INVESTIGATION AND COMPUTATIONAL ANALYSIS OF DIVERGENT ORIFICE IN FUEL INJECTOR NOZZLE

Sachin Prabhakar Badgujar[1], P. L. Sarode[2], S. V. Yeole[3], P. S. Patil[4]

[1]*PG student, Department of Mechanical Engineering, RCPIT, Shirpur, MS, India*
[2]*Assistant Professor, Department of Mechanical Engineering, RCPIT, Shirpur, MS, India*
[3]*Assistant Professor, Department of Mechanical Engineering, RCPIT, Shirpur, MS, India*
[4]*Assistant Professor, Department of Mechanical Engineering, RCPIT, Shirpur, MS, India*

Abstract

Diesel engine performance and emissions are strongly influenced with fuel atomization and spray processes. Atomization of fuel is very important part in controlling combustion inside a direct injection engine. Good atomization which ultimately decreases the exhaust emissions. Atomization is first occurs in the vicinity of the orifice due to turbulence and cavitations. Nozzle parameter such as orifice geometry is helpful to increase cavitations. The work investigates coefficient of discharge considering different orifice geometries using CFD analysis. The result shows the importance of K-factor for design of orifice geometries which ultimately useful to understand the value of discharge coefficient. For negative K value the discharge coefficient increases but it significantly decrease the axial velocity..

Keywords: *CFD Analysis, Cavitation, Diesel injector, Discharge coefficient, Atomization etc…*

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1. INTRODUCTION

The performance and emission characteristics of compression ignition engines are largely governed by fuel atomization and spray processes which in turn are strongly influenced by the flow dynamics inside the injector nozzle. Modern diesel engines utilize micro-orifices with different orifice designs, and it is significant to check the effects of various designs on engine performance and emissions.

Sibendu Som et.al, investigated primary breakup model, which shows the effects of cavitation and turbulence generated inside the injector nozzle, also it incorporated into CFD software. Results indicate that cavitation and turbulence inside the nozzle orifice reduces due to conicity and hydro grinding, which reducing dispersion, slows down primary breakup and spray penetration increases [1]. Author further studied cavitation and turbulence inside a diesel injector. Fuel injected through nozzle is associated with two-phase flow field, which characterized by large pressure and small geometries of orifice. In addition, a new criterion for cavitation based on the total stress is implemented. Results indicate that under practical diesel engine conditions, the new cavitation criterion affects the cavitation patterns inside the orifice [2].

A. Dorri et.al, carried out a numerical analysis to check the effects of the hole shape in high pressure injector nozzles. Results shown that pressure variation inside the holes changes with the conicity of orifice [5].

John C. Kayser et.al, studied the compressible flow behavior of light gases through small orifices for the purpose of discharge coefficient. Results give the discharge coefficients correlation with the throat Reynolds number for both circular and elliptical entrance nozzles. The correlation shows that as the Reynolds number is decreased with decrease in discharge coefficient but For Higher Reynolds's number the discharge coefficient increases slowly with increasing Reynolds number [7].

J. Kong et.al, investigated that tapered nozzle hole. The result shows velocity was higher for conical hole than cylindrical hole. [3].

J. Benajes et.al, performed experimental study for check the role of injector nozzle hole conicity towards exit and cavitation in diesel engine. The results show that the atomization can be improved by the use of both convergent and cavitation nozzles, thus reducing the soot emissions. The NOx emission, being dependent of the injection rate and the mixing process of fuel and air, does not necessarily increase with the use of more convergent nozzles [4].

2. PHYSICAL AND NUMERICAL MODEL

The effect of orifice convergence geometry on the discharge coefficient was examined by considering a nozzle with same outlet diameter, which was previously investigated for better atomization of fuel spray [6]. The injector consists of five holes with 0.219mm diameter. For simulation a single orifice was used.

$$K\text{-factor} = (D_{entry} - D_{exit})/10$$

K-factor shows the conicity of the orifice. The outer diameter is considered to be fix and inner diameter varies to get convergent shape of orifice. The results gives that discharge coefficient increases with increase in the conicity [6]. These higher discharge coefficient causes to enhance the atomization due cavitation effect. Cavitation increases with increase in the discharge coefficient but after higher value of discharge coefficient the cavitation may be avoided. The below Fig 1 shows the relation between coefficient of discharge verses cavitation number and which indicate that there was always advantageous to get higher coefficient of discharge.

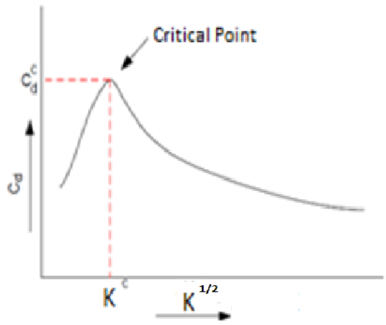

Fig. 1 Discharge coefficients as a function of square root of cavitation number

Present work consist of divergent shape of nozzle and investigate the effect of it. Numerical analysis had been done with the help of gambit and fluent combination. Gambit is the mesh developer in which model is created and meshing it. Fluent is the analysis software in which different models are used to solve the model.

2.1 Gambit Process

Fuel injector consists of nozzle through which fuel is injected into the cavity. Fuel injector nozzle consists of five hole, each having 0.219 mm diameter. For simplification single orifice is consider. Numerical model was divided into six parts namely Inlet, internal wall, upper wall, external wall, outlet and axis. Since the geometry is based on symmetricity, so only half of the geometry was calculated by considering symmetry boundary conditions along the axis limitations. Boundary conditions were set for constanr pressure for inlet and a zero slip boundary condition was used at the wall. Finer mesh was done near the inlet and outer condition of geometry. The cross-section of the nozzle is almost square (width, Y-axis = 219 µm) and the length is 880 µm (X-axis), as shown in Fig 2.

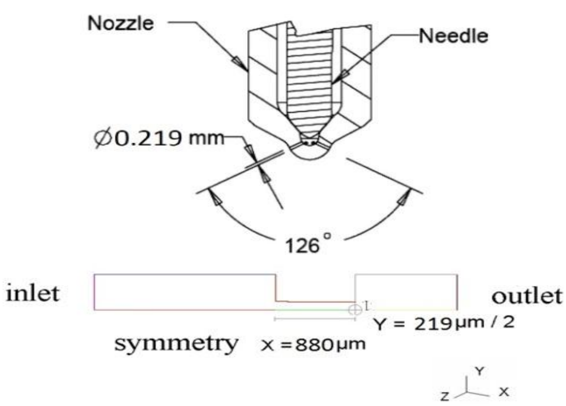

Fig 2 Geometry of computation domain

2.2 Fluent Process

A series of simulations were performed at various inlet diameters. The simulations were performed until a steady mass flow rate at the inlet and the outlet is attained. Boundary conditions were applied consisting of 101325pa operating conditions, Green Gauss cell based solver was used for two dimensional steady implicit Pressure based.

3. RESULT AND DISCUSSION

The nozzle is selected for the simulation which having -0.7 K-factor that is smaller inner diameter and fix outer diameter. The simulation gives the distribution of coefficient of discharge, axial velocity and static pressure. Also the static pressure contours shown below Fig 3.

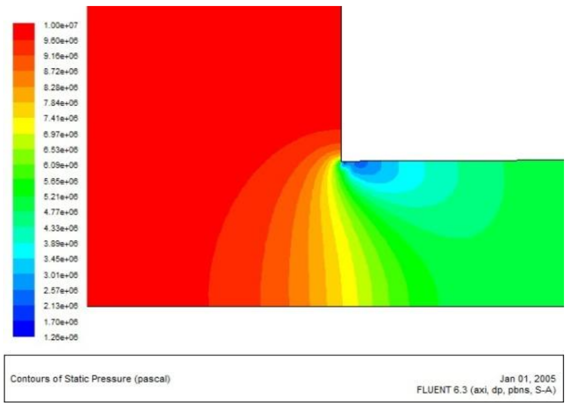

Fig 3: Contours of static pressure of nozzle for K=-0.7

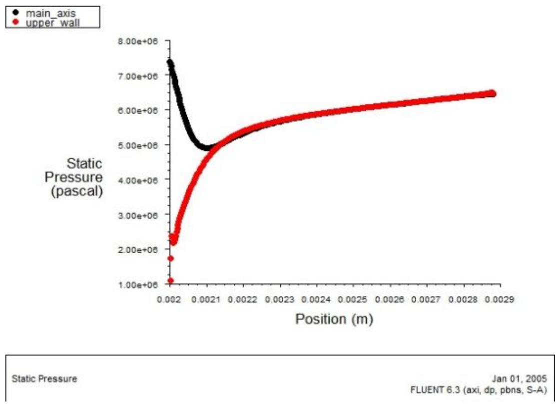

Fig 4: Static pressure distribution of nozzle for K=-0.7

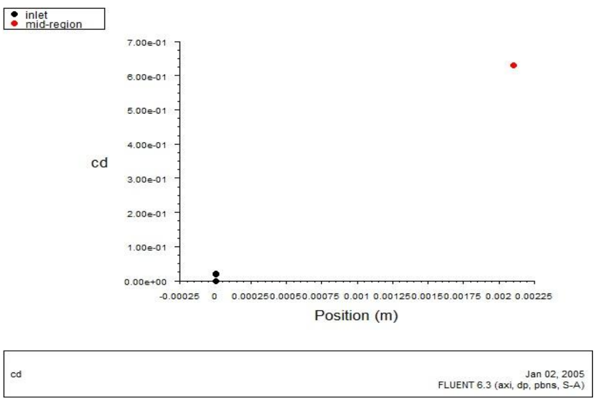

Fig 5: Coefficient Discharge at mid region of nozzle for K=-0.7

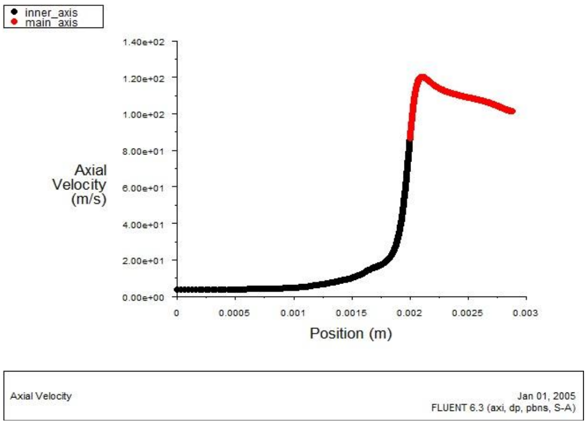

Fig 6: Axial velocity distribution of nozzle for K=-0.7

Further it can be check for higher negative value of K. The Fig.7 shows that discharge coefficient increases with the increase in the K-value. Axial velocity of orifice is also important Fig. 8 shows that axial velocity for different K-values and it clearly indicates that velocity decreases and fuel burst at the vicinity only which ultimately cause to incomplete burning of fuel.

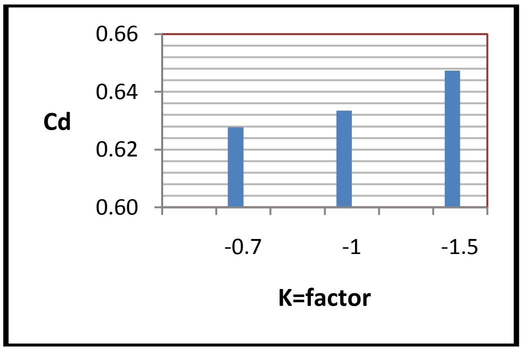

Fig 7: Comparison of various discharge coefficients

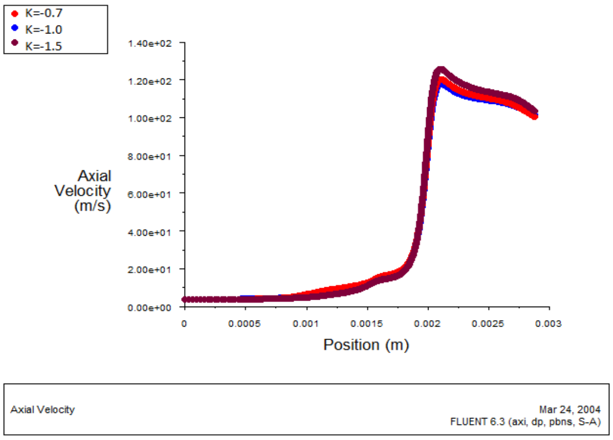

Fig. 8: Comparison of velocity magnitude for known nozzles geometry

4. CONCLUSIONS

Fuel injector nozzle design is critical. Nozzle shape causes to increase atomization. Cavitation is the main source for primary atomization in the vicinity of nozzle. Cavitation causes to increase atomization but higher cavitation may reduce atomization, so there is higher discharge coefficient gives more cavitation up to certain limit. From the present simulation the main conclusions is that the coefficient of discharge was slightly increases with increase in negative conicity of nozzle. The divergent shape towards the exit greatly modifies the coefficients of discharge during the injection process. But negative conicity may be reduces the axial velocity .

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