

FLAME PROPAGATION IN SPARK IGNITION ENGINE COMBUSTION
PROCESS USING COMPUTATIONAL FLUID DYNAMICS (CFD)

HANIF BIN KASMANI

Report submitted in partial of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

MAY 2011

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS

JUDUL: **FLAME PROPAGATION IN SPARK IGNITION ENGINE
COMBUSTION PROCESS USING COMPUTATIONAL FLUID
DYNAMICS (CFD)**

SESI PENGAJIAN: 2010/2011

Saya **HANIF BIN KASMANI (880826-56-6405)**
(HURUF BESAR)

mengaku membenarkan tesis (Sarjana Muda/~~Sarjana~~ /~~Doktor Falsafah~~)* ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Pahang (UMP).
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan ()

SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh:

(TANDATANGAN PENULIS)

Alamat Tetap:

**1094 JLN SEMARAK 20,
TMN PANCHOR JAYA,
70400 SEREMBAN,
NEGERI SEMBILAN.**

Tarikh: **30 MAY 2011**

(TANDATANGAN PENYELIA)

Nama Penyelia:

MR. MOHD FADZIL RAHIM

Tarikh: **30 MAY 2011**

CATATAN:*
**

Potong yang tidak berkenaan.
Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh tesis ini perlu dikelaskan sebagai atau TERHAD.
Tesis dimaksudkan sebagai tesis bagi Ijazah doktor Falsafah dan Sarjana secara Penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).

TABLE OF CONTENTS

		Page
SUPERVISOR'S DECLARATION		ii
STUDENT'S DECLARATION		iii
DEDICATION		iv
ACKNOWLEDGEMENT		v
ABSTRACT		vi
ABSTRAK		vii
TABLE OF CONTENTS		viii
LIST OF TABLES		xi
LIST OF FIGURES		xii
LIST OF SYMBOLS		xiii
LIST OF ABBREVIATIONS		xiv
CHAPTER 1	INTRODUCTION	
1.1	Background of Study	1
1.2	Problem Statement	2
1.3	Objectives of the Project	2
1.4	Project Scopes	2
1.5	Flow Chart	3
1.6	Organization of Thesis	4
CHAPTER 2	LITERRATURE REVIEW	
2.1	Introduction	5
2.2	Combustion In Spark Ignition Engine	5
	2.2.1 Ignition and Flame Development	7
	2.2.2 Flame Propagation in SI Engine	7
	2.2.3 Flame Termination	8
2.3	Kernel Formation	9

2.4	Combustion Modeling Using CFD	11
2.5	CFD Approach in SI Simulation by Previous Reseachers	12
	2.5.1 Effect of Various Parameters into Flame radius	13
2.6	Summary	15

CHAPTER 3 METHODOLOGY

3.1	Introduction	16
3.2	Baseline Engine Specification	16
3.3	Engine Modeling	17
3.4	The Governing Equation for CFD	18
	3.4.1 Mass Conservation Equation	19
	3.4.2 Momentum conservation Equation	19
	3.4.3 Energy Conservation Equation	20
3.5	Mesh Generation	21
3.6	Solution Setup	23
	3.6.1 Initial Condition	23
	3.6.2 Boundary Condition Setup	23
	3.6.3 Input Data for Premix	24
3.7	Flame Radius Measurement Method	24
3.8	Technical Specification of Workstation	26
3.9	Validation Method	26
3.10	Limitations of Current Study	27

CHAPTER 4 RESULTS AND DISCUSSION

4.1	Introduction	28
4.2	Effect Of Iteration on Cylinder Pressure, Flame Propagation and Flame Radius	28
	4.2.1 Cylinder Pressure	29
	4.2.2 Visualization of Flame Propagation In Terms	32

	Of Progress Variable	
4.2.3	Flame Radius	33
4.3	Computational Time	36
4.4	Result Justification	36
	4.4.1 Model Geometry and Input Data Properties	36
	4.4.2 Processor Limitation	37
4.5	Summary	37
 CHAPTER 5 CONCLUSSION AND RECOMMENDATIONS		
5.1	Conclusion	38
5.2	Recommendations	39
 REFERENCES		40
 APPENDICES		
A	Simulation Data	41

LIST OF TABLES

Table No.	Title	Page
3.1	Mitsubishi Magma 4G15 1.5L engine specification	17
3.2	Initial condition at 2000 rpm	23
3.3	Boundary condition at 2000 rpm	24
3.4	Input data for premix-mixture properties	24
3.5	Technical specification of the computers used for simulation study	26
4.1	Comparison of peak pressure value	30
4.2	Peak pressure timing	30
4.3	Total computational time for both cases	36

LIST OF FIGURES

Table No.	Title	Page
1.1	Project flow chart	3
2.1	Cylinder pressure in the combustion chamber of a SI engine as a function of crank angle	6
2.2	Average flame speed	8
2.3	Initial flame kernel temperature	10
2.4	Initial flame kernel radius	11
2.5	Flame kernel radius with various engine speeds	13
2.6	Flame kernel radius with various intake manifold	14
2.7	Flame kernel radius with various air fuel mixture	15
3.1	Isometric view of engine modeling	18
3.2	Mesh generation	22
3.3	Points within combustion chamber	25
4.1	Comparison of measured and simulated cylinder Pressure for each case	29
4.2	Cylinder pressure in the combustion chamber of a SI engine as a function of crank angle	31
4.3	Visualization of flame propagation	32
4.4	Flame kernel with 1500 iterations	33
4.5	Assumption of flame propagation structure	34
4.6	Flame radius using different RPM	35

LIST OF SYMBOLS

e	Specific total energy
F_i	External body force in i direction
h	Sensible enthalpy
J_j	Diffusion flux of species j
K_{eff}	Effective conductivity
m_j	Mass fraction of species j
\dot{m}	The rate of mass of the object generated in the system
S_h	Additional volumetric heat sources
u_j	The j th Cartesian component of instantaneous velocity
μ	Fluid dynamic viscosity
ρ	Fluid density
p	Static pressure
$\rho \mathbf{g}_i$	Gravitational body force
τ_{ij}	Stressor pressure
δ_{ij}	Kronecker delta

LIST OF ABBREVIATION

3D	Three dimensional
ABDC	After bottom dead center
ATDC	After top dead center
BBDC	Before bottom dead center
BTDC	Before top dead center
CA	Crank angle
CFD	Computational Fluid Dynamic
CPU	Central processing unit
DNS	Direct numerical simulation
DSM	Differential stress models
EGR	Exhaust gas recirculation
EVM	Eddy viscosity models
K	Kelvin
LES	Large-eddy simulation
NLEVM	Non-linear eddy-viscosity models
Pa	Pascal
RANS	Reynolds-Average Navier Stokes
RPM	Revolution per minute
TDC	Top dead center
SI	Spark ignition