

Design Evaluation and Optimization of Nozzle Used in Diesel Engine Fuel Injector

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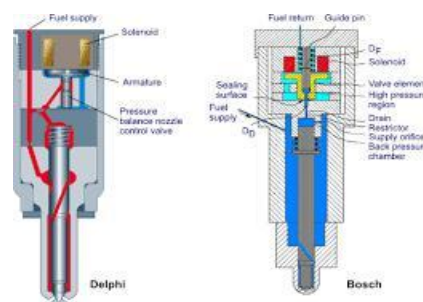
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ABSTRACT: The nozzle is used to convert the chemical thermal energy generated in the combustion chamber into kinetic energy. The nozzle converts the low velocity, high pressure, high temperature gas in the combustion chamber into high velocity gas of lower pressure and temperature. Nozzle is a device designed to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that exhaust from them. Nozzles come in a variety of shapes and sizes depending on the mission of the rocket, this is very important for the understanding of the performance characteristics of rocket. Convergent divergent nozzle is the most commonly used nozzle since in using it the propellant can be heated in combustion chamber. In this thesis the convergent divergent nozzle changing the different nozzle diameters and different fluids at different velocities. We modeled convergent divergent nozzle changing with different nozzle diameters and Analyzed the convergent divergent nozzle with different mass flow rates to determine the pressure drop, heat transfer coefficient, and velocity and heat transfer rate for the fluid by CFD technique.

KEY WORDS: Finite element analysis, nozzle, CFD analysis, thermal analysis.

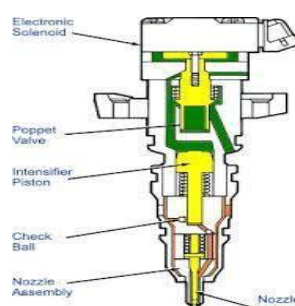
I. INTRODUCTION

The primary challenges towards developing new diesel engines for passenger cars lie in the strict future emission legislation in combination with the customer's demands for steadily improving performance. For example, the emission limitations of Tier 2 Bin 5 require an advanced after treatment system and a robust combustion process that minimizes emissions in the process of them being formed. Advancements in the technology of Diesel Injection (DI) systems have played an important role in the improvements that have been made up to this point. Combining the reduction in nozzle orifice diameters through enhanced flow characteristics with increased injection pressures provides an opportunity to develop engines featuring high power density and reduced emissions. The primary drawback to these modern spray hole geometries is that they often suffer a reduction of power output during long term operation. Other studies have identified these critical formations of deposits as the main reason for this behavior.



Basic mechanisms can be used to explain the formation and removal of deposits in internal combustion engines. These mechanisms act independently of the location of formed deposits (e.g. injection nozzles, heat changer) and of the combustion process (e.g. IDI, DI; diesel or gasoline).

The model described in the study illustrates the interaction of a wall with the enclosing flow regime. The transport of particles to the wall is based on the process of thermosphere's. In this process, results in the force of gas particles in the direction of the temperature depression. It is amplified with an increasing temperature differential between wall (cold) and fluid (hot). This process results in an increasing concentration of deposit-building particles near the wall.



High 2 turbulence near the wall may reduce the force of the aerosol again to a mean value, compensating for an increased temperature difference. The deposits are composed of attached particles (solid and liquid) and gas (Figure 1). Condensation and adsorption of gaseous compounds at the cold wall promotes the formation process. At this point, the growth of the deposits is now mainly influenced by the sticking, impaction and incorporation of particles. The adsorption of gaseous components and the chemical reactions (as pyrolysis, dehydration and polymerization, etc.), lead to the compaction of the deposits]. The removal of deposits has analogous physical mechanisms.

The chemical mechanism is oxidation destroying the organic compounds in the coating. Evaporation and desorption reduce the gaseous fraction dissolved in the deposits. Abrasion is caused by strong aerodynamic forces and breaking-off, due to high temperature changes, resulting in inhomogeneous extensions of the wall and deposit layer.

The corresponding shearing stresses initiate the breaking-off process. The soluble fraction of the deposits is washed off by solvents (e.g. water as solvent for salt compounds)

II. LITERATURE REVIEW

Design and Optimization of Fuel Injection System in Diesel Engine Using Biodiesel – A Review H. M. Pate

Fuel injection is systems for supplying high pressurized 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 cylinder 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 chocking 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.

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 glass Plexiglas 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 investigated 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.

III. PROBLEM DESCRIPTION

The objective of this project is to make a 3D model of the convergent divergent nozzle changing with different nozzle diameters and Analyzed the convergent divergent nozzle with different mass flow rates to determine the pressure drop, heat transfer coefficient, and velocity and heat transfer rate for the fluid by CFD technique.

The methodology followed in the project is as follows:

Create a 3D model of the nozzle using parametric software pro-engineer.

Convert the surface model into Para solid file and import the model into ANSYS to do analysis. Perform thermal analysis on the nozzle for thermal loads. Perform CFD analysis on the existing model of the surface of nozzle for Velocity inlet to find out the mass flow rate, heat transfer rate, pressure drop.

IV. INTRODUCTION TO CAD/CAE

Computer-aided design (CAD), also known as **computer-aided design and drafting (CADD)**, is the use of computer technology for the process of design and design-documentation.

INTRODUCTION TO PRO-ENGINEER

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing

innovation and quality to ultimately create exceptional products.

Different modules in pro/engineer

Part design, Assembly, Drawing & Sheet metal.

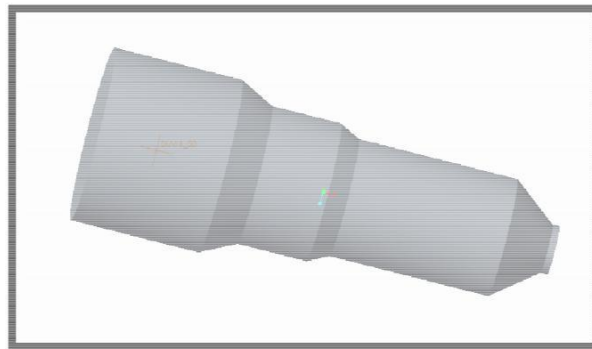
INTRODUCTION TO FINITE ELEMENT METHOD:

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions. Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

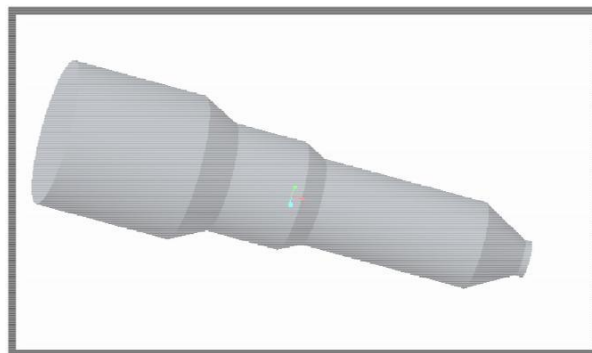
V. RESULTS AND DISCUSSIONS

Models of nozzle using pro-e wildfire 5.0: The nozzle is modeled using the given specifications and design formula from data book. The isometric view of nozzle is shown in below figure. The nozzle profile is sketched in sketcher and then it is revolved up to 360° angle using revolve option.

3D MODEL OF DIESEL NOZZLE WITH 50DIA



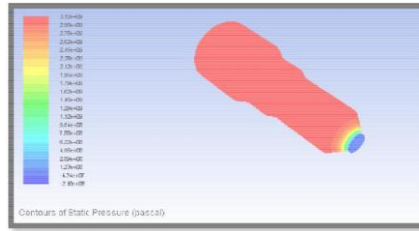
NOZZLE WITH 40DIA



CFD ANALYSIS OF NOZZLE

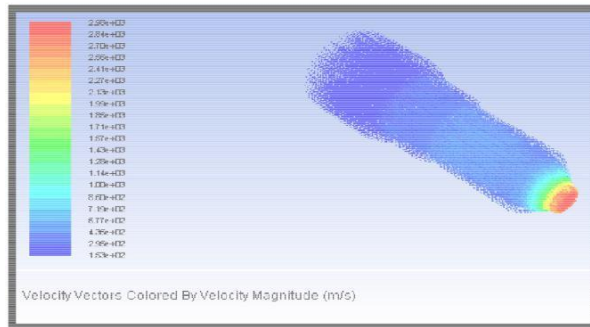
FLUID-DIESEL

Velocity inlet = 200m/s, 300m/s & 400m/s



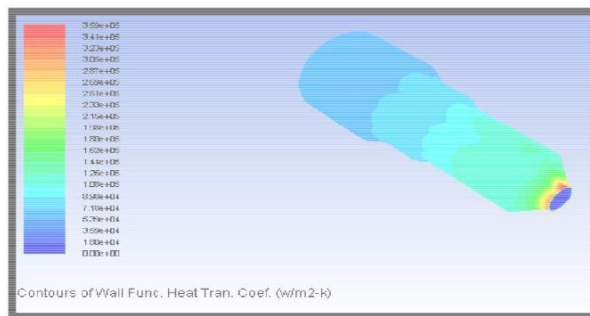
According to the above contour plot, the maximum pressure is 3.12×10^9 Pa and minimum static pressure is 2.10×10^8 Pa.

VELOCITY



According to the above contour plot, the maximum velocity is 2.96×10^3 m/s and minimum velocity is 1.53×10^2 m/s.

HEAT TRANSFER CO-EFFICIENT



According to the above contour plot, the maximum heat transfer coefficient is 3.59×10^5 W/m²-k and minimum heat transfer coefficient is 1.80×10^4 W/m²-k.

MASS FLOW RATE HEAT & TRANSFER RATE

Mass Flow Rate		(kg/s)
inlet		285.04138
interior- <u>msbr</u>		17727.344
outlet		-286.18833
wall- <u>msbr</u>		0
Net		-1.1389465
Total Heat Transfer Rate		(W)
inlet		2889323.3
outlet		-2908863.8
wall- <u>msbr</u>		0
Net		-11540.5

VI. RESULTS AND DISCUSSIONS

CFD ANALYSIS RESULT TABLE

Nozzle dia.	Inlet velocity (m/s)	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (W/m ² -k)	Mass flow rate (kg/s)	Heat transfer (W)
50	200	3.12×10^9	2.98×10^3	3.59×10^5	1.138945	11540.5
	300	6.96×10^9	4.46×10^3	5.10×10^5	0.289245	2927.5
	400	1.25×10^{10}	5.99×10^3	6.56×10^6	3.087343	31294
40	200	4.53×10^9	3.58×10^3	3.76×10^5	1.0457764	10600

	300	1.03e+10	5.38e+03	5.30e+05	2.192199	22219
	400	1.83e+10	7.17e+03	6.80e+05	2.9847107	30249
30	200	1.04e+10	5.36e+03	6.90e+05	0.16120148	1634.3125
	300	2.34e+10	8.05e+03	8.05e+03	0.44642	4520.625
	400	4.18e+10	1.07e+04	1.25e+06	0.8333587	8450.75

VII. CONCLUSION

Nozzles come in a variety of shapes and sizes depending on the mission of the rocket, this is very important for the understanding of the performance characteristics of rocket. Convergent divergent nozzle is the most commonly used nozzle since in using it the propellant can be heated in combustion chamber. In this thesis the convergent divergent nozzle changing the different nozzle diameters and different fluids at different velocities. We modeled convergent divergent nozzle changing with different nozzle diameters. By observing the cfd analysis of diesel engine nozzle the pressure, velocity, heat transfer rate and mass flow rate values are increases by increasing the inlet velocities and decreasing the nozzle dia. So it can be concluded the diesel engine nozzle efficiency were more when the nozzle dia. decreases.

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