Performance Analysis of Fuel Injector in CRDI System by ICEM CFD

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ABSTRACT

Common Rail Direct Injection (CRDI) system is one of the most advanced technologies used in current diesel engines. CRDI has maximum injection pressure of 1800 bar where as conventional Direct Injection (DI) system generates around 300 bar. Conventional DI system has to create optimum injection pressure repeatedly for each operating cycle. But in case of CRDI system, it maintains the constant injection pressure level throughout the engine operating cycle. This advancement improves the fuel atomization process which directly leads to improved engine performance, fuel efficiency and lower emission level. This research work is based on the analysis to identify the possible methods to improve the CRDI system performance. The various parameters such as fuel injection pressure, combustion chamber temperature that are included in engine combustion have greater influence in engine's performance, fuel economy and emission. The simulation analysis were carried out for various injection pressure between 500 bar to 1800 bar using ANSYS FLUENT. A fuel injection system was modelled using PTC CREO V3.0. The influence of temperature on engine performance, fuel economy and emissions has been analysed. The optimum injection pressure for improved engine performance with lesser emission level has been predicted for various engine configuration and impact of fuel properties such as viscosity, flow velocity, inlet properties, fuel economy and emissions are also analysed.

KEY WORDS: Atomization, Injection pressure.

1. INTRODUCTION

As always emission control legislation is the driving force behind all injection system innovations and one of the latest of these is high pressure common rail injection systems. One inherent problem with most injection systems is the lack of control of injection pressures. The fuel injection is the key point of engine and it plays important role to improve the performance of engine. Common rail engines have been used in marine and locomotive applications for some time. The Cooper-Bessemer invented the hydraulically operated common rail diesel engine, also known as a modified common rail. Vickers used common rail systems in submarine engines at 1916. Doxford Engines Ltd., used common rail system in opposed-piston heavy marine engines from 1921 to 1980 whereby a multi-cylinder reciprocating. Camshaft-operated mechanical timing valves were used to supply the spring-loaded Brice/CAV/Lucas injectors, which injected through the side of the cylinder into the chamber formed between the pistons. Early engines had a pair of timing cams, one for ahead running and one for astern. Later engines had two injectors per cylinder, and the final series of constant-pressure turbocharged engines were fitted with four injectors per cylinder. This system was used for the injection of both diesel oil and heavy fuel oil. The common rail system is suitable for all types of road cars with diesel engines. The main suppliers of modern common rail systems are Robert Bosch GmbH, Delphi, Denso, and Siemens VDO.

Armored Fight Vehicles (AFVs) play an important role in any war scenario. The recent development in diesel engine is CRDI system with electronic fuel injection system. It provides better performance of engine compare to conventional engines. Conventional fuel injection pumps used uprated 1000 hp engine do not have a feature for regulating fuel as function of charge air temperature, coolant temperature and shutdown mechanism for low engine oil pressure and low coolant level. These features are essential for operation at high ambient temperature and also for fool proof engine performance. CVRDE has developed Electronic Fuel Injection system (EFIS) jointly with Indian Institute of Technology, Madras, to introduce electronic governor in place of mechanical governor, to Develop microprocessor based engine

Controller unit is introducing for actuator to regulate the fuel delivery for up-rated 100 HP engine. The ECFIS (Engine Control Fuel Injection System) consist of sensors, actuators, control system and software. The system senses the engine speed, load, charge air temperature and accelerator pedal position. The input data is fed into the electronic controller, which gives signal to the actuator and that in turn moves the control rack. Indigenously developed microprocessor based controllers and actuator have been integrated with fuel injection pump (FIP) and is evaluated in FIP test bench. FIP integrated with the engine also been evaluated in the test bed. The system successfully control the fuelling based on charge air temperature, coolant temperature, etc., and met all the system requirements.

2. MATERIALS AND METHOD

Modelling of fuel injector: The fuel injector is designed by using PTC CREO version 3.0 modeling software. It is advancement from proE modeling software. The dimensions are taken; Length of the nozzle is 27 mm, diameter

6 mm, nozzle diameter 1 mm. it is single hole type nozzle. Fuel injector and Nozzle section is shown below Figure.1 and 2.


Figure.1. Fuel Injector Model


Figure.2. Nozzle Section

Analysis and Investigation: The flow analysis of fuel injector nozzle is carried out using ANSYS FLUENT 14.0 flow analysis software. It is a multi-capable tool for various analyses.

In the flow analysis Quadrilateral type of meshing is done by ICEM CFD. It a very efficient tool to make the meshing. This meshing gives very accurate solution. The total number of quadrilateral un-structural meshing is 395000 elements. The engine specification was taken from Development and validation of a GEP model to predict the performance and exhaust emission parameter of a CRDI assisted with single cylinder diesel engine coupled with EGR. Engine specification and fuel injector specification is shown in Table.1.

Table.1. Specification of Engine and Fuel injector

S.no	Specification	Resource
1.	No of cylinder	1
2.	Bore	120 mm
3.	Stroke	139.7 mm
4.	Displacement	1580 cc
5.	Injection pressure	10- 120 MPa
6.	Nozzle diameter	1 mm
7.	Injection angle	120^0

3. RESULTS DISCUSSIONS

The performance characteristic of fuel injecting nozzle and two dimensional flow characteristics at a particular pressure was carried out by using analysis software. The transient k-kl model omega model has been taken at viscous laminar for bringing accuracy of flow analysis. All the boundaries are considered as a wall except nozzle section. Pressurized diesel is an input. Turbulent intensity and turbulent length scale have a constant value are constant for two dimensional flow analysis. The fluid is diesel and the viscosity of diesel is 4.5×10^{-3}. These are some required properties of the fuel.

The flow analysis is carried out by following Pressure 700 bar, 1000 bar, 1300 bar and 1600 bar. The output pressure and velocity contour of above pressure is shown below figure 4.1 to 4.8 respectively.

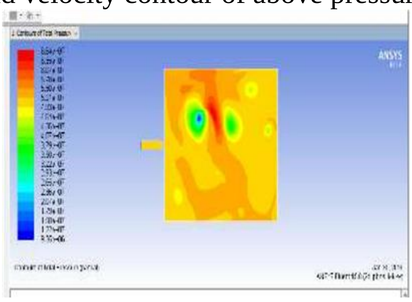
Figure.3. the pressure contour of 700 bar

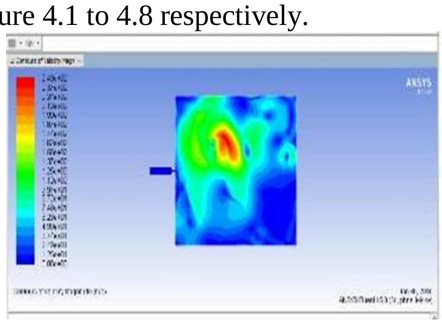
Figure.4. the velocity contour of 700 bar

Fig.3 and .4 shows the contour images of pressure and velocity for the pressure of 700 bar. The peak pressure is indicating by red in color and minimum pressure is blue in color. The pressure contour shows the total pressure obtained in the chamber was 663.510 bar. The total pressure developed inside the chamber was less compare with input pressure. The applied pressure created the velocity inside the chamber was 249.265 m/s. similar trend were observed at pressure 1000 bar and 1300 bar.

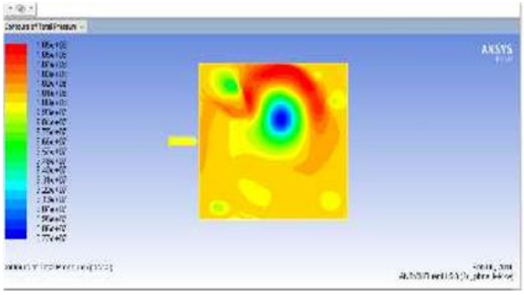

Figure.5. Pressure contour of 1000 bar

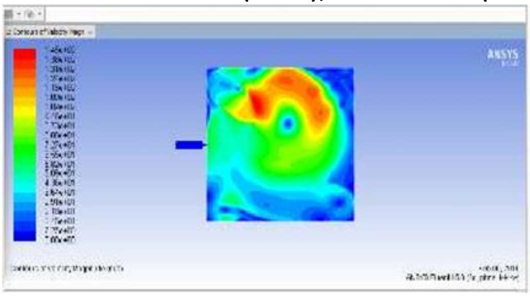

Figure.6. Velocity contour of 1000 bar

Fig.5 and 6 shows the pressure and velocity contour of 1000 bar. The pressure contour shows the total pressure obtained in the chamber was 1054.970 bar. The total pressure developed inside the chamber was higher compare with input pressure. The applied pressure created the velocity inside the chamber was 145.463 m/s.

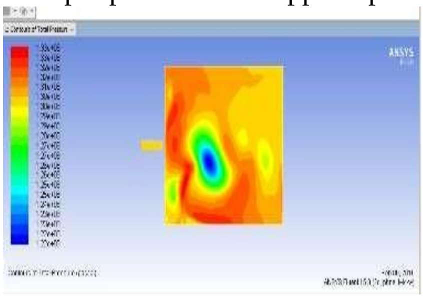

Figure.7. Pressure contour of 1300 bar

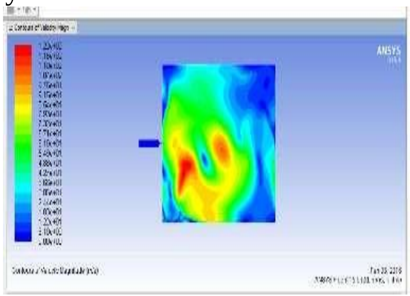

Figure.8. Velocity contour of 1300 bar

Fig.7 and 8, shows the pressure and velocity contour of 1300 bar. The pressure contour shows the total pressure obtained in the chamber was 1333.856 bar. The total pressure developed inside the chamber was higher compare with input pressure. The applied pressure created the velocity inside the chamber was 122.028 m/s. Finally from the above result the pressure increases gradually the velocity get decreases. The rail pressure as same as the inlet injection pressure. The increasing inlet pressure produces the enhanced total pressure. It produces the high performance of the diesel engine.

Table.2. Analytical Investigation

S.No.	Boundry Condition	Result Obtained pressure (bar)			Velocity
	Inlet Pressure (bar)	Dynamic Pressure	Static Pressure	Total Pressure	(m/s)
1.	700	264.068	544.318	663.510	249.265
2.	1000	89.928	1021.121	1054.970	145.463
3.	1300	6.328	1313.858	1333.856	122.028

Table.2, shows the analytical investigation of the fuel flow. Various kinds of results were obtained in flow analysis. Dynamic pressure, Static pressure and total pressure. The below Fig 4.7 shows the relation between the total pressure obtained inside the chamber and pressure supplied to the chamber.

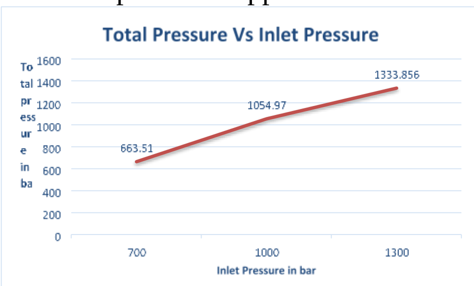

Figure.9. Total pressure vs Inlet pressure

4. CONCLUSION

In compression ignition engines higher the injection pressure gives higher the combustion efficiency. Normally designed CRDI was the high pressure injection system. The CRDI system integrated with electronic control unit has more accurate control on this flow analysis produces the high pressure supplying is maintaining high pressure inside the combustion chamber. It also helps to maintain constant pressure throughout engine operating cycle in CRDI. This will lead to better performance of the system. Engine operating parameters related to engine performance and emission levels. The CRDI system which gives maximum pressure (up to 1800 bar) that is required for perfect atomization to takes place inside the combustion chamber. This research was carried out for various pressure obtained in the fuel injection system.

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