PERFORMANCE STUDY ON THE EFFECT OF DIFFERENT EXHAUST LENGTH FOR MOTORCYCLE ENGINE

MOHD RIZAN BIN ABDUL

A thesis submitted in partial
fulfilment of the requirement for the award of the
Degree of Master of Mechanical Engineering

Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

JULY 2015

For my beloved wife, sons, daughter and father

ACKNOWLEDGEMENT

The author would like to express his sincere appreciation to the supervisor Ing Dr. Mohd Faisal Hushim for the support given throughout the duration for this research.

The cooperation given by the staffs of the Department of Plant and Automotive Engineering, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia also highly appreciated.

Appreciation also goes to everyone involved directly or indirectly towards the completion of this thesis.

ABSTRACT

This research provides an overview of the performance on the effect of the different exhaust length for motorcycle engine. The research also covers the effect in terms of emissions. The engine used was a motorcycle 125cc 4-stroke gasoline engine. There are two method was used; experiment and simulation. For experiment, load applied to the engine with different lengths of exhaust pipe. The engine speed of this study was controlled in the range of 800 – 1000 rpm. The test engine has been attached to the dynamometer. The engine specifications and measured components of exhaust system were used for modelling and visualization using GT-Power simulation software. The different length of exhaust will be used for the simulation. Brake power, brake mean effective pressure (BMEP) and brake specific fuel consumption (BSFC) of the engine are discussed as the performance of the engine. Besides that carbon dioxide (CO_2), carbon monoxide and hydrocarbon (HC) was discussed as the emissions of the engine. The performance test was conducted to investigate the different lengths of exhaust manifold will affect the engine performance and exhaust-out emissions.

ABSTRAK

Kajian ini dihasilkan bagi mendapatkan kesan perbezaan panjang ekzos motosikal terhadap kecekapan enjin. Kajian ini juga mengkaji kesan pencemaran yang terhasil daripada ketiga-tiga jenis ekzos. Enjin yang digunakan ialah enjin motosikal empat lejang dengan kuasa 125cc. Terdapat dua kaedah yang digunakan iaitu secara eksperimen dan simulasi. Bagi eksperimen, beban berbeza dikenakan pada enjin dengan pemasangan saiz ekzos yang berbeza. Kelajuan enjin dikawal pada keadaan 800 – 1000 putaran per minit. Enjin disambungkan dengan *dynamometer*. Bagi proses simulasi, spesifikasi dan saiz komponen bagi sistem ekzos dimasukkan ke dalam perisian GT-Power. Tiga jenis ekzos dengan panjang berbeza digunakan di dalam proses simulasi. *Brake power (BP), brake mean effective pressure (BMEP)* dan *brake specific fuel consumption (BSFC)* yang terhasil daripada keputusan eksperimen dan simulasi pada enjin merupakan elemen yang dikaji bagi menilai tahap kecekapan enjin manakala karbon dioksida (CO_2), karbon monoksida and hidrokarbon (HC) bagi menilai tahap pencemarana daripada enjin. Ujian penilaian kecekapan ini menunjukkan perbezaan panjang ekzos memberikan kesan terhadap kecekapan enjin dan kadar pencemaran daripada enjin.

CONTENTS

TITLE			i
DECLARATION			ii
DEDICATION			iii
ACKNOWLEDGEMENT			iv
ABSTRACT			v
ABSTRAK			vi
CONTENTS			vii - ix
LIST OF TABLES			x
LIST OF FIGURES			xi - xiii
LIST OF SYMBOLS AND ABBREVIATIONS			xiv
LIST OF APPENDICES			xv
CHAPTER 1	**INTRODUCTION**		
	1.1	Background of study	1
	1.2	Problem statement	1-2
	1.3	Objectives	2
	1.4	Scopes of study	2
	1.5	Significant of study	2

CHAPTER 2 LITERATURE RIVIEW

2.0 Literature review	3
2.1 Stroke system	4
2.2 Exhaust stroke	4-5
2.3 Exhaust component	5
2.3.1 Exhaust manifolds or EKE	5-6
2.3.2 Catalytic converter	6
2.3.3. Mufflers	7
2.4 Exhaust system	7-8
2.5 Types of exhaust systems.	8
2.5.1 Single exit pipe	8-9
2.5.2 Dual rear exit	9
2.5.3 Opposite dual exhaust	9-10
2.5.4 Dual side exhaust	10
2.5.5 High performance exhaust systems	10
2.6 Performance exhaust analysis	11-14
2.7 Motorcycle engine	14-15
2.8 GT Power	15-17
2.9 Dynamometer	17-18
2.10 Pollution of gasoline engine	19-21

CHAPTER 3 METHODOLOGY

3.0 Methodology	22-23
3.1 Engine selection and exhaust measurement	24-25
3.2 Simulation setup	25-29
3.3 Experiment setup	30-34
3.4 Performance parameters	35-36

CHAPTER 4 RESULTS AND DISCUSSIONS

4.0 Results and discussions	37

	4.1 Engine performance by simulation investigation	37
	4.1.1 Brake Power	38
	4.1.2 Brake Mean Effective Pressure	39
	4.1.3 Brake Specific Fuel Consumption	40
	4.2 Exhaust emissions by simulation investigation	41
	4.2.1 Carbon Dioxide	41-42
	4.2.2 Carbon Monoxide	42-43
	4.2.3 Hydrocarbon	43-44
	4.3 Engine performance by experimental study	44
	4.3.1 Brake Power	44-45
	4.3.2 Brake Mean Effective Pressure	45-46
	4.3.3 Brake Specific Fuel Consumption	46-47
	4.4 Exhaust emissions by experimental study	47
	4.4.1 Carbon Dioxide	47-48
	4.4.2 Carbon Monoxide	49
	4.4.3 Hydrocarbon	50
CHAPTER 5	**CONCLUSION AND RECOMENDATIONS**	
	5.1 Conclusion	51-52
	5.2 Recommendations	52
	REFERENCES	53-56
	APPENDICES	57-59

LIST OF TABLES

3.1	The specification of 125cc 4-Stroke Motorcycle Gasoline engine.	24
3.2	The different length of exhaust	25
3.3	Different exhaust length setting in GT Power	27

LIST OF FIGURES

2.1	The example of exhaust manifold	6
2.2	Details of three way catalytic converter	6
2.3	The variation in heat carried away by exhaust gases in % with backpressure on engine for different load conditions using exhaust diffuser system	12
2.4	Result for varition of backpressure with engine speed	13
2.5	The different speed effect to the brake power	13
2.6	The different speed effect to brake specific fuel consumption (BSFC)	14
2.7	The basic schematic of engine model in GT Power	16
2.8	Systems model in the simulation modeling	17
2.9	Eddy Current Dynanometer	18
2.10	Schematic of a Speed Controlled test of engine	18
2.11	Relation between exhaust emissions and air/fuelratio for Gasoline Engines	20
2.12	Estimated annual air pollutant emission loads of HC, CO, PM, NO_2 and SO_2 from motor vehicles for 2009 and 2010	20
3.1	Flowchart for research process	23
3.2	Component development in GT Power	26
3.3	Complete component connection GT Power	26

3.4	The exhaust component parameter settings in GT Power	27
3.5	Engine speed setting in GT Power	28
3.6	Simulation process in GT Power	28
3.7	Simulation results using graphs in GT Power	29
3.8	Simulation results using the table in GT Power	29
3.9	The schematic drawings for the experiment testing	30
3.10	Dynamometer	31
3.11	Blower	31
3.12	Emission Analyser	32
3.13	Ono Sokki Mass Flow Meter	33
3.14	Standard length of exhaust	34
3.15	Short length of exhaust	34
3.16	Long length of exhaust	34
4.1	The result for Brake Power in simulation	38
4.2	The result Brake Mean Effective Pressure in simulation	39
4.3	The results of Brake Specific Fuel Consumption (BSFC) in simulation	40
4.4	The result for Carbon Dioxide in simulation	42
4.5	The results for Carbon Monoxide in simulation	
4.6	The results of the simulation for Hydrocarbons for three types of exhaust at different RPM	43
4.7	The result for Brake power in experiment	45
4.8	The result for Brake mean effective power in experiment	46
4.9	The result for Brake specific fuel consumption in experiment	47
4.10	The result for CO_2 in experiment	48

4.11	The result for CO in experiment	49
4.12	The result for Hydrocarbon in experiment	50

LIST OF SYMBOLS AND ABBREVIATIONS

$\dot{m}$	-	Fuel Flow Rate
n_c	-	Number Of Cylinder
V_d	-	Engine efficient volume
B	-	Size Of Bore
BMEP	-	Brake Mean Effective Pressure
BP	-	Brake Power
BSFC	-	Brake Specific Fuel Consumption
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
HC	-	Hydrocarbon
L	-	Length Of Stroke
N	-	Shaft Speed
O_2	-	Oxygen
PPM	-	Parts per million
RPM	-	Rotation per minute
T	-	Torque
UTHM	-	Universiti Tun Hussein Onn Malaysia

LIST OF APPENDICES

APPENDIX	TITLE	PAGES
A	Gannt Chart PS 1	58
B	Gannt Chart PS 2	59

CHAPTER 1

INTRODUCTION

1.1 Background of study

Exhaust system is a part of vehicle components. Nowadays, there are a few types of exhaust system that already developed to provide a specific user's demand. Mohiuddin, Rahamn, & Dzaidin, (2007) stated, the exhaust. According to Mohiuddin et al., (2007), a well-designed exhaust system is one of the cheapest ways of increasing engine efficiency, and therefore increasing engine power. Dynamometer is a device for measuring force, torque, or power. Han-chi, Hong-wu, & Yi-jie, (2012) reported, GT-Power is the industry standard engine simulation tool, used by all leading engine and vehicle makers and their supplier. Many assumptions and simplifications were made to the system in order to complete the model. Then, data will be recorded for analysis and discussion.

1.2 Problem statement

The exhaust system is one of the components in the vehicle. The exhaust stroke is a system that works to remove the product of combustion from the internal combustion engine. Combustion residues through the exhaust valves and out into the environment. When the exhaust pressure occurs during the reversal of the

exhaust process, it's disrupted the level of efficiency of the engine. Therefore the size (length) of the exhaust is very important in ensuring the level of efficiency of the engine can achieve the maximum level.

1.3 Objectives

The objectives of this study are:

i. To determine the optimum length of exhaust manifold for achieving good performance using GT-Power software.
ii. To investigate the effect of different lengths of exhaust manifold to the performances of motorcycle engine.

1.4 Scopes of study

To ensure that the studies will be done accordingly, all the scopes related to the study must be focused on. Here is a list of the scopes of study:

i. This research focused on motorcycle engine with capacity of 125cc.
ii. Simulation and analysis study were carried out using GT-Power software.
iii. The engine was operated at steady state condition with variable dynamometer loads for experimental investigation.

1.5 Significant of study

The study is to provide a new information on the impact of size (length) of exhaust manifold for motorcycle engine with the engine capacity of 125cc. Exhaust size is important to improve the efficiency of the engine of the vehicle.

CHAPTER 2

LITERATURE REVIEW

One of the important components in a vehicle's is exhaust system. The exhaust system is designed to collect the exhaust gases from the engine cylinders, direct them to the muffler, where exhaust noise is reduced, and discharge them into the atmosphere. In addition, exhaust gases may be used to drive a turbocharger for improved air induction for combustion. The exhaust may also be used to eject dirt and dust from the air cleaner into the atmosphere. The exhaust is a component on the burning waste before the engine is released into the atmosphere. Combustion wastes discharged after-stroke exhaust complete operating in the engine.

At present, there are many different types of exhaust have been produced. This is to meet the needs of the production exhaust design that can improve the efficiency of the engine as well as the manufacturing cost. Mohiuddin, Rahamn, & Dzaidin (2007) explained, a well designed exhaust system is one of the cheapest ways of increasing engine efficiency, and therefore increasing engine power. Patil, Navale, & Patil (2014) stated that energy efficient exhaust system development requires minimum fuel consumption and maximum utilization of exhaust energy for reduction of the exhaust emissions and also for effective waste energy recovery system such as in turbocharger, heat pipe etc. from combustion engine system. Mamat, Fouzi, Sulaiman, & Alias (2010) stated that optimum engine cylinder charging was achieved by breathing of an engine dependent on the design of intake and exhaust system.

2.1 Stroke System

According to Mat & Salim (2011) studied, combustion is one of the chemical reactions that always happen in around the world especially in automotive vehicle. Today, different types of internal combustion engines are the most common used on vehicles such as cars, buses, trucks and motorcycles is the engine four-stroke, whether gasoline engines or diesel engines. One-stroke refers to the movement of the piston from the top to the fixed point fixed point or vice versa then the four-stroke engine gets its name from four-stroke each perform a function special entries, compression, procurement authority and the removal of the exhaust gas.

4-stroke engine, also known as Otto cycle engine start patented by Eric b. Davidson and Felice Matteucci in 1854, followed by the first prototype in 1860. They also conceptualized by French engineer, Alphonse Beau de Rochas in 1862 and independently, by German engineer Nicolaus Otto in 1876. Power cycle consists of compression, the addition of heat, expansion and removal of heat, represented by characters four strokes, or the movement of the piston in the cylinder fluctuation. Following are the order of stroke system for four-stroke gasoline and diesel engine :

i. Intake stroke
ii. Compression stroke
iii. Combustion/power stroke
iv. Exhaust stroke

2.2 Exhaust stroke

Exhaust system is designed to evacuate gases from the combustion chamber quickly and efficiently. V S N Ch, M Pradeep, & B Shyam (2014) explained exhaust gases are not produced in a smooth stream; exhaust gases originate in pulses. The exhaust process consists of two steps. Pilkrabek (2003) stated, the first step is blowdown and the second step is exhaust stroke. When the exhaust valve opens near the end of the expansion stroke, the high temperature gases are suddenly subjected to a pressure

decrease as the resulting blowdown occurs. This process call blowdown process. A large percentage of the gases leaves the combustion chamber driven by the pressure different across the open exhaust valve. The pressure finally equalized after across the exhaust valve. Pilkrabek (2003) also explained, the cylinder is still filled with exhaust gases at the exhaust manifold pressure of about one atmosphere. The piston travel from the bottom dead center until top dead center and the pushed out the exhaust gases. This process call exhaust stroke.

2.3 Exhaust component

The main Components in engine exhaust system are as following sub-sections.

2.3.1 Exhaust manifolds or EKE

From the Application and Installation Guide, engine exhaust manifolds collect exhaust gases from each cylinder and channel them into an exhaust outlet. The manifold is designed to give minimum backpressure and turbulence. Reddy & Reddy (2012) stated, after completion of fuel combustion process in engine, high pressure gases are released. These gases are enters into the Exhaust manifold through pipes. V S N Ch et al. (2014) clarify, an exhaust manifold is a series of connected pipes that bolt directly onto the engine head. Figure 2.1 show the example of exhaust manifold.

Figure 2.1: The example of exhaust manifold (Reddy & Reddy, 2012)

2.3.2 Catalytic converter

Reddy & Reddy (2012) explained, it is a device used for convert harmful gases like carbon monoxide (CO), nitrogen oxides (NO) into harmless gases like CO_2 and N_2 etc., In present days "three-way" (oxidation-reduction) catalytic converters are widely used on diesel engines to reduce hydrocarbon and carbon monoxide emissions. Figures 2.2 shows details of three way catalytic converter.

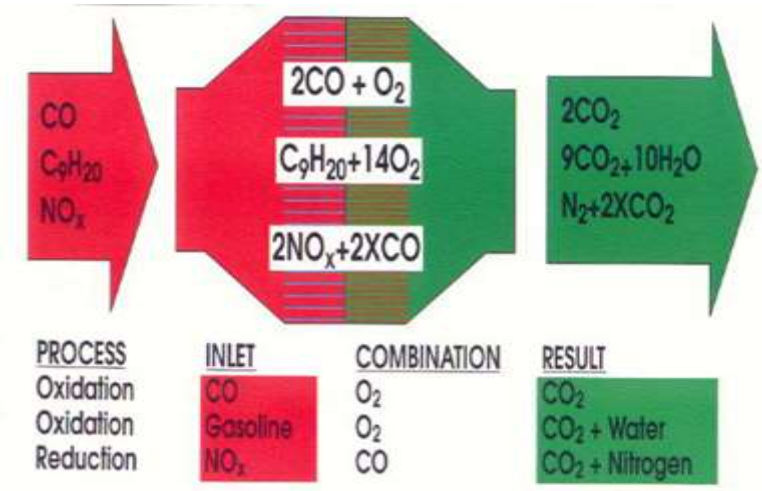

Figure 2.2: Details of three way catalytic converter (Reddy & Reddy, 2012)

2.3.3 Mufflers

Reddy & Reddy (2012) defined, the muffler is defined as a device for reducing the amount of noise emitted by a machine. To reduce the exhaust noise, the engine exhaust is connected via exhaust pipe to silencer called muffler. The various types of mufflers used in automobiles are:

i. Baffle type
ii. Resonance type
iii. Wave cancellation type
iv. Combined resonance and absorber type
v. Absorber type mufflers.

Purpose of Muffler:

i. to reduce the amount of noise emitted by a vehicle.
ii. use neat technology to cancel out the noise.
iii. installed along the exhaust pipe as a part of the exhaust system of an I.C. engine to reduce its exhaust noise.
iv. To reduces exhaust noise by dampening the pulsations in the exhaust gases and allowing them to expand slowly.
v. usually made of sheet steel, coated with aluminum to reduce corrosion. Some are made of stainless steel.

2.4 Exhaust System

A car exhaust system consists of several parts assembled together to move noxious gases from the inside of the car and release it outside. Aside from this, the exhaust system serves other purposes. First, it dampens the sound made by the engine and second, it transforms unspent fuel into spent fuel. Exhaust systems all work in the

same manner, although there are many different variations and configurations. All types of vehicles, not just cars, have exhaust systems, and may vary slightly. According to Ahmet Selamet (1999) explained, a new automobile exhaust system reduces pollution and boosts engine power at the same time. The single design takes the place of multiple parts in the standard auto exhaust assembly, including the manifold, muffler and catalytic converter. Rynne (1994) clarify; the effect of vehicle exhausts system components on performance and noise in firing spark-ignition engine. Abraham JA (2010) stated, noise is an unwanted sound at amplitude which causes annoyance or interferes with communication. Noise has been known as menace that can cause a several serious health effect. According to Hultgren, (2011), the noise maybe generated by aerodynamic effects or due to forces that result from combustion process or may result from mechanical excitation of rotating or reciprocating engine components.

2.5 Types of Exhaust Systems

Nowadays, many type of exhaust produce to make various of exhaust. Different design of exhaust also want to increase performance of engine and reduce emission. Types of exhaust system below:

2.5.1 Single Exit Pipe

Based on Types of exhaust systems, (2001) explained, Single Exit Pipe also well-known as single side exhaust, is a standard type of exhaust system, used by auto manufacturers in vehicle production. As derived from the name, the system has one exhaust pipe to release the exhaust gases away from the engine. The tail pipe is commonly located behind the rear wheel on the passenger's side of a car, truck. Single side exhaust is a cost effective system that comes factory-installed on most cars and trucks. The-best-performance-exhaust-systems, (2011) stated, a single side exit exhaust has only one exhaust pipe located on one side of the car. The pipe for

this type is often located at the back of the back wheel on the passenger side. It is one of the less expensive types of exhaust, but it generally provides lesser horsepower.

2.5.2 Dual Rear Exit

Dual Side Exhaust system has nearly the same design and location, as the single pipe exhaust system. The one and major difference is in the quantity of exit pipes. This type of exhaust systems is constructed with two pipes. Both pipes are located near each other on the same side of the vehicle behind the rear passenger's side. Depending on the diameter of the exit pipes the sound of system's performance may vary. When the diameter is smaller, the deeper sound will be produced. A dual side exit exhaust has 2 pipes located on the same part of the vehicle. If you want a louder sound than the single side exit, this is your best bet. It also provides less restriction on your car's exhaust system. The canister exhaust for this type is often larger than the actual size of the cylinder. With this type of exhaust, the pipes are located beneath the bumper and are not bent around the rear wheels. It is often said that a dual rear exit exhaust looks better than the other types.

2.5.3 Opposite Dual Exhaust

Dual Rear Exit Exhaust is a popular exhaust system among those vehicles owners, who want their car, truck or SUV look sportier and sound more aggressive. Like dual side exhausts system, this type has the same quantity of pipes. The difference is in pipes location. Dual rear exit exhaust system comes with two pipes that are fixed on the opposite sides under the rear bumper. Contrary to some other types of exhaust systems, the pipes are not bent around the vehicle's wheels. Comparing with the single exit pipe system, this type of exhaust is more efficient. Moreover, a driver will experience deeper sound, giving an impression of high-power engine under the hood. An opposite side dual exhaust is slightly different from the dual rear exit in

terms of the location of the pipes. It provides the same sound and performance. For this exhaust, the two pipes wrap around on each side of the rear wheels. This type of exhaust is suitable for trucks or cars that often tow other vehicles. The downpipe and the exhaust pipe are generally made from stainless steel.

2.5.4 Dual Side Exhaust

Opposite Dual Exhaust is also called extreme dual exit exhaust. It is a variation of the dual rear exhaust system. Opposite dual exhaust is mainly used on vehicles that tow heavy cargo. In order to improve the filtering process, the length of the pipes is increased and they are bent around the wheels. This construction makes it possible to decrease the residue that is released on the object that is towed. Besides the length and location of the pipes there is no major difference towards the other exhaust systems.

2.5.5 High Performance Exhaust Systems

High Performance Exhaust is usually offered as an aftermarket add-on. The system is custom-designed to fit the exact make and model. High performance exhausts comparing to standard exhaust systems are more expensive though they have more advantages. They can improve the performance of the engine, as well as increase its efficiency. Moreover, this type of exhaust systems is a stylish option which offers radically different sounds. Installation of the high performance exhaust is one of the ways to customize the vehicle.

REFERENCES

Abraham JA. (2010). *Fundamentals of Materials Science and Engineering: An Integrated Fundamentals of Materials Science and Engineering* (3rd edition). Inc., 111 River Street, Hoboken, New Jersey.: John Wiley & Sons, Inc.

Ahmet Selamet. (1999). Exhaust System Reduces Auto Emissions, Boosts Engine Performance, ScienceDaily, Ohio State University.

Bagri, S., & Chaube, D. A. (2013). Effect of SC5D Additive on the Performance and Emission \nCharacteristics of CI Engine. *International Journal of Modern Engineering Research (IJMER)*, *3*(5), 2831–2835.

Bisen, H. B., & Suple, Y. R. (2013). Experimental Investigations of Exhaust Emissions of four Stroke SI Engine by using direct injection of LPG and its analysis. *International Journal of Modern Engineering Research (IJMER)*, *3*(ISSN: 2249-6645), 1600–1605.

B.P.PUNDIR. (2010). *IC Engines : Combustion and Emissions*. Oxford, U.K.: Department of Mechanical Engineering, Indian Institute of Technology Kanpur, India.

Department of Environment Malaysia. (2011). A Guide to Air Pollution Index, Kuala Lumpur.

Department of Transport Malaysia. (2011). Annual Pollution Report.

Donaldson, D. (2008). Medium- and Heavy-Duty Exhaust Products Guide. *EDonaldson Company, Inc.*, 9.

Faisal, M., Hushim, B., Jais, A., Alimin, B., Faizal, M., Mohideen, B., Mohd, B. (2010). a Review and Investigation Framework on Port-Fuel Injection for Small 4-Stroke Single Cylinder Engine. In *Postgraduate Seminar 2010*, Universiti Tun Hussein Onn Malaysia.

Faiz, A., Weaver, C. S., & Walsh, M. P. (1996). Air pollution from motor vehicles. *Annals of the New York Academy of Sciences*, *136*(12), 277–301.

Gitano, H. (2007). *Dynamometer Basics*, (n.d), University of Science Malaysia, Malaysia.

Han-chi, H., Hong-wu, H., & Yi-jie, B. (2012). Optimization of Intake and Exhaust System for FSAE Car Based on Orthogonal Array Testing. *International Journal of Engineering and Technology*, *2*(3), 392–396.

Heywood, J. B. (1988). *Internal Combustion Engine Fundamental, Director*, Sloon Automotive laboratory, Massachusetts Institute of Technology.

Hultgren, L. (2011). *Full-Scale Turbofan-Engine Turbine Transfer Function Determination Using Three Internal Sensors*. Portland: NASA Glenn Research Center.

Ioannis Gravalos, Dimitrios Moshou, Theodoros Gialamas, Panagiotis Xyradakis, D. K. and Z. T. (2011). Performance and Emission Characteristics of Spark Ignition Engine Fuelled with Ethanol and Methanol Gasoline Blended Fuels. (M. Manzanera, Ed.).

Mamat, M. H., Fouzi, M. S. M., Sulaiman, M. A., & Alias, M. A. (2010). *Prediction Of 4 Stroke Engine Performances At Varying Load* . Universiti Malaysia Pahang: Undergraduate Project Report.

Martyr, A. J., & Plint, M. A. (2007). *Engine Testing Theory and Practice*. Published by Elsevier Ltd, Jordan Hill, Oxford OX2 8DP.

Mat, S., & Salim, M. A. (2011). Journal of Electrical and Mechanical Engineering The Performance Improvement for Plenum inside Intake Manifold in Automotive Vehicles Engine, *2*(1), 13–20.

Mohd Faisal, H., Ahmad Jais, A., Hazlina, S., & Mohd Taufiq, M. (2013). PFI System for Retrofitting Small 4-Stroke Gasoline Engines. *International Journal of Environmental Science and Development*, *4*(4), 375–378.

Mohiuddin, A. K. M., Rahamn, A., & Dzaidin, M. (2007). Optimal Design Of Automobile Exhaust System Using Gt- Power. *International Journal of Mechanical and Materials Engineering (IJMME)*, *2*(1), 40–47.

Mohsin, R., & Majid, Z. A. (2013). Comparative study on exhaust emission and engine performance of single cylinder spark-ignited engine operated on gasoline and natural gas. *International Journal of Engineering and Technology*, *1*, 35–43.

Obodeh, O., & Ogbor, a. D. (2009). Improving the performance of two-stroke motorcycle with tuned adjustable exhaust pipe. *Research Journal of Applied Sciences, Engineering and Technology*, *1*(2), 59–65.

Patil, A. A., Navale, L. G., & Patil, V. S. (2014). Design , Analysis of Flow Characteristics of Exhaust System and Effect of Back Pressure on Engine Performance. *International Journal of Engineering , Business and Enterprise Applications (IJEBEA)*, 99–103.

Pilkrabek, W. W. (2003). *Engineering Fundamentals Of The Internal Combustion Engine*. Second edition, Published by , University of Wisconsin.

Reddy, M. R., & Reddy, K. M. (2012). Design And Optimization Of Exhaust Muffler In Automobiles. *International Journal Of Engineering Research and Applications (IJERA)*, *2*(5), 395–398.

Rynne, E. F. (1994). *EngineeringAcoustics:Acoustic Measurements and Instrumentation*. Code 711, 496640 Gate Road, Room 19,San Diego, California 92152-6242,: , ChairNaval Command, Control and Ocean Surveillance Center, RDTE Division.

The-best-performance-exhaust-systems. (2011). http://www.carsdirect.com. Retrieved from 16 Mac 2015

Types of exhaust systems. (2001). http://www.helixsf.com/types/. Retrieved from 16 Mac 2015

V S N Ch, D., M Pradeep, V., & B Shyam, S. (2014). Thermal Analysis on 4 – 1 Tubular Type IC-Engine Exhaust Manifold through Anysis, *International Journal of Applied Engineering Research*, *9*(6), 615–622.