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Nozzle Holes Effect on Unburned Fuel in Injected and In-Cylinder Fuel of Four Stroke Direct Injection Diesel Engine

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Abstract: The fuel nozzle is an important aspect for diesel engine combustion performance. The model of four-stroke direct-injection diesel engines is developed in the research to investigate the injected and in-cylinder fuel diesel engine in unburned fuel effect from the fuel nozzle multi holes geometries. Model and simulation in this research is using GT-POWER from the GTise-6.2 software were specially development for internal combustion engines performance simulation. The selected diesel engine is opened, breakdown and measurement of all its components size to input to the window engines component menu of the model. The investigation results output of the simulation is focuses on nozzle holes effect in unburned fuel in injected and in-cylinder fuel process of diesel engine. The holes nozzles from 1 hole until 10 holes in difference orifice diameter have been examined using GT-POWER model simulation and the results shown that the 5 holes nozzle provided the best burning fuel results in any variation engine speeds.

Key words: Diesel engines, nozzle holes, unburned fuel

INTRODUCTION

In this research, a four-stroke direct-injection diesel engine typical was measured and modeled using GT-POWER computational model. The simulation is explored of single-cylinder diesel engine performance effect based on engine rpm (Bakar *et al*., 2007). 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 (Gamma Technologies, 2004). The details of the diesel engine design vary significantly over the engine performance and size range. 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 engine cylinder (Heywood, 1998; Gamma Technologies, 2004; Ramadhas, 2006; Jamil *et al*., 2007). This simulation research is designed to investigate the effect of fuel nozzle multi holes geometries on unburned fuel of the diesel engines.

MATERIALS AND METHODS

The development of the single cylinder modeling and simulation for four-stroke Direct-Injection (DI) diesel engine was presented in this paper. Specification of the selected diesel engine model was presented in Table 1. To develop the engine model using GT-POWER software is step by step, the first step is open all components of the selected diesel engine, then measure the engine components part size one by one. Then, the engine components size data will be input to the GT-POWER library of the all engine components data. To create the GT-POWER model, select Window and then Tile with Template Library from the menu. This will place the GT-POWER template library on the left hand side of the screen. The template library contains all of the available templates that can be used in GT-POWER. Some of these templates those that will be needed in the project need to be copied into the project before they can be used to

Table 1: Specification of diesel engine

Engine parameters	Value	Engine parameters	Value
Model	CF186F	Intake valve close (°CA)	530
Bore (mm)	86.0	Exhaust valve open (°CA)	147
Stroke (mm)	70.0	Exhaust valve close (°CA)	282
Displacement (cc)	407.0	Maximum intake valve open (mm)	7.095
Number of cylinder	1	Maximum exhaust valve open (mm)	7.095
Connecting rod length (mm)	118.1	Valve lift periodicity (deg)	360
Piston pin offset (mm)	1.00	Fuel nozzle diameter (mm)	0.1
Intake valve open (°CA)	395	Fuel nozzle hole number	4

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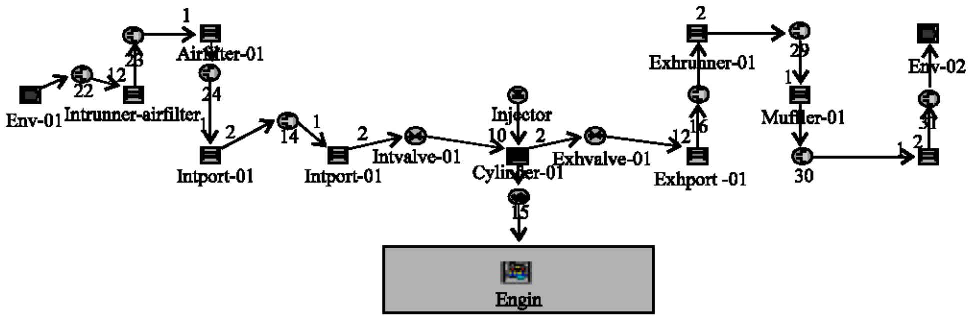

Fig. 1: GT-POWER model for Single-cylinder diesel engine

create objects and parts. For the purpose of this model, click on the icons listed and drag them from the template library into the project library. Some of these are templates and some are objects that have already been defined and included in the GT-POWER template library (Gamma Technologies, 2004).

In this model of the engine is according to Bakar *et al*. (2007) was breakdown to the tree system, there are intake system, engine cylinder and fuel injection system and exhaust system. In the selected diesel engine, the intake system its have any component, size and different data. The system was started from environment till the intake valve. The engine cylinder and fuel injection system is focused in engine cylinder performance were support diesel fuel from fuel injection system, fresh air intake system and exhaust gas to exhaust system. There are any components in the engine cylinder and fuel injection system in the diesel engine. The components, size and data must be record and inserted to the GT-POWER form. The components are injector, cylinder and engine. The last system in the diesel engine is the exhaust system. In this system was started from exhaust valve and finished in the environment. All of this diesel engine components connected by orifficeconn. Then, the modeling the diesel engine model using GT-POWER software in this research can be developed. The modeling focuses on fuel injection shown in Fig. 1. Data component and fuel nozzle hole needed for building an engine model. A list of information that is needed to build a model in GT-POWER is included in library.

Data in engine characteristics are compression ratio, firing order, inline or V configuration, V-angle (optional), 2 or 4 stroke. Data in cylinder geometry are bore, stroke, connecting rod length, pin offset, piston TDC clearance height, head bowl geometry, piston area and head area. Data in intake and exhaust system is geometry of all components. Data in throttles are throttle location and discharge coefficients versus throttle angle in both flow directions. Data in fuel injectors are location and number of injectors, number of nozzle holes and nozzle diameter, injection rate, fuel type and LHV.

Data in intake and exhaust valves are valve diameter, lift profile, discharge coefficient, valve lash. Data in ambient state are pressure, temperature and humidity. Performance data can be very useful when tuning a model after it has been built.The research is focuses in variation of diameter and number of fuel nozzle hole geometries effect on diesel engine in-cylinder unburned fuel. The variations of fuel nozzles injection holes number are 1 till 10. And the diameters of fuel nozzle injection holes geometries are start from the wide and single hole then finished on multi holes and very small diameter. Total area of the fuel nozzle on one hole till to ten holes is the same with the original fuel nozzle holes area. Before running the model the preparing to run the model simulation needed. Preparing to run the model simulation are review the completed model, run setup, case setup, plot requests and plot setup.

RESULTS AND DISCUSSION

Whenever a simulation is running, GT-SUITE produces several output files that contain simulation results in various formats. Most of the output is available in the post-processing application GT-POST. GT-POST is powerful tool that can be used to view animation and order analysis output (Gamma Technologies, 2004). After the simulation was finished, report tables that summarize the simulations can be produced. The computational simulation of the engine model result is informed the engine performance. The running simulation result in this research is focuses on the engine performance data based on variation of fuel nozzle material hole diameter size, diameter number and the different engine speed (rpm). The diesel engine model was running on any different engine speed in rpm, there

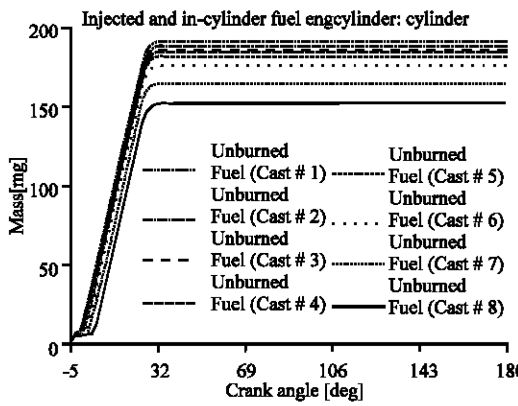

Fig. 2: Unburned fuel 1 holes

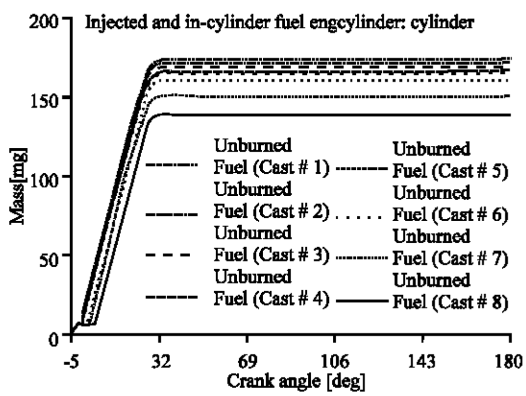

Fig. 3: Unburned fuel 2 holes

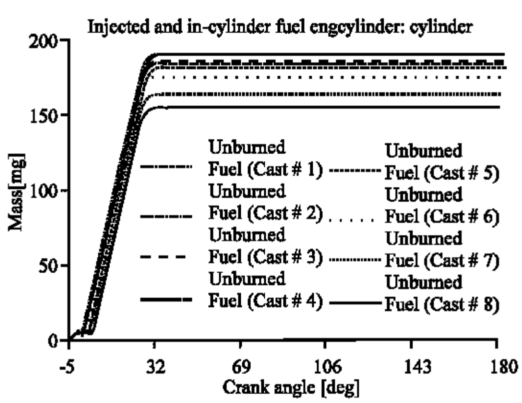

Fig. 4: Unburned fuel 3 holes

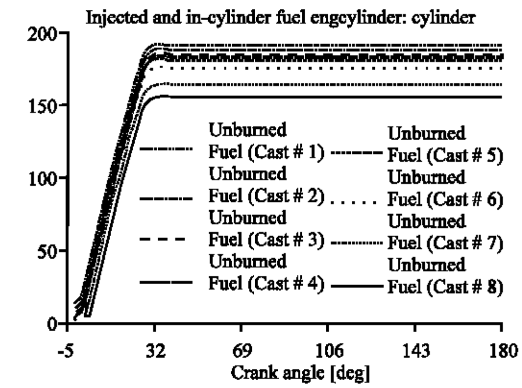

Fig. 5: Unburned fuel 4 holes

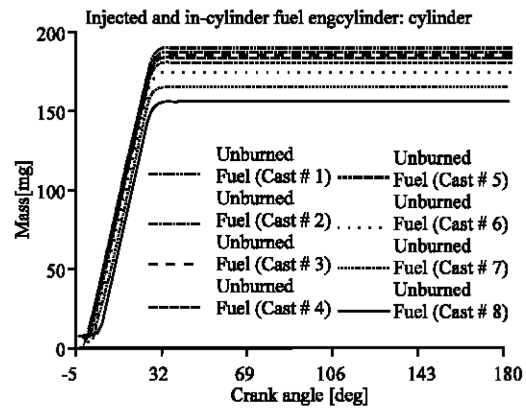

Fig. 6: Unburned fuel 5 holes

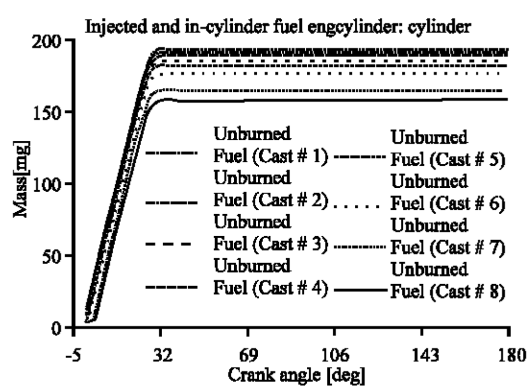

Fig. 7: Unburned fuel 6 holes

are 500, 1000, 1500, 2000, 2500, 3000, 3500 and 4000. In the simulation model, there are start from fuel nozzle 1 hole until 10 holes on the same of total fuel nozzle holes area. The simulation result is shown in Fig. 2-11.

The most important part of the injection system is the nozzle. The fuel is injected through 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 engines is used the sac hole nozzle. The sac holes nozzle has an additional volume below the needle seat. Depending on the particular application, different nozzle holes geometries are used today. The cylindrical hole

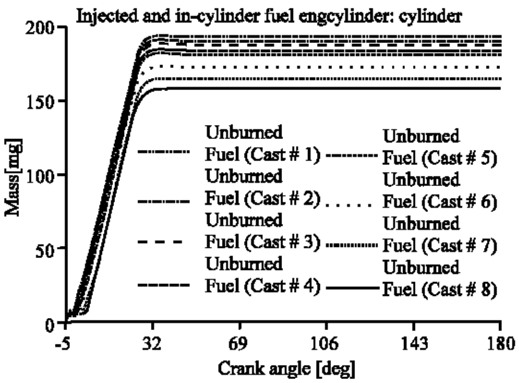

Fig. 8: Unburned fuel 7 holes

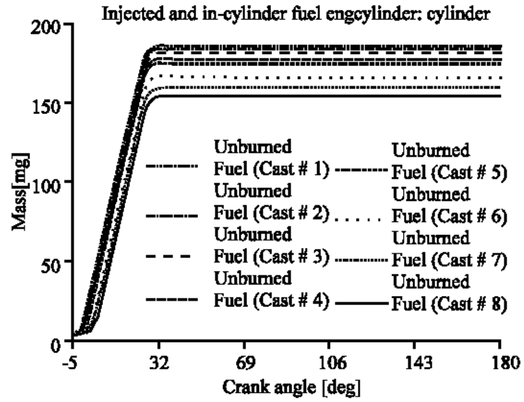

Fig. 10: Unburned fuel 9 holes

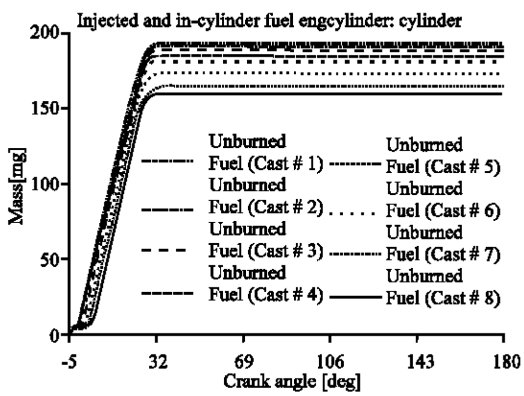

Fig. 9: Unburned fuel 8 holes

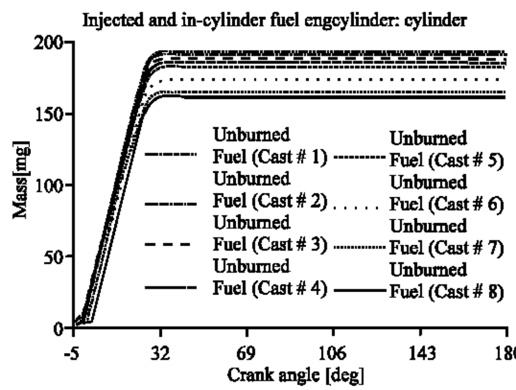

Fig. 11: Unburned fuel 10 holes

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.

Numerous simulations have suggested that decreasing the injector nozzle orifice diameter is an effective method of increasing fuel air mixing during injection. Smaller nozzle holes were 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. Unfortunately, decreasing nozzle holes size causes a reduction in the turbulent energy generated by the jet.

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. 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. For excessively small nozzle size, the improvements in mixing related to decreased plume size may be negated by a reduction n radial penetration. This behavior is undesirable because it restricts penetration to the chamber extremities where a large portion of the air mass resides. Furthermore, it hampers air entrainment from the head side of the plume because the exposed surface area of the plume is reduced. It has been suggested that a nozzle containing many small holes would provide better mixing than a nozzle consisting of a single large hole. This hypothesis has been tested by studying injectors with varying numbers of nozzle holes.

The optimal nozzle design would be one that provided the maximum number of liquid fuel burn in combustion process and minimum number of liquid fuel unburned. Theoretically, a 10 holes nozzle satisfies this requirement. Unfortunately, jets emerging from a 10 holes nozzle tended to be very susceptible. All of the nozzles examined in the simulation and the result shown that the 5 holes nozzle shown in Fig. 6 is provided the best results of unburned fuel for any different engine speed in simulation.

CONCLUSION

The fuel nozzles injector from 1 hole until 10 holes in difference orifice diameter have been examined using simulation and the result shown that the 5 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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