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ANALYSIS OF FUEL SPRAY INJECTION ORIENTATION WITH DIFFERENT GEOMETRY BOWL SHAPES IN A DI DIESEL ENGINE: THROUGH CFD SIMULATION

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Abstract:

In direct injection (DI) diesel engines the effect of injection orientation on velocity vector components has high influence on engine performance as well as exhaust gas emissions. The fuel injection orientation plays very important role in fuel air mixing. A single cylinder four stroke DI diesel engine with fuel injector having multi-hole nozzle injector is considered for the analysis and a computational fluid dynamics (CFD) code, STAR-CD is used for the simulation. Effect of injection orientation angle on in-cylinder fluid flow characteristics were analysed through Analysis of Fuel Spray in DI diesel engine through CFD simulation. Two bowls are considered for this analysis i.e. Mexican Hat Bowl (MHB) and Toroidal Bowl (TB). The Present analysis injection orientation angle is considered for simulation, is 100^0. In case of Toroidal Bowl (TB) at 100^0 injection orientation angle the fluid flows towards squish region. In case of Mexican Hat Bowl injection orientation at 100^0 spray is spreading uniform into the high turbulent zone compared with Toroidal Bowl. Hence at Mexican Hat Bowl injection orientation angle is reasonably good for the fuel spray.

Key Words: Diesel Engine, Direct Injection, Spray, Mexican Hat, Bowl Fuel Spay, Toroidal Bowl, CFD

1. Introduction:

To illustrate the potential for multidimensional modeling of internal combustion engine fluid flow and flow field, the results of which are presented in terms of Fuel Spray components [1, 2]. The flow in X-direction is called U-velocity components, in Y-direction is called V-velocity component and Z-direction in called W-velocity component. Large amounts of information on the fluid flow through velocity vectors are generated. It is difficult to present entire information, hence at selected crank angles which are felt necessary are only discussed in their respective section [3, 4]. It is logical to present the details in 2-D planes for better understanding, through the 3-D flow field. Velocity vectors are generated using CFD Code [5, 6]. It is observed that the variation of flow in Y-direction (V- Fuel Spray components) swirls around the axis of the bowl at minimal. Where X and Z direction flow field variation is observed to be more. Hence, X-Z plane Fuel Spray components give more information than the other planes. In the X-Z plane at the middle of the fuel spray gives more information than that of the other planes about the fuel spray spreading and other local information. Hence it is selected as X-Z plane at middle of the injector which is selected for the present analysis [7, 8]. In this section the fluid flow field during part of compression and expansion strokes for injection orientation of 100^0 is discussed and analyzed on the basis of the fluid flow calculation plots in X-Z plan [9 10]

2. Methodology:

A. EngineGeometry and Specifications: In the present work, 45^0 sector is taken for the analysis due to the symmetry of eight-hole injector in the model. The computational mesh when the piston is at Top Dead Center (TDC) is shown in figurre 1.

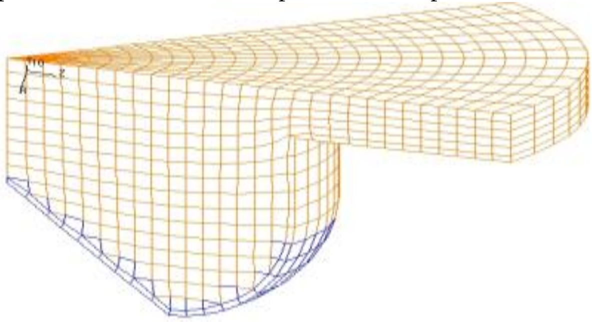

Figure 1: Computational Sector mesh used in the engine simulation at TDC

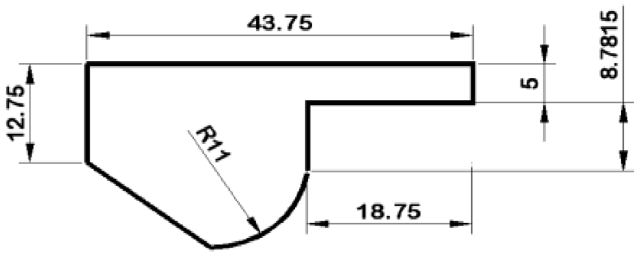

Figure 2: Geometric dimensions of Piston Bowl

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The computational domain comprises of the combustion chamber with piston crown. The number of cells in the computational domain at TDC is 10608.

Table 1: Engine Specifications

Bore	87.5 mm
Stroke	110 mm
Connecting rod length	232 mm
Engine speed	1500 rpm

Piston bowl dimensions are given in figure.2. Engine details are given in table.1 and fuel and injection details are given in table.2.

Table 2: Injection Parameters

Fuel	Dodecane
Injection duration	7^0
Start of injection	10^0bTDC
End of injection	3^0bTDC
Spray orientation angle	100^0
Total fuel injection per cycle	13.76 mg
Nozzle hole Diameter	0.4 mm
Number of injector holes	8

B. Initial and Boundary Conditions: It is important to study the in-cylinder fluid dynamics during the later part of combustion and initial part of expansion strokes in DI diesel engines. Analysis is carried out from 40^0 before TDC (bTDC) to 80^0 after TDC (aTDC), as fuel injection combustion and pollutant formations are taken place during this period. The initial swirl is taken as 2m/s and the constant absolute pressure and temperatures as 9.87 bar, 583 K respectively. The turbulent model has the Intensity-Length scale as 0.1 and 0.001 respectively and it shows no traces of fuel and exhaust gases. The initial surface temperatures of combustion dome region and piston crown regions are taken as 450 K and the cylinder wall region has temperature of 400 K.

3. Analysis of Fuel Spray at 100^0 Injection Orientation with Two Different Geometry Bowl Shapes:

Liquid fuel is injected through the nozzle by the fuel injection system into the cylinder at the end of compression stroke. The liquid jet leaving the nozzle becomes turbulent and spreads out as it entrains and mixes with the in-cylinder air. The outer surface of the fuel jet breaks up into droplets. The initial mass of fuel evaporates first thereby generating a fuel vapour-air mixture sheet around the liquid containing core. Larger droplets provide a higher penetration but smaller droplets are requisite for quicker mixing and evaporation of the fuel. The sprayed fuel stream encounters the resistance from the dense in-cylinder fluids and at a particular distance from the tip of the nozzle breaks into small droplets, this distance is called the breakup distance. Further they vaporize and mix with compressed high temperature and high pressure in-cylinder fluids. At this stage the in-cylinder fluids have attained self-ignition temperature. It causes the fuel to ignite spontaneously and initiate the combustion in the combustion chamber. The spray impingement on wall of the cylinder is unavoidable, because of the compactness of high-speed DI diesel engines. In fact due to the short distance between injector nozzle and the cylinder walls, and also due to high injector pressures, fuel spray may impinge on the cylinder walls before vaporization takes place. Accordingly spray wall interaction becomes an important phenomenon in high speed DI diesel engines. The spray impingement has a great influence on the distribution of fuel jet, evaporation and subsequent combustion processes. Accordingly injection orientation angle is highly influencing on the spray impingement and subsequent phenomena. These plots are obtained from CFD package STAR-CD. The fuel injection begins at 10^0 before TDC and ends at 3^0 before TDC. The duration of fuel injection is 7^0 Crank Angle (CA) and the mass flow rate of fuel is considered as 0.0177 kg / sec. A fuel injector with eight nozzles has been considered for the analysis.

4. Comparison of Injection Orientation Angle:

A. At 8^0 before TDC: The 3-D fuel spray plots at 8^0 before TDC for the fuel injection at 100^0 orientation angle is shown in Fig.3. The figures reveal the spray orientation and its travelling path

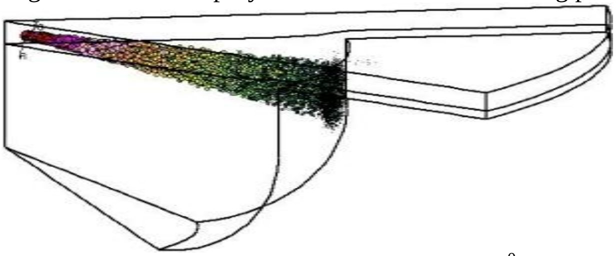


Figure 3(a): Mexican Hat Bowl at 100^0

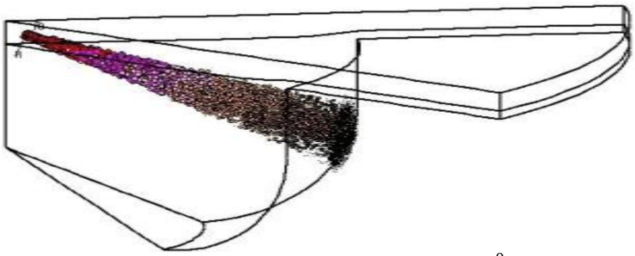


Figure 3(b): Toroidal Bowl at 100^0

Figure 3(a) & 3(b): 3D Spray Plots at 8^0 before TDC in X-Z Plane at Various orientation

B. At 6^0 before TDC: The 3-D plots for 100^0 injection orientation angle is shown in Fig.4. At 4^0 CA i.e. 6^0 before TDC after start of the fuel injection is shown in Figure 4. In case of Mexican Hat Bowl at 100^0 orientation Fig.4(a) half of the spray spreading towards the bottom side of the bowl, another half of the spray moving towards the cylinder head, a trace of the fuel spray is moving towards the squish region is also noticed.

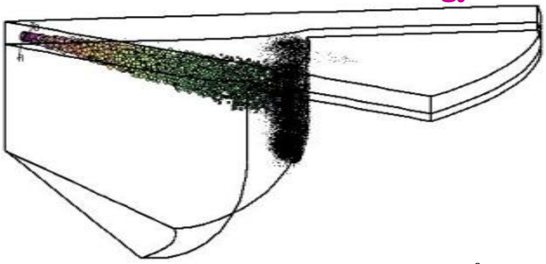


Figure 4(a): Mexican Hat Bowl at 100^0

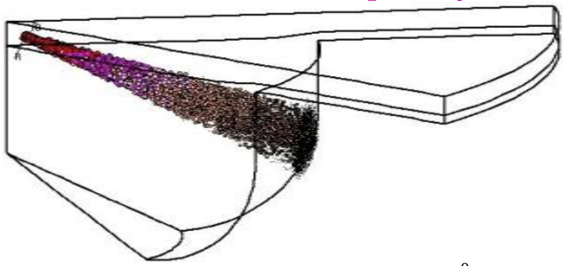
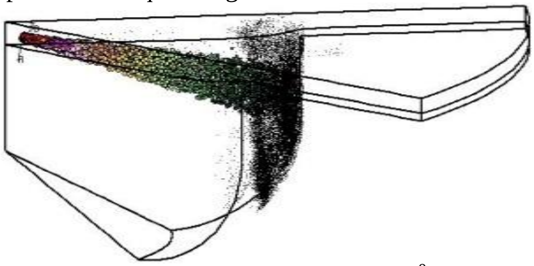


Figure 4(b): Toroidal Bowl at 100^0

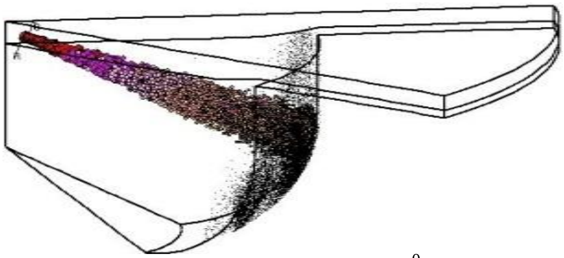
Figure 4: 3D Spray Plots at 6^0 before TDC in X-Z Plane at Various orientation

In case of Toroidal Bowl at 100^0 injection orientation angle shown in Fig.4(b) the three fourth of the spray spreads towards the bottom side of bowl and one fourth spreads towards the piston head is noticed.

C. At 4^0 before TDC: The 3-D plots for 100^0 injection orientation angle is shown in Fig.5 i.e. 6^0 CA i.e. 4^0 before TDC after the fuel injection starts. It is observed that the fuel injection is still continuing. In case of Mexican Hat Bowl at 100^0 injection orientation from the Fig.5 (a) it is observed that a uniform spreading of fuel and wall wetting area is noticed. A trace of sprayed fuel droplets in the squish region is also noticed.



(a) Mexican Hat Bowl at 100^0

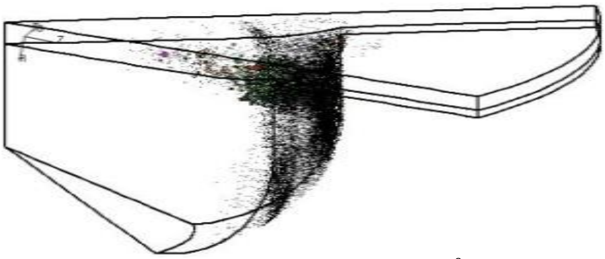


(b) Toroidal Bowl at 100^0

Figure 5: 3D Spray Plots at 4^0 before TDC at Various Injection orientation

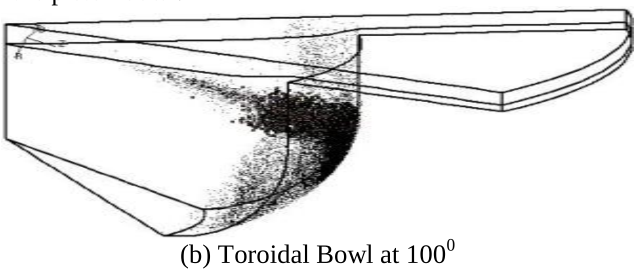
Major part of the spray which is spreading towards the cylinder head is diverting parallel to the cylinder head towards the axis of the cylinder. In case of Toroidal Bowl at 100^0 injection orientation angle from the figure it is noticed that Figure 5 (b) , major portion of the spray is moving towards the bowl, a fraction of spray moving towards the cylinder head is noticed, in this case there is no traces of fuel is moving towards the squish region.

D. At 2^0 before TDC: The 3-D plots at 2^0 before TDC for the 100^0 injection orientation angle is shown in Fig 6, at 8^0 CA i.e. 2^0 before TDC after the fuel injection starts. From the 3-D plots it has been observed that a lump of fuel spray is moving towards the bowl.



(a) Mexican Hat Bowl at 100^0

In case of Mexican Hat Bowl at 100^0 injection orientation angle shown in Fig.6 (a), it is observed that the fuel is spreading uniformly into the cylinder. In case of Toroidal Bowl 100^0 orientation the Fig.6 (b) it is noticed that, there is more concentration of fuel on the walls of the piston bowl.



(b) Toroidal Bowl at 100^0

Figure 6: 3D Spray Plots at 20 before TDC at Various Injection orientation

5. Summary on Fuel Spray Analysis:

From this analysis of 3-D plots, it is confirmed that incase of Toroidal Bowl there is more wetting area in the squish region, and more fuel is accumulated. This is not preferable because the spray goes into the narrow space in squish area. Hence at this region vaporization becomes delay due to lack of air as well as turbulences in this quiescent zones, and it gives adverse effects on combustion and emission formation. In case of Mexican Hat Bowl the spreading of fuel spray is noticed more uniform in the cylinder compared with the Toroidal Bowl.

6. References:

1. M. Auriemma, G. Caputo, F. E. Corcione, G. Valentino " Influence of a Swirling Air flow on an evaporating Diesel spray from a Common Rail injection Injection System under Realistic Engine Conditions" S.A.E. paper 2007-24-0021.
2. K. Kajiyama, K. Nishida, A. Murakami, M. Arai, H. Hiroyasu An Analysis of Swirling Flow in Cylinder for Predicting D. I. Diesel Engine Peformance. S. A. E. paper 84051.
3. T. Bo, D. Clerides, A. D. Gosman and P. Theodossopoulos "Prediction of the Flow and Spray Processes in an Automobile DI Diesel Engine" S.A.E. paper 970882.
4. A. D. Gosmen "State of the art of multi-dimensional modeling of engine reacting flows" oil and gas science technology, Vol.54(1999).
5. Paul Rodatz, German Weisser, and Franz X. Tanner "Assessment of CFD Methods for Large Diese Engines Equipped with Common Rail Injection System" S.A.E. paper 2000-01-0948.
6. Mehta P. S., Singal S. K. and Pundir B. P., "Fuel Spray-Air Motion Interaction in DI Diesel Engines: A Review" S.A.E. paper 930604.
7. Timoney and Smith "Influences of Fuel Injection and Air Motion Energy Sources on Fuel-Air Mixing Rates in a D.I. Diesel Combustion System" S.A.E. Paper No: 960035.
8. McCracken and Abraham "Swirl-Spray Interactions in a Diesel Engine" S.A.E. Paper No: 2001-01-0996.
9. Lee, "Effect of Solid Body Rotating Swirl on Spray Tip Penetration" S.A.E. paper 970798
10. A. D. Gosmen "State of the art of multi-dimensional modeling of engine reacting flows" oil and gas science technology, Vol.54 (1999).