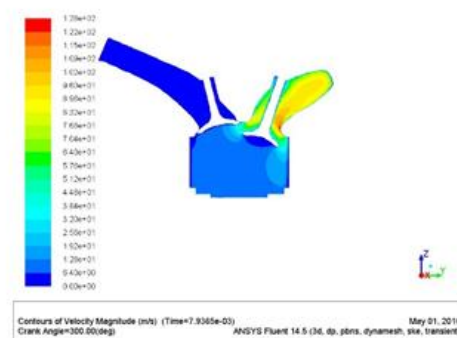


Fig 7.d

Fig 7 Velocity contours for different connecting rod lengths when the exhaust velocity is maximum at 2100 rpm and at corresponding crank angle

Fig 8 shows the velocity contour for connecting rod lengths of 150mm, 170mm, 180mm & 200mm when the exhaust velocity is maximum at 5000 rpm and at corresponding crank angles. In **Fig 8.a**, for 150 mm connecting rod length, the maximum exhaust velocity obtained is 375m/s at a crank angle of 320°. In **Fig 8.b**, For 170 mm connecting rod length, the maximum exhaust velocity obtained is 373m/s at a crank angle of 320°. In **Fig 8.c** for 180 mm connecting rod length, the maximum exhaust velocity obtained is 375m/s at a crank angle of 320°. In **Fig 8.d**, For 200 mm connecting rod length, the maximum exhaust velocity obtained is 371m/s at a crank angle of 320°.

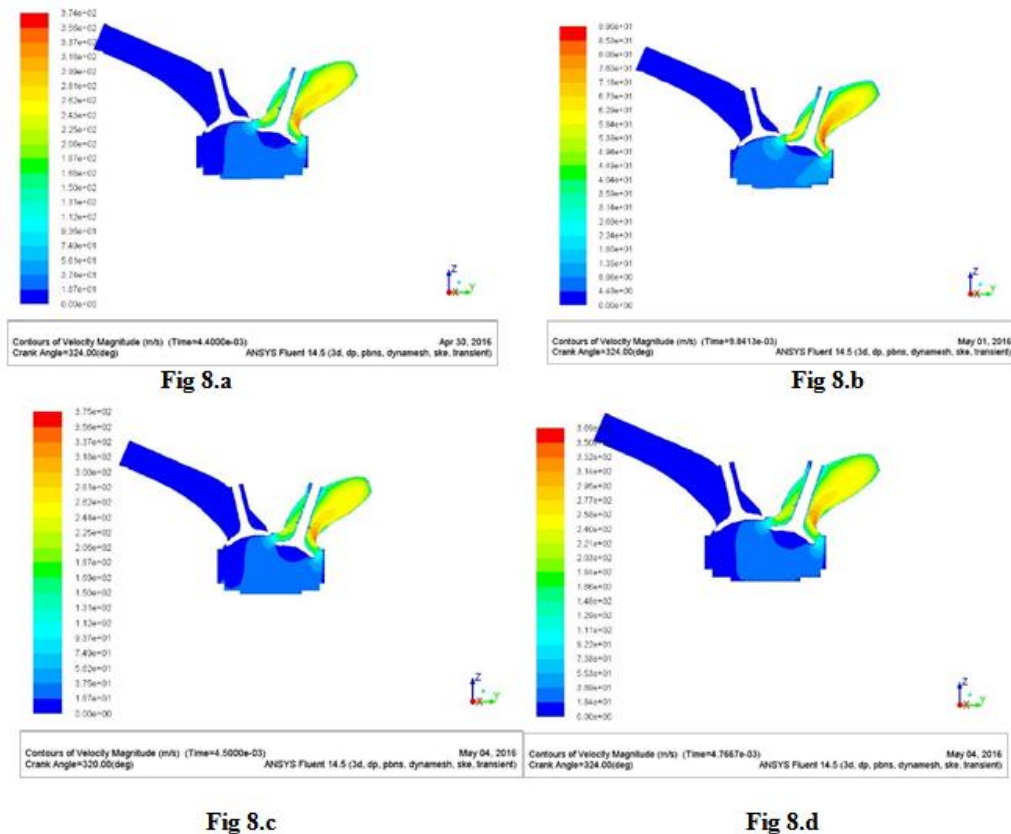


Fig 8 Velocity contours for different connecting rod lengths when the exhaust velocity is maximum at 5000 rpm and at corresponding crank angles

IV. Conclusion

The variation of the swirl ratio a for different lengths of connecting rod has been studied at 2100rpm and 5000rpm of the engine. The smallest connecting rod of length 150 mm gives maximum swirl ratio in the intake stroke when compared to the maximum swirl ratio in the intake stroke given by engines with longer connecting rods of length 170mm, 180mm and 200mm for 2100rpm. Hence, for an engine to achieve the maximum intake swirl ratio at low rpms, the connecting rod length can be varied without affecting the swirl behaviour at higher rpms. The shorter the length of the connecting rod the higher the value of maximum swirl ratio in the intake stroke can be achieved. This would amount to better combustion of the fuel without any residues left in the exhaust and thus increase power and efficiency of the engine.

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