UNIVERSITI TEKNIKAL MALAYSIA MELAKA

STUDY OF FLUID FLOW IN DIFFERENT FUEL RAIL USING CFD SIMULATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Mechanical Engineering Technology (Automotive Technology) (Hons.)

by

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DECLARATION

I hereby, declared this report entitled "Study of Fluid Flow in Different Fuel Rail using Computational Fluid Dynamics (CFD) Simulation" is the results of my own research except as cited in references.

Signature :...

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Date :...

APPROVAL

This report is submitted to the Faculty of Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the Bachelor's Degree in Mechanical Engineering Technology (Automotive Technology) with Honours. The member/person of the supervise is as follow:

....

(Project Supervisor)

Najiyah Safwa Binti Khashi'ie

ABSTRACT

The Electronic Fuel Injection (EFI) system is the introduction of fuel in an internal combustion engine and most commonly automotive engine. This system consists of fuel tank, fuel pump, fuel rail and injectors. A fuel rail is essentially a pipe and usually resembling a rail, the main function of the fuel rail is to deliver the fuel to individual fuel injectors on the internal combustion engine. It is designed to assemble or that fits with the fuel injectors of the engine as well as an inlet for a fuel supply. The fuel rail is important for the optimal distribution of the fuel (petrol) to the injectors in the internal combustion engine. The engine system will have pressure loss in the fuel rail in order to supply fuel at the higher engine speed. The amount of fuel injected at each injector due to the weakness design of standard fuel rail. In this project, two fuel rails with different diameter were designed by using Computer Aided Design (CAD) and the fluid flow of fuel in these different fuel rails were studied by using Computational Fluid Dynamics (CFD). By the end of this project, the result have shown the performance fuel rail is more better than standard fuel rail in fuel flow. Other than that, the pressure of the fuel flow to the rail is increase when using performance fuel rail.

ABSTRAK

Sistem suntikan bahan api elektronik adalah pengenalan sistem bahan api dalam enjin pembakaran dalaman dan banyak digunakan dalam enjin automotif. Sistem ini terdiri daripada tangki bahan api, pam bahan api, rel bahan api dan penyuntik. Sebuah rel bahan api pada dasarnya adalah paip dan biasanya berbentuk rel, fungsi utama rel bahan api adalah untuk menyampaikan bahan api kepada setiap satu penyuntik bahan api pada enjin pembakaran dalaman. Ianya direka bentuk untuk dipasang atau disesuaikan dengan penyuntik bahan api enjin sesebuah kenderaan serta sebagai kemasukan untuk sistem bekalan bahan api. Rel bahan api adalah penting untuk pengagihan optimum bahan api (petrol) kepada setiap penyuntik dalam enjin pembakaran dalaman. Sistem enjin akan kehilangan tekanan dalam rel bahan api untuk membekalkan bahan api pada kelajuan enjin yang lebih tinggi. Jumlah bahan api yang disuntik pada setiap penyuntik mempunyai kelemahan disebabkan oleh reka bentuk rel bahan api yang sedia ada. Dalam projek ini, dua rel bahan bahan api dengan diameter yang berbeza telah direka dengan menggunakan Lukisan Terbantu Komputer dan aliran cecair bahan api di dalam rel bahan api yang berbeza telah dikaji dengan pengiraan menggunakan Computational Fluid Dynamics (CFD). Pada akhir projek ini, keputusan telah menunjukkan rel bahan api ubahsuai adalah lebih baik berbanding rel bahan api sedia ada dari segi aliran bahan api. Selain itu, tekanan aliran bahan api kepada rel bahan api adalah meningkat apabila menggunakan rel bahan api prestasi ataupun ubahsuai.

DEDICATIONS

I would like to dedicate to my beloved parents, my supervisor (Ms Najiyah Safwa Binti Khashi'ie), my co-supervisor (Mr Mohd Suffian Bin Ab Razak) in guiding me from beginning of this project until the completing this project. I also would like to dedicate to all my friends in supporting me during to finishing this project research.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

CAD	-	Computer Aided Design
CATIA	-	Computer Aided Three-Dimensional Interactive Application
CFD	-	Computational Fluid Dynamics
$K-\varepsilon$	-	K-epsilon
K	-	Kelvin
m	-	metre
mm	-	millimetre
m/s	-	metre per second
Re	-	Reynold Number
SA	-	Sparlart-allmaras
SST	-	shear stress transport
Pa	-	Pascal
τ	-	shear stress
μ	-	absolute (dynamic) viscosity
$\frac{dV}{dy}$	-	time rate of strain
f	-	Darcy friction factor

CHAPTER 1

INTRODUCTION

1.0 Introduction

Chapter 1 is the framework of this project that including brief introduction about the Electronic Fuel Injection (EFI), fuel rail, objective and scope of this project.

1.1 Background of Study

The Electronic Fuel Injection (EFI) has applied to automobiles in mass production use was first introduced in the late 1960s. This is a system for introducing fuel into internal combustion engines and into automotive engines in particular. On diesel engines, fuel injection is a necessity, whilst on petrol engines fuel injection is an alternative to the carburetor. Most of the spark ignition internal combustion engines operate with a stoichiometric air petrol ratio since it enables the catalyst to control emissions level (Chalet & Chesse, 2016). They is differences between carburetor and fuel injection. The primary difference is that fuel injection atomizes the fuel through a small nozzle under high pressure, while a carburetor relies on suction created by intake air accelerated through a venturi tube to draw the fuel into the airstream.

The vehicles maker; Volvo and Volkswagen used Bosch D Jetronic analog system widely. This system was well engineered and quite reliable given the technology available at the time. Electronic Fuel Injection (EFI) uses solenoid valves called injectors to meter fuel delivery. The fuel injection system used by Scania is called Extra High Pressure Injection (XPI) and is a so called Common Rail (CR) system developed by Cummins and Scania (Engineering, 2011).

According to (Injectors, n.d.), the nominal injection pressure for most Ford vehicles that used EFI system is 39.15psi (270kPa). Most vehicles today use one injector per cylinder. When the solenoid is energized, fuel sprays out into the valve port. Fuel is delivered to the injector by a high pressure electric pump at around 40 psi. Fuel delivery is controlled by the injectors which are cycled by the computer. The computer produces a signal to open the injectors for a certain length of time depending on engine conditions relayed by sensors. The more fuel is injected, the longer that the injector is open.

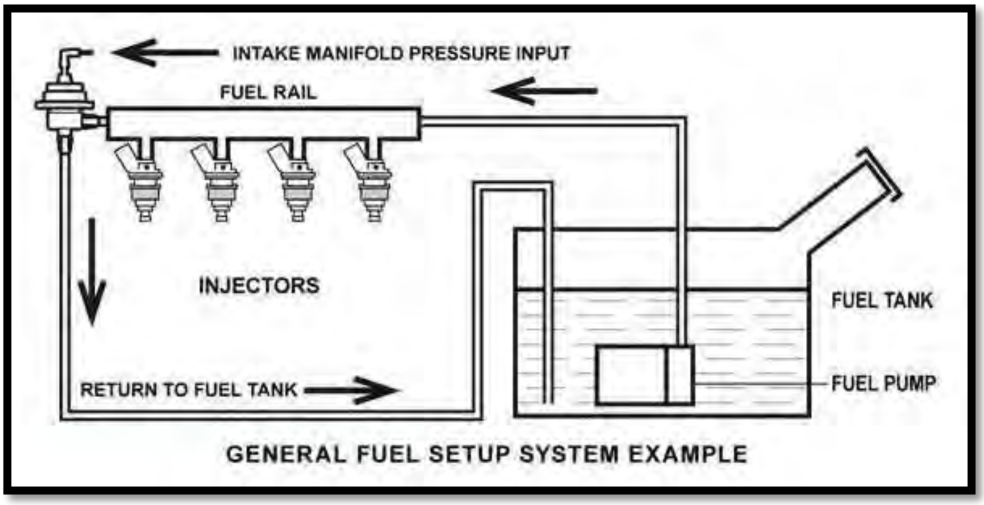


Figure 1.1: The General Fuel Rail System
(http://zilvia.net/f/showthread.php?t=549436).

The Electronic Fuel Injection (EFI) system consists of a tank, pump, fuel rail, regulator, injectors and return line. Fuel is drawn from the tank by the pump through fuel filter and then fuel rail which the pressure is around 40 psi. Fuel pressure is controlled by the fuel pressure regulator located on one end of the fuel rail by bleeding fuel back to the tank through the return line. The pump always puts out an excess of fuel so large quantities are returned back to the tank during idle and low speed conditions and less as engine demand increases.

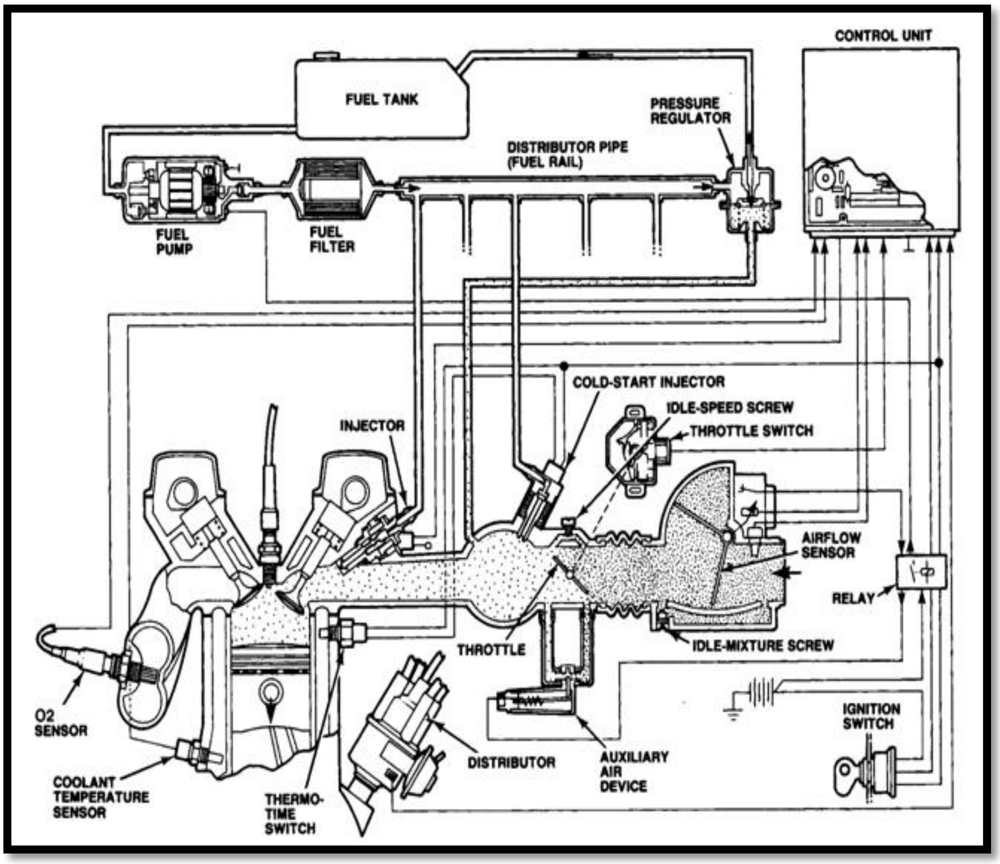


Figure 1.2: The Bosch L-Jetronic system has been used on various Japanese, European and domestic vehicles (Bosch).

The fuel rail is important in the optimal distribution of the fuel (petrol) to the injectors in high or low pressure supply systems of engines. It consists of a duly sized piping that fits the injector housings, the fixing brackets to the air intake manifold or to the motor cylinders head, connections for fuel inlet and, if necessary, fuel recirculation in the tank, the housings for the fuel temperature and pressure sensors, the housing for an internal discharge control valve, if necessary, and the supports for the electrical wirings of the assembled electromechanical components. The fuel rail for petrol engines can be made in thermoplastic material with high mechanical, thermal, chemical resistance or in steel. The operating pressure is obtained and maintained through a pressure regulator that can be incorporated into the rail (systems equipped with fuel recirculation) or in the fuel pump (systems without recirculation). Rail design is based on instantaneous flow rate control requirements.

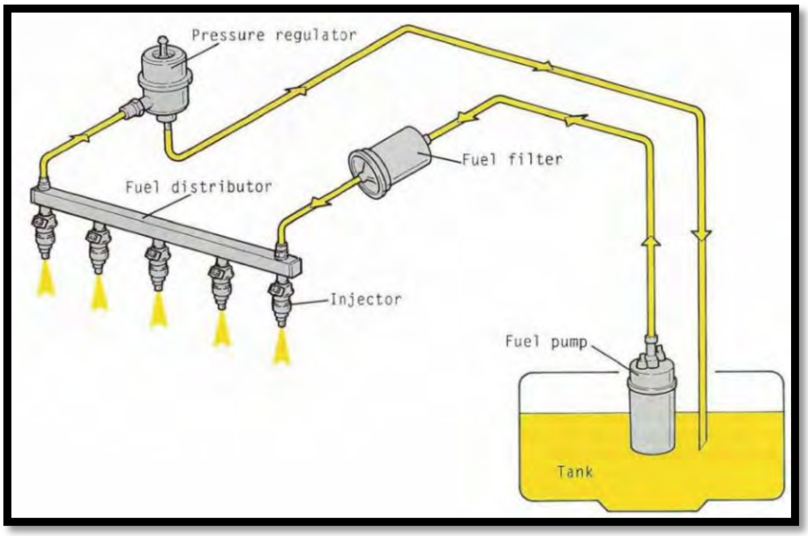


Figure 1.3: Fuel Rail System for In-line Five Engine
(http://forums.quattroworld.com/s4s6/msgs/21108.phtml).

The fuel rail is essentially a tubular fuel manifold designed to carry fuel to the injectors as well as hold them in place on the intake manifold. Along to the electric fuel pump, fuel filter, injection valves, and pressure regulator, the fuel rail forms part of the fuel supply system which always supplies the engine with the necessary amount of fuel under all operating conditions. The fuel pump generated the pressure applied to all injection valves by way of the fuel rail. Then, the unused fuel flows back to the fuel tank via a pressure regulator. In most cases, the pressure regulator (fuel rail – conventional design with pressure regulator) uses the intake manifold pressure as a reference. The use of this typical pressure and the flow through the fuel rail prevent the formation of any unwanted vapour bubbles in the fuel.

1.2 Problem Statement

There are many type of fuel rails depend on the car type respectively and some vehicles are equipped with a return less fuel supply. The problem with the Electronic Fuel Injection (EFI) engine design is to maintain sufficient amount of fuel supplied to the combustion chamber, at various engine speed. The engine system will experience pressure drops in the fuel rail when the injectors continuously open the injection valves in order to supply fuel at the higher engine speed. So, the amount of fuel injected at each injector is different when the higher engine speeds due to the weakness design standard fuel rail.

There also are lot of processes in car upgrade process and one of the processes is upgrading fuel rail system by doing change the standard fuel rail to the performance fuel rail. This process is to flow more fuel in the system fuel rail and to get better fuel flow in the system fuel rail. Upgrade the fuel rail also is to increase the pressure of fuel flow to the rail. According to the (Aalam & Saravanan, 2015), the fuel injection pressure is more important for the better atomization of injected fuel and allows it for complete combustion and to reduce the emissions. So, the purpose of this project is to compare the standard fuel rail and performance fuel rail either fuel rail mentioned give significant effect on pressure to the engine system of car. The fuel flow inside the both fuel rail (standard and performance) need further analysis.

1.3 Project Objective

The objectives of this project are stated below:

1. To design a Computer Aided Design (CAD) model for standard and performance fuel rail in the engine vehicle (petrol).
2. To study the fluid flow properties in the fuel rail system using Computational Fluid Dynamic (CFD) simulation.
3. To compare the performance of both fuel rails based on CFD results.

1.4 Scope of Project

The scope of this project is to study the fluid flow properties in the fuel rail system for the gasoline engine and study change in pressure loss in branched pipe in the fuel rail by using Computational Fluid Dynamic (CFD) simulation. Then, focus on the engine 4G13/15 that used Electronic Fuel Injection (EFI) system. This is because the design or dimension of the fuel rail is different based on the type of the car. The project work scope also to compare the fluid flow properties between the standard fuel rail and the performance fuel rail.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter will discuss mainly on the theory of the vehicle engine and the fuel rail in the Electronic Fuel Injection (EFI) engine. This chapter also will focus about the material of the fuel rail and the fluid flow properties in the fuel rail.

2.1 Engine Vehicle

There are a various number of different types of the automotive car engines in today's road and racing cars. The number is growing especially with rising innovations like Hybrids and electric motors start to become even more advanced. Most conventional automotive cars these days use what is called a four-stroke combustion cycle to convert gasoline into kinetic motion. This four-stroke approach is known as the Otto cycle, in honour of Nikolaus Otto who developed it in 1867.

2.1.1 Four Stroke Combustion Engine Cycle

According to Robert Bosch GmbH (2006), the majority of the internal combustion engines used as vehicle power plants are of the four stroke type. Modern vehicle engines are highly engineered power plants. These engines are designed to meet the performance and fuel efficiency demands of the public. These engines have been replaced by compact, lightweight and fuel efficient engines (Ken Pickerill, 2010). The four stroke combustion engine cycle also known as the Otto engine cycle. Figure 2.1 shows the four stroke combustion engine cycle.

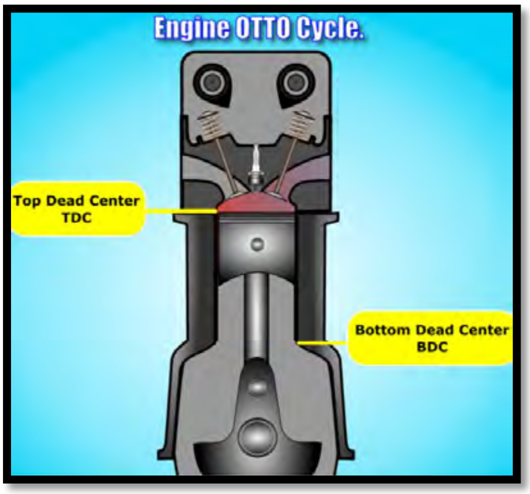
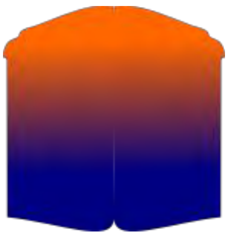


Figure 2.1: Four Stroke Combustion Engine Cycle.

Table 2.1: The complete working cycle of the four stroke engine (Robert Bosch, 2006).

Stroke:	Descriptions:
1. Intake Stroke 	Position: Top Dead Center (TDC) to Bottom Dead Center (BDC). Fresh air and fuel are taken into the chamber as the cylinder moves downwards making a vacuum. The inlet valves open to allow fresh air and fuel mixture from the induction. The combustion chamber reaches maximum volume at BDC.
2. Compression Stroke 	Position: BDC to TDC. The upstroke of the cylinder increasing pressure and density compress mixture of air and fuel. Then, denotation is ready, the inlet valves is closed allowing no air and fuel to escape. The combustion chamber volume is at minimum at TDC.

3. Combustion Stroke 	Position: TDC to BDC. Before the piston reaches TDC, the spark plug initiates the combustion of the air and fuel mixture at a given ignition point. Ignited the compressed air and fuel mixture by a spark plug and the explosive expansion of the gases, forces the cylinder downwards. Known as the power stroke, the crankshaft and flywheel is continued motion to creates power.
4. Exhaust Stroke 	Position: BDC to TDC. Starting the cycle again with the intake stroke, waste gases are forced out of the combustion chamber via the exhaust port. To allows the hot exhaust gases to escape, the outlet valves are now open.

The admission and outlet ports open and near permit air to be drawn into the chamber and fumes gasses to be removed amid the Intake and Exhaust stroke. We comprehend that the motor is adequately a gadget which sucks in air, packs it, touches off it and after that blows the let some circulation into again to making energy to the street wheels on the ignition stroke. As far as the execution increases conceivable, there are a tremendous large number of various procedures and advances we will cover in motor updates. As a matter of first importance we should get a comprehension of the diverse sorts of motor designs generally found in autos today. As Engines can arrive in a variety of various plans, including Straight, V Type, W Type, Boxer, Rotary Diesel, Hybrid, Electric and even Motorbike Car Engine. Most of the spark-ignition internal combustion engines operate with a stoichiometric air-gasoline ratio since it enables the catalyst to control emissions level (Chalet & Chesse, 2016).

A fuel infusion framework for a diesel motor has fuel pump driven by the motor for creating exceedingly pressurized fuel, a typical rail for putting away the pressurized fuel in that and infusion spouts for infusing the pressurized fuel put away in the normal rail into the motor. The infusion