International Journal of
I.C. Engines and Gas Turbines

ISSN: 2582-290X
Volume 8, Issue 2, 2022
DOI (Journal): 10.37628/IJICEGT

http://mechanical.journalspub.info/index.php?journal=JIEGT&page=index

Research IJICEGT

Study of the Fuel Injector Nozzle of the CI Engine

Chanchal*

Abstract

A fuel injector nozzle is a component of a fuel injection system that is responsible for delivering fuel into the combustion chamber of an internal combustion engine in a precise and controlled manner. The nozzle atomizes the fuel into a fine spray, allowing it to mix more thoroughly with the air in the combustion chamber and burn more efficiently. The study discussed various fluids flowing at different velocities and convergent and divergent nozzle diameters. Thermal and chemical energy are transformed into kinetic using the nozzle. The component of an injector referred as the nozzle is where liquid fuel is shot into the combustion chamber. It is employed in diesel engines where air is taken into the cylinder during the suction stroke and separate fuel is fed through the injector at the conclusion of the compression stroke. The combustion chamber's low speed, high pressure, and high temperature gas is transformed into high velocity, lower pressure, and lower temperature gas by the nozzle. Nozzles regulate the stream that exits from them in terms of flow rate, speed, direction, mass, and pressure. By using the CFD technique, it is possible to estimate the pressure drop, temperature coefficient, velocity, and heat transfer rate for fluids.

Keywords: Nozzle, thermal analysis, CFD analysis, finite element analysis

INTRODUCTION

A fuel injector shown in Figure 1 is a mechanical device that is electronically controlled and used to pump or pour (like a syringe) fuel into an engine in order to generate the proper air-fuel balance, which in turn allows the engine to burn fuel efficiently.

Currently, people are taking environmental protection more seriously, and any new technology that is developed should highlight the importance of the environment. The greatest difficulties in developing new diesel engines for automobiles are due to future emissions from combustion and consumer demand for continually better performance.

The benefits of current advancements in CI engines outweigh the disadvantages of present spray hole geometry, which is that long-term operation frequently results in a decrease in power production. The major goal is to reduce emissions.

As the temperature difference between the fluid and the wall increases, it intensifies. In this process, the amount of deposit-forming particles close to the wall increases [1–5].

A compression ignition (CI) engine's fuel injector nozzle is in charge of supplying a thin mist of fuel to the engine's combustion chamber. A homogenous mixture that is simple to ignite is produced by atomizing the fuel into tiny droplets and combining it with air. Productivity, fuel efficiency, and

***Author for Correspondence**
Chanchal
E-mail: vermachanchal786@gmail.com

Student, Department of Mechanical Engineering, Noida International University, Noida, Uttar Pradesh, India

Received Date: February 07, 2023
Accepted Date: February 14, 2023
Published Date: February 20, 2023

Citation: Chanchal. Study of the Fuel Injector Nozzle of the CI Engine. International Journal of I.C. Engines and Gas Turbines. 2022; 8(2): 30–35p.

emissions of an engine are significantly influenced by the design and positioning of the nozzle. Basic nozzle designs include those with a single hole, various holes, and solenoid functioning. The type of nozzle of using is determined by a number of elements, such as the engine design, the fuel used, and the desired performance.

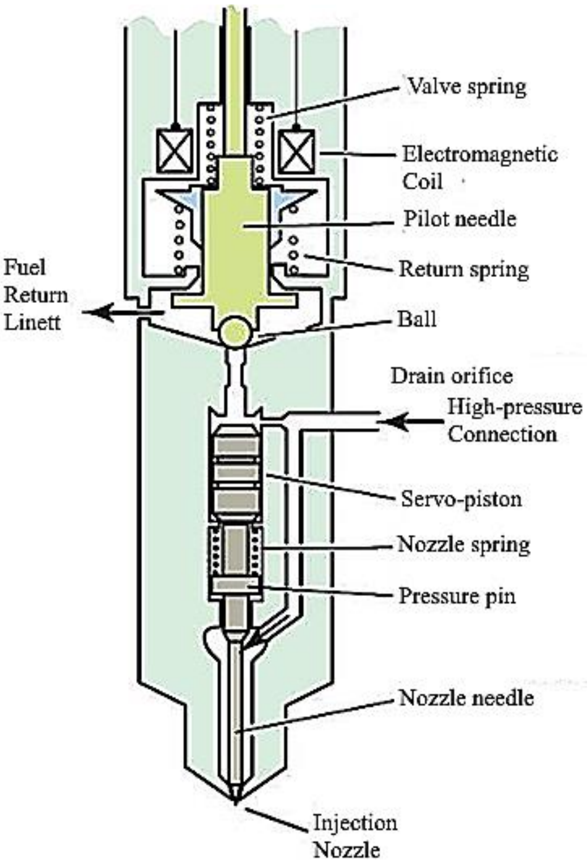

Figure 1. Fuel injector nozzle.

The creation of the deposits, which are made up of gas compounds and related particles, is aided by the cold wall's ability to absorb gases.

The adhering impaction and integration of particles are now the key factors influencing the growth of the deposits at this point. The eradication of deposits has a physical mechanism that comprises the chemical reaction and gaseous component adsorption.

Stages of Working of a Fuel Injector Nozzle

Fuel delivery: The fuel pump sends fuel to the injector nozzle, often under high pressure.

Solenoid activation: The fuel injector nozzle is regulated by a solenoid in exhaust gas recirculation (EGR injection (EFI) systems. The solenoid opens the injector and let us fuel flow into the nozzle when it is triggered.

Atomization: Fuel is atomized into small droplets as it travels through the nozzle using either precision-drilled holes or unique nozzle designs. To deliver successful combustion, the spray pattern and droplet size are carefully regulated.

Delivery to the engine: The combustion chamber of the engine receives the atomized fuel, where it is combined with air and pressurized.

Ignition: The fuel-air solution is then ignited, either by a sparking in an engine that employs a spark plug or by the high pressure and temperature of a compression-ignition engine [6].

Generally, the fuel injector nozzle is a large component that greatly impacts an engine's efficiency and performance. For the engine to operate at its best, the nozzle's exact design and control are crucial.

PROBLEM STATEMENT

- The primary goal of this project is to build a 3D model of the convergent diverging nozzle that changes with different nozzle diameters and analyse the convergent divergent nozzle with various mass flow rates in order to figure out the pressure and velocity using the CFD approach.
- Create a 3D model of the nozzle using CAD software including such solid works.
- Convert the model into a solid file using the analysis software ANSYS.
- Thermal study of the nozzle model.

CAD

By using computers to help in the construction, modification, analysis, or optimization of a design, the term "computer-aided design" (CAD) is used.

When employed in patent applications, designs created with CAD software are beneficial in preserving goods and inventions.

CAD software for mechanical design either creates raster graphics to represent the overall appearance of designed objects or vector-based graphics to depict the objects of traditional drafting.

FEA

Finite element analysis, or FEA, is a crucial approach for solving and supplementing complex problems with simpler ones and generating approximations of answers. The flexible finite element approach is applied in a variety of industries to address a variety of real-world engineering issues. The relative findings can be produced using the Finite Element approach.

METHODOLOGY/DESIGN

- C*omputational fluid dynamics* (CFD) is the process of statistically simulating a fluid flow-related physical phenomenon and solving it numerically with the aid of computational power.
- A CFD software analysis looks at fluid flow in regard to its physical attributes, including velocity, pressure, temperature, density, and viscosity. Figure 2 shows 3D Fuel injector CAD Model.
- Since there might be a significant reduction in the quantity of physical prototypes, CFD analysis is a crucial component in creating a sustainable product development process.

The main parts of a fuel injector nozzle are:
Nozzle body: a metal-based injector nozzle's main body, which contains the internal parts and spray apertures.

Solenoid: The solenoid controls the fuel flow through the injector nozzle in electronic fuel injection systems. The nozzle is opened and closed by the solenoid to regulate the flow of fuel to the engine.

Needle valve: The injector nozzle's fuel pressure and flow are controlled by the needle valve. Usually attached to a solenoid, the needle valve opens and closes in response to inputs from the engine control unit (ECU).

Spray holes: The fuel is atomized and supplied into the combustion chamber of the engine through the spray holes, which are precisely drilled orifices. The quantity, size, and distribution of the spray holes impact the atomization quality and pattern of the fuel spray.

O-ring seals: To stop fuel leaks and provide a tight seal between the nozzle and the fuel rail or fuel delivery lines, O-ring seals are utilised.

Electrical connectors: The injector nozzle is connected to the engine's electrical system by electrical connectors, which also allow it to receive control signals from the ECU.

These are the essential parts of a fuel injector nozzle, though the precise arrangement and number of parts may differ depending on the engine and nozzle type.

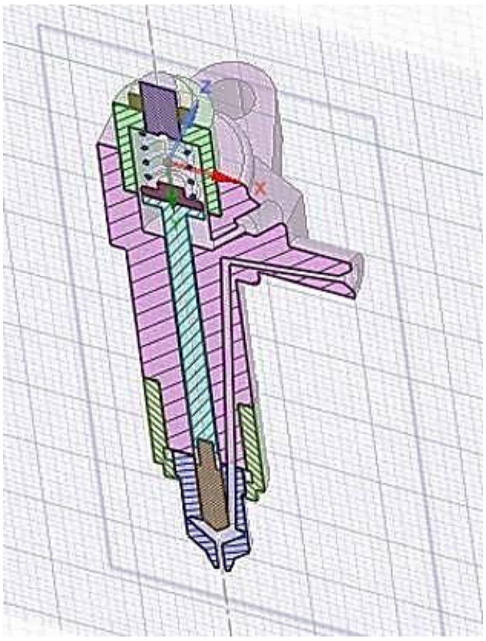

Figure 2. 3D fuel injector CAD model.

LITERATURE SURVEY

One of the initial observations of fuel injector nozzle cavitation was reported in 1959 by Bergwerk [7]. He observed the flow through a spray hole that was like to a fuel injector in size. In his study, he connected the spray hole's flow to factors like cavitation number, Reynolds number, upstream edge sharpness, and length to diameter ratio (L/D), and he also showed that cavitation occurs inside the nozzle. He also brought out the flow sensitivity brought on by nozzle geometry flaws. Another research on flow through a real-size transparent nozzle was carried decades later. Even though the pressure conditions were lower than those in an injector, scientists saw a cavitation film form at the inlet corner as the pressure differential was raised.

Later on, this study was expanded by Chaves *et al.* [8]. They employed a steady flow apparatus with an intake pressure range of up to 100 MPa and a back pressure constant at 0.1 MPa (atmospheric pressure).

Fuel injector nozzles are widely used in compression ignition (CI) engines, also known as diesel engines, in various applications, including:

Automotive: In trucks, autos, and other machinery with diesel engines, fuel injector nozzles are employed. In addition to ensuring effective combustion, they are in charge of supplying fuel to the engine's combustion chamber.

Industrial and agricultural equipment: Tractors, generators, and other large pieces of agricultural and industrial gear all employ fuel injector nozzles.

Marine: Marine diesel engines, such as those used in boats used for fishing and shipping, use fuel injector nozzles.

Power generation: Motor generators and other power generation machines require equipment that functions reliably and effectively, such as fuel injector nozzles.

Military: In military vehicles and equipment like tanks, helicopters, and submarines, where great performance and dependability are essential, fuel injector nozzles are employed.

Locomotives: In diesel-electric locomotives, fuel injector nozzles are used to supply fuel to the engine's combustion chamber and generate power for the trains.

Construction equipment: Heavy construction machinery like bulldozers, excavators, and cranes require fuel injector nozzles to power and control the machinery.

Mining equipment: To power and manage huge mining equipment like haul trucks, shovels, and draglines, fuel injector nozzles are employed.

Off-highway vehicles: A variety of off-highway vehicles, including mining trucks, logging trucks, and heavy equipment vehicles, employ fuel injector nozzles to power and regulate the machinery.

Railway rolling stock: In order to power and manage the trains, diesel-electric multiple units (DMUs) and diesel-hydraulic locomotives employ fuel injector nozzles.

CI engines use fuel injector nozzles for a variety of purposes, some of which are listed here. By precisely controlling fuel distribution and atomization with fuel injector nozzles, engine performance, efficiency, and emissions are increased. Fuel injector nozzles are essential for supplying the engine with fuel and managing the combustion process, which has an impact on the engine's efficiency and performance [9, 10].

RESULTS AND DISCUSSIONS

Result Table

After successfully completing the design and CFD analysis, we came to this results as shown in below

Fuel Injector. 1.50 mm (Nozzle Dia.)

Parameters	*Values*
Inlet mass flow	0.0017 kg/sec,
Outlet pressure	8 bar,
Outlet Velocity	1.9 m/s, and
Inlet pressure	8 bar.

Fuel injector 0.50 mm (Nozzle dia.)

Parameters	*Values*
In let mass flow	0.0017 kg/sec,
Outlet pressure	8 bar,
Outlet Velocity	15 m/sec, and
Inlet pressure	10 bar.

CONCLUSION

The fuel injector CFD analysis was performed satisfactorily. The next stage was to modify the geometry of the original model in a way that may improve performance characteristics after the simulation's validity was demonstrated (pressure and velocity). The convergent divergent nozzle adjusts the several fluids and nozzle diameters at various speeds. We model the changing convergent divergent nozzle with various nozzle sizes. We desire a fluid exit velocity of 1 m/sec. As a result of the foregoing finding, a fuel injector with a 1.50 mm nozzle provides 1.9 m/sec of fluid velocity at 8 bar pressure. With an injector nozzle with a 0.50 mm diameter gives us a fluid velocity of 15 m/s at 10 bar of pressure. In order to exert that pressure, it will gain additional power. As a result, when we compare a fuel injector with a 1.50 mm diameter nozzle and a 0.50 mm diameter nozzle, the 1.50 mm diameter nozzle is satisfied since it will provide the velocity at a lower pressure than the 0.50 mm diameter fuel injector.

REFERENCES

1. Taylor CF. The Internal-combustion Engine in Theory and Practice: Combustion, fuels, materials, design. USA: MIT press; 1985.
2. Noor MM, Kadirgama K, Devarajan R, Sani MSM, Nawi MFM, Yusaf TF. CFD Simulation and Validation of The In-Cylinder Within a Motored Two Stroke Si Engine. International Conference on Science & Technology: Applications in Industry & Education. 2008; 1461–1468.
3. Harrington DL, Bolt JA. Analysis and digital simulation of carburettor metering. SAE Technical Paper 700082. 1970.
4. White C, *et al*. The hydrogen-fuel internal combustion engine: a technical review. Int J Hydrog Energy. 2006; 31(10): 1292–1305.
5. Shimada K, Ichihara T. Fuel supply system and fuel supply method for in-cylinder direct fuel injection engine. Google Patents. 2004.
6. Zhao F-Q, *et al*. A review of mixture preparation and combustion control strategies for spark-ignited direct-injection gasoline engines. SAE Technical Paper 970627. 1997.
7. Bergwerk W. Flow Pattern in Diesel Nozzle Spray Holes. Proc Inst Mech Engrs. 1959; 173(25): 655–674. https://doi.org/10.1243/PIME_PROC_1959_173_054_02.
8. Chaves H, *et al*. Experimental Study of Cavitation in the Nozzle Hole of Diesel Injectors Using Transparent Nozzles. SAE Technical Paper 950290, 1995
9. Merker Günter P, Rüdiger Teichmann, editors. Grundlagen Verbrennungsmotoren – Funktionsweise Simulation Messtechnik. 7th Edn. Wiesbaden: Springer; 2014; 179. ISBN 978–3–658–03194–7.
10. A Timeline Overview of Motorola History 1928-2009. [Online]. Motorola. Archived from the original (PDF) on 20 June 2011. Retrieved 20 January 2014.

