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COMPARING DIFFERENT VALVE LIFTS IN AN IC ENGINE USING COLD FLOW SIMULATION

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ABSTRACT
Fluid flow dynamics inside an engine combustion cylinder plays an important role for air-fuel mixture preparation. IC Engine model is developed using CATIAV5R20 tool. The model is then imported to Finite Element preprocessing tool HYPER MESH for the meshing analysis. The model is then imported to Finite Element solver tool. ANSYS FLUENT is used for post processing the results. The flow dynamics inside the cylinder for different minimum valve lift is studied using FEA. Dynamic motion is visualized and velocity magnitude is plotted for different crank angle from 0° to 730°. Finally velocities and crank angles for various valve lifts are compared.

KEYWORDS: Cold Flow Simulation, Flow dynamics, Valve if

INTRODUCTION
Analytical, experimental or lower dimensional computation method are used for design purpose in the fluid dynamics of IC Engines. To simulate and visualize the complex fluid dynamics, multidimensional CFD modeling is used by solving the governing physical laws for momentum, energy transport and mass on a 3D geometry. CFD analysis helps in design of parts, such as pistons, valves, and ports as well as engine parameters like valve timing and fuel injection. In terms of fluid dynamics, the combustion and volumetric efficiency are dependent on the engine manifolds and cylinders.

IC Engine System available in the CFD software includes

- Powerful geometry modeling tools in design modeler.
- Bidirectional CAD connectivity to mainstream CAD systems.
- Flexible meshing using ANSYS Meshing.
- Solution using ANSYS Fluent.
- Powerful post processing in CFD-Post.

COLD FLOW IN-CYLINDER ANALYSIS
Cold flow analysis involves modeling the airflow and possibly the fuel injection in the transient engine cycle without reactions. The goal is to capture the mixture formation process by accurately accounting for the interaction of moving geometry with the fluid dynamics of the induction process. The changing characteristics of the airflow jet that tumbles into the cylinder with swirl via intake valves and the exhaust jet through the exhaust valves as they open and close can be determined, along with the turbulence production from swirl and tumble due to compression and squish.

The preprocessing from geometry to solver setup is typically time consuming and challenging to separate or decompose the geometry into moving and stationary parts. Typically, the intake ports are split off from the cylinder and valves. The combustion chamber and piston region may be also decomposed or separated into smaller parts. Then each part can be meshed accordingly for the solver setup. Any errors at this stage can lead to failures downstream during the solution process.

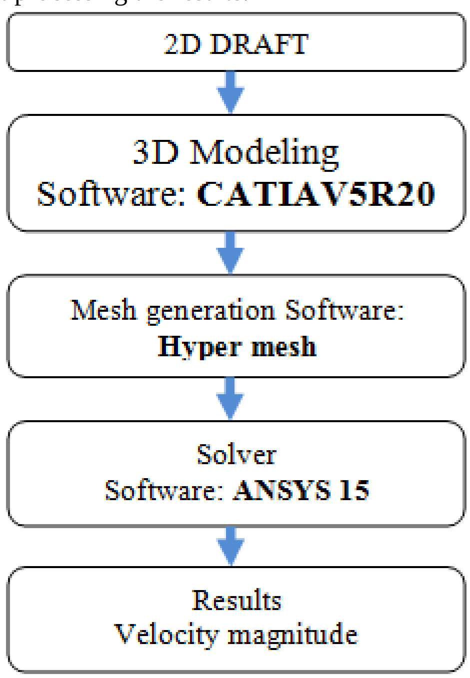
The run times for solver runs can be fairly long since the motion is typically resolved with small time steps (approximately 0.25 crank angles) to get accurate results and the simulation is run for two or three cycles to remove the initial transients. Finally, the large volume of transient data that results from the CFD solution needs to be post processed to obtain useful insight and information. Thus cold flow analysis would also benefit from design automation and process compression.

OBJECTIVE

- To create IC Engine model using CATIA V5R20 tool and solve by ANSYS FLUENT.
- To study the flow dynamics inside the cylinder for different valve lift using FEA.
- To compare the valve lifts of 0.1mm and 0.2mm for different velocities.

METHODOLOGY

Finite Element analysis was used to determine the characteristics of the IC Engine. For the purpose of this study, the IC Engine model were developed using CATIAV5R20 tool. The model was then imported into Finite Element preprocessing tool HYPER MESH for the meshing analysis. The model was then imported into Finite Element solver tool ANSYS FLUENT for post processing the results.



Parts created by CATIA tool is assembled as shown in Fig.6. The model is prepared with CAD software. The engine is four stroke single cylinder diesel engine with canted valves namely inlet valve and exhaust valve. It is an in-cylinder engine having piston and cylinder in line. Valve seats are provided in both the valves. By using Scheme file it automatically sets up necessary motions for valves and pistons along with solution parameters for the in-cylinder simulation.

Figure.1 ***Assembled part of Engine***

The next stage is to create a proper "meshing" for the 3D model. "The discritzation of a continuous system with infinite degree of freedom (DOF) to finite degree of freedom (DOF) by nodes and elements is known as meshing". The accuracy of the analysis is purely based on the level of meshing attained by the designer. Hyper mesh tool is used to carry out the meshing as shown in Fig.7.

Figure.2 ***Mesh structure for the geometry***

Technical specifications considered for an IC Engine (Diesel Engine) for fluid dynamic analysis purpose [2] is as shown in Table 1.

Table 1. Specifications of Engine model

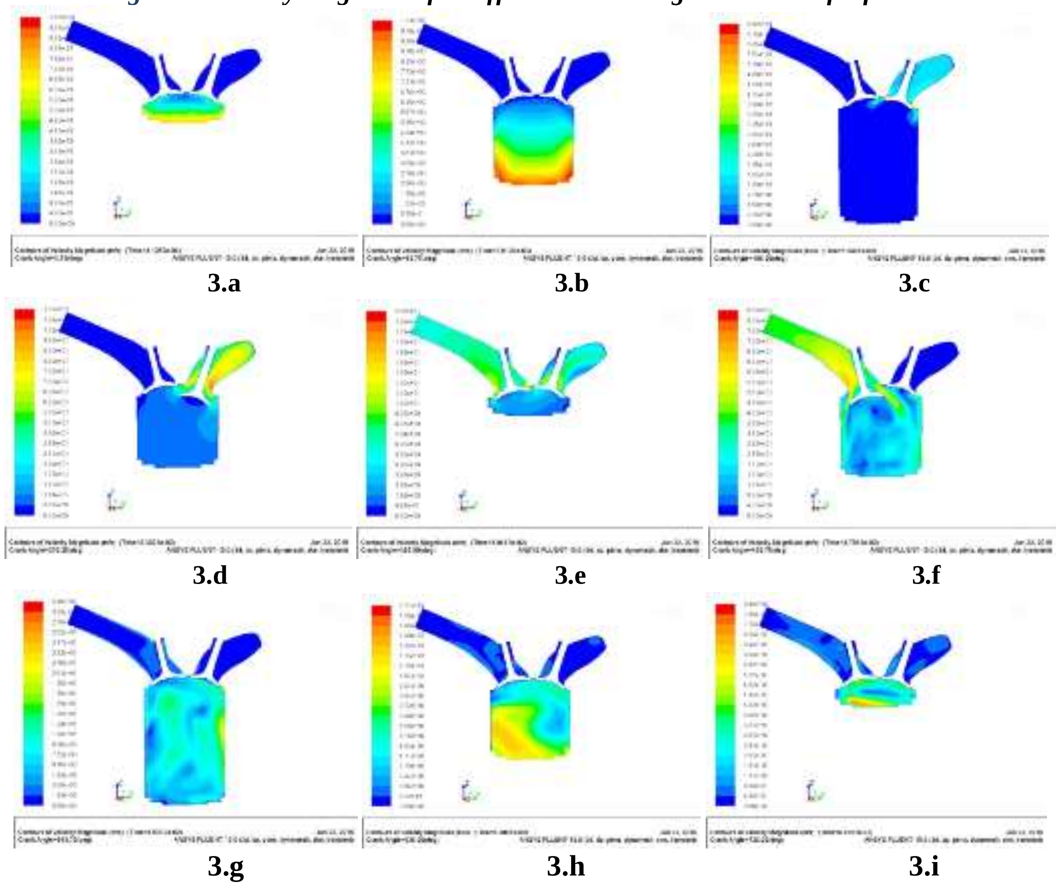
SN	PARTS	DIMENSIONS
1	Connecting rod length	144.3 mm
2	Crank radius	45 mm
3	Wrench	0
4	Engine speed	2000 rpm
5	Minimum lift	0.1 mm

VELOCITY CONTOURS FOR VALVE LIFT of 0.1mm

Dynamic meshing of the IC Engine fluid computational domain was done and analysis was performed. Then velocity magnitudes for different crank angle were plotted.

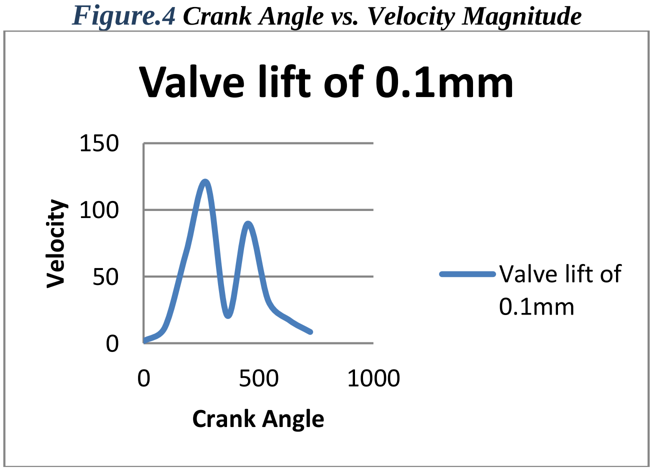
Fig.3.a shows contours of velocity magnitude. Maximum velocity obtained at 3.75° is 1.80m/s.
Fig.3.b shows contours of velocity magnitude at 93.75°. Maximum velocity obtained at 93.75° is 12.1m/s.
Fig.3.c shows the contours of velocity magnitude at 186.25°. Maximum velocity obtained at 186.25° is 68.2m/s.
Fig.3.d shows the contours of velocity magnitude at 276.25°. Maximum velocity obtained at 276.25° is 120m/s.
Fig.3.e shows the contours of velocity magnitude at 365°. Maximum velocity obtained at 365° is 20.6m/s.
Fig.3.f shows contours of velocity magnitude at crank angle 453.75°. Maximum velocity is 89.5m/s.
Fig.3.g shows the contours of velocity magnitude at 543.75°. The maximum velocity is 31.6m/s.
Fig.3.h shows contours of velocity magnitude at 636.25°. Maximum velocity obtained at 636.25° 17.1 m/s.
Fig.3.i shows contours of velocity magnitude at 726.25°. Maximum velocity obtained at 726.25° is 8.43 m/s.

Figure:3 ***Velocity magnitude for different Crank angles at valve lift of 0.1mm***



The plots of velocity magnitude for different crank angle from 0° to 730° at valve lift of 0.1mm are shown in Fig.10. X-axis indicates Crank Angle in “degrees” and Y-axis indicates Velocity Magnitudes in “m/s”. Maximum velocity obtained is 120m/s at 272.5°.

Figure.4 ***Crank Angle vs. Velocity Magnitude***



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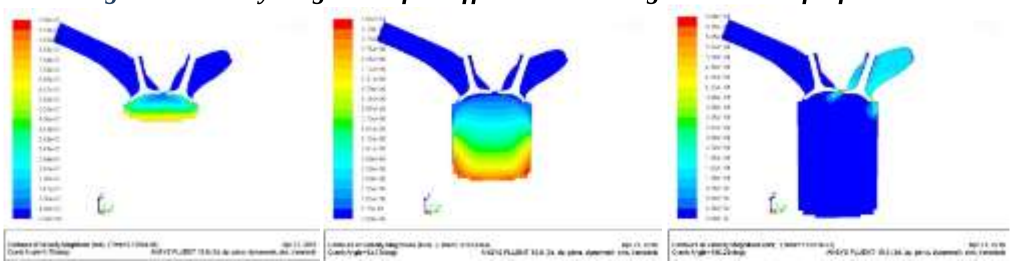
VELOCITY CONTOURS FOR VALVE LIFT OF 0.2mm

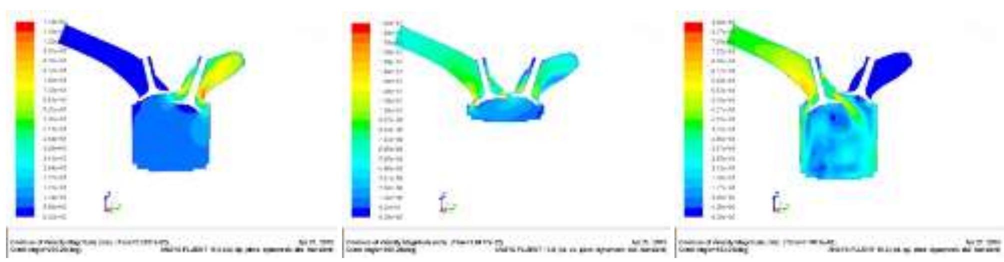
Valve lift for the same IC Engine model was changed from 0.1mm to 0.2mm. Technical specifications considered for an IC Engine (Diesel Engine) for fluid dynamic analysis purpose for valve lift of 0.2mm is same as shown in Table 1 except for minimum valve lift.

Fig.5.a shows the contours of velocity at 3.75° crank angle. Maximum velocity obtained at 3.75° is 0.98m/s
Fig.5.b shows the contours of velocity at 93.75° crank angle. Maximum velocity obtained at 93.75° is 10.3m/s.
Fig.5.c shows the contours of velocity magnitude at 186.25°. Maximum velocity obtained at 186.25° is 65 m/s.
Fig.5.d shows the contours of velocity magnitude at 276.25°. Maximum velocity obtained at 276.25° is 114 m/s.
Fig.5.e shows the contours of velocity magnitude at 365°. Maximum velocity obtained at 365° is 19.8 m/s.
Fig.5.f shows the contours of velocity magnitude at 453.75°. Maximum velocity obtained at 453.75° is 85 m/s.
Fig.5.g shows the contours of velocity magnitude at 543.75°. Maximum velocity obtained at 543.75° is 30.9 m/s.
Fig.5.h shows the contours of velocity magnitude at 636.25°. Maximum velocity obtained at 636.25° is 16.4 m/s.
Fig.5.i shows the contours of velocity magnitude at 726.25°. Maximum velocity obtained at 726.25° is 8.04 m/s.

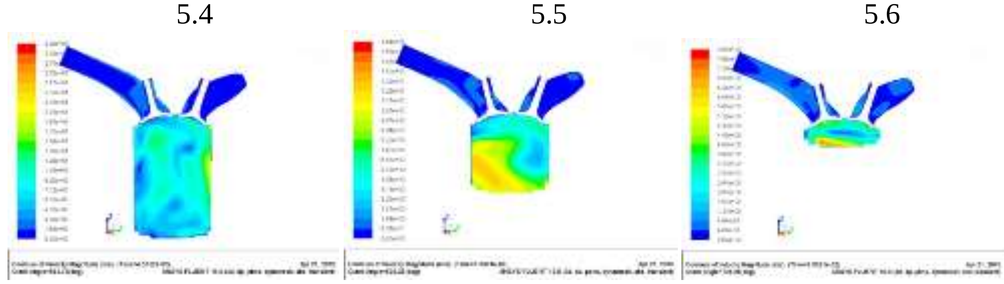
Figure.5** **Velocity magnitude for different Crank angles at valve lift of 0.2mm



5.1 5.2 5.3



5.4 5.5 5.6



5.7 5.8 5.9

The plots of velocity magnitude for different crank angle from 0° to 730° at valve lift of 0.2mm is shown in Fig.12. X-axis indicates Crank Angle in “degrees” and Y-axis indicates Velocity Magnitudes in “m/s”. Maximum velocity obtained is 114m/s at 272.5°.

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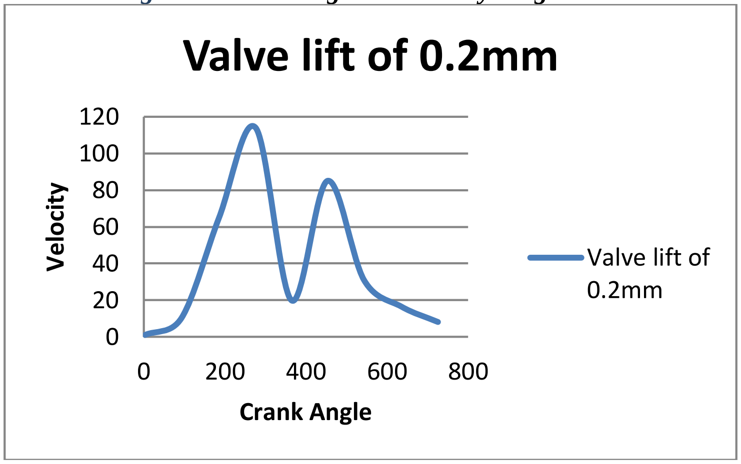
Figure.6 ***Crank Angle vs. Velocity Magnitude.***



VELOCITY CONTOURS FOR VALVE LIFT OF 0.3mm

Valve lift for the same IC Engine model was changed from 0.2mm to 0.3mm. Technical specifications considered for an IC Engine (Diesel Engine) for fluid dynamic analysis purpose for valve lift of 0.3mm is same as shown in Table 1 except for minimum valve lift.

Fig.7.a shows the contours of velocity magnitude at 3.75° crank angle. Maximum velocity obtained at 3.75° is 0.931m/s.

Fig.7.b shows contours of velocity magnitude at 93.75° crank angle. Maximum velocity obtained at 93.75° is 9.79m/s.

Fig.7.c shows contours of velocity magnitude at 186.25° crank angle. Maximum velocity obtained at 186.25° is 61.8 m/s.

Fig.7.d shows contours of velocity magnitude at 276.25° crank angle. Maximum velocity obtained at 276.25° is 108m/s.

Fig.7.e shows contours of velocity magnitude at 365° crank angle. Maximum velocity obtained at 365° is 18.9m/s.

Fig.7.f shows contours of velocity magnitude at 453.75° crank angle. Maximum velocity obtained at 453.75° is 80.7m/s.

Fig.7.g shows contours of velocity magnitude at 543.75° crank angle. Maximum velocity obtained at 543.75° is 30.9m/s.

Fig.7.h shows contours of velocity magnitude at 636.25° crank angle. Maximum velocity obtained at 636.25° is 15.6 m/s.

Fig.7.i shows contours of velocity magnitude at 726.25° crank angle. Maximum velocity obtained at 726.25° is 7.63 m/s.

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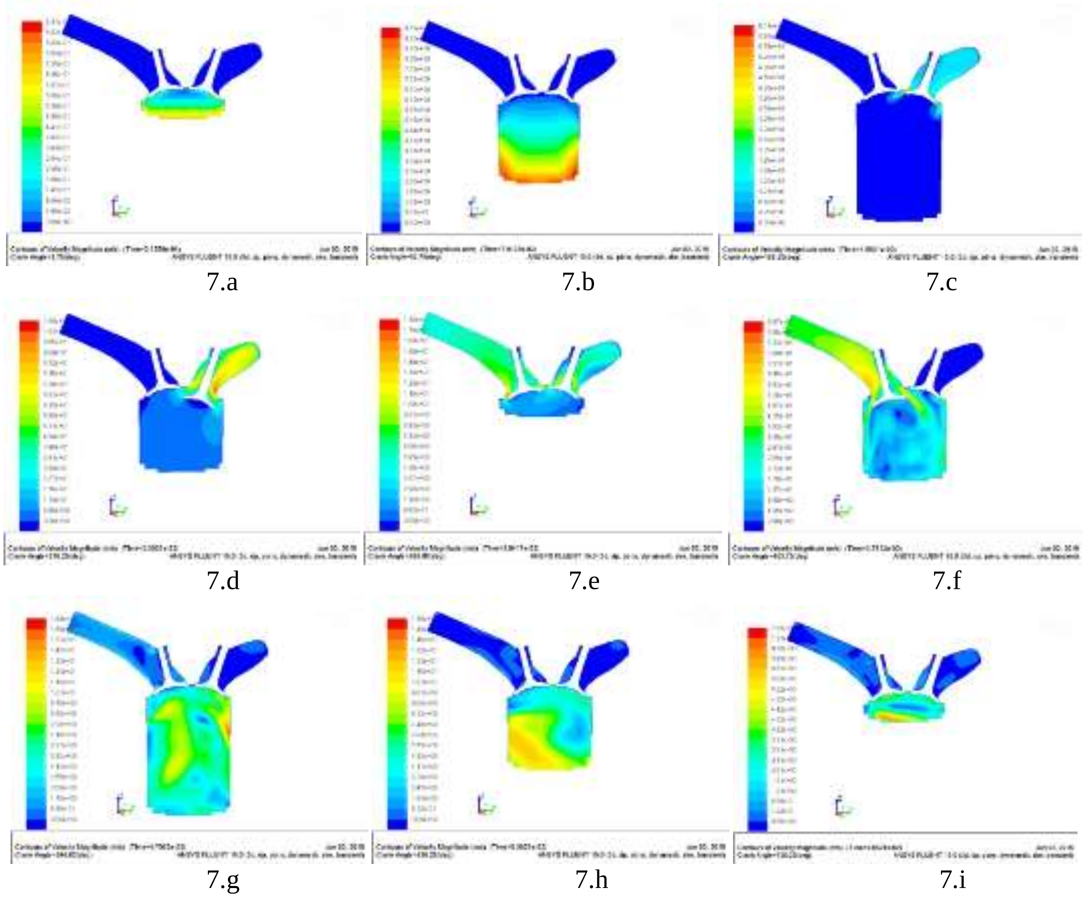
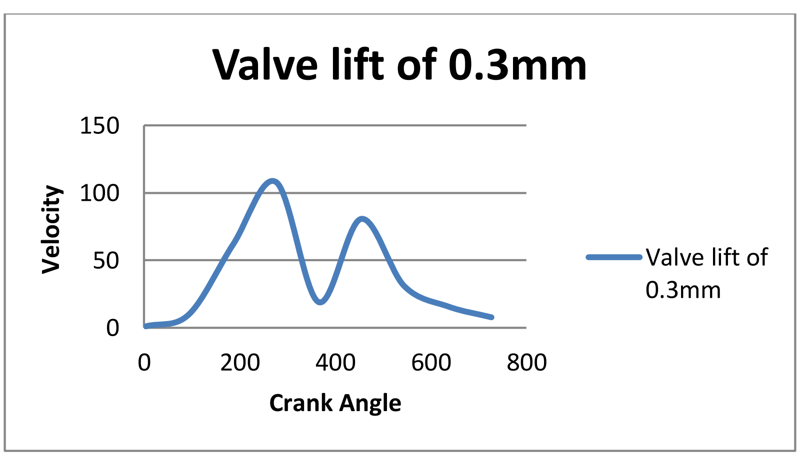
***Figure 7* Velocity magnitude for different Crank angles at valve lift of 0.3mm**



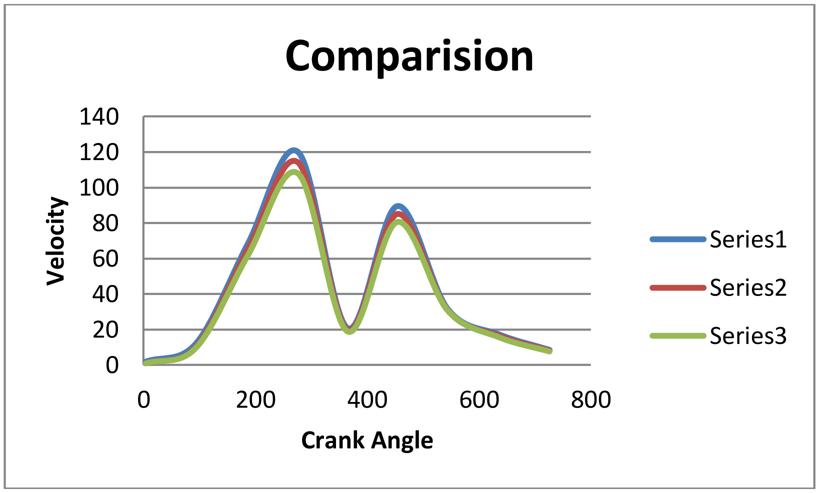
The plots of velocity magnitude for different crank angle from 0° to 730° at valve lift of 0.3mm is as shown in Fig.39. X-axis indicates Crank Angle in “degrees” and Y-axis indicates Velocity Magnitudes in “m/s”. Maximum velocity obtained is 109m/s at 272.5 deg.

***Figure.8* Crank Angle vs. Velocity Magnitude**



COMPARISON FOR VALVE LIFTS OF 0.1MM, 0.2MM AND 0.3MM

Fig.9 shows the plots of velocity magnitude for various crank angles at different valve lifts. X-axis indicates Crank Angle in "degrees" and Y-axis indicates Velocity Magnitudes in "m/s". For first half cycle 270° is the highest peak and for second half cycle, 450° is the highest peak Fig.9 indicates that as valve lift increases the velocity decreases.



CONCLUSION

All four strokes and their effect on in cylinder air motion in an IC engine are studied effectively and following conclusions are obtained:

- Dynamic motion is visualized and velocity magnitude is plotted for different crank angle from 0° to 730°.
- When the valve lifts increases velocity obtained decreases.

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