

**NEW FUELLING STRATEGIES FOR PORT
INJECTION SPARK IGNITION ENGINES
TOWARDS IMPROVEMENT IN FUEL
CONSUMPTION AND EXHAUST EMISSION**



***BUREAU OF RESEARCH AND CONSULTANCY (BRC)
MARA UNIVERSITY OF TECHNOLOGY (UiTM)
40450 SHAH ALAM, SELANGOR
MALAYSIA***

**PROF. IR. DR. OW CHEE SHENG
DR. SAQAFF AHMED ALKAFF
DR. HAKIM A. ABBAS
PROF. MADYA DR. ABDUL RAHMAN OMAR**

MAY 2001

CONTENTS

Pengharagaan	i
Surat Penyerahan Laporan	ii
Kumpulan Penyelidik	iii
Abstract	iv
Chapter 1	THEORY AND PRINCIPLES OF THE INDUCTION SYSTEM OF SPARK IGNITION ENGINES
1.0	Introduction 1
1.1	Review 4
1.2	Fuelling System 12
1.2.1	Intake Manifold 12
1.2.2	Flow Through Intake Manifold and Inlet Valve 16
1.3	Electronic Fuel Injection In SI Engine 19
1.3.1	Single Point Fuel Injection (Central) 19
1.3.2	Port (Multi-Point) Fuel Injection 21
1.3.3	Direct Fuel Injection 21
1.4	Problems Arise With Carburetted Induction System 22
1.4.1	Transient Air Fuel Ratio Excursion 22
1.4.2	Fuel Transportation Process 23
1.5	Problems Associated With Port Fuel Injection 24
1.5.1	Mixture Strength Charged At Transient Running 24
1.5.2	Fuel Impingement 25
1.5.3	Fuel Deposition 26

1.6	Formation Of Spray And Its Characteristics	26
1.6.1	Mechanism Of Atomisation	26
1.	Dripping Region	27
2.	Smooth Jet	27
3.	Wavy Jet	28
4.	Partially Sprayed Jet	28
5.	Spray	29
1.6.2	Fuel Droplet Size	29
1.6.3	Shape And Spatial Distribution of Spray	30
1.6.4	Fuel Spray Penetration	32
1.6.5	Spray Evaporation Process	33
1.6.6	Effect Of Air Swirl On Spray	34

**Chapter 2 TWO-DIMENSIONAL TWO PHASE FLOW ANALYSIS
IN PORT INJECTED SPARK IGNITION ENGINES**

2.0	Introduction	35
2.1	Numerical Model For Mixture Preparation In The Induction System.	38
2.2	Modelling	39
2.2.1	Air-Flow Modelling	39
2.2.2	Fuel Spray Modelling	41
2.2.3	Single Droplet Evaporation	42
(a)	Turbulence Spray Jet	43
(b)	Velocity Variation Along The Spray Jet Axis	44
(c)	Variation of Temperature Along The Spray Jet Axis	45

ABSTRACT

Multi-point fuel injection (port injection) become popular with most passenger cars as it eliminates most fuel transportation problems through the induction system. It provides an excellent fuel distribution, fuel consumption and less exhaust emission. However, fuel deposition on the inlet port wall and on the valve stem and shoulder, in particular, during transient and low speed running forced many car manufacturers to investigate the direct fuel injection as an alternative fuelling strategy. In this method, the fuel is injected directly inside the cylinder. Therefore, problems related to fuel deposition and cyclic combustion variation will be eliminated completely. Mixture preparation of the air and fuel injection at the inlet port has considerable effect on the engine performance, fuel economy and emission characteristics. Therefore, enhancement of mixture formation before induction into the cylinder was the major concern of many investigators.

In this study investigation is carried for the direct fuel injection through a three-dimensional, two-phase computer model. Fluent software is used to model the air flow and the fuel spray behaviour. The engine geometry is based on a WIRA 1.6 engine. The study was conducted with different engine speeds, spray location, and fuel injection angles. Maximum air velocity is found to be at the exit of the inlet valve. There are two highly turbulent domains observed on both sides of the inlet valve and a stagnant domain below the valve face. The fuel injection angle has to be offset by a 30° relative to the valve stem axis, gives a significant spray distribution in the cylinder.

A Laser Imaging System is used to investigate the fuel spray developments in terms of the spray angle, spray penetration and the radial axis. The fuel spray characteristics in terms of the fuel droplet velocities in two dimensional and the fuel droplets diameter, was studied by the Particle Dynamic Analyzer (PDA) system.

Fuel spray generated from a fuel injector was used in the experimental investigation. The fuel injector is extended from the modification of the fuel system of the Wira 1.6L engine. It was found that the spray angle stays at 36.8° at all engine speed. This is because the fuel pressure at the nozzle inlet (at the main trail) is constant. Results reveals that te diameter is in a range of 65 um to 80 um. The droplet diameter show a tendency to increase with high engine speed.

A further study was carried out to explore the behavior of the flow inside the cylinder. Three different configurations concerning the shape and design of the piston head and combustion chamber were investigated. The direct injection inside the cylinder during the compression stroke (as the case in CI engines) is conducted at an engine speed of 2000 rpm. The piston is located at three different positions from the top dead. Results show that with a flat piston head, about 70 % of the fuel spray move towards the right side of the inlet valve leads to poor improper mixing of the air and the fuel. However the modified piston head controls effectively the distribution of the fuel within the cylinder, providing a swirl effect enhancing a better mixing of the fuel and air. As the piston moves up towards the top dead center the air velocity increase as noticed in all the cases studied. The modified combustion chamber with a normal piston show a slight better air fuel distribution. It was noticed that piston shape has more significant effect on the velocity distribution compared to the other cases. Moreover the velocity of the air fuel mixture is increasing towards the core of the cylinder providing optimum mixing of the charge around the spark plug.