SPRAY DEVELOPMEN[illegible] TION FOR SIMPLE

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ABSTRACT

This thesis is related to the simulation results conducted to injectors and combustion chamber using a simple computational Fluid Dynamic. Injectors and combustion chamber design using SolidWorks 2012 and flow simulation software used is from SolidWorks Flow Simulation 2012. Simulation to be carried out based on the differential pressure injector to inject. While for simulated combustion chamber front, it is carried out based on the difference in pressure at the injectors and air/fuel ratio, the normal level of 13:1. Simulation of the combustion chamber is also carried out with four different strokes, the intake stroke, compression stroke, power stroke and exhaust stroke. It is possible to identify differences in contour in every stroke. Characteristics that need to be identified in this injector simulation are an area of wide angle spray and spray. The findings from the simulations carried out were then compared with the results of the experiment conducted by engineers and researchers in the selected journal.

ABSTRAK

Tesis ini berkaitan dengan hasil simulasi yang dijalankan kepada pemancit dan kebuk pembakaran yang ringkas mengunakan Computational Fluid Dynamic. Rekabentuk pemancit dan kebuk pembakaran menggunakan perisian SolidWorks 2012 manakala simulasi aliran yang digunakan adalah dari perisian Solidworks Flow Simulation 2012. Simulasi untuk pemancit dijalankan berdasarkan perbezaan tekanan terhadap pemancit. Manakala untuk simulasi kebuk pembakaran pula, ianya dijalankan berdasarkan tekanan pada pemancit dan nisbah campuran bahan api dan udara berada pada tahap normal iaitu 13:1. Simulasi kebuk pembakaran juga dijalankan dengan empat lejang yang berbeza, iaitu lejang masukan, lejang mampatan, lejang kuasa dan lejang ekzos. Ia dilakukan untuk mengenalpasti perbezaan kontor dalam setiap lejang yang berbeza. Ciri-ciri yang perlu dikenalpasti dalam simulasi pemancit ini adalah sudut semburan dan keluasan lebar semburan. Hasil dapatan dari simulasi yang dijalankan kemudiannya dibandingkan dengan hasil dari experiment yang dijalankan oleh jurutera-jurutera dan penyelidik-penyelidik didalam jurnal yang dipilih.

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The fuel injection system is the most vital component in the working of combustion ignition engines. The engine performance, power output, economy etc. is greatly dependent on the effectiveness of the fuel injection system. The injection system has to perform the important duty of initialing and controlling the combustion process. (Ganesan, 2007)

In a successful effort to deal with some of these shortcomings in the face of economic and political pressure to reduce fuel consumption nationally, as well as to reduce pollution, particularly unburned hydrocarbons and oxides of nitrogen, fuel injection has been almost universally adopted. Throttle-body fuel injection offers the possibility of controlling the amount of fuel introduced more precisely, as well as reducing the droplet size somewhat, but still suffers from some of the problem of the carburetor with regard to distribution. (Lumley, 1999)

Gasoline Direct injection has potentials for enhanced power output and better fuel economy, improved transient response, and reduced cold-start hydrocarbon emission levels if it comes with precise control of fuel-air mixture formation. On a side-mount gasoline direct injection engine, an injector is mounted on the cylinder wall and injects fuel directly into the combustion chamber. Gasoline direct injection engines are characterized by less pumping loss and higher compression ratio, and better volumetric efficiency comparing to Port Fuel Injection engines. Thus gasoline direct injection engines with well optimized spray structure and injection strategy are required to meet the ever-tightening emission standards and fuel economy regulations. Since a gasoline direct injection engine delivers fuel at a compression stroke when it runs in a stratified mode, piston whiting and resultant harmful emissions are major issues. (Matsumoto et all, 2010)

When the fuel in injected into the combustion chamber towards the end of the compression stroke, it is atomized into very fine droplets. These droplets vaporize due to heat transfer from the compressed air and form a fuel air mixture. Due to continued heat transfer from hot air to the fuel, the temperature reaches a value higher than its self-ignition temperature. This causes the fuel to ignite spontaneously initiating the combustion process. (Ganesan, 2007)

Combustion in the engine occurs when the chemical reaction in which certain elements of the fuel like hydrogen and carbon combine with the oxygen liberating heat energy and causing an increase in temperature of the gases.

1.2 PROBLEM STATEMENT

Most modern spark ignition engines, typically operated on gasoline, use one of two main fuel injection technologies present in the market. The standard manifold port fuel injection system employs low-pressure, generally around 0.4 MPa, supplied directly from an in-tank, electric fuel pump. Individual cylinder fuel injectors deliver a liquid spray into the intake port, upstream of the intake valves. In contrast the high-pressure spark ignition direct injection fuel system consists of an additional, mechanically driven fuel pump which boosts fuel pressure in the range of 3 to 20 MPa. The fuel injectors are relocated to inject the fuel directly into the combustion chamber. The high pressure results in improved mixture preparation. (Davis et all, 2008)

Spray development is critically related to mixture formation and the injection strategy must be well optimized in order to exploit the potential of the engine. If sprays hit a piston bowl during stratified operation, this impingement should be studied more for better understanding of mixture formation. It has been reported that the piston impingement must be taken into account for a better simulation result. Overestimation of volumetric efficiency for fuel was found and a suggestion was presented to create a sub-routine to accurately simulate impingement, vaporization, and heat transfer on a piston surface. The previous work on wall impingement discovered that the wall temperature strongly affected the vapor phase propagation after the spray hit the surface. (Matsumoto et all, 2010)

The main problem of this project is spray development phenomena difficult to understand. The spray phenomena such as spray angle and spray atomization. In gasoline engines, spray development is critically related to mixture formation and injector strategy must be well optimized in order to exploit the potential of the engine. Although swirl injectors had widely studied for gasoline engine, multi-hole injector were found to be more suitable for spray-guided gasoline engines because they offer advantages of stable spray pattern and flexibility in spray plume targeting. Especially, independence of spray cone angle on ambient pressure is preferred for direct injection operation. (Matsumoto et all, 2010). The simulation has been used to investigate and identify the spray development for gasoline engines.

1.3 OBJECTIVES

The main objective of this study is investigating and identifying the spray development at different range of pressure using flow simulation. The spray developments in the study are spray angle at difference range of injector pressure.

The second objective of this study is analyzing the combustion region in a simple combustion chamber using flow simulation. This study involved the intake stroke, compression stroke and power stroke.

1.4 SCOPE OF PROJECT

The scope of the study is studying the spray development such as spray angle at difference range of injector pressure of 20 MPa to 100 MPa. This study is using single-hole injector at a diameter of the nozzle is 1.0 mm. The studies of the combustion region at an injector pressure of 60 MPa and using environment pressure in the combustion chamber for intake stroke. This study uses SolidWorks 2012 for designing and SolidWorks Flow Simulation for analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The literature review is a study related to the project. All these things are important to the planned targets and objectives can be achieved. In addition, it also helps in the course of the project so that the movement is smooth and perfect. If the layout is not fully dealt with this will cause the target cannot work properly and effectively achieved, the results obtained do not meet the work requirements of the objective.

2.2 FUEL SPRAY STUDY

Injectors are widely used in industry for fuel supply, therefore an enormous amount of research on atomization techniques have been done over the past decades. By the same token, in the field of the internal combustion engine, the port fuel injection technique has been developed because it is imperative to lower the emissions and fuel consumption of fuel injected engines, which are usually diesel or direct injection gasoline engines. Therefore, the primary characteristics of fuel injection, including droplet breakup, evaporation from droplets and wall impingement, have been studied.

In applying the injector in general purpose utility engines to supply fuel, a unique intractableness, which is different from automobile or motorcycle applications, exists. General purpose utility engines have two desirable, but contradictory aspects: compactness and high power at wide open throttle. The latter condition especially makes applying fuel injectors challenging, because a large amount of fuel is needed and a certain quantity of fuel accumulates as fuel wall film at wide open throttle conditions that exerts a harmful influence on the exhaust gas. Therefore, the studies about the fuel wall film have been done in the past. However, in order to apply fuel injection in general purpose utility engines, research on the wall film on conditions typical for an intake port are still needed. In this study, in order to develop a prediction technique that can be used in the development of port fuel injection small utility engines, the wall film thickness measurement and calculation in the intake port are taken into consideration. (Toshiro et all, 2008)

2.3 FUEL SPRAY CHARACTERISTICS

The fuel spray characteristics are of significant importance to direct-injection gasoline combustion systems. The parameters such as the spray angle, mean drop size, spray penetration and fuel delivery rate are known to be critical, and the optimum matching of these parameters in the airflow field, piston bowl geometry and spark location usually constitute the essence of a gasoline direct injection combustion system development project.

In contrast, the primary fuel spray characteristics of a port fuel injector generally have much less influence on the subsequent combustion event, mainly due to the integrating fuel effect of the residence time on the closed valve, and due to the secondary atomization that occurs as the induction air flows through the valve opening. For direct injection in both gasoline direct injection and diesel engines, however, the mixture preparation time is significantly less than is available for port fuel injection, and there is much more dependent on the primary sprays characteristics to prepare and distribute the fuel to the optimal locations.

It is well established that a port-injected gasoline engine can operate quite acceptably using a spray of 200 mm sauter mean diameter of a fuel spray, whereas a gasoline direct injection engine will generally require atomization that is an order of magnitude finer. Most gasoline direct injection applications will require a fuel spray having an sauter mean diameter of a fuel spray of less than 25 mm, and may require as low as 15 mm, in order to achieve acceptable levels of unburned hydrocarbons emissions and coefficient of variation of indicated mean effective pressure. The diesel engine, of course, generally requires a fuel spray having a sauter mean diameter of a fuel spray that is less than 10 mm, as the fuel is less volatile than gasoline. (Zhao et all, 1999)

2.3.1 Fuel Spray Angle

The spray angle of the droplet should be optimized to provide the best atomization while avoiding cylinder liner wetting. Droplet size empirical correlation showed that wider spray angle produces better atomization. Work indicate that spray impingement upon the cylinder liner is an important source of hydrocarbon emission in gasoline direct injection engines. Thus, to get the best atomization, to avoid fuel wastage, and to minimize hydrocarbon emission, the practical limit of the spray angle should be the maximum point before it wet the cylinder liner. On the contrary, for two-stroke engine application, where gasoline is premix with lubricant, a slight cylinder liner wetting might be a wise approach to lubricate the system.

For the specified engine, at 6000 RPM spray impingement is likely to occur at 60° before top dead center. With the injector placed at the center of the pent-roof, the maximum spray angle at that particular crank angle should not exceed 38.28°.

However, the optimum spray angle for wall-guided approach should depend on the geometry of the piston bowl. Thus, as shown in Figure 2.1, at any crank angle, the optimum spray angle is given by arc tan (b/a), where a is a function of crank angle. (Azhar et all, 2000)

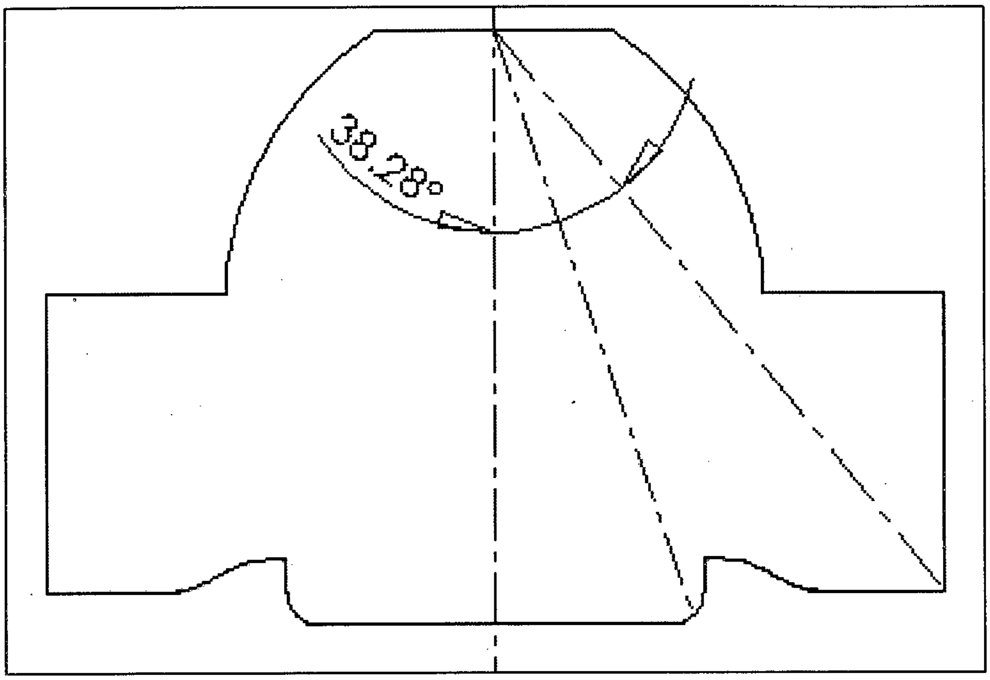

Figure 2.1: Combustion chamber cross-section

Source: Azhar et all (2000)

2.3.2 Injector Spray Pattern Development

Significant development effort was focused on identifying the injector spray characteristics to optimize and balance overall engine performance. Many methods exist for optimizing multi-hole injector spray characteristics. Swirl-type injectors were considered in the early stages of the program along with a wide variety of multi-hole designs.

In addition to the choice of direct injection injector type – swirl or multi-hole– there are several design features and options which can influence engine performance. For swirl injectors, these parameters include:

- Injector flow rate
- Fuel pressure capability
- Spray targeting:
  - Cone angle
  - Tilt or Gamma angle

For multi-hole injectors there is additional design variable that needs to be defined. The parameters included in the evaluation matrix for multi-hole injectors include:

i. Injector flow rate
ii. Fuel pressure capability
iii. Hole / orifice geometer
  - Diameter
  - Length
  - L/D
  - Cross-section

- Straight
- Stepped hole
- Number of holes
- Individual beam cone angle
- Spray targeting

Multi-hole injectors offer a wider variety of options for targeting of the fuel spray than do swirl injectors. The number of holes or orifices as well as their orientation can be adjusted.

The simplest and most common arrangement of the holes is a circular pattern. These patterns are defined by the "Alpha" angle which is the included angle of the cone formed by the individual beams and by the "Gamma" angle which is the inclination or offset of the cone relative to the injector centerline. For a given injector location and installation angle, the Alpha angle determines the size of the cone and the Gamma angle determines the direction it is aimed. An example of a 6 hole, circular spray pattern with a 15 degree Alpha angle and 10 degree Gamma angle is shown in Figure 2.2. (Davis et all, 2008)

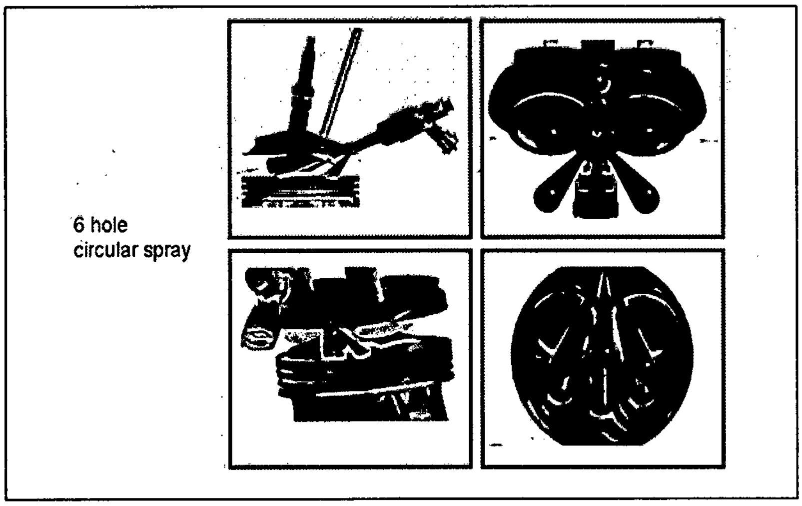

Figure 2.2: Spray targeting for six-hole circular spray

Source: Davis et all (2008)

2.4 TYPE OF FUEL SPRAY

The centrepiece of this component set is an injector with a solenoid drive and a multi-hole nozzle suited for all mounting configurations and combustion methods. The first generation component design had a swirl-type spray design and was well suited for fuel economy concepts with lean burn engine operation. Spray atomization quality of swirl and multi-hole injectors are comparable but the multi-hole injector shows superior performance relative to back pressure resistance. The cone angle of swirl injectors can be varied within a range, whereas multi-hole injectors allow for a very high geometric variety of the spray configuration. The multi-hole injector spray pattern can be adjusted to any given combustion chamber geometry in an optimum manner.

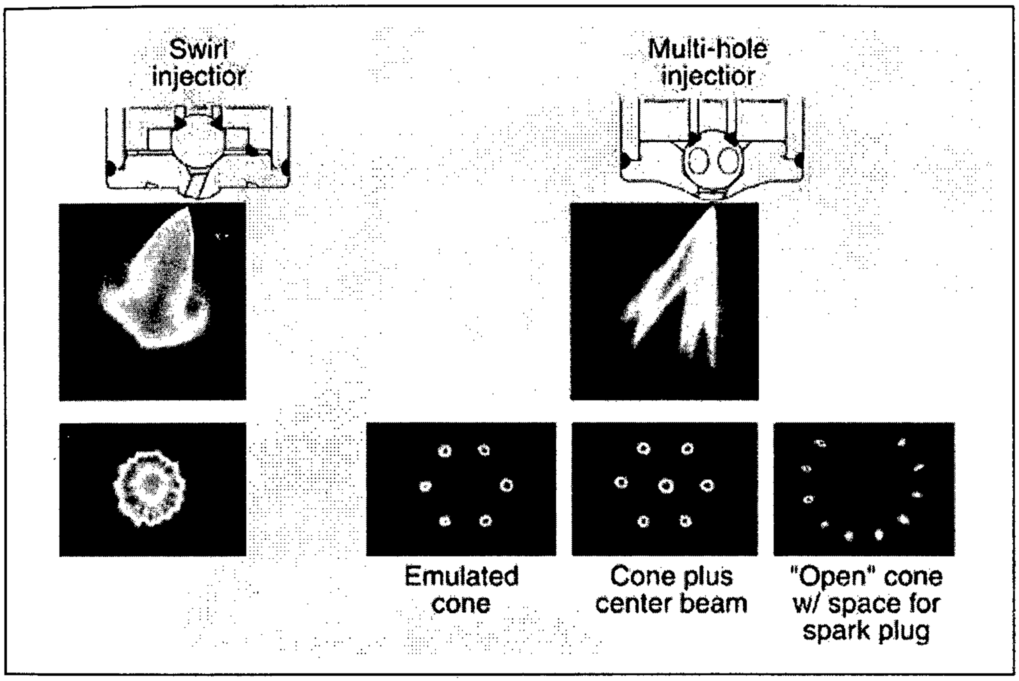

Figure 2.3: High pressure injectors and variability of spray geometry

Source: Davis et all (2008)

Choosing a spray pattern that is not symmetrical about the spray pattern centreline allows raw, engine-out emissions to be reduced drastically compared to an emulated hollow cone. In combination with control of the injection timing, spray targeting of the individual beams in a multi-hole injectors can minimize wetting of the inlet valves, the spark plug, the wall of the cylinder, and the piston.

The penetration length of a multi-hole injector lies between that of a swirl injector pre-jet and main spray. The penetration of a multi-hole injector converges with that of a swirl injector main jet at later times after the start of injection. (Davis et all, 2008)

2.5 COMBUSTION CHAMBER

The location and orientation of the fuel injector relative to the ignition source are critical geometric parameters in the design and optimization of a gasoline direct injection combustion system. During high-load operation, the selected injector spray axis orientation and cone angle must promote better fuel air mixing with the induction air in order to maximize the air utilization. For late injection, the spark plug and injector locations should ideally provide an ignitable mixture cloud at the spark gap at an ignition timing that will yield the maximum work from the cycle of a range of engine speeds. In general, no single set of positions is optimum for all speed-load combinations; thus the positioning of the injector and spark plug is nearly always a compromise.

In extending the time-honoured considerations for designing port fuel injected engine combustion chambers to the design of gasoline direct injection combustion chambers, a number of additional requirements must be satisfied. To minimize the flame travel distance, and to increase the knock-limited power for a specified octane requirement, a single spark plug is generally positioned in a near-central location. As with port fuel injection systems, this location usually provides the lowest heat losses during combustion.

The alignment of the injector relative to the intake port is another design challenge for implementing a side-mounted injector. The use of an intake port configuration largely identical to a port fuel injected port design leads to a very shallow injector elevation angle above the horizontal plane. Such a configuration does provide an intake port with known, good flow characteristics, but the spray may impact the intake valves for early injection, possibly causing deposit formation. This can be partially overcome by using either an angled spray or a steeper injector inclination angle. With a steeper injector inclination angle, the interaction between the spray and the target piston cavity is less dependent on the engine crank angle. (Zhao et all, 1999)

2.6 COMBUSTION CHARATERISTICS

The combustion characteristics of the gasoline direct injection engine change significantly with the combustion control strategy that is used. Using flame luminosity analysis, combustion associated with early injection is characterized by the flames that are typical of premixed lean or stoichiometry mixtures. The flame luminescence that is observed is attributed to OH and hydrocarbons chemiluminescence, as well as to CO–O recombination emission. Luminescence at the longer wavelengths normally associated with soot radiation was not observed. In the case of late injection, it was found that the major component of the flame luminosity consists of continuous blackbody radiation emitted from soot particles formed inside the cylinder, which is typical of a stratified-charge combustion process. The soot radiation was found to decrease abruptly after sufficient air has been engrained into the reaction zone.

For heavy-load operation, soot may be generated for some injection timings as the result of the presence of a liquid film on the piston crown, which can occur for injection early in the intake stroke or for a fuel injector having a large spray droplet size. Another cause of soot generation is an insufficient time for fuel–air mixing, which can occur for high load injection late in the intake stroke. A number of design parameters such as the piston crown geometry, spray cone angle and penetration, injection timing, and the in-cylinder air motion must be optimized to minimize soot formation.

For the port fuel injected engine operating at the idle condition, the combustion rate is low, and the combustion stability is generally marginal, primarily because of a large amount of residual gas. In the case of the gasoline direct injection engine at idle, the initial combustion rate was reported to be approximately the same as that for the full-load condition. The initial flame kernel develops rapidly in the rich mixture region near the spark gap; however, the rate of flame propagation is reduced in the lean outer region of the stratified charge. (Zhao et all, 1999)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The methodology is defined as the analysis of the principles of methods, rules and postulates employed by a discipline or the development of methods to be applied within a discipline. Basically methodology is a particular procedure or sets of procedures. Besides that, methodology also includes a collection of theories concepts or ideas. Furthermore, it also contains comparative study of different approach plus analysis or perspective of the individual methods.

All processes in the work plan typically include the selection policy, the means used to achieve the project objectives. Policy is part pointer towards resolved by group members. These rules are effective explanation of how, when and what tasks would be done in completing this project. Explain of how the steps for running the specified programs