Design and Optimization of Fuel Injection System in Diesel Engine Using Biodiesel – A Review

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Abstract- Fuel injection is systems for supplying high pressurize fuel to maximum mixing of fuel with air in an internal combustion engine. Direct Injection (DI) Systems as used in DI engines, in which the fuel is injected directly into a combustion chamber formed in the clylinder itself. The fuel injector directly injects fuel into the direct fuel injection system. The injector is a very complicated part, and massive research has been done to improve it.In my work indicating the development of fuel injector system to reduce chocking problem which is generally happen in bio diesel engine. The injection nozzles and their respective nozzle holders are vitally important components situated between the in-line injection pump and the diesel engine, its functions are as metering the injection of fuel, management of the fuel, defining the rate-of-discharge curve, Sealing-off against the combustion, chamber. Mechanical type injectors used in direct injection system. When biodiesel is used in the diesel engine choking problem is created in fuel injector. Therefore, we optimize the design of fuel injector component, and tried to prevent the chocking problem. The diesel fuel injector system directly injects fuel into the system without chocking.

Keywords – Injection system, fuel injector, nozzle, biodiesel

I. Introduction

Often called 'the heart of the engine', the fuel injection system is without any doubt one of the most important systems. It meters the fuel delivery according to engine requirements, it generates the high injection pressure required for fuel atomization, for air-fuel mixing and for combustion and it contributes to the fuel distribution in the combustion system-hence it significantly affects engine performance emissions and noise. The components of the fuel injection system require accurate design standards, proper selection of materials and high precision manufacturing processes. They lend themselves to mass production techniques and they become complex and costly. As the applications of diesel engines diversified so did the fuel injection systems. Along with the conventional pump-line nozzle systems new concepts evolved such as distributor pumps, common-rail systems, accumulator systems, unit pumps, unit injectors, etc. In addition, the 'intelligence' of electronics enhanced the capability of the 'muscle power' of hydraulics making the combustion system much more flexible and responsive to new parameters: pressure, temperature, engine speed, etc.Combustion can be thus optimized for best performance, emissions, smooth operation etc., according to the needs of the application. The net result of this integration is an advanced diesel engine with high power density, very low emissions, low noise and superior drivability. Probably the most dynamic application of advances in fuel injection and electronic management is in the area of light-duty vehicles (passenger cars, light trucks, sport utilities) where constraints of high performance, low emissions, low noise, low cost, etc., render optimization very challenging. The research and development in fuel injection systems continues at a very sustained pace.

1.1 Working fuel injection system.

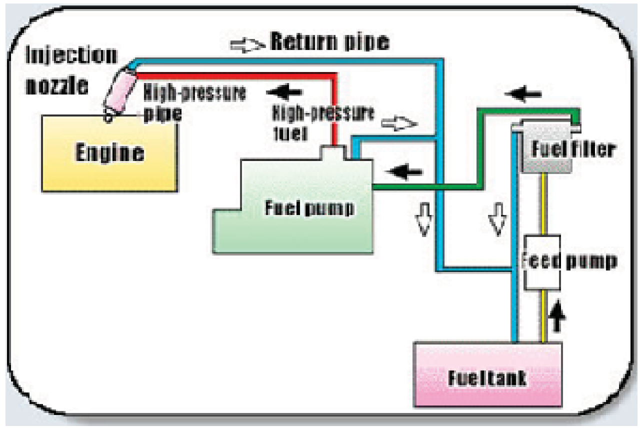

Fig.1 Fuel injection system[18]

The fuel-injection system is responsible for supplying the diesel engine with fuel. To do so, the injection pump generates the pressure required for fuel injection. The fuel under pressure is forced through the high-pressure fuel-injection tubing to the injection nozzle which then injects it into the combustion chamber. The fuel-injection system includes the following components and assemblies: the fuel tank, the fuel filter, the fuel supply pump, and the injection nozzles.

1.2 Requirement of diesel injection system

The fuel should be introduced into the combustion chamber within a precisely period of the cycle. The rate of injection should be such that it results in the desired heat release pattern. The quantities of the fuel metered should vary to meet changing speed and load requirements.The injected fuel must be broken into very fine droplets, i.e., good atomization should be obtained.The spray-pattern must be such that it results in rapid mixing of fuel and air The beginning and the end of injection should be sharp, i.e., there should not be any dribbling or after injection. The injection timing, if desired, should be change to suit the engine speed and load requirements. In the case multi cylinder engines, the distribution of the metered fuel among various cylinders should be uniform. In addition to the above requirements, the weight and the size of the fuel injection system must be minimum.

II.DIRECT INJECTION SYSTEM IN DIESEL ENGINE

Direct Injection (DI) Systems as used in DI engines, in which the fuel is injected directly into a combustion chamber formed in the clylinder itself, i.e. between suitably shaped non-stationary piston crown and a fixed cylinder head in which is mounted thefuel injector with its single or multiple spray orifices or nozzles.

III.HOLE-TYPE NOZZLES

There are a very wide variety of different nozzle-and-holder assemblies for hole-type nozzles on the market. In contrast to the throttling-pintle nozzles, the hole-type nozzles must be installed in a given position. The spray holes are at different angles in the nozzle body and must be correctly aligned with regard to the combustion chamber. The nozzle and holder assembly is therefore fastened to the cylinder head with hollow screws or claws. A special mount is used to lock the nozzle in the correct position. The hole-type nozzles *(*Fig.3) have needle diameters of 4 mm (Size P) and between 5 and 6 mm (Size S). The seat hole nozzle is only available as a Size P version. The nozzle pressure springs must be matched to the needle diameters and to the high opening pressures which are usually above 180 bar. The nozzle-sealing function is particularly important at the end of injection because there is a risk of the combustion gases blowing back into the nozzle and in the long run destroying it and causing hydraulic instability. Precision matching of the pressure spring and the needle diameter ensures efficient sealing. In certain cases, it may be necessary to take into account the oscillations of the pressure spring. There are three designs for the arrangement of the spray holes in the nozzle cone. These three designs also differ from each other with respect to the amount of fuel which remains inside the injector and which can evaporate into the combustion chamber when injection has finished. Versions with cylindrical blind hole, conical blind hole, and seat hole, have decreasing fuel quantities in this order. Furthermore, the less fuel that can evaporate from the nozzle, the lower are the engine's hydrocarbon emissions. The levels of these emissions therefore also correspond to the (nozzle) order given above.

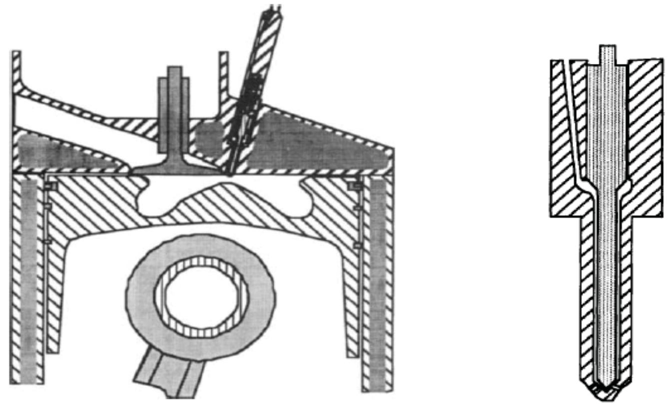

Fig.2 HSDI and hole-type nozzle to inject fuel into the combustion chamber.[3]

The nozzle cone's mechanical integrity is the limiting factor in the length of the spray hole. At present, spray-hole length is 0.6-0.8 mm in the case of the cylindrical and conical blind holes. With the seat-hole nozzle, the minimum spray-hole length is 1 mm, whereby special hole-making techniques must be applied. Developments are proceeding towards shorter hole length, because as a rule the shorter the hole, the better the engine's smoke values.

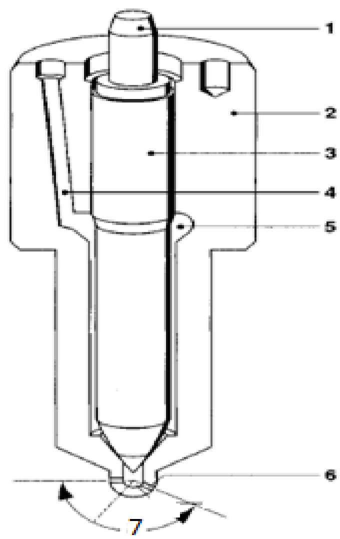

Fig.3Hole-type nozzle[3]

1 Pressure pin, 2 Nozzle body, 3 Nozzle needle, 4 Inlet passage, 5 Pressure chamber, 6 Spray hole, *7.*Spray-hole cone angle.

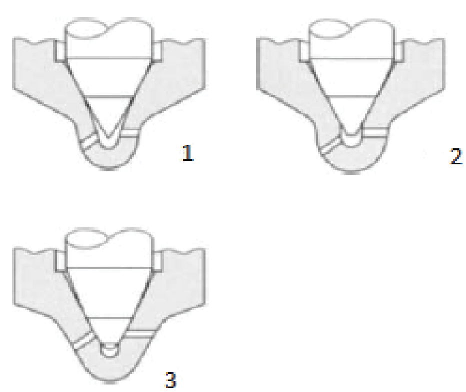

Fig.4(a).Hole-type nozzle with conical blind hole, (b)Hole-type nozzle with cylindrical blind hole.(c)Seat-hole nozzle[3]

Bio-diesel

Biodiesel is the name of a clean burning alternative fuel, produced from domestic, renewable resources. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in compression-ignition (diesel) engines with no major modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulphur and aromatics. Biodiesel can be used as a pure fuel or blended with petroleum in any percentage. B20 (a blend of 20 percent by volume biodiesel with 80 percent by volume petroleum diesel) has demonstrated significant environmental benefits with a minimum increase in cost for fleet operations and other consumers.

IV. LITERATURE REVIEW

M. Volmajer et al [4] had numerical and experimental results of the nozzle fuel flow analysis for a four-hole injection nozzle Bosch DLLA 148 S 311376 are presented. The fuel flow coefficients obtained from the experimental results at steady flow conditions in the nozzle are compared with the results of the CFD analysis. The fuel flow coefficients obtained from the experimental results at steady flow conditions in the nozzle are compared with the results of the CFD analysis. From the presented results the following conclusions could be made. Flow coefficient testing device constructed at the ERL yields sufficiently precision, with reasonable uncertainties of the measurement. 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 glasslPlexiglas cylinder with proper circle cross-section. the presented testing device also enables the measurement of the flow coefficient separately for each nozzle hole, which brings better comparison with the results of CFD analysis when the simplified models, introducing only one hole, are applied.

Zhijun Li et al [5]had investigates the effects of manufacturing variations in fuel injectors on the engine performance with emphasis on emissions. The variations are taken into consideration within a Reliability-Based Design Optimization (RBDO) framework. A reduced version of Multi-Zone Diesel engine Simulation (MZDS), MZDS-lite, is used to enable the optimization study. The numerical noise of MZDS-lite prohibits the use of gradient-based optimization methods. Therefore, surrogate models are developed to filter out the noise and to reduce computational cost. Three multi-objective optimization problems are formulated, solved and compared: deterministic optimization using MZDS-lite, deterministic optimization using surrogate models and RBDO using surrogate models. The obtained results confirm that manufacturing variation effects must be taken into account in the early product development stages. The effects of manufacturing variations in fuel injectors on the engine performance with emphasis on emissions. The results obtained using deterministic and probabilistic optimization formulations demonstrated the need for RBDO to improve not only performance but also reliability.

LI Minghai et al [7] had indicated forced lubrication is adopted for the new injector nozzle matching parts, which can reduce failure rate and increase service life. If the patented product is used widely, economic efficiency and social efficiency will be obtained.

Benny Paul et al [8] had indicated effect of helical, spiral, and helical-spiral combination manifold configuration on air motion and turbulence inside the cylinder. Swirl inside the engine is important for diesel engine. Hence, for better performance they recommended a helical-spiral inlet manifold configuration.

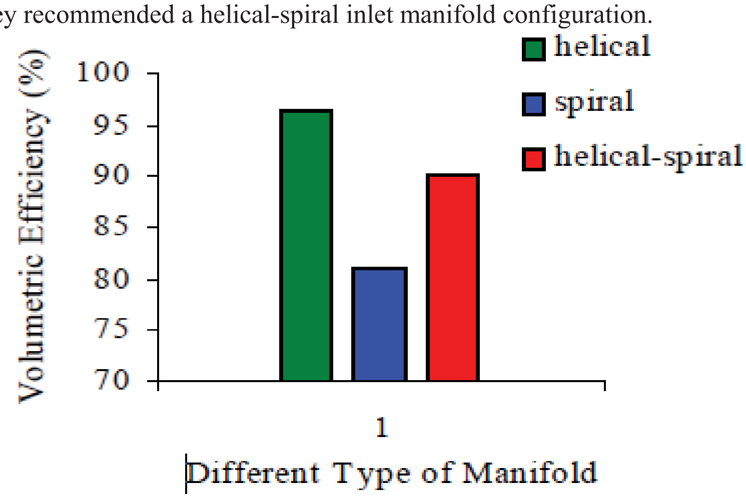

Fig.5.Manifold/Volumetric efficiency (%) [8]

After the analysis of different manifolds in the previous sections, analysis is extended to compare the effect of different manifold configurations on flow structure. The helical-spiral manifold geometry creates higher velocity component inside the combustion chamber at the end of compression stroke. Swirl ratio inside the cylinder and turbulent kinetic energy are higher for spiral manifold. Volumetric efficiency for the spiral-helical combined manifold is 10% higher than that of spiral manifold. Helical-spiral combined manifold creates higher swirl inside the cylinder than spiral manifold. Helical manifold provides higher volumetric efficiency. Helical-spiral combined manifold provides higher mean swirl velocity at TDC of compression. The average RMS of turbulent swirl velocity fluctuation inside the piston bowl at TDC of compression is less affected by the induced swirl created by the manifold configurations. However, further investigations based on combustion and heat release rate analysis is essential for getting a better understanding of the flow inside the cylinder and its effect on the emissions.

Kamal Kishore Khatri et al [9] had indicated preheated Karanj-Diesel blend with optimized fuel injection timing can be used in CI engines more efficiently than the blend at standard injection timing. It is found that substitution of Diesel oil by Karanj oil to the extent of 40% is best possible in the temperature range of 55-60 ºC as the viscosity of blend becomes equal to that of pure Diesel.

Nanthagopal K et al[11]had experiments were conducted to study the performance and emission characteristics of a direct injection diesel engine using blends of karanja methyl esters with diesel on a 10, 20, 30, 40 and 50% volume basis, respectively .Emission characteristics of CO, HC and smoke were found lower with biodiesel blends. However, oxides of nitrogen were 26% higher for 50% biodiesel blend as compared to diesel. Conclusively, the performance and emissions characteristics blends of the biodiesel from karanja are analysed and compared with that of the diesel. It was found out that biodiesel blends have lower brake thermal efficiency than diesel. Emissions of NOx are found to be high for biodiesel blends. CO, HC and smoke emissions are lower for biodiesel blends as compared to diesel.

J.Mohammadhassani et al [12] had artificial neural network is used to model the relationship between NOx emissions and operating parameters of a direct injection diesel engine. To provide data for training and testing the network, a 6-inline-cylinder, four-stroke, diesel test engine is used and tested for various engine speeds, mass fuel injection rates, and intake air temperatures. 80% of a total of 144 obtained experimental data is employed for training process. In addition, 10% of the data (randomly selected) is used for network validation and the remaining data is employed for testing the accuracy of the network. The mean square error function is used for evaluating the performance of the network.

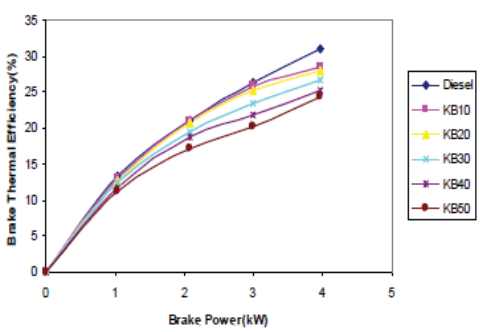

Fig.6.Brake power/Brake thermal efficiency [11]

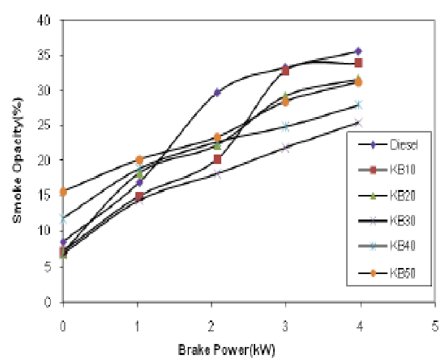

Fig.7.Brake power/smoke capacity[11]

The results show that the artificial neural network can efficiently be used to predict NOx emissions from the tested engine with about 10% error.

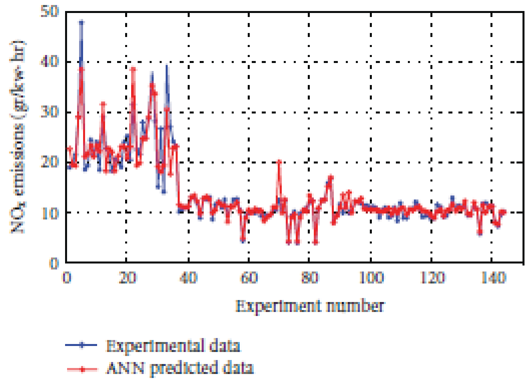

Fig.8.A comparison of the predicted and measured NOx emissions for different operating conditions [12].

The operating parameters involving speed, intake air temperature, and mass fuel rate of a DI diesel engine have been used to train the ANN to predict NOx emissions from the engine. The results of this research reveal that a three-layer neural network along with LM training algorithm leads to a desirable mapping between the inputs and outputs of the network case. The proposed ANN model for prediction of the NOx emissions gives the correlation factors of 0.92, 0.98, and 0.89 for training, validating, and testing the network, respectively. It is concluded that, ANN model is a potentially feasible tool for prediction of NOx emissions from a diesel engine with respect to the engine operating parameters, especially in medium engine speeds.

Bizhan Befrui et al[10] had indicated corollary of the combined LES / RANS(Large-Eddy-Simulation Method/REYNOLDS-AVERAGED SIMULATION METHOD)simulation activity is that the discrepancy between measured and predicted spray plum foot-print geometry is likely associated with the inability of the RANS simulation of the injector internal flow to predict the deviation angle between the nozzle hole axis and the issuing liquid jet.

Avinash Kumar Agarwal [13] had indicated B100 gives highest spray tip penetration, cone angle and spray area followed by KB20, KB5 and diesel respectively because of fuel density differences. The spray area of KB100 is highest for all chamber pressures conditions followed by KB20, KB5 and diesel respectively. Fuel density and viscosity are two main properties affecting the spray characteristics. In the present experimental investigations, viscosity and density of biodiesel is reduced by blending with diesel and spray characteristics investigations are carried out in a constant volume spray chamber. Experiments were conducted with a constant fuel injection pressure (200 bars) under varying chamber air pressure (1, 4, 7 and 9 bars).

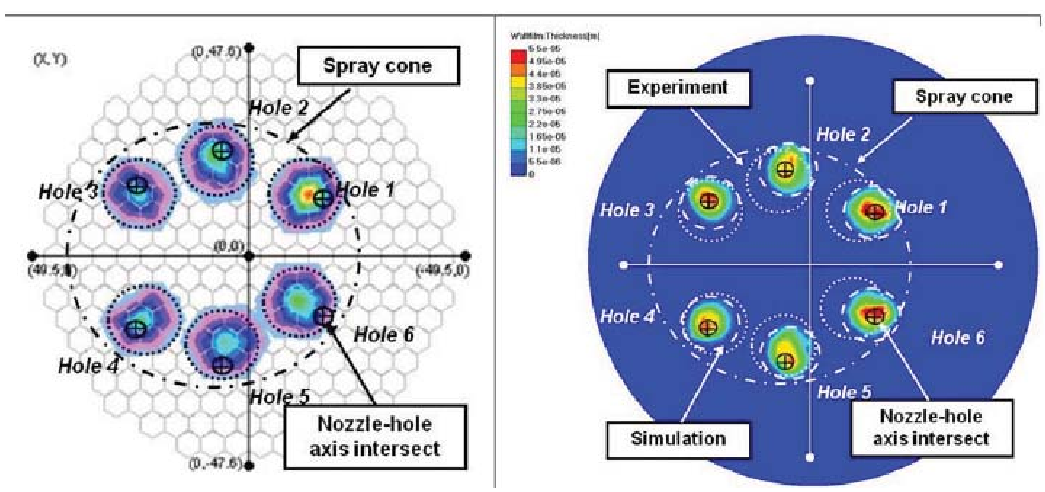

Fig.5 (a) Measured multiple injection accumulated liquid height [10]. (b) CFD simulation of single injection spray plume foot Spray plume foot-print Print liquid height [10].

Important spray characteristics namely spray tip penetration, spray cone angle and spray area were investigated. It was concluded that spray tip penetration decreases with increasing chamber pressure. KB100 gives highest spray tip penetration followed by KB20, KB5 and diesel respectively. The spray cone angle increases as the chamber pressure increases because of increasing resistance to the droplets from the ambient air. The cone angle of KB100 is highest for all chamber pressures condition followed by KB20, KB5 and diesel respectively. The spray area also increases with increasing chamber pressure. The spray area of KB100 is highest for all chamber pressures conditions followed by KB20, KB5 and diesel respectively. Data of pixel intensity values along the radial direction in the images was analyzed which indicates the droplet density level at two different measurement locations (6.77 and 10.59 cm from the injector tip) on the spray axis. It was concluded that length of peak intensity level is higher at measurement location 2 compared to measurement location 1. This indicates higher accumulation of same density fuel droplets at measurement location 2. According to the pixel intensity values, KB20, and KB5 have better spray and atomization characteristics compared to KB100.

R K Singh [14] had investigated thus this study suggests that the jatropha oils can be used as a source of triglycerides in manufacture of biodiesel by esterification and/or transesterification. But the production of biodiesel from edible oils is currently much more expensive than diesel fuels due to relatively high cost of edible oils. There is a need to explore non-edible oils as alternative feed stock for the production of biodiesel. On edible oil like Jatropha (J. curcas) is easily available in many parts of the world including India and it is cheaper compared to edible oils.

Table. 1 Comparison properties of Jatropha oil with Diesel.

Property	Unit	Jatropha oil	Jatropha Oil methyl ester	Diesel
Density at 15°C	kg/m^3	918	880	850
Viscosity at 40°C	mm^2/s	35.4	4.84	2.60
Flash point	°C	186	162	70

Rosli et al [15] had indicated this study shows that in-cylinder CFD predictions yield reasonably accurate results that allow improving the knowledge of the air flow characteristics during the intake and Compression strokes. Since the air motion at TDC strongly influences the development of the injection and combustion processes in the combustion chamber of Diesel engines, the analysis presented here represents a first step towards their understanding. In this sense CFD represents an efficient design tool to develop less polluting and more efficient direct-injection Diesel engines.

In this my work we create 3D Model of BOSS KDL 59P9M mechanical type injector direct fuel injection system. I changes following component injection nozzle and needle this when biodiesel using choking problem create so optimize this two component design reduce problem. In my research work we changes niddle length (increase or decrease), change in taper angle(increase or decrease),nozzle and niddle clearance changes, orifice size also optimize and reduced choking problem in cfd analysis. Also hole size, injection pressure, temperature, viscosity, density changes.

V. CONCLUSION

The injection and the fuel spray characteristics connected with the combustion chamber geometry control the Combustion and pollutant formation processes. Therefore the engine operation characteristics could be improved by improving one of the above mentioned fuel injection systems- or engine-parts. Even though in recent years many researchers have been made considering the fuel injection systems. The fuel Injection nozzle still presents quite an unresearched area. When direct fuel injection system biodiesel using its density, viscosity is more compare to diesel in injector component nozzle body and needle valve between chocking problems create so we optimize this two component dimensions and reduced chocking problem.

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