International Journal of Engineering Research & Management Technology
ISSN: 2348-4039
January- 2015 Volume 2, Issue-1
Email: editor@ijermt.org www.ijermt.org

Design and Simulation of W20 IC Engine Using Eddy Dissipation, Direct Injection and Layering Approaches

Rahul Pratap Yadav Research scholar
Dr. Durgesh Sharma Professor
O.P. Umrao Associate Professor

IMS Engineering College, Ghaziabad

ABSTRACT

The continuous increasing demand on the subject of smooth operation, performance and fuel economy have led to the progress of existing engines and the development of advanced engines. 20 Cylinder is the eminence of engine design and it is the sign of opulence class vehicles.TheW20 increased its displacement to 10.26 liters and equipped with direct fuel injection for greater power, torque and greater efficiency. The 10.26L W20 engine provide the performance like sports and muscle car performance with 840Nm@5000rpm.The new W20 engines represents a successive new engine phase. The W engines place excessive demands on design. Large numeral of cylinders was adapted to the exceedingly concise dimensions of the engine. In this process, more consideration was paid to lightweight of W20 engine design. The engine is exceptionally smooth running and performance at high speeds and engine loads. For effective design computer fluid dynamics techniques is used such as eddy dissipation, direct injection and layering approaches. Advantages of these approaches to increase fuel efficiency and smooth power output.

Keywords: - W20 Engine, Design, Simulation, Eddy dissipation, Direct injection, Layering Approach

INTRODUCTION:

The object to make even more concise engines with a large number of cylinders, the design factor of the V and VR engines were integrate to create the W engines. As with the V engines, the cylinders are distributed to two banks. In the W8 and W12 engines, these banks of cylinders are aligned at a V-angle of 72 degrees in relation to one another. As in the VR engine, the cylinders within each bank continue a V-angle of 15 degrees. When the W engine is viewed from the front, the cylinder alignment looks like a double-V. Put the two V of the right and left cylinder banks together, and you get a W. This is how the name “W engine “Came in to form. To make engines shorter, the cylinders in the V engines are arranged at an angle of between 60 degrees and 120 degrees, with the centerlines of the cylinders intersecting with the centerline of the crankshaft. Advantage: Relatively short engines. Drawback: The engines are relatively wide, have two separate cylinder heads, and therefore require a more complex design and a larger engine compartment volume.

The engines of the W family are a combination of two “VR banks” based on a modular design principle. The cylinders of one bank have an angle of 15 degrees relative to each other while the two VR banks are combined at a V-angle of 72 degrees. Proven components from the modules of the VR engine family were integrated into the new W engine concept. The principle is very simple. Two concise engines from the VR series are integrated to produce a W engine. The result is a series of concise gasoline engines ranging from the W8 to the W20.Numerous components of the VR and W series are identical:

- Valve seat inserts, valve springs and Valves.
- Roller rocker fingers.
- Valve clearance compensating elements.

This allows many sports and muscle cars to manufacture many parts in high volumes .In the development of the 6-cylinder engine, the VR6 engine attract attention due to its compactness. It is much shorter than the comparable inline engine, and narrower than the V engine. Joining together two VR6 engines with a cylinder angle of 72 degrees produces a W12 engine. A W16 engine is obtained by combining two cylinders to each cylinder bank of a W12 engine. Splitting the W16 in the middle leaves two W8 engines. A W10 engine consisting of two VR5 engines is also a possibility. This covers the complete range of W engines. But In case of W20 engine 20 cylinder W type engine with a V angle of 15^o and a bank angle of 62^o is taken.

2. W20 ENGINE DESIGN

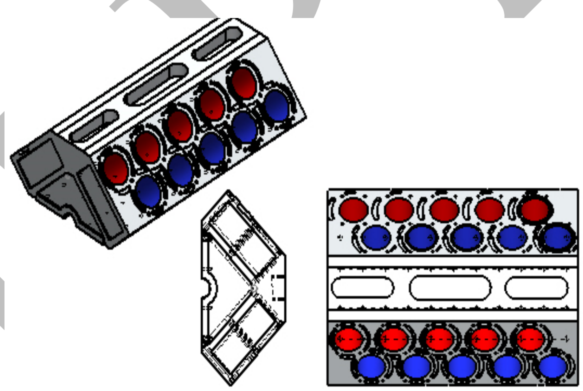
20-cylinder gasoline engine with four rows of five cylinders arranged in a W configuration
More compact dimensions than a comparable
V8 and any other engine

- Length: 31.5 in (800 mm)
- Width: 31.5 in (800 mm)
- Height: 27.5 in (700 mm)

– Two cylinder heads with four valves per cylinder and two camshafts per bank
– Engine is controlled by a multi-element chain drive
– FSI direct injection with twin high-pressure fuel pumps, twin fuel rails and six-port high pressure injectors
– Recuperation system for energy recovery
During deceleration phases

Cylinder Block

Compared with the other engine 10.26L W20 engine, cylinder bore has been enlarged to 3.35 in (85.0 mm). The cylinder block is cast from a lightweight, high strength aluminum-silicon alloy. The bottom section has a cast iron cross member with embedded main bearing pedestals.



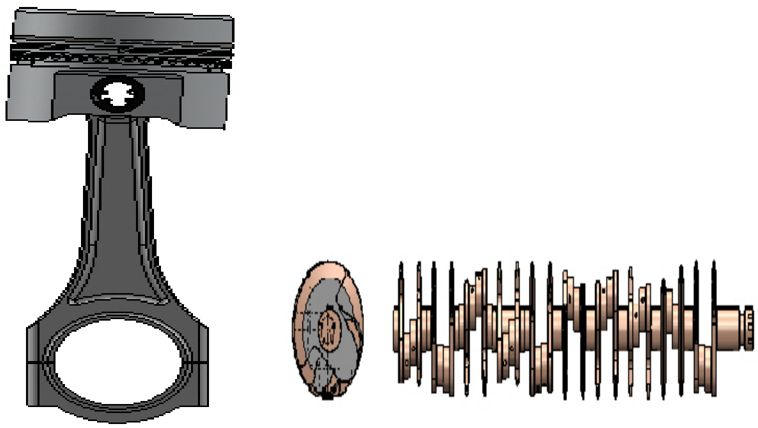
3D view/CAD Design of Cylinder block design with 2D views of W20 IC engine

The “aluminum” crankcase upper section is made of a hypereutectic aluminum-silicon alloy (AlSi17CuMg).Hypereutectic means that pure silicon crystals initially precipitate out of the aluminum-silicon melt while it cools before aluminum /silicon crystals form.

Crankshaft

The forged crankshaft has a 26° crankpin offset angle. This allows the fuel mixture of each cylinder to be ignited at the ideal interval of every 36° of crankshaft rotation.

Views/CAD Design of W20 Engine Pistons and Connecting Rods with crankshaft



The pistons are forged from high strength light alloy and have angled crowns to compensate for the cylinder bank angle. The shape of the piston crowns have been designed especially for the FSI engine. The design of the W20 engine necessitated the use of high pressure injectors with different placement angles in the cylinder head. For this reason, the "outer" cylinders (1, 3, 5, 7, 9, 12, 14, 16, 18 and 20) have different pistons than the "inner cylinders (2, 4, 6, 8, 10, 11, 13, 15, 17 and 19).

3. CALCULATION

3.1 Bore is the diameter computation of the cylinders in a piston engine.

Bore= 85mm (3.35in).

3.2 Stroke, The stroke length is detected by the cranks on the crankshaft. Stroke can assign to the distance the piston moves.

Stroke = 90.5mm (3.56in)

3.3 Engine Displacement: Engine displacement , is the volume swept by all the pistons inside the cylinders of a reciprocating engine in a single movement from top dead centre (TDC) to bottom dead centre (BDC). It is commonly specified in litres (l),cubic centimeters (cc or cm^3), or (mainly in North America) cubic inches (CID). Engine displacement does not include the total volume of the combustion chamber.

Displacement (in) = 3.14/4 x $(BORE)^2$ X STROKE X NO. OF CYLINDER

Displacement = 3.14/4 X $(3.35)^2$ X 3.56 X 20

Displacement = 627.566 Cubic inch

3.4Working fluid volume: A working fluid is a liquid or pressurized gas that actuates a machine.

Volume (in) = 3.14/4 X STROKE X $(BORE)^2$

Volume = 3.14/4 X 3.56 X $(3.35)^2$

Volume = 31.378 Cubic Inch

3.5Crankpin Offset

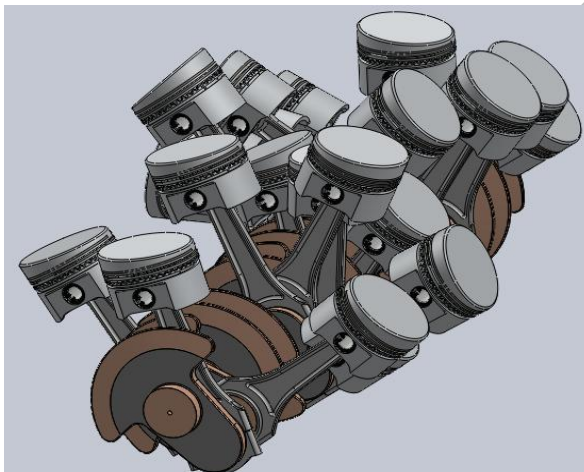
Crankpin offset controls the relative positions of the pistons in the cylinders for an evenly timed firing sequence. All four-cycle internal combustion engines complete their cylinder firing sequences within two complete revolutions. This amounts to a crankshaft rotation of 720 degrees.

The W20 engine has a crankpin offset of +26 degrees.

Similarly, a 20-cylinder engine requires 36 degrees of crankshaft rotation between the ignition cycle of each cylinder through 720 degrees of crankshaft rotation ($720/20 = 36^o$). For this configuration, to determine the optimum crankpin offset of +26 degrees, the 36 degrees of crankshaft rotation between ignition cycles is subtracted from the 62-degree V-angle of the cylinder banks.

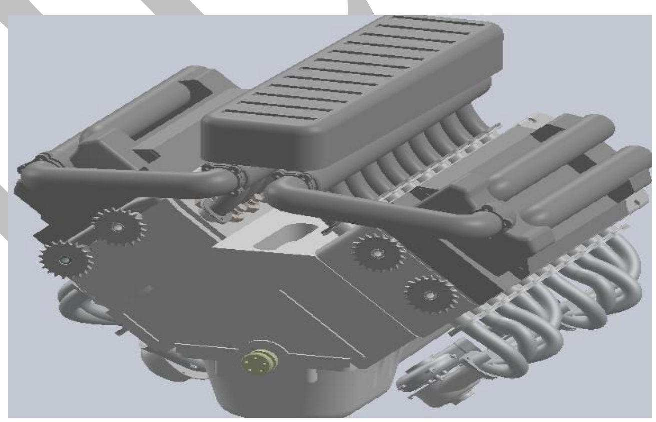
$$62 - 36 = +26^o$$

3D view/CAD Design of crankshaft assembled with connecting rod and piston at 26^o crankshaft journal offset

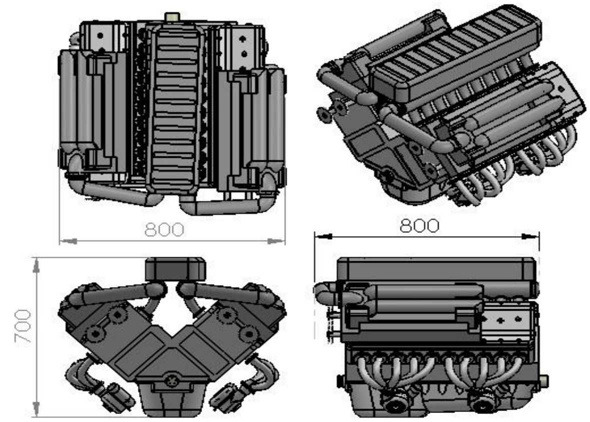


Engine sub assembly

4. W20 IC ENGINE SPECIFICATION



3D model/ CAD design of W20 IC Engine with its views



Displacement	627.566 cu in (10.265 cc)
Number of cylinders	20
Number of cylinder heads	2
Bore	3.35 in (85 mm)
Stroke	3.56 in (90.5 mm)
Offset	± 0.492 in (12.5 mm)
Bank offset	0.512 in (13 mm)
V-angle of cylinder heads between banks	62 degrees
V-angle of cylinders in a bank	15 degrees
Crankshaft journal offset	26 degrees
Number of valves	4 per cylinder
Length of connecting rod	120mm
Firing order	1-11-9-19-3-13-7-17-5-15-10-20-2-12-8-18-4-14-6-16
Maximum Torque	840@5000rpm

5. SIMULATION

The simulation of the engine first need to import engine geometry. The geometry which was imported from CAD (Computer Aided Design) software is divided into smaller volumes before meshing. This provides each volume to be meshed individually. To break down partitions a volume into sub-volumes and then the sub-volumes are meshed separately. Each volume will be meshed into hex or tet elements, depending upon the techniques.

There are certain mesh topology requirements for valves and pistons. The pistons might have at TDC (Top dead center) before the geometry is decomposed with the piston at TDC, the volume is the Smallest In general it is more difficult to satisfy the mesh topology requirement at TDC,

But this provides the advantage that the mesh will behave properly when the piston moves away from TDC. However the simulation requires a minimum valve lift between the valve and valve seat so that layered cells can be placed at the region of minimum valve lift. This ensures that the gap between the valve and valve seat will not disappear. A non-conformal interface is used to completely shut the valve. Even though in theory an arbitrarily small minimum valve lift can be used, in reality a value of 0.05 mm to 0.5 mm has been successfully used to run simulations using ANSYS Fluent.

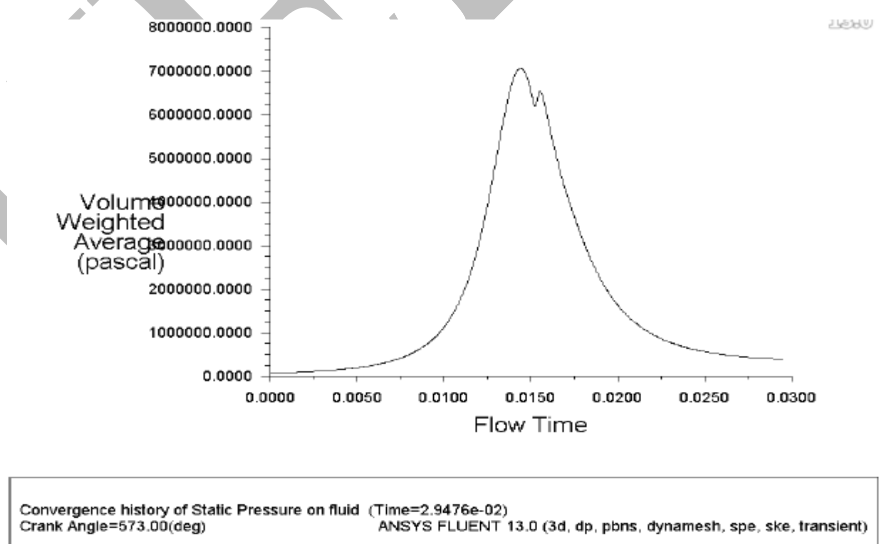
5.1 Eddy-Dissipation

Fuel is directly injected into the combustion chamber when the piston is close to top dead center (TDC). Due to high temperature and pressure, the fuel will auto ignite after some delay, and then there will be full combustion. The combustion process can be assumed to be non-premixed. Model of a 4-stroke diesel engine which corresponds to one fuel injector is used to model compression and power stroke

In this technique pressure based solver is utilized with absolute value formation. And for dynamic mesh parameter layering mesh method is used using in cylinder category which is based on height based strategy with split factor 0.4 and collapse factor is .04

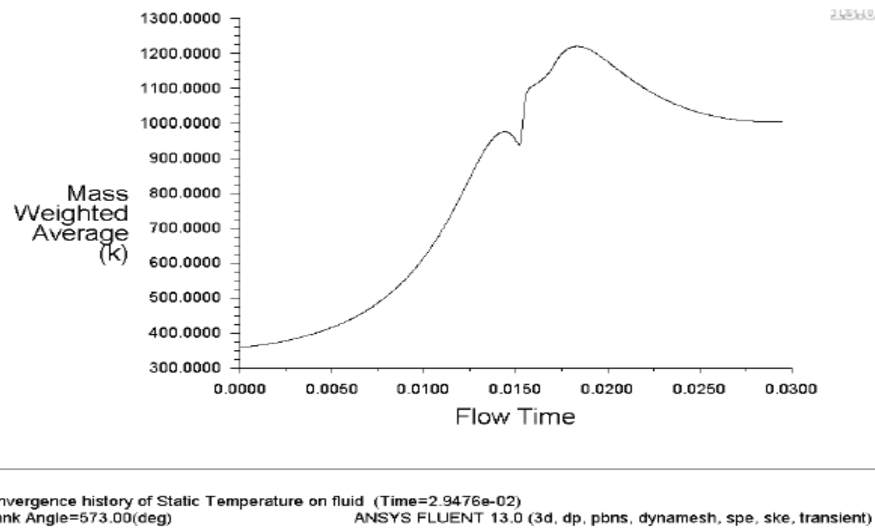
Parameters for these techniques

Parameters	value
Crank Shaft Speed(rpm)	2117
Starting Crank Angle(deg)	360
Crank Period(deg)	720
Crank Angle Step Size(deg)	.2
Piston Stroke(in)	3.56in(85mm)
Connecting Rod Length(in)	4.723in (120mm)

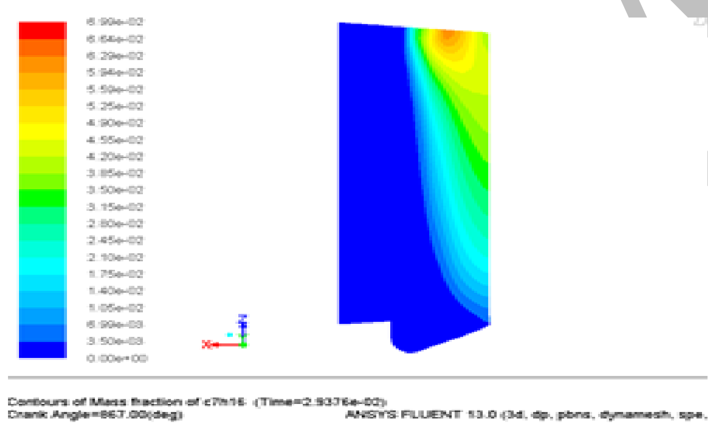


Pressure as function of time

Temperature as function of time



Eddy-dissipation model to simulate combustion in a diesel engine and contours of mass fraction



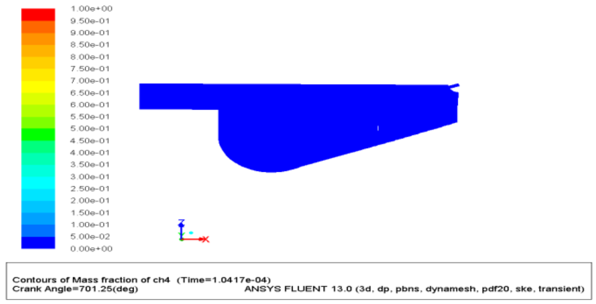
5.2 Direct injection

Process of non-premixed combustion in a direct injection natural gas engine. Direct injection natural gas engines are used in many heavy duty vehicles. gas mixes with the high pressure air in the combustion chamber and combustion occurs. Due to the non-premixed nature of the combustion occurring in such engines, non-premixed combustion model of ANSYS can be used to simulate the combustion process.

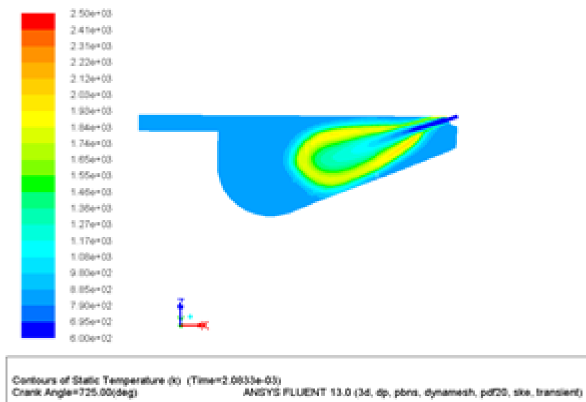
Transient time based solver is used with pressure based type and absolute volume formulation.

Parameter	Value
Crank Shaft Speed (rpm)	2117
Starting Crank Angle (deg)	360
Crank Period (deg)	720
Crank Angle Step Size (deg)	.25
Piston Stroke (in)	3.56in(90.5mm)
Connecting Rod Length (mm)	4.723in (120mm)

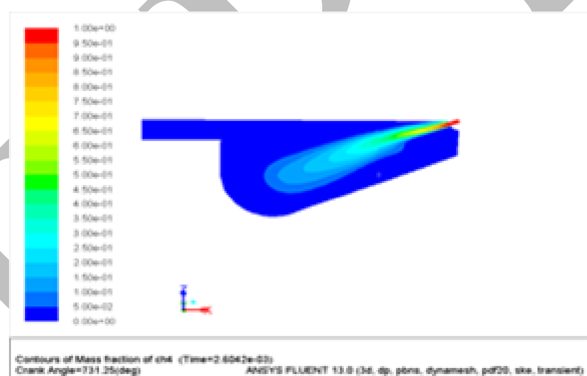
Direct injection at Crank angle 701.25 deg



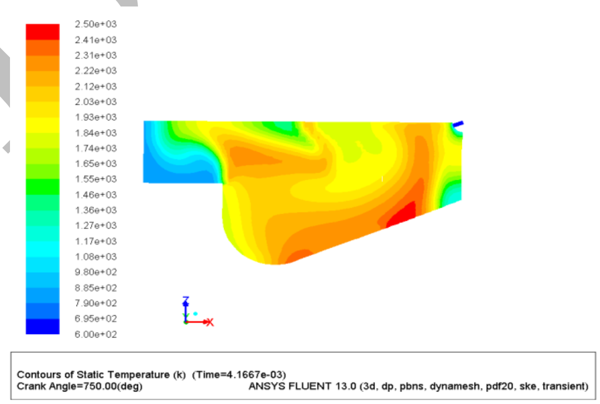
Crank angle 725 deg



Crank angle 731.25 deg



Crank angle 750deg



This explained entire process from setting up the dynamic mesh model for an IC engine to setting up the non-premixed model for combustion in the engine.

5.3 Layering and hybrid approach

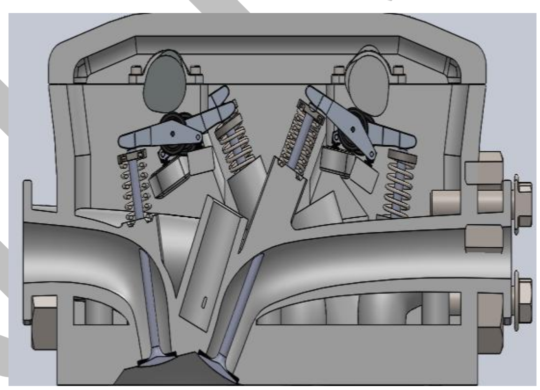
The layering approach is used for engines with vertical valves like most diesel engines, while the hybrid approach is typically used for engines with canted valves. Required parameters for the process

Parameters	value
Crank shaft speed(rpm)	2117
Crank angle step size (deg)	.25
Piston stroke (in)	3.56in
Connecting rod length(in)	4.723in

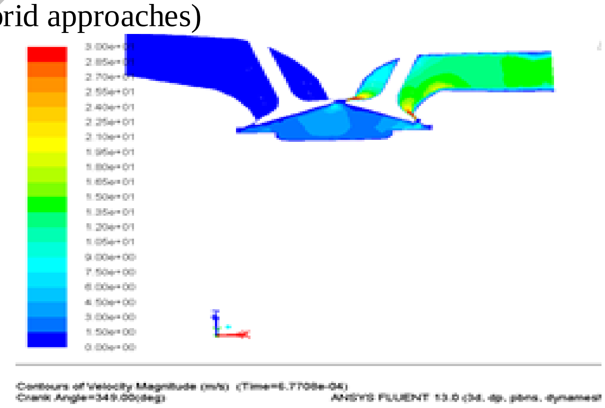
While using viscous model formulation k-epsilon (2eqn), standard model is used with standard wall function. Model constant are as follows

cmu	.085
C1-epsilon	1.45
C2-epsilon	1.95

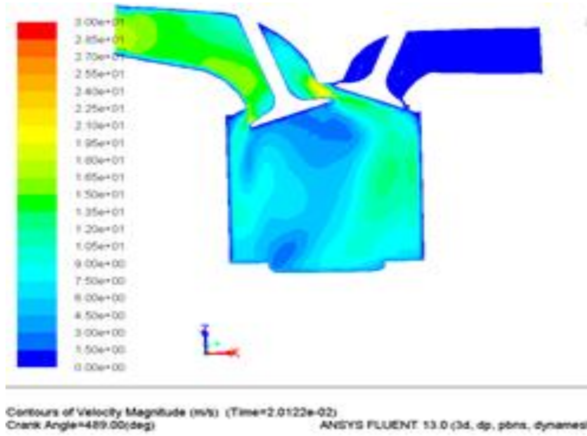
CAD Model Section view of cylinder head



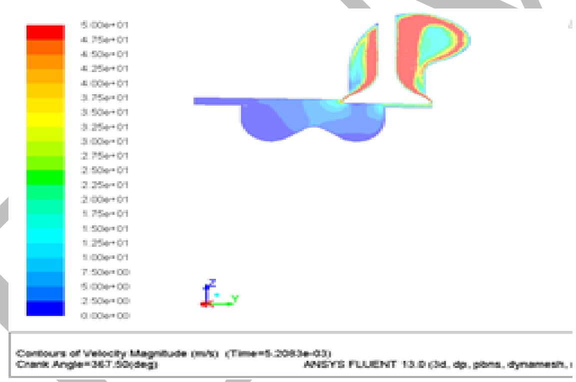
Crank angle = 349 deg (using hybrid approaches)



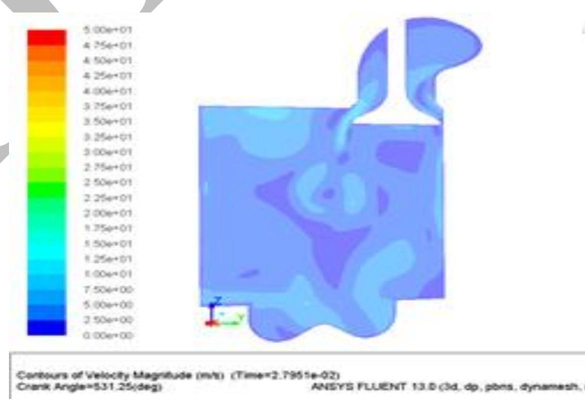
Crank angle = 489 deg



Crank angle = 367.50deg (using layering approach)



Crank angle = 531.25 deg



This is all cold flow case setup of 20 cylinders IC engine.

6. CONCLUSION:

Here is the complete design of W20 IC Engine. And we have effective result of design using different techniques and approaches. And it provides a unique design solution; require less space with compact dimension, high torque and speed. SOLIDWORKD and Ansys software is used for this purpose.

And the graph and plots of contour of velocity magnitude with time defined thermal condition at different crank angle.

7. FURTHER POSSIBLE WORK:

There is many more method that can formulate to know about whether design and mechanism will run properly or not such as partial pre-mixed, pre-mixed and ECFM model etc. So these methods can used to improve other factors of W Engine series.

8. ACKNOWLEDGEMENT:

I owe great many thanks to a great many people who helped me and supported me during the writing of this paper.

My deepest thanks to lecturer Dr. Durgesh Sharma, professor, IMS Engineering College Ghaziabad for guiding and correcting various documents of mine regarding this paper.

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