ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 5, September 2013

Fuel Flow Analysis of Injector Nozzle

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Abstract— ***The geometry of the diesel fuel injection nozzle and fuel flow characteristics in the nozzle significantly affects the processes of fuel atomization, combustion and formation of pollutants emissions in a diesel engine. In this paper numerical and experimental results of the nozzle fuel flow analysis for a single-hole injection nozzle Bosch DLLA 148 S 311376 are presented. To describe the nozzle fuel flow, a three-dimensional computational fluid dynamics (CFD) model is employed. The CFD package ANSYS WORKBENCH (Fluent) is used for computation. The results represent the fuel flow characteristics for steady state flow conditions at different needle opening and at the different angles. For this purpose several three-dimensional models representing different needle lifts and for each needle lift at different angles are made .The inlet pressure are varied for 100 bar, 200 bar, 300 bar for each injector and each needle lift at each angle. The fuel flow coefficients obtained from the CFD results at steady flow conditions in the nozzle are validated with the results of the CFD analysis in the [1]. Then the variations of flow coefficient with the change in injection angles is calculated and plotted. It is inferred that with the increase in injection angle the flow coefficient increases and it also depend on the angle in which the injector is positioned.***

Key words: **Ansys Workbench, Injection angles, Flow coefficient, K-£ turbulence model.**

I. INTRODUCTION

A modern compression ignition engine should meet ecological and economical requirements. It should have high performance-fuel consumption ratio, low maintenance costs and it should enable operation under prescribed emission regulations. As the process of combustion and further the production of pollutants and noise emissions is mainly controlled by the process of fuel injection, a lot of effort is put into the development of new and improvement of existing diesel fuel injection systems. In Diesel engine the fuel is injected into the cylinder through the fuel injector at high pressure, to enhance the atomization and spray characteristics of the injected fuel and to improve the combustion efficiency. High fuel pressure is needed to overcome the air resistance (back pressure) to get penetrated into the chamber. The high fuel pressure available at the nozzle seat (100-400 bar) is converted in to kinetic energy at the loss of pressure energy as it passes through the nozzle orifice. By the nozzle flow characteristics analysis, the flow coefficient represents very important parameter of the injection nozzle characteristics. The higher the value of flow coefficient is, the larger fuel quantity is injected per time, which yields higher outflow velocity (suppose no changes in outflow cross-section) and by this better atomization. In the last few years, analysis using computational fluid dynamics (CFD) programs became important, since this is a relative easy way to analyze the fuel injection process on newly designed or re-designed fuel injection systems. By using CFD programs a lot of manufacture and experimental work could be spared, since there is no need to produce every tested variant. In this way many variants could be analyzed in a relatively short period of time. The fuel injection pressure is varied from 100 bar to 400 bar and a comparative study of flow characteristics is done to all the injection lifts at the different angles.

II. INJECTOR FLOW COMPUTATIONAL MODEL

To analyze the flow characteristics of the in-nozzle flow eighteen different nozzle models, representing nozzle lifts from 0.1 to 0.3 mm between the angles of 90 to 130 degrees, were made, that the pressure drop in nozzle is significant only in the area of the needle seat, sac chamber and nozzle holes, the meshes were modeled only for the above mentioned parts. Some further simplifications considering the use of one outlet model of the nozzle were made according to the results of previously made analysis [4], which indicated no significant difference between the results using either a real model or an one half model of the nozzle. The mesh models at maximum needle lift of 0.2 mm with relevant number of mesh nodes and elements for this model is presented. The boundary conditions for the given model is inlet conditions of 100 bar ,and outlet conditions of 30 bar as the outlet is inside the cylinder at the temperature of 293 K. the density 825 kg/nr' and kinematic viscosity of 2.6 mmvs. K-£ turbulence model is employed. Since maximal velocities are much smaller than the speed of sound, the fluid is supposed to be uncompressible.

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ISO 9001:2008 Certified
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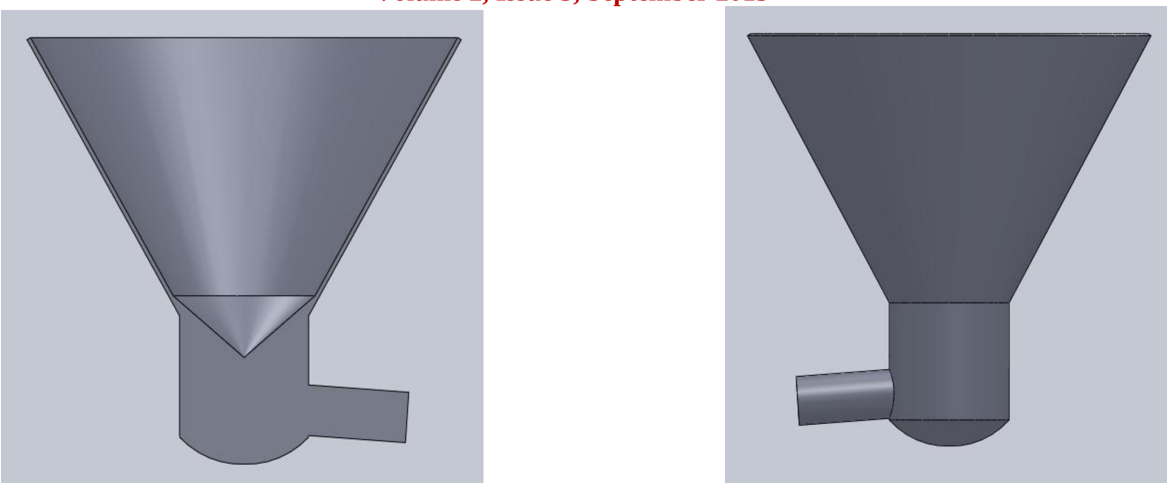
Volume 2, Issue 5, September 2013



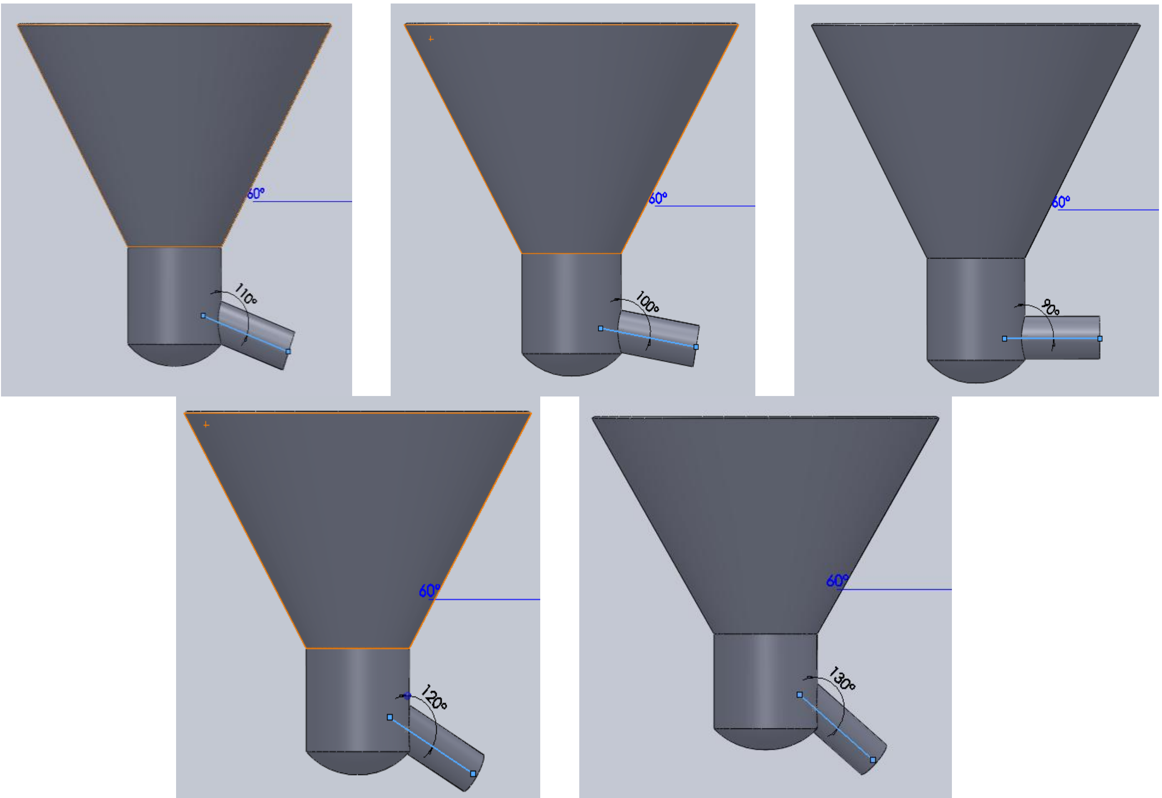
INITIAL AND BOUNDARY CONDITIONS:

INJECTOR FLOW CHARACTERIZATION

Flow coefficient: FLOW COEFFICIENT is defined as ratio between the measured or real *(Vreal)* and theoretical *(Vth)* volume flow injected through the nozzle. According to Bernoulli equation, the theoretical outflow velocity can be derived from the pressure difference *(L1p)* and fuel density.

$$\mu = \frac{Vreal}{Vth} = \frac{Vreal}{Ad\sqrt{\frac{2\Delta P}{\rho}}}$$

MODELS FOR ANALYSIS:



MESHED MODELS:

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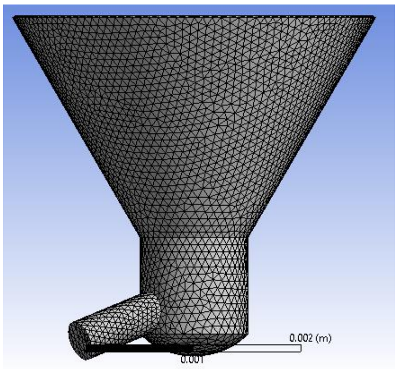
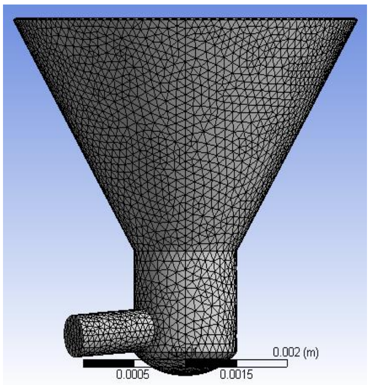
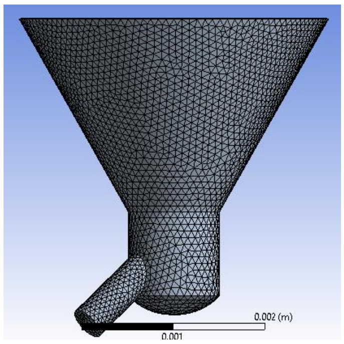
FUEL PROPERTY	DIESEL
Density at 25 °C, [kgm–3]	730
Viscosity at 25 °C, [kgms–1]	0.00224
Surface tension at 25 °C, [Nm–1]	0.0020
Vapor pressure at 25 °C, [Pa]	1280







GRID USED: Tetrahedron (Grid Independence is achieved)

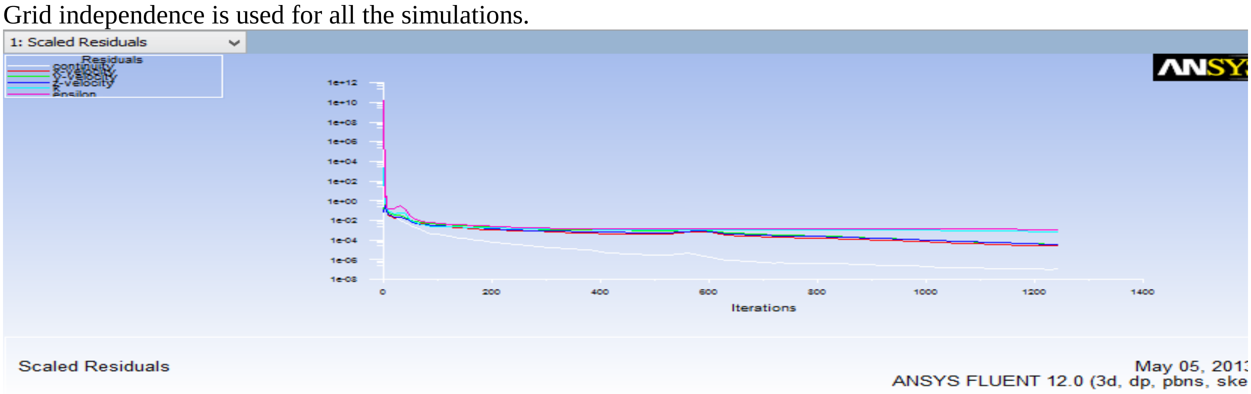
No of Grids : ** 36782 **No of Nodes : 44546

III. RESULTS AND DISCUSSIONS

The thermo physical properties of the fuel i.e. diesel taken for the analysis are given in the table below giving all the values are

CONVERGENCE CRITERIA:

Grid independence is used for all the simulations.




```
reversed flow in 2307 faces on pressure-inlet 6.

reversed flow in 138 faces on pressure-inlet 5.

reversed flow in 2293 faces on pressure-inlet 6.
! 1240 solution is converged
  1240 1.0926e-07 2.4604e-05 3.5921e-05 3.2329e-05 6.3246e-04 9.8368e-04  0:02:26  760

                  Area-Weighted Average
                       Velocity Magnitude                 (m/s)
-------------------------------- --------------------
                               outlet            110.35173
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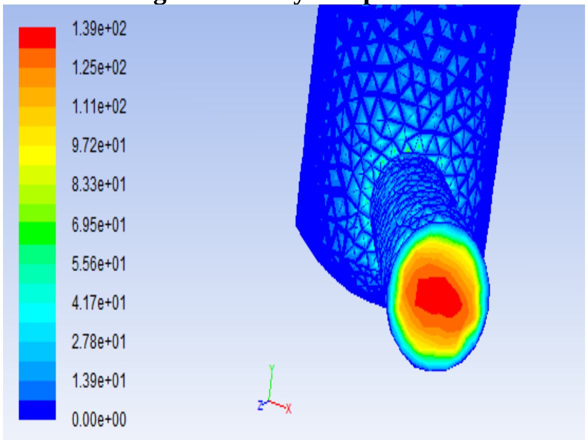
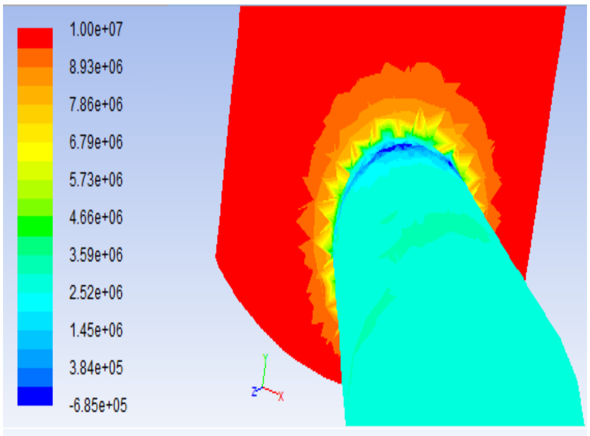
VALIDATON:

The velocity obtained is 110.35173 and from the theoretical calculation the velocity obtained is 167.70. So, the flow coefficient is the ratio of 110.35173/167.70= 0.65802. We validated the results with an error of 1.7044 percent and then we varied the angle.

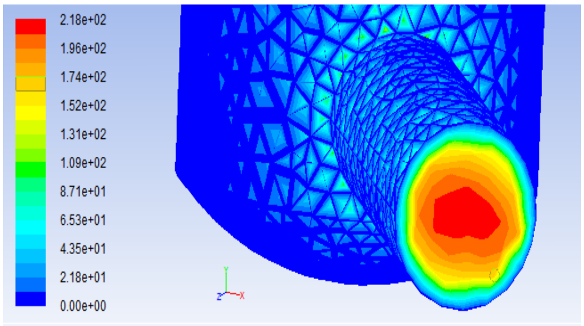
Contours obtained:

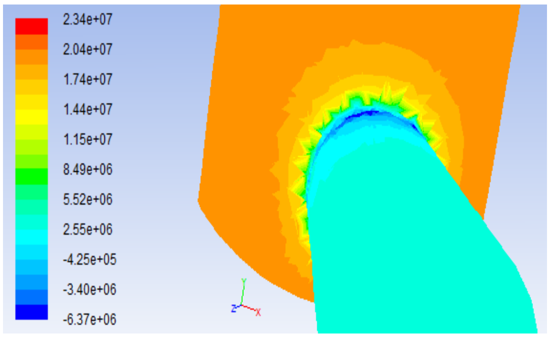
H0.2 at 95 degrees velocity and pressure at 100bar:



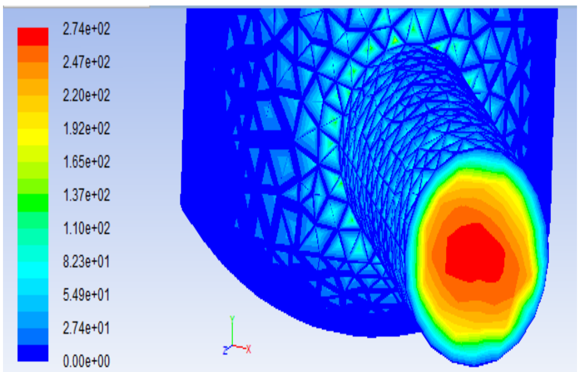


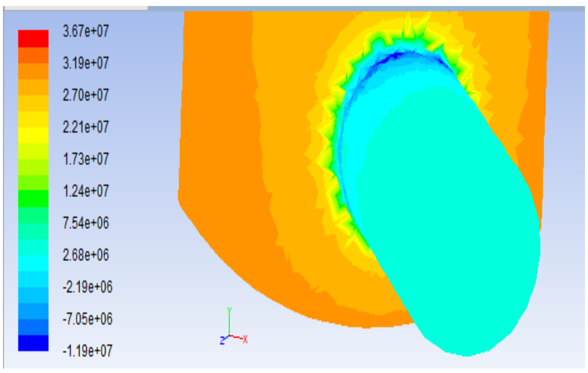
H0.2 at 95 degrees at pressure and velocity at 200bar:





H0.2 at 95 degrees at pressure and velocity at 300bar:





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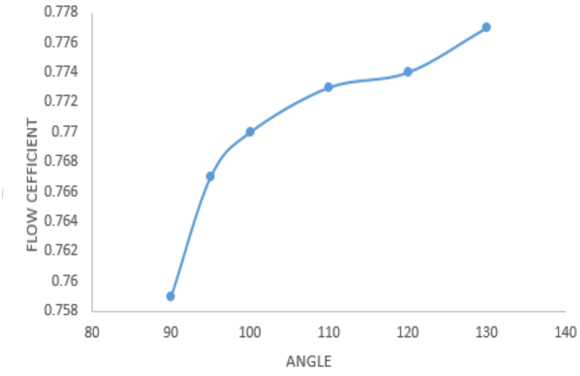
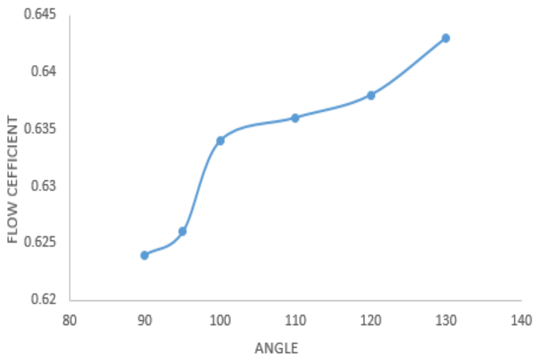
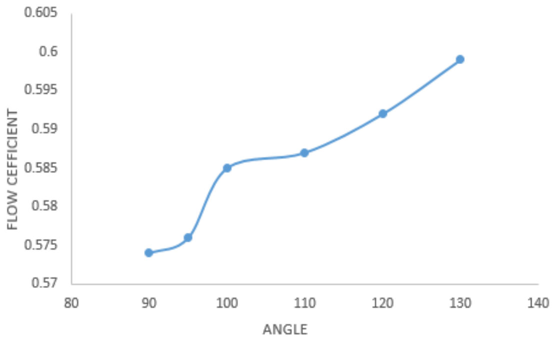


At Needle lift 0.1 FLOW COEFFICIENT VS ANGLE



At Needle lift 0.2 FLOW COEFFICIENT VS ANGLE



At Needle lift 0.3 FLOW COEFFICIENT VS ANGLE

The angle in which the injector is positioned and from the other pressures it is interpreted that when the pressure is increased. Consequently, the flow coefficient increases, given condition that injector angle increases. But the optimal angle can be calculated only by knowing the angle with which the injector is inserted with the central axis.

IV. CONCLUSION

The injector flow characteristics for the diesel fuel injector is done at the different angles of 90,95,100,110,120,130 at different needle lifts of 0.1,0.2,0.3. With the increase of the injector angles, pressure, and needle lift the flow coefficient increases. The maximum optimal angle can be only formulated by both the injector angle and the angle at which the injector is placed with respect to the central axis. In the future analysis the optimal angle for different injectors placed at different angles is analyzed by the 3-d spray pattern of the flow.

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