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DESIGN EVALUTION AND OPTIMIZATION OF NOZZLE USED IN DIESEL ENGINE FUEL INJECTOR

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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: *Nozzle, Pressure Drop, Heat Transfer Coefficient, and Velocity and Heat Transfer Rate for the Fluid by CFD technique.*

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 [1, 2]. 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 in important role in the improvements that have been made up to this point [1]. 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 [2]. 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.

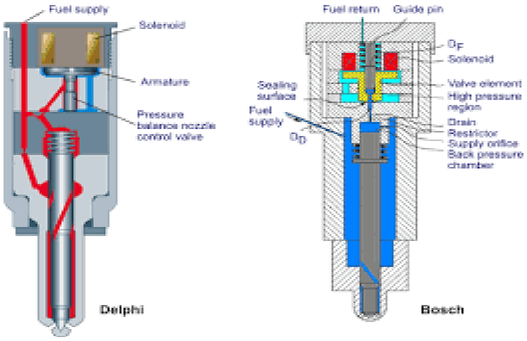


Fig. 1 sectional view of fuel injector

The model described in the study illustrates the interaction of a wall with the enclosing flow regime [4]. The transport of particles to the wall is based on the process of thermosphere's is this process results in the force of gas particles in the direction of the temperature depression [4]. It is amplified with an increasing temperature differential between wall (cold) and fluid (hot). This process results is an increasing concentration of deposit-building particles near the wall [5].

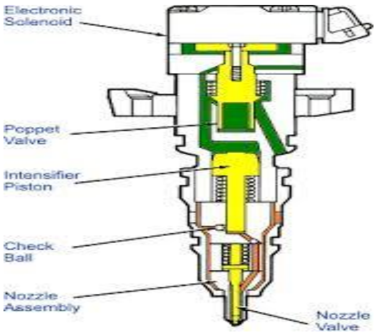


Fig. 2 components in fuel injector

High 2 turbulence near the wall may reduce the force of the aerosol again to a mean value, compensating for an increased temperature difference [5]. 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 [4, 5]. 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] [5]. 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 [6]. Abrasion is caused by strong aerodynamic forces and breaking-off, due to high temperature changes, resulting in inhomogeneous extensions of the wall and deposit layern [6].

The corresponding shearing stresses initiate the breaking-off process [6]. The soluble fraction of the deposits is washed off by solvents (e.g. water as solvent for salt compounds)

II. APPLICATION OF A THERMOCOUPLE AT THE NOZZLE TIP

Initial test cell investigations measured nozzle tip temperatures during operation. Production parts were adapted during the project with thermocouples [6, 7]. The concept implied the ability to run the engine at rated power and to avoid any influence on the combustion process. Thus, the requirements led to a design, where the thermocouples are integrated inside the body of the nozzle holder [7]. The thermocouple was then located between nozzle and heat shield

Fuel and lubricant

In order to ensure safe engine operation, the fuel complied with standard EN 590. Therefore, a mineral oil-based fuel from an independent refinery (MIRO, Karlsruhe) was chosen with an additional bio diesel share of five percent [6, 7]. Latter fraction is required by legislation [34]. On the other hand, the fuel was required not to possess characteristics, specific to a certain oil company, so the diesel contained no additives [6]. The intended investigation on the chemical parameter zinc necessitated zinc-free oil (comparable to FUCHS TITAN CARGO MAXX 5W-30), since the quantity of oil flowing into or through the spray holes could not be determined.

Effect of injector nozzle holes on fuel in engine cylinder

simulation results are shown in every cases, such as case 1 is on 500 rpm, case 2 is on 1000 rpm, case 3 is on 1500 rpm, case 4 is on 2000 rpm, case 5 is on 2500 rpm, case 6 is on 3000 rpm, case 7 is on 3500 rpm and case 8 on 4000 rpm [6]. Numerous studies have suggested that decreasing the injector nozzle orifice diameter is an effective method on increasing fuel air mixing during injection (Baik, 2001) [7]. Smaller nozzle holes have found to be the most efficient at fuel/air mixing primarily because the fuel rich core of the jet is smaller. In addition, decreasing the nozzle hole orifice diameter, would reduce the length of the potential core region [6, 7].

Unfortunately, decreasing nozzle holes size causes a reduction in the turbulent energy generated by the jet [7]. Since fuel air mixing is controlled by turbulence generated at the jet boundary layer, this will offset the benefits of the reduced jet core size [8]. Furthermore, jets emerging from smaller nozzle orifices were shown not to penetrate as far as those emerging from larger orifices. This decrease in penetration means that the fuel will not be exposed to all of the available air in the chamber [8].

Purpose of fuel injection system

The main purpose of the fuel injection system is to deliver fuel into the cylinders of an engine. In order for the engine to effectively make use of this fuel [8]. Fuel must be injected at the proper time, that is, the injection timing must be controlled and the correct amount of fuel must be delivered to meet power requirement, that is, injection metering must be controlled [8]. However, it is still not enough to deliver an accurately metered amount of fuel at the proper time to achieve good combustion [9]. Additional aspects are critical to ensure proper fuel injection system performance including: Fuel atomization, Bulk mixing, Air utilization.

III. OBJECTIVES

The primary goals of this study were to investigate the major causes of the formation of deposits in the spray hole and to establish the leading parameters that promote the formation and the decay of deposits [9]. The following step was to find measures that would slow down or even inhibit the formation of these deposits. It was decided to divide the study into two sub-projects [8]. The first sub-project handled the experimental investigations, including a detailed deposit analysis.

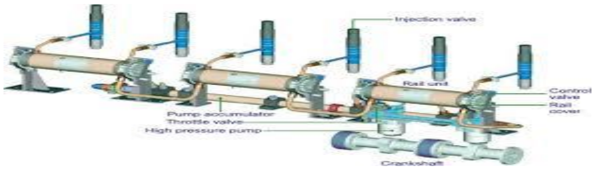


Fig.3 series of fuel injector

The focal point of the other sub-project was on simulating the effects of various nozzle types (cylindrical, ks-nozzle) on heat transfer and fluid flow, utilizing coupled CFD- and thermal modeling. In addition, research was conducted on the thermal situation of the nozzle, which included a sensitivity analysis regarding the thermal conditions at the injector tip [8, 9]. Cavitations and thermal effects were also included as a part of the investigation. This document highlights the experimental results, including the deposit analysis [10]. The results of the other sub-project are partially published.

IV. EXPERIMENTAL PROCEDURES AND TEST ENGINE

Tests were conducted with the medium-duty truck engine OM 906. It has a maximum power output of 210 kW at 2200 min-1 [10]. The engine is EURO IV certified and uses a SCR after treatment system. The Direct Injection (DI) diesel engine features a Unit Pump (UP) system. Specific for this system is the injection synchronous high-pressure generation [9, 10].

The maximum fuel pressure is higher than 1800 bar. The high-pressure system in the OM 906 has no leakage [10]. The high pressure pump is lubricated by engine oil. Therefore, in principal traces of lubricant can enter the fuel system. During the testing three different sac-hole nozzles were applied to the engine [9].

Fig.4 experiment setup

Type 1: Cylindrical spray hole geometry including a non rounded orifice inlet
Type 2: The standard nozzle for this engine features hydro-erosive rounding of the spray holes to improve the flow regime at the inlet of the nozzle orifice and, thus, to reduce cavitation [31], [32]. The cavitation is reduced in comparison to type 1.
Type 3: The also called ks nozzles feature a high level of rounding at the orifice inlet in combination with a conical spray hole geometry to prevent cavitation.
The nozzles are protected during engine braking mode and motoring through a heat shield (see Appendix).

CFD analysis of diesel engine nozzle fluid- diesel

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

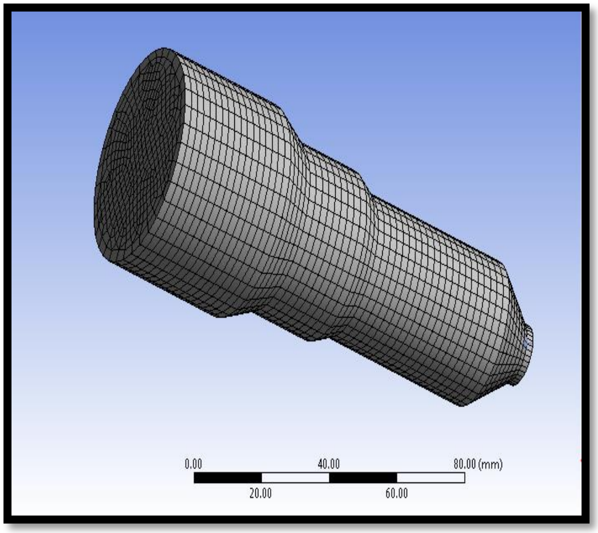


Fig. 5 Meshed model

Specifying the boundaries for inlet & outlet

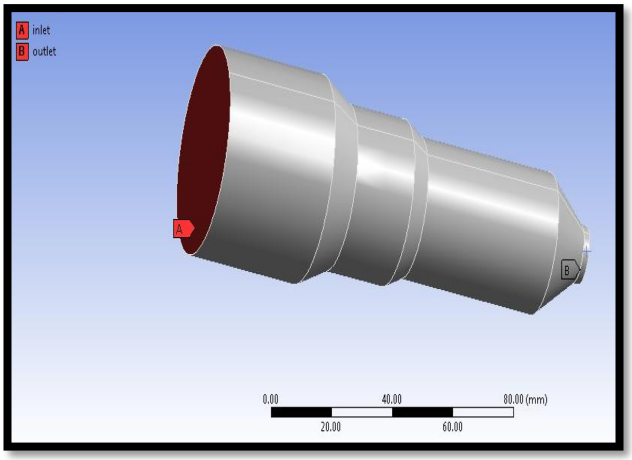


Fig. 6 Boundary conditions for fuel injector

Fluid- diesel engine nozzle dia. 50mmvelocity inlet = 200m/s

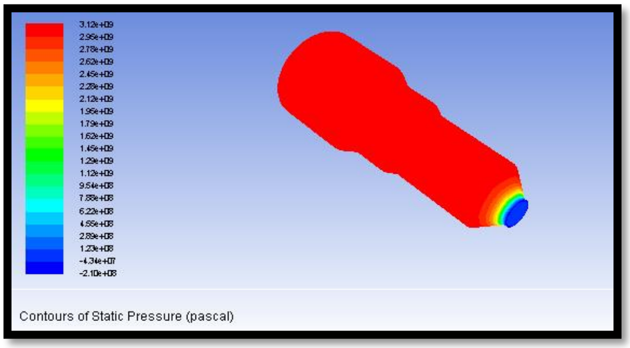


Fig.7 Pressure variation in Fuel injector with inlet velocity 200m/sec

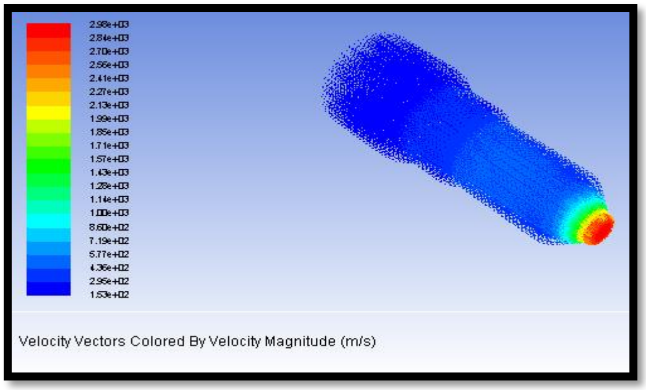


Fig.8 velocity variation in Fuel injector

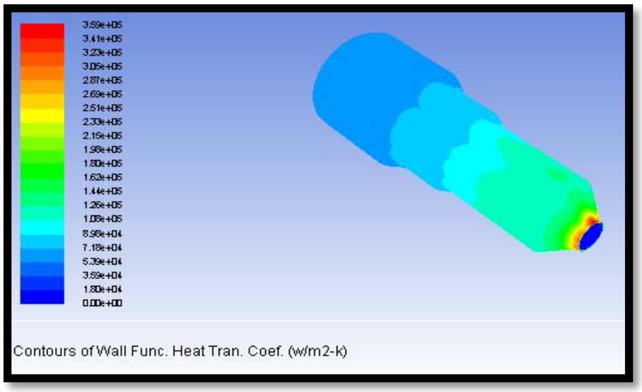
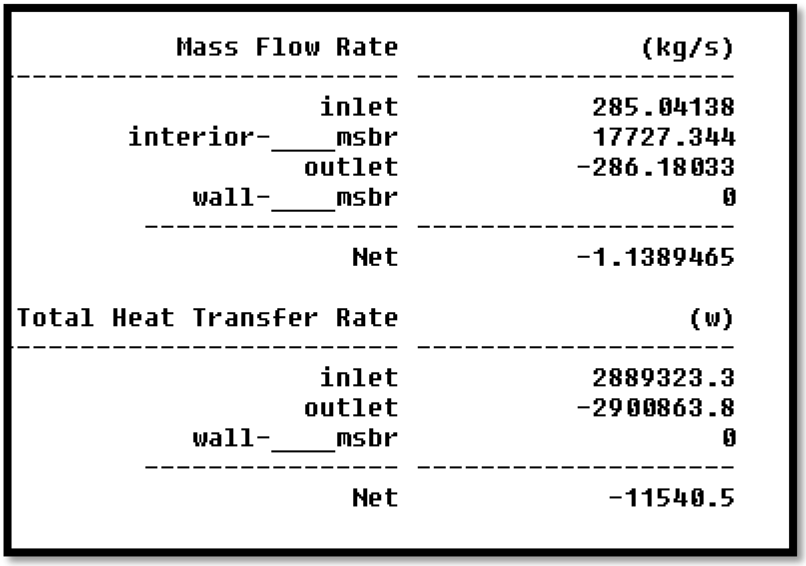


Fig.9 Heat Transfer Coefficient

Mass flow rate & heat transfer rate



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                Mass Flow Rate                     (kg/s)
-------------------------------- --------------------
                         inlet              285.04138
             interior-____msbr              17727.344
                        outlet             -286.18033
                 wall-____msbr                      0
                ---------------- --------------------
                           Net             -1.1389465

Total Heat Transfer Rate                          (w)
-------------------------------- --------------------
                         inlet              2889323.3
                        outlet             -2900863.8
                 wall-____msbr                      0
                ---------------- --------------------
                           Net               -11540.5
```

V. RESULT TABLE

Nozzle dia.	Inlet velocity (m/s)	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (w/m2-k)	Mass flow rate (kg/s)	Heat transfer (W)
50	**200**	3.12e+09	2.98e+03	3.59e+05	1.138945	11540.5
	300	6.96e+09	4.46e+03	5.10e+05	0.289245	2927.5
	400	1.25e+10	5.99e+03	6.56e+06	3.087343	31294
40	**200**	4.53e+09	3.58e+03	3.76e+05	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
	200	1.04e+10	5.36e+03	6.90e+05	0.16120148	1634.3125

30	**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

VI. 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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