

# CFD Analysis & Optimization of Fuel Injector by Changing It's Geometry -A Review

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## Abstract

A proper and synchronized fuel injection is paramount for a good engine performance, since it provides a homogeneous combustion among the cylinders. The use of alternative fuels such as Ethanol, Methanol and Natural Gas in automotive applications has increased due to the strict environmental regulations. These are used to reduce automotive emissions, especially in heavy trucks and city bus fleets. Most of these vehicles use diesel fuel as their primary fuel. Trucks and buses with Detroit Diesel engines have the option to operate using methanol as their primary fuel instead of diesel fuel. Due to the low lubricity of methanol fuel, the unit fuel injectors injecting methanol fuel have a shorter operating life than those injecting diesel fuel do. Using the computational fluid dynamics programs CFX and CFX obtained the pressure and velocity profiles for pre-selected locations in the fluid path of the injector. Locations of high and low velocity areas were determined to be performance inhibitors and possible failure points and Find the way to minimize failure points.

**Keywords: Fuel Injector, Emission control, Fuel Flow Penetration, Nozzle Diameter, Nozzle geometry, Back Pressure, Cone Angle, Transient Fuel Spray Formation, optimization.**

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## I. INTRODUCTION

Effect of injector nozzle geometry and operating pressure condition such as opening pressure, ambient pressure, and injection pressure on the transient fuel spray behavior have been examined by experiment. In order to clarify the effect of internal flow inside nozzle on the external spray, flow details inside model nozzle and real nozzle were also investigated both experimentally and numerically. For the effect of injection pressure, droplet sizes and velocities were obtained at maximum line pressure of 21 MPa and 105 MPa. 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 be 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. The cavitating flow in diesel injector nozzles has been extensively investigated by a number of researchers due to its strong impacts on the fuel spray atomization and consequent spray combustion in Diesel Engines. From an early study about cavitating flow in small nozzles and stated that cavitations creates large amplitude of disturbance which results in enhancing jet atomization and examined cavitations in various nozzles with different geometries.

Below is the general layout construction and modelling of common fuel injector in Solid works with its all parts.

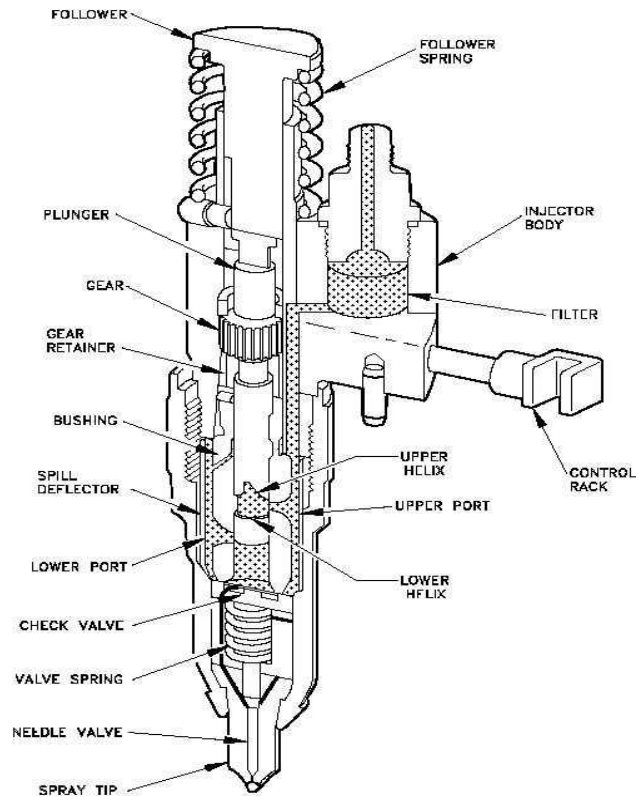


Fig. 1: General Layout of Fuel Injector

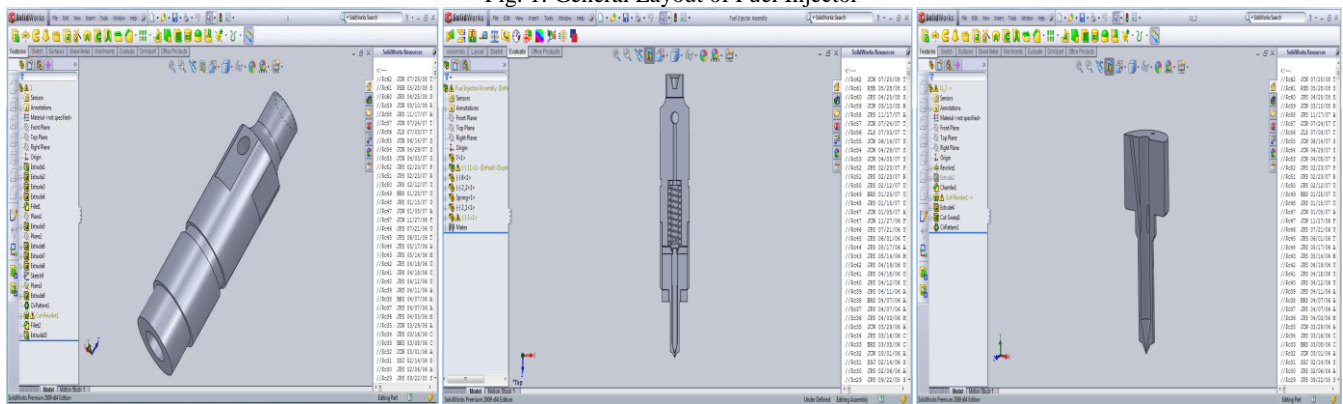


Fig. 2: Modeling Images of Fuel Injector

The most important parts in it are as bellow:

- Follower & Follower Spring
- Plunger
- Spill Deflection
- Needle Valve
- Check Valve
- Control Rack
- Filter
- Bushing
- Upper & Lower Port
- Upper & Lower Helix

## II. LITERATURE REVIEW ON DIESEL FUEL INJECTOR

**A. *The Effect Of Fuel Injector Nozzle Geometry and Operating Pressure Condition On Transient Fuel Spray Behavior, Ja ye koo, School Of Aerospace and Mechanical Engg. Hankuk Aviation University, Kyunggi-do 412-791, Korea, KSME International Journal, Vol. 17 No. 3, PP 617-625, 2003.***

In this paper researcher analysis that The distribution of fuel in the combustion chamber at the start of combustion is critical to the subsequent combustion. Fuel efficiency and exhaust emission depend on fuel spray atomization and mixture formation. Better understanding of atomization process break-up mechanism is necessary to achieve optimum fuel distribution in the combustion chamber for the low pollutant emission and high engine performance. In the quest for improved emission, fuel distribution strategies have been changed. Certain techniques have been shown to be effective in reducing certain emission. For Example, high pressure injection in diesel engine is useful for simultaneously reduction of NO<sub>x</sub> and particular emission.

From an integrated study that is carried out from this literature are (1)The sharp entrance nozzle has smaller Sauter mean diameter and wider spray angle, which is partly due to the higher turbulence intensity at an exit plane near wall. (2) At lower opening pressure with lower ambient pressure, a protrusion can be observed which might be injected into the chamber at the opening of the needle from the fuel in the volume of injector. (3) As increase of opening pressure spray tip penetration and spray angle were increased at both lower ambient pressure and higher ambient pressure. (4)The increase of injection velocity changes the tip of the velocity profile and increases the number density of droplet that are likely to breakup due to the high relative velocity even though the droplet diameters are shifted lower ranges.

**B. *Experimental And Numerical Analysis Of Fuel Flow In The Diesel Engine Injection Nozzle, Martin Volmajer, Breda Kegl, University of Maribor, Faculty of mechanical engineering, Smetanova 17, S/-2000 Marihor, Slovenia, Journal of Kones. Combustion Engines, Vol. B, No 1-2,2001.***

In this paper researcher analysis that the geometry of the diesel fuel injection nozzle and fuel flow characteristics in the nozzle significantly affects the processes of fuel atomisation, 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 four-hole injection nozzle Bosch DLLA 148 S 311376 are presented

Conclusion: To refine the precision of the measurement, by defining the exact value of the pressure difference, the pressure downstream of the nozzle should be measured, or the nozzle position should be changed so, that the fluid would be injected directly into the measuring Plexiglas. For the same purpose, Plexiglas cylinder with high ovalness should be replaced with the Glass Plexiglas cylinder with proper circle cross-section

**C. *Diesel nozzle geometry influence on spray liquid-phase fuel penetration in evaporative conditions, R. Payri , F.J. Salvador, J. Gimeno, L.D. Zapata, CMT-Motores Te ´rmicos, Universidad Polite ´cnica de Valencia, Camino de Vera s/n, E-46022, Spain, Science Direct, Fuel 87(2008)1165-1176***

In this paper researcher to study about An experimental study of real multi-hole Diesel nozzles is performed under current DI Diesel engines operating conditions. The aim of the investigation is to study the influence of orifice geometry on the flow at the nozzle exit and to analyse its effect on the spray in evaporative conditions. Special attention is taken in the study of the influence of cavitation on the orifice internal flow and spray development. The spray liquid-phase fuel penetration has been characterized. It is widely known that the nozzle hole geometry of a diesel injector affects the fuel/air mixing process, and therefore the fuel atomization, which directly influence the combustion and the exhaust emissions. Nowadays, diesel nozzle geometry is considered a major issue in order to fulfil new stringent emissions regulations while maintaining or improving the efficiency of the engine. It is believed that cavitation caused by the nozzle geometry can indeed favour atomization according to several research.

The aim of this paper has been to study the influence of nozzle geometry and cavitation phenomena on internal flow, fuel/air mixing process and vaporization. For this purpose, in the paper, three 6-hole sac nozzles differing in the orifices degree of conicity have been characterized geometrically and hydraulically. Furthermore, measurements of liquid-phase fuel penetration in evaporative environment and, for different engine conditions, have been performed. By means of the analysis of results, a link has been established through flow parameters, between nozzle geometry and LL. In order to help to understand the influence of nozzle geometry and cavitation phenomena on the internal flow, spray formation and fuel/air mixing, various stages were followed.

**D. *Mixture distribution in a multi-valve twin-spark ignition engine equipped with high-pressure multi-hole injectors, N. Mitroglou, C. Arcoumanis, K. Mori, Y. Motoyama, Centre for Energy and the Environment, School of Engineering and Mathematical Sciences, City University, London IYamaha Motor Company, Japan, Journal of Physics: Conference Series 45 (2006) 46–58***

In this paper researcher main objective is to design the potential of high-pressure multihole injectors in creating homogeneous as well as stratified mixture distributions in a five-valve twin spark ignition engine. A motored single-cylinder optical engine was used, with a fully optical quartz liner, which featured a centrally mounted injector and two spark-plugs located at opposite sides of the cylinder. Laser induced fluorescence was employed to reveal fuel concentration and local air/fuel ratio measurements

along a central plane of the cylinder, with a 6.5mm offset relative to the spark-plug plane. The twin-spark combustion concept featuring central injection is generally offering advantages in HC and smoke emissions relative to its side-injection, wall-guided counterpart. Additionally, the previously observed problem of cocking in multi-hole injectors can be minimised due to reduced injector tip temperatures, as a result of twin-spark combustion.

**E. Effect Of The Number Of Fuel Injector Holes On Characteristic Of Combustion & Emission In a Diesel Engine, B. H. LEE, J. H. SONG, Y. J. CHANG and C. H. JEON, Department of Mechanical Engineering, Pusan National University, Busan 609-735, Korea, International Journal of Automotive Technology, Vol. 11, No. 6, pp. 783–791 (2010)**

This papers state and explain that The results show that increasing the number of holes significantly influences evaporation, atomization, and combustion. However, when the number of holes exceeds a certain threshold, there is an adverse effect on combustion and emissions due to a lack of the air entrainment required for the achievement of a stoichiometric mixture. The concentration of liquid fuel, penetration length, and spray angle injected from a single injector decreases mainly because of the reduced momentum of the liquid fuel as the hole number increases. Nonetheless, liquid spray atomization and evaporation is promoted by the smaller droplet size. The eight-hole injection geometry yields the best combustion behavior and engine performance (the lowest BSFC) among all tested injections, which results from

the competing effects of temperature influenced by the local distribution of the fuel vapor-air mixture and wall impingement. Lower soot emissions were observed with the eight hole injection compared with the six-hole injection primarily due to the combined effects of reduced temperature and the absence of fuel-rich zones. There is slight penalty on NO<sub>x</sub> emissions with the eight-hole injection system, but the emissions are not significantly different from those with the six-hole system. The optimal number of injector holes in the particular engine used for this study is determined to be eight when parameters such as engine performance, combustion, and overall emissions are considered.

### III. CONCLUSION

As per review of research papers, we can see that during all circumstances and combustion process there will be major output change with changing the several parameters likewise plunger spring tension, nozzle diameter, angle of attack (cone angle), tip formation, number of holes of injector, intensity of pressure, stoichiometric level of mixture etc will increase the combustion efficiency and reduce the level of NO<sub>x</sub> emission gases.

### REFERENCES

- [1] Ja ye koo "The Effect Of Fuel Injector Nozzle Geometry and Operating Pressure Condition On Transient Fuel Spray Behavior", School Of Aerospace and Mechanical Engg. Hankuk Aviation University, Kyunggi-do 412-791, Korea, KSME International Journal, Vol. 17 No. 3, PP 617-625, 2003.
- [2] Martin Volmajer, Breda Kegl "Experimental And Numerical Analysis Of Fuel Flow In The Diesel Engine Injection Nozzle", University of Maribor, Faculty of mechanical engineering, Smetanova 17, S/-2000 Maribor, Slovenia, Journal of Kones. Combustion Engines, Vol. B, No 1-2, 2001.
- [3] R. Payri, F.J. Salvador, J. Gimeno, L.D. Zapata, "Diesel nozzle geometry influence on spray liquid-phase fuel penetration in evaporative conditions", CMT-Motores Térmicos, Universidad Politécnica de Valencia, Camino de Vera s/n, E-46022, Spain, Science Direct, Fuel 87(2008)1165-1176.
- [4] N. Mitroglou, C. Arcoumanis, K. Mori "Mixture distribution in a multi-valve twin-spark ignition engine equipped with high-pressure multi-hole injectors", Y. Motoyama Centre for Energy and the Environment, School of Engineering and Mathematical Sciences, City University, London | Yamaha Motor Company, Japan, Journal of Physics: Conference Series 45 (2006) 46–58.
- [5] B. H. LEE, J. H. SONG, Y. J. CHANG and C. H. JEON "Effect Of The Number Of Fuel Injector Holes On Characteristic Of Combustion & Emission In a Diesel Engine", Department of Mechanical Engineering, Pusan National University, Busan 609-735, Korea, International Journal of Automotive Technology, Vol. 11, No. 6, pp. 783–791 (2010).