

**STUDY OF ENGINE PERFORMANCE WHEN USING ETHANOL
AS BLENDED FUEL FOR SPARK IGNITION ENGINE**

By

MOHD AZRA'IN ZAINUDIN

Dissertation report submitted in partial fulfillment
of the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

MAY 2009

**Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan**

ABSTRACT

The energy crisis created an incentive to study and evaluate alcohols as an alternative fuel in spark-ignition engines. Since energy resources are limited, energy conservation and its efficient use has become a major option. In those days of plentiful gasoline, concerns about dependence on crude oil did not exist. Interest in the ability of a vehicle to consume a fuel other than gasoline was encouraged by a desire for energy independence and convenience.

This project investigates the effect of using ethanol-gasoline blends on spark ignition engine performance. The engine parameters that have been focused in this study are the fuel consumption, engine's torque and power produced. There are many other engine parameters that can be studied to measure the engine performance but it is not convenient to investigate all of them due to the given duration for this project. The other engine parameters are such as the equivalence air-fuel ratio, volumetric efficiency, brake thermal efficiency, brake specific fuel consumption, and exhaust emissions (CO, CO₂ and HC). Some of these engine parameters will be discussed literally in conducting this project.

A single cylinder spark ignition engine will be used for conducting this study. Engine performance tests will be conducted for fuel consumption, engine torque and power produced, using unleaded gasoline-ethanol blends with different percentages of fuel at three-fourth throttle opening position and variable engine speed ranging from 1000 to 3500 rpm with increment of 500 rpm. From the literature studies, the results showed that blending gasoline with ethanol increases the fuel consumption, brake torque and brake power. After all, the optimum ethanol-blend percentage is to be determined from the 6 fuel blends used in the experiment, which are E-0, E-5, E-10, E-15, E-20 and E-85.

TABLE OF CONTENTS

CHAPTER 1:	INTRODUCTION	
1.1	Project Background . . . . .	. 1
1.2	Problem Statement . . . . .	. 1
1.3	Objectives and Scope of Study . . . . .	. 3
CHAPTER 2:	LITERATURE REVIEW	
2.1	Alcohol Fuel History . . . . .	. 5
2.2	Properties of Ethanol . . . . .	. 6
2.3	Anti Knock Index . . . . .	. 7
2.4	Oxygenates Additive . . . . .	. 8
2.5	Optimum Blending Percentage . . . . .	. 9
2.6	Availability and Usability of Ethanol as Fuel. . . . .	. 16
2.7	Fuel Efficiency . . . . .	. 17
CHAPTER 3:	METHODOLOGY	
3.1	Process Flow . . . . .	. 18
3.2	Project Planning . . . . .	. 20
3.3	Experimental Setup . . . . .	. 21
3.4	Experimental Procedures . . . . .	. 24
3.5	Fabrication of Mini Fuel Tank. . . . .	. 24
CHAPTER 4:	RESULT & DISCUSSION	
4.1	Experiment Result . . . . .	. 26
CHAPTER 5:	CONCLUSION & RECOMMENDATION	. 33
REFERENCES	. . . . .	. 34
APPENDICES		

APPENDIX

The fuel consumption is estimated by measuring the fuel consumed per unit time and the calculated values of the density for different fuel blends through Equation (1) and Equation (2) given below:

$$\dot{m}_f = \frac{3.6Q_f \rho_b}{t} \quad (1)$$

$$\rho_b = \sum \rho_i v_i \quad (2)$$

The volumetric efficiency is defined as follows:

$$\eta_v = \frac{\dot{m}_a R_a T_0}{30PV_s N} \quad (3)$$

where

$$\dot{m}_a = (\text{AFR})_{\text{act}} \dot{m}_f \quad (4)$$

The equivalence air–fuel ratio is defined as

$$\phi = \frac{(\text{AFR})_{\text{st.b}}}{(\text{AFR})_{\text{act}}} \quad (5)$$

where

$$(\text{AFR})_{\text{st.b}} = \sum (\text{AFR})_{\text{st.i}} v_i \quad (6)$$

The brake power is calculated by measuring the engine speed and the engine torque and is given by Equation (7). The specific fuel consumption is defined as the ratio of the fuel consumption to the brake power, as shown in Equation (8). The brake thermal efficiency is defined as the ratio of the brake power to the heat input for each blend, as shown in Equation (9) as below:

$$B_p = \frac{NT}{9549.29} \quad (7)$$

$$\text{BSFC} = \frac{\dot{m}_f}{B_p} \quad (8)$$

$$\eta_{\text{b.th}} = \frac{3600B_p}{\dot{m}_f (\text{LHV})_b} \quad (9)$$

where

$$(\text{LHV})_b = \sum \left(\frac{\rho_i v_i}{\rho_b} \right) (\text{LHV})_i \quad (10)$$

LIST OF FIGURES

Figure 1	Malaysia & World Crude Price from 1978 until 2009	2
Figure 2	The effect of ethanol addition on the fuel consumption rate by M. Al-Hassan	11
Figure 3	Cross section illustration of a basic carburetor for car	12
Figure 4	The effect of ethanol addition on the brake torque by M. Al-Hassan	14
Figure 5	The effect of ethanol addition on the brake power by M. Al-Hassan	15
Figure 6	Project workflow	19
Figure 7	Schematic diagram of the experimental setup	23
Figure 8	Fuel Consumption Rate vs. Engine Speed	27
Figure 9	Fuel Consumption Rate vs. Ethanol Percentage	27
Figure 10	Brake Torque vs. Engine Speed	29
Figure 11	Brake Torque vs. Ethanol Percentage	29
Figure 12	Brake Power vs. Engine Speed	30
Figure 13	Brake Power vs. Ethanol Percentage	30

LIST OF TABLES

Table 1	Properties of Ethanol and Iso-octane	6
Table 2	Project Gantt chart	20
Table 3	Engine specification	22
Table 4	Volume of Ethanol and Iso-octane	25
Table 5	Relationship between Ethanol Additions in Gasoline with Engine Parameter	26
Table 6	Experiment results	31

Weekly Malaysia Tapis Blend Spot Price FOB (Dollars per Barrel)

Year-Month	Week 1		Week 2		Week 3		Week 4		Week 5	
	End Date	Value	End Date	Value	End Date	Value	End Date	Value	End Date	Value
2000-Jan	01/07	25.43	01/14	25.43	01/21	24.36	01/28	24.36		
2000-Feb	02/04	24.36	02/11	24.36	02/18	27.41	02/25	27.41		
2000-Mar	03/03	27.41	03/10	27.41	03/17	27.41	03/24	30.12	03/31	30.12
2000-Apr	04/07	30.12	04/14	30.12	04/21	24.10	04/28	24.10		
2000-May	05/05	24.10	05/12	24.10	05/19	24.10	05/26	27.98		
2000-Jun	06/02	27.98	06/09	27.98	06/16	27.98	06/23	30.07	06/30	30.07
2000-Jul	07/07	30.07	07/14	30.07	07/21	30.07	07/28	31.17		
2000-Aug	08/04	31.17	08/11	31.17	08/18	31.17	08/25	31.62		
2000-Sep			09/08	31.62	09/15	31.62	09/22	31.62	09/29	34.67
2000-Oct	10/06	34.67	10/13	34.67	10/20	34.67	10/27	34.17		
2000-Nov	11/03	34.17	11/10	34.17	11/17	34.17	11/24	33.05		
2000-Dec	12/01	33.05	12/08	33.05	12/15	33.05	12/22	33.05	12/29	28.15
2001-Jan	01/05	28.15	01/12	28.15	01/19	28.15	01/26	28.15		
2001-Feb	02/02	28.15	02/09	26.18	02/16	26.18	02/23	26.18		
2001-Mar	03/02	28.70	03/09	28.70	03/16	28.70	03/23	28.70	03/30	28.70
2001-Apr	04/06	26.87	04/13	26.87	04/20	27.99	04/27	27.99		
2001-May	05/04	27.99	05/11	27.99	05/18	28.88	05/25	28.88		
2001-Jun	06/01	28.88	06/08	28.88	06/15	28.88	06/22	28.88	06/29	28.88
2001-Jul	07/06	29.13	07/13	29.13	07/20	26.60	07/27	26.60		
2001-Aug	08/03	26.60	08/10	26.60	08/17	26.60	08/24	25.85	08/31	25.85
2001-Sep	09/07	25.85	09/14	25.85	09/21	27.15	09/28	27.15		
2001-Oct	10/05	27.15	10/12	27.15	10/19	27.15	10/26	27.15		
2001-Nov	11/02	21.68	11/09	21.68	11/16	21.68	11/23	21.68	11/30	21.68
2001-Dec	12/07	21.68	12/14	21.68	12/21	21.68	12/28	21.68		
2002-Jan	01/04	20.31	01/11	20.79	01/18	20.05	01/25	19.67		
2002-Feb	02/01	19.98	02/08	19.92	02/15	20.04	02/22	20.34		
2002-Mar	03/01	20.34	03/08	22.11	03/15	23.38	03/22	23.95	03/29	24.64
2002-Apr	04/05	26.13	04/12	25.47	04/19	25.26	04/26	26.32		
2002-May	05/03	26.51	05/10	25.89	05/17	26.83	05/24	26.00	05/31	25.24
2002-Jun	06/07	24.97	06/14	24.19	06/21	25.02	06/28	25.48		
2002-Jul	07/05	25.48	07/12	25.90	07/19	26.89	07/26	26.59		
2002-Aug	08/02	26.36	08/09	26.32	08/16	27.23	08/23	28.03	08/30	28.02
2002-Sep	09/06	27.79	09/13	28.44	09/20	27.86	09/27	28.55		
2002-Oct	10/04	28.62	10/11	28.07	10/18	28.07	10/25	27.74		
2002-Nov	11/01	27.27	11/08	26.63	11/15	25.97	11/22	26.86	11/29	27.81
2002-Dec	12/06	27.99	12/13	28.56	12/20	30.65	12/27	31.94		

Weekly Malaysia Tapis Blend Spot Price FOB (Dollars per Barrel)

Year-Month	Week 1		Week 2		Week 3		Week 4		Week 5	
	End Date	Value	End Date	Value	End Date	Value	End Date	Value	End Date	Value
2003-Jan	01/03	32.54	01/10	31.84	01/17	31.43	01/24	32.45	01/31	31.89
2003-Feb	02/07	32.74	02/14	33.84	02/21	34.18	02/28	34.52		
2003-Mar	03/07	34.15	03/14	34.34	03/21	30.56	03/28	27.87		
2003-Apr	04/04	28.59	04/11	27.74	04/18	27.91	04/25	28.28		
2003-May	05/02	26.14	05/09	26.03	05/16	27.03	05/23	27.14	05/30	26.88
2003-Jun	06/06	26.96	06/13	27.58	06/20	26.80	06/27	27.08		
2003-Jul	07/04	27.67	07/11	28.05	07/18	29.08	07/25	28.67		
2003-Aug	08/01	28.67	08/08	30.28	08/15	30.66	08/22	30.17	08/29	31.47
2003-Sep	09/05	31.03	09/12	29.78	09/19	28.83	09/26	28.51		
2003-Oct	10/03	30.10	10/10	31.52	10/17	33.15	10/24	31.87	10/31	31.02
2003-Nov	11/07	30.08	11/14	30.83	11/21	30.99	11/28	30.98		
2003-Dec	12/05	30.22	12/12	30.96	12/19	31.63	12/26	32.03		
2004-Jan	01/02	31.90	01/09	32.71	01/16	33.85	01/23	33.94	01/30	34.16
2004-Feb	02/06	34.14	02/13	34.19	02/20	35.37	02/27	35.47		
2004-Mar	03/05	36.64	03/12	36.61	03/19	35.31	03/26	35.11		
2004-Apr	04/02	34.64	04/09	33.54	04/16	35.94	04/23	35.57	04/30	36.26
2004-May	05/07	37.95	05/14	39.24	05/21	40.75	05/28	40.27		
2004-Jun	06/04	40.07	06/11	37.85	06/18	37.82	06/25	38.48		
2004-Jul	07/02	37.42	07/09	40.21	07/16	40.60	07/23	41.35	07/30	42.85
2004-Aug	08/06	45.01	08/13	46.78	08/20	48.50	08/27	49.13		
2004-Sep	09/03	47.18	09/10	47.14	09/17	47.33	09/24	47.87		
2004-Oct	10/01	50.16	10/08	51.38	10/15	53.55	10/22	53.35	10/29	54.00
2004-Nov	11/05	50.75	11/12	47.49	11/19	44.32	11/26	46.30		
2004-Dec	12/03	44.53	12/10	37.66	12/17	37.84	12/24	40.61	12/31	38.41
2005-Jan	01/07	41.53	01/14	45.09	01/21	47.68	01/28	49.24		
2005-Feb	02/04	48.30	02/11	47.60	02/18	49.39	02/25	51.97		
2005-Mar	03/04	55.13	03/11	56.79	03/18	57.62	03/25	58.32		
2005-Apr	04/01	56.84	04/08	60.44	04/15	57.39	04/22	55.86	04/29	57.50
2005-May	05/06	54.09	05/13	52.45	05/20	49.44	05/27	48.94		
2005-Jun	06/03	50.88	06/10	53.93	06/17	55.00	06/24	57.37		
2005-Jul	07/01	58.57	07/08	60.00	07/15	60.42	07/22	58.63	07/29	59.33
2005-Aug	08/05	62.92	08/12	65.92	08/19	68.25	08/26	68.31		
2005-Sep	09/02	70.26	09/09	69.12	09/16	66.94	09/23	67.40	09/30	66.52
2005-Oct	10/07	65.46	10/14	62.42	10/21	61.40	10/28	59.95		
2005-Nov	11/04	60.14	11/11	60.00	11/18	57.64	11/25	57.61		
2005-Dec	12/02	57.47	12/09	60.50	12/16	63.73	12/23	62.36	12/30	61.97

Weekly Malaysia Tapis Blend Spot Price FOB (Dollars per Barrel)

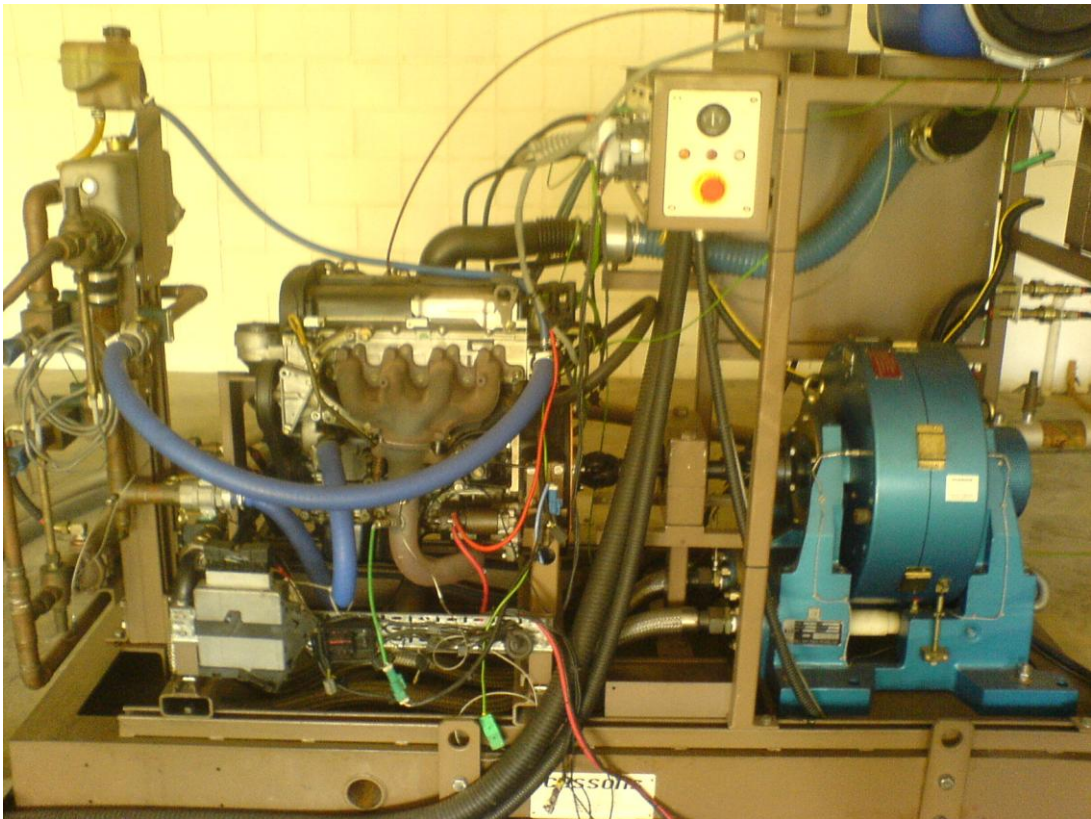
Year-Month	Week 1		Week 2		Week 3		Week 4		Week 5	
	End Date	Value	End Date	Value	End Date	Value	End Date	Value	End Date	Value
2006-Jan	01/06	65.56	01/13	68.23	01/20	69.06	01/27	71.41		
2006-Feb	02/03	71.61	02/10	68.71	02/17	65.41	02/24	64.98		
2006-Mar	03/03	65.98	03/10	66.72	03/17	66.11	03/24	65.96	03/31	67.55
2006-Apr	04/07	70.55	04/14	72.72	04/21	76.24	04/28	76.76		
2006-May	05/05	76.99	05/12	75.16	05/19	73.57	05/26	72.18		
2006-Jun	06/02	72.96	06/09	72.84	06/16	72.94	06/23	71.96	06/30	74.15
2006-Jul	07/07	76.67	07/14	77.63	07/21	79.75	07/28	78.16		
2006-Aug	08/04	79.37	08/11	81.38	08/18	78.58	08/25	77.54		
2006-Sep	09/01	76.26	09/08	73.62	09/15	70.24	09/22	67.38	09/29	65.35
2006-Oct	10/06	64.60	10/13	62.69	10/20	62.46	10/27	62.31		
2006-Nov	11/03	61.13	11/10	60.76	11/17	62.75	11/24	60.77		
2006-Dec	12/01	62.82	12/08	65.48	12/15	65.05	12/22	66.29	12/29	65.57
2007-Jan	01/05	63.47	01/12	58.90	01/19	56.79	01/26	58.26		
2007-Feb	02/02	60.81	02/09	63.85	02/16	63.54	02/23	62.87		
2007-Mar	03/02	66.37	03/09	67.14	03/16	66.98	03/23	66.22	03/30	70.11
2007-Apr	04/06	74.29	04/13	74.97	04/20	74.63	04/27	74.51		
2007-May	05/04	74.61	05/11	72.95	05/18	74.94	05/25	76.92		
2007-Jun	06/01	76.40	06/08	75.40	06/15	74.31	06/22	75.97	06/29	75.07
2007-Jul	07/06	76.26	07/13	79.43	07/20	80.57	07/27	80.76		
2007-Aug	08/03	80.90	08/10	78.25	08/17	75.09	08/24	74.41	08/31	75.76
2007-Sep	09/07	79.06	09/14	80.90	09/21	82.50	09/28	84.40		
2007-Oct	10/05	84.04	10/12	83.49	10/19	87.26	10/26	88.81		
2007-Nov	11/02	94.33	11/09	97.38	11/16	95.66	11/23	97.80	11/30	98.44
2007-Dec	12/07	94.10	12/14	94.59	12/21	96.63	12/28	97.60		
2008-Jan	01/04	100.53	01/11	100.92	01/18	96.65	01/25	93.69		
2008-Feb	02/01	97.13	02/08	95.89	02/15	98.50	02/22	102.41	02/29	104.21
2008-Mar	03/07	106.62	03/14	109.91	03/21	111.71	03/28	107.88		
2008-Apr	04/04	109.78	04/11	113.12	04/18	116.72	04/25	120.88		
2008-May	05/02	121.02	05/09	122.41	05/16	129.05	05/23	134.97	05/30	138.43
2008-Jun	06/06	133.00	06/13	140.90	06/20	142.13	06/27	142.19		
2008-Jul	07/04	148.60	07/11	148.64	07/18	151.97	07/25	139.87		
2008-Aug	08/01	135.03	08/08	129.89	08/15	123.38	08/22	121.18	08/29	123.48
2008-Sep	09/05	117.08	09/12	109.60	09/19	99.84	09/26	105.38		
2008-Oct	10/03	101.11	10/10	88.26	10/17	79.40	10/24	72.28	10/31	66.97
2008-Nov	11/07	63.96	11/14	59.65	11/21	53.87	11/28	50.75		
2008-Dec	12/05	48.87	12/12	45.29	12/19	47.76	12/26	42.99		
2009-Jan	01/02	39.83	01/09	48.23	01/16	47.43	01/23	46.01	01/30	48.31
2009-Feb	02/06	46.96	02/13	49.50	02/20	47.14	02/27	46.63		
2009-Mar	03/06	48.31	03/13	47.49	03/20	49.47	03/27	53.94		



Front View of Fuel Tank



SideView of Fuel Tank



Experimental Setup



Top View of Mini Fuel Tank



Side View of Mini Fuel Tank



3/4" PVC Joint