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INFLUENCE OF THE NUMBER OF NOZZLE HOLES ON THE UNBURNED FUEL IN DIESEL ENGINE

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ABSTRACT: *The objective of this paper is to present the influence of the number of nozzle holes on the unburned fuel in four stroke direct injection diesel engine using computational simulation. The four-cylinder direct injection diesel engine model is developed in this research to simulate the fuel nozzle holes number performance in unburned fuel in engine cylinder. The research concentrated on the one dimensional model and focuses on fuel nozzle hole numbers variation.*

KEYWORDS: *Diesel engine, computational simulation, unburned fuel, 1D CFD, fuel nozzle*

INTRODUCTION

In the last decades, the legislation on internal combustion engines (ICEs) has severely reduced the limits for pollutant and noise emissions. These requirements have established the research activity at design phase as a key stage in the engine production process. Therefore, an intensive investigation on ICEs has been carried out, focusing on the optimization of performances and fuel consumption. In particular, an important effort has been done seeking the improvement of the combustion and gas exchange processes, using tools such as Computational Fluid Dynamics (CFD).

The details of the diesel engine design vary significantly over the engine performance. In particular, different combustion chamber geometries and fuel injection characteristics are required to deal effectively with major diesel engine design problem achieving sufficiently rapid fuel-air mixing rates to complete the fuel-burning process in the time available [1].

One of the primary objectives in engine simulations is the improvement of the accuracy of spray models due to the strong role of the spray dynamics on evaporation rate, flow field, combustion process and emissions [2-6]. The breakup of the liquid fuel jet plays a decisive role in the evolution of a diesel spray and its associated subsequent processes such as air-fuel mixture formation, auto-ignition and chemical reactions. Consequently, the fuel atomization directly influences the efficiency and the pollutants formation and hence can make a fundamental contribution to an efficient and clean engine operation. From this point of view, the modeling of the atomization process plays an important role in the predictive capability of a spray model. With increasingly stricter emission regulations and greater demand on fuel economy, the injector perhaps has become the most critical component of modern diesel engines. Consequently, it is important to characterize the effects of orifice geometry on injection, atomization and combustion behavior, especially as the orifice diameter keeps getting smaller and the injection pressure higher.

COMPUTATIONAL SIMULATION OF ENGINE

The GT-POWER computational model shown is four-cylinder diesel engine performance. GT-POWER is the leading engine simulation tool used by engine and vehicle makers and suppliers and is suitable for analysis of a wide range of engine issues [7]. GT-POWER is designed for steady-state and transient simulation and can be used for analyses of engine and powertrain control. It is applicable to all type of Internal Combustion Engines and provides the user with many components to model any advanced concept. GT-POWER is based on one-dimensional (1D) gas dynamics, representing the flow and heat transfer in the piping and in the other component of an engine system. GT-POWER is one model from GT-SUITE software applications [7].

The details of the direct injection diesel engine design vary over the engine performance and size range. In particular, fuel injection and different combustion chamber geometries characteristics are required to deal effectively with major diesel engine design problem achieving sufficiently rapid fuel-air mixing rates to complete the fuel-burning process in the time available. A wide variety of inlet cylinder head and piston shapes, port geometries, and fuel-injection patterns are used to accomplish this over the diesel size range.

MAIN ENGINE DATA

The development of the four cylinder modeling and simulation for four-stroke direct-injection (DI) diesel engine was described in [8]. This paper focused on fuel nozzle hole of fuel injector. The fuel nozzle holes would be changed in wide diameter of nozzle hole and in different number of nozzle hole. The data of the selected diesel engine model was presented in Table 1.

Table 1. Specification of the engine

Engine Parameters	Value
Bore (mm)	100
Stroke (mm)	100
Displacement (cc)	3142
Number of cylinder	4
Compression ratio	18
Connecting rod length (mm)	152
Piston pin offset (mm)	0
Intake valve open (0CA)	340
Intake valve close (0CA)	-137
Exhaust valve open (0CA)	127
Exhaust valve close (0CA)	376
Brake power (KW)	120.9
Brake torque (Nm)	384.8
Fuel nozzle diameter (mm)	0.3
Fuel nozzle hole number (pc)	5
Model: Four Cylinder, Four-Stroke, Vertical, Air Cooling.	

The Figure 2 shown the four-stroke and four-cylinder direct-injection diesel engine modeling using GT-POWER modeling.

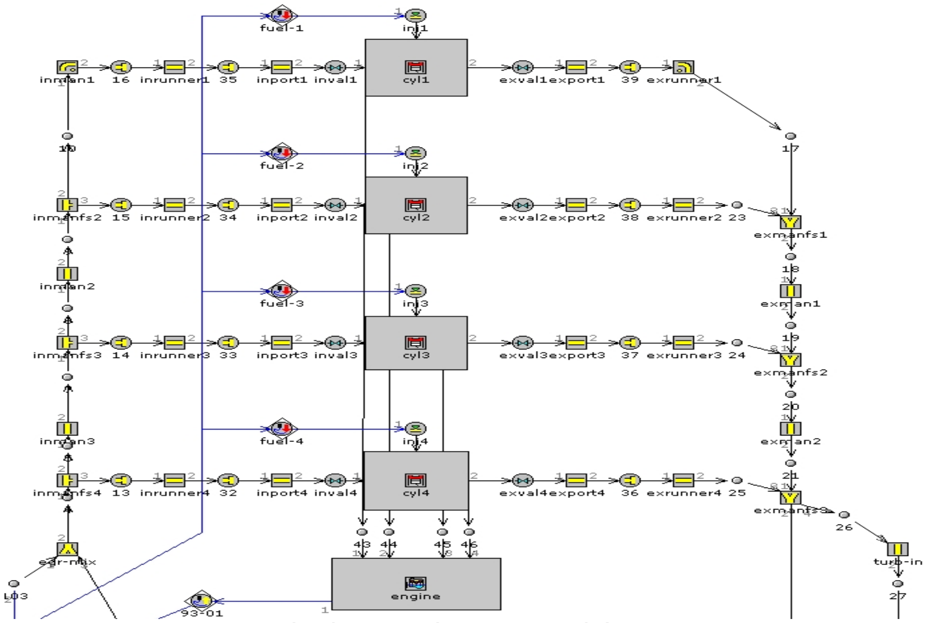

Figure 1. Four-cylinder Diesel engine modeling using GT-POWER

One of the most important of the injection system is the nozzle. The fuel is injected trough the nozzle holes into the combustion chamber. The number and size of the nozzle holes depends on the amount of fuel that has to be injected, the combustion chamber geometry and the air motion inside the cylinder. In this direct injection diesel engine is used the sac hole nozzle. The sac hole nozzle has an additional volume below the needle seat. The cylindrical hole produces the strongest cavitations and results in an increased spray break up with a large spray divergence near the nozzle. The axis symmetric conical geometry suppresses cavitations by gradually reducing the effective cross-sectional area along the hole. Many studies have suggested that decreasing the injector nozzle orifice diameter is an effective method on increasing air fuel mixing during injection [9, 10, 11, 12].

Smaller nozzle holes were the most efficient at air-fuel mixing primarily because the fuel rich core of the jet is smaller. The decreasing the nozzle hole orifice diameter would decrease the length of the core region. Unfortunately, decreasing nozzle holes diameter causes a reduction in the turbulent energy generated by the jet. Because air fuel mixing is connected by turbulence generated at the jet boundary layer, this will offset the benefits of the reduced jet core size. The jets emerging from smaller nozzle orifices not to penetrate as far as those emerging from larger orifices. This reduce in penetration means that the fuel will not be exposed to all of the available air in the chamber. For excessively small nozzle diameter, the improvements in mixing related to decreased plume size may be negated by a reduction radial penetration. This deportment is undesirable because it restricts penetration to the chamber extremities where a large portion of the air mass resides. Is *unknown from the literature is that a nozzle containing many small holes would provide better mixing than a nozzle consisting of a single large hole. It has been tested by injectors with varying numbers of nozzle holes.*

RESULT AND DISCUSSION

The diesel engine model was running on any different engine speed in rpm, there are 1000, 1500, 2000, 2500, 3000 and 3500. The variations of fuel nozzle material holes number are multi holes and several number holes, the simulation model there are start from the fuel nozzle 2-10 holes.

The influence of fuel nozzle holes number and geometries of in-cylinder engine liquid fuel shown in Figure 2-12.

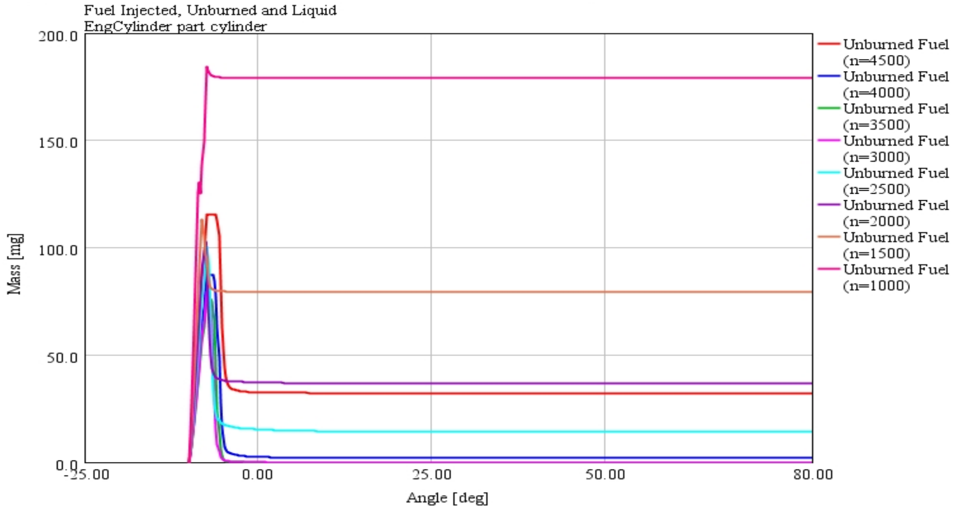

Figure 2. In-cylinder unburned fuel of nozzle 2 holes

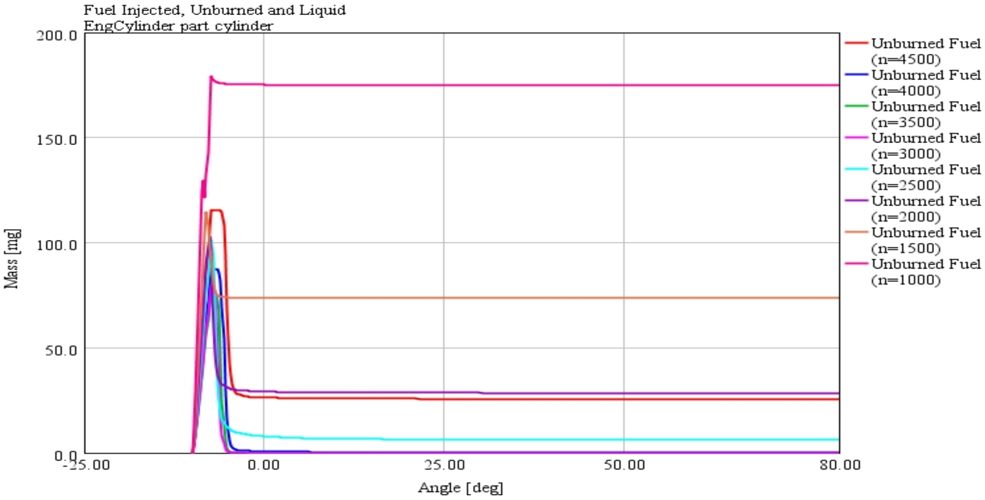

Figure 3. In-cylinder unburned fuel of nozzle 3 holes

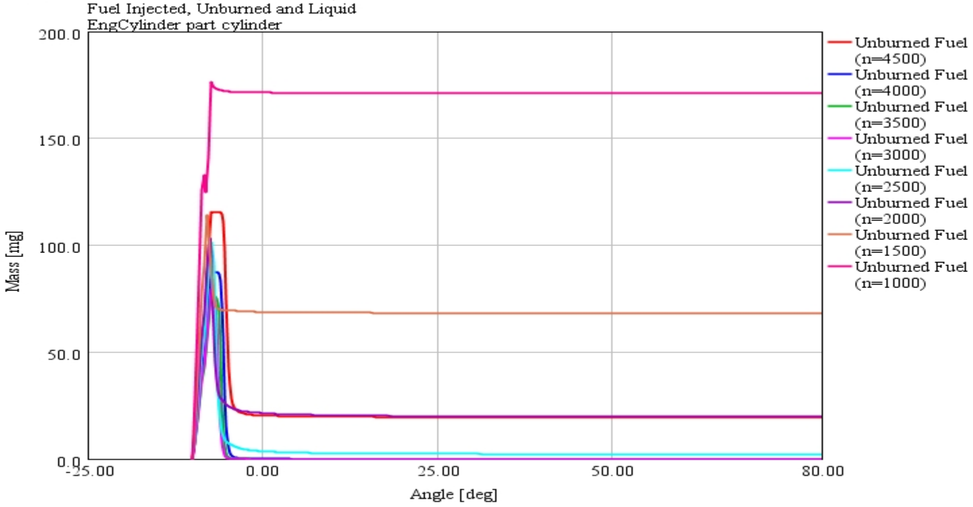

Figure 4. In-cylinder unburned fuel of nozzle 4 holes

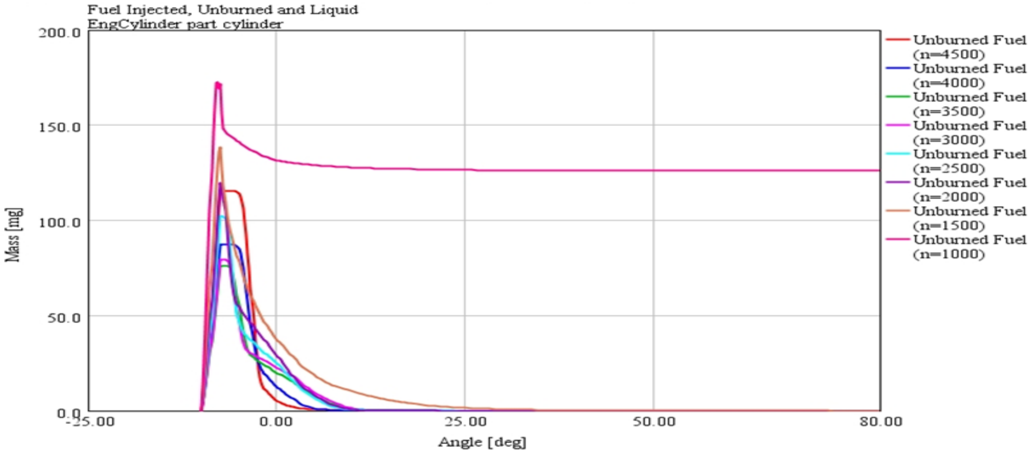

Figure 5. In-cylinder unburned fuel of nozzle 5 holes

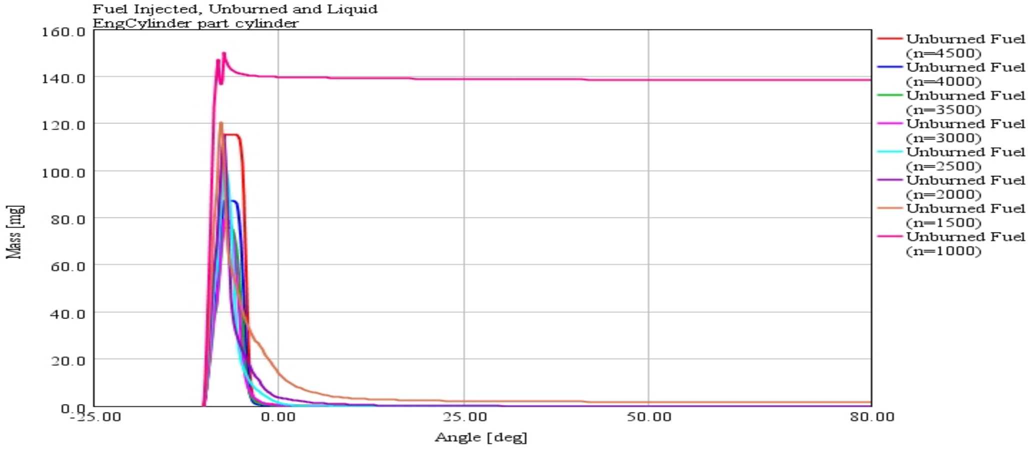

Figure 6. In-cylinder unburned fuel of nozzle 6 holes

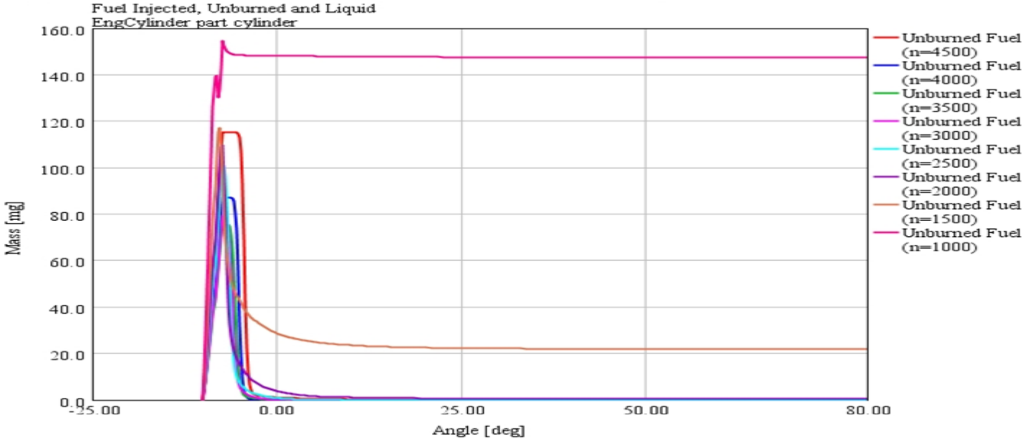

Figure 7. In-cylinder unburned fuel of nozzle 7 holes

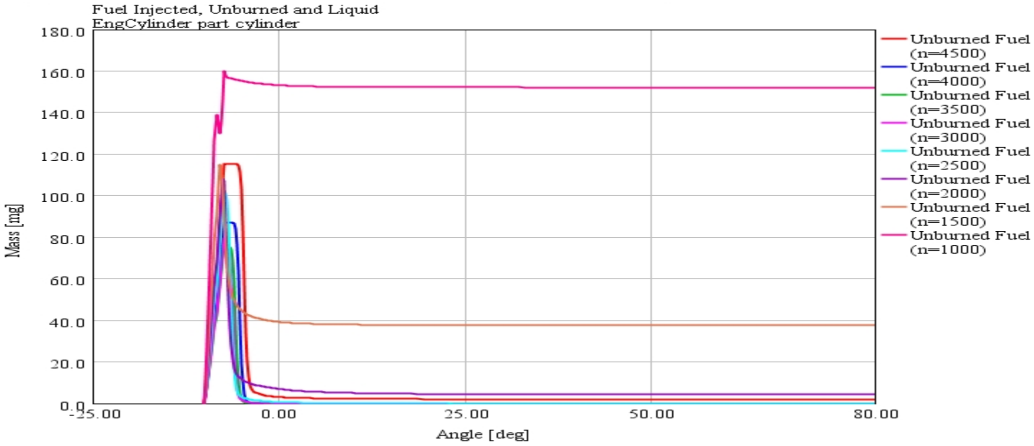

Figure 8. In-cylinder unburned fuel of nozzle 8 holes

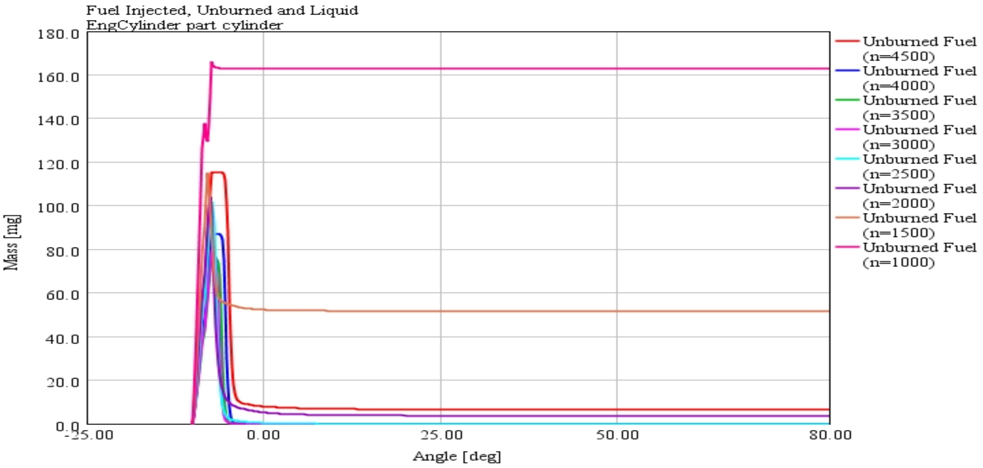

Figure 9. In-cylinder unburned fuel of nozzle 9 holes

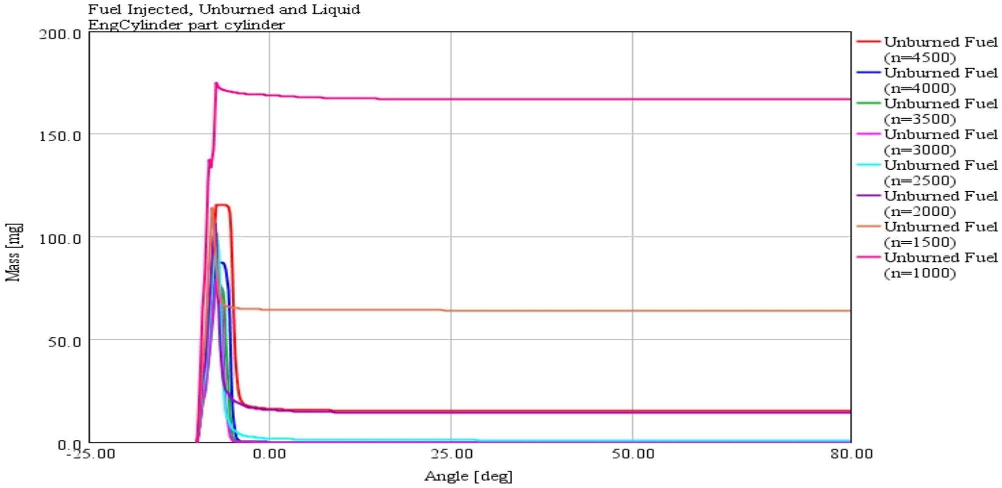

Figure 10. In-cylinder unburned fuel of nozzle 10 holes

The optimal nozzle construction would be one that provided the maximum number of liquid fuel burn in combustion process and minimum number of liquid fuel unburned. All of the nozzles examined in the simulation and the result shown that the 6 holes nozzle shown in Fig. 6 is provided the best results of unburned fuel for any different engine speed in simulation.

CONCLUSIONS

The fuel nozzles construction from 2 hole until 10 holes in difference orifice diameter have been examined using simulation and the result shown that the 6 holes nozzle provided the best burning fuel results in any different engine speed in simulation and the best burning is in low speed engine. For the future work in engine performance effect, all of the nozzles holes need more simulation to provide the best results for indicted power, indicated torque and indicated specific fuel consumption in any different engine speed.

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