Enhancement of Engine Performance by Studying the Effect of Cam Profiles Design on Modenas Motorcycle using 1-D Simulation Analysis

by

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LIST OF ABBREVIATIONS

A_d	Displacement of volume
A_p	Area of piston wall
a	Crank offset
B	Bore
BDC	Bottom dead center
bMEP	Brake mean effective pressure
D	Displacement
F	Force
IC	Internal Combustion
k	Ratio of Specific heat
MEP	Mean effective pressure
m	unit mass of gas
N	Engine speed
N_c	Number of engine cylinder
n_R	Amount of crank revolution
n	Number of revolution per cycle
OPD	Output per displacement
P	Pressure
R	Ratio of connecting rod length to crank offset
R_o	Gas constant
r_c	Compression ratio
S	Stroke
SI	Spark ignition
SP	Specific power
SV	Specific volume
SW	Specific weight
T	Torque
TDC	Top dead center
U_p	Average piston speed
Vc	Clearance volume
W	Work
W_b	Brake work of one revolution
x	Distance of piston traveled

η_m	Mechanical efficiency
η_v	Volumetric efficiency
α	Crank angle
α_o	Start of the combustion process
Δ_a	Combustion duration
$\dot{m}$	Mass flow rate
ρ_a	Air density

Peningkatan Prestasi Enjin Motosikal Modenas Melalui Variasi Aci Sesondol Menggunakan Analisis Parameter

ABSTRAK

Dalam dunia permotoran, meningkatkan prestasi sesuatu enjin merupakan satu tugas utama bagi menambah baik keseluruhan prestasi bagi sesuatu enjin dan kenderaan. Peningkatan dan setiap penambahbaikan, mampu menyelesaikan setiap isu atau permasalahan yang timbul dalam edisi enjin yang terdahulu di samping meningkatkan kuasa dan daya kilasan sesuatu enjin. Terdapat banyak komponen yang boleh diambil kira bagi mencapai objektif tersebut seperti laluan kemasukan campuran udara dan minyak ke dalam enjin, bahagian ekzos dan juga aci sesondol. Oleh hal yang demikian, penyelidikan ini dicadangkan bagi meningkatkan prestasi keseluruhan enjin dengan menambah baik dari segi aspek aci sesondol untuk model MODENAS CT115S. Prestasi semasa motosikal MODENAS CT115S masih tidak mencapai piawaian pesaing-pesaing lain. Dengan menjalankan analisis geometri, lima reka bentuk baru telah dicadangkan dengan berlainan nilai jejari tapak aci sesondol dan juga bentuk profil aci sesendol tersebut. Dengan bantuan perisian teknologi simulasi AVL, data bagi prestasi semasa enjin telah dikenalpasti dan dibandingkan dengan data sebenar bagi memastikan simulasi 1-D yang dicadangkan adalah tepat. Apabila data simulasi tersebut berada dalam julat yang dibenarkan, reka bentuk-reka bentuk baru yang dicadangkan akan diuji bagi mendapatkan keputusan injap yang terbuka dan juga sifat aci sesondol tersebut. Daripada graf injap yang dibuka, bentuk aci sesendol yang baru akan mengalami simulasi bagi mendapatkan graf prestasi enjin. Berdasarkan kelima-lima reka bentuk, reka bentuk D yang dengan jejari tapak sebanyak 14.5 mm menghasilkan nilai bukaan injap yang kedua tertinggi namun menghasilkan nilai kuasa dan daya kilasan yang tertinggi. Oleh hal yang demikian, aci sesendol D adalah rekaan bentuk yang terbaik antara lima reka bentuk, dengan nilai yang terhasil adalah 8.89 N-m pada kelajuan 7000 RPM dan 7.25 kW kuasa pada 9000 RPM.

Enhancement of Engine Performance by Studying the Effect of Cam Profiles Design on Modenas Motorcycle using 1-D Simulation Analysis

ABSTRACT

In the automotive industry, enhancing and improving the engine performance is one of the major work for improving the overall performance of the engine and vehicle. Every iteration of the engine, will overcome the issues raised in the previous batch of the engine as well as improve the brake power and brake torque of the engine. There are a lot of aspects need to be considered in achieving this objective such as intake part, exhaust part, camshaft and cam profiles. Thus, this research is proposed to enhance overall engine performance by improving current cam profiles for MODENAS CT115S model. The current performance for MODENAS CT115S below than other competitors. By using geometrical analysis, five new designs were proposed with different cam parameters including circle base radius and cam profile. By the aid of AVL Advance Simulation Technology software, the benchmarking of real and baseline data were conducted in order to verify 1-D simulation planning for the simulation purposes. Once the result of the simulation was in the acceptable range, the new designs can be investigated to find the valve lift and cam characteristics. From the valve lift curve, new cam designs were undergoing simulation to determine the engine performance curve. Among all new cam designs, cam design D, with 14.5 mm plotted the second highest maximum valve lift but generated the highest brake power and brake torque curve. Therefore, this cam design was the optimum design among all five designs with the best performance curve, with 8.89 N-m at 7000 RPM of brake torque and produced 7.25 kW of brake power at 9000 RPM.

CHAPTER 1

INTRODUCTION

This chapter briefly discusses and describes the research background, problem statement, objectives and the scope of the research. All of the listed sections are discussed in detail and as an introduction to the whole research which includes the interest and area of research.

1.1 Research Background

Syarikat Motosikal dan Enjin Nasional Sdn Bhd or well known as MODENAS is the national automotive company that produces moped and scooter type motorcycles normally below 200cc, two stroke and four stroke motorcycle engines. Basically, internal combustion applications, either for two strokes or four stroke engines, are powered by both compression and spark setting ignition. There are four vital processes in four-stroke internal combustion engine which are intake, compression, exhaust and power stroke. During the intake stroke, the mixture of air and fuel is driven into the internal combustion chamber. Meanwhile, in the compression stroke, the pushed air-fuel mixture is compressed for ignition purpose. Then, the compressed air-fuel mixture is ignited by sparks from spark plug before the disposal gas is pushed from the combustion chamber in the exhaust stroke.

The internal combustion engine is the engine where normally an oxidizer like air will take place in the combustion of the process. The combustion process happens in the combustion chamber as a fundamental role of the operational fluid flow path. Throughout the combustion process, the extension of pressure gasses and critical heat temperature produces the combustion force that applies a direct force for certain engine components. The corresponding force moves the component for a certain distance and converts chemical energy from fuel or gasoline to mechanical energy.

Recently, many active research activities have been conducted in improvising engine performance. MODENAS, as one of motoring commercial enterprises, is also involved in research activity since there is tight competitiveness among motorcycle industry in Malaysia. To enhance the performance of a motorcycle engine, a lot of aspects can be improved and researched such as exhaust system, intake system, chassis modification, the suspension and fuel system. Besides, the camshaft can also contribute in increasing the engine performance. Basically, the camshaft is used to control the movement of the exhaust and intake valves in adjusting the volume of air-fuel mixture entering the combustion chamber and disposal gasses exiting through the exhaust valve after combustion are complete.

Figure 1.1 shows the performance for almost all the available motorcycles in Malaysia with 110 CC until 115 CC. The best performance is Yamaha Lagenda 115ZR, in which the brake torque value is 9.9 Nm at 6500 RPM and the brake power is 7.4 kW at 7750 RPM. The next one is Suzuki Smash. Its peak output brake power is 6.4 kW, while the output brake torque is 9 Nm. The brake torque value for Suzuki Smash is higher than MODENAS CT115S but the value of brake power is below CT115S value. Then, it is followed by Honda Wave Dash 110cc with 8.15 Nm at 5500 RPM and 6.1 kW at 7500 RPM. The fourth motorcycle with the highest value of brake torque and brake power is MODENAS CT115S, with 6.6 kW output brake power at 9000 RPM and 8.1 Nm at 5000 RPM. The last one with lowest output performance is SYM Sport Bonus. Its brake torque value is 7.94 Nm at 4000 RPM and the brake power is 5.3 kW at 7500 RPM of engine speed.

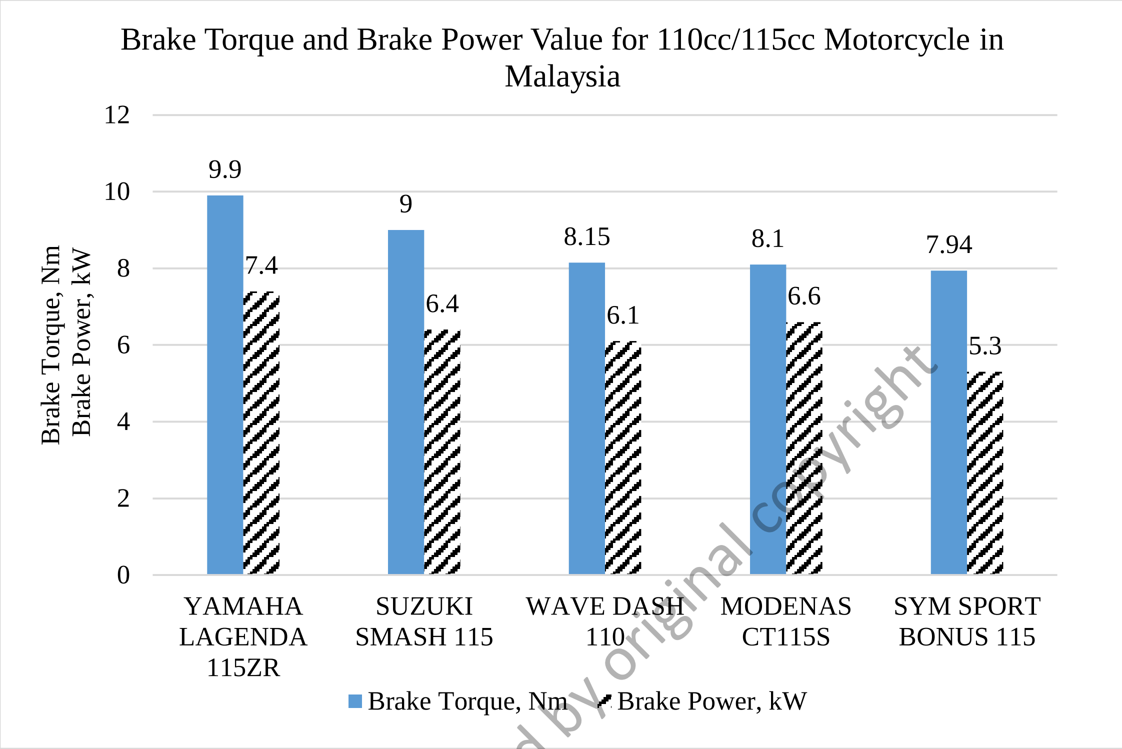

Figure 1.1: The performance of available motorcycle in Malaysia, retrieved on September 2015 (http://www.yamaha-motor.com/,http://suzuki.com.my/, http://www.sym.net.my/sym/, http://www.boonsiewhonda.com.my/).

It can be observed that MODENAS overall position in terms of brake power and brake torque ranking is in the fourth position. Therefore, the task is to increase the engine performance of MODENAS engine to a certain level that matches or exceeds the competition in the same class.

Cam lobe profile controls the valve timing by controlling the time taken to open and close the engine intake and exhaust valve; thus, it affects the engine performance. By applying the fitting outline of the angle between intake and exhaust with cam profile, it can help to improve the valve timing and consequently increase the engine performance.

1.2 Problem Statement

MODENAS is producing a motorcycle with a small capacity engine. There are numerous of motorcycle that been produced since being founded in 1995. For the example is Kriss, GT130, MR1, MR2, Krisstar and CT series. The latest CT series that been launched is MODENAS CT115S. Among all the available motorcycle in Malaysia with the same or near the category of engine size, the performance of MODENAS CT115S ranked in the fourth position by referring to Figure 1.1. The value of maximum brake torque for CT115S is 8.1 Nm and 6.6 kW for maximum brake power output. The best motorcycle in the same category is Yamaha Lagenda 115ZR.

There is plenty reason that contributes to the overall performance of MODENAS CT115S, which is including the engine parts of MODENAS CT115S such as intake manifold and port, exhaust port and muffler, camshaft and airbox. Apart from that, the camshaft is another element that impacts the engine performance. Camshaft controls the opening of the intake and exhaust valve in order to allow the mixture of air fuel mixture to enter the combustion chamber for combustion stroke.

One of the technique to boost the performance of an engine is inducing more air fuel mixture into the combustion chamber. Theoretically, a greater amount of air fuel mixture generates more combustion rate and producing a higher value of maximum brake torque and brake power (Abdullah, Shahruddin, Mamat, Mamat, & Zulkifli, 2014). Among the vital parameter in the camshaft is cam lobe profile. The various cam lobe profile producing the variety of valve lift and overlapping region. Valve lift referring to the distance of valve lifted once the cam rotates (František, Oto, & Danka). In the meantime, overlapping a region determine the angle for both valves open simultaneously (Dhavale, 2012). Best value for both consideration needed in the cam lobe profile in order to boost the overall engine performance for both maximum values of brake torque and brake power.

1.3 Objectives

The target of this research is to enhance MODENAS engine performance in terms of brake power and brake torque. This aim can be fulfilled by achieving the following objectives:

I. To study and analyze camshaft parameters that affect engine performance curve by using parametric analysis.

II. To obtain a new cam profile design, with the best valve lift graph that increases the engine performance.

1.4 Scopes

The scopes for this research are:

I. Identify the geometric parameter that can improve valve lift for MODENAS CT115S.

II. Benchmark the current cam profiles and engine with several designs of cam lobe profiles.

III. Verify proposed designs and simulations of high engine performance between baseline data by using 1-D simulation software.

IV. Analyze new proposed cam lobe profiles by using the AVL Excite Timing Drive and verify its effect to overall engine performance curve in AVL Boost.

1.5 Organization of Thesis

Generally, this thesis consists of five main chapters. Every chapter is elaborated in detail with regard to the improvement of the engine performance curve in cam profiles aspects.

The report starts with Chapter 1 which gives a general idea regarding MODENAS Company, internal combustion engine, camshaft function and history of engine development. It is trailed by a brief explanation regarding current problem statements as well as the research objectives. Apart from that, Chapter 1 also includes the research scopes which briefly describe the area of knowledge and methodology in this research.

Chapter 2 provides the relevant literature reviews of a research topic that will act as a guideline in the completion of this thesis. It deliberates about the overall engine operation, the function of engine components, intake and exhaust parts, camshaft parts and its function and current research in improving overall engine performance.

Chapter 3 covers all the involved methods and the process applied in order to achieve the research objectives. It includes all related theories, the calculation involved and software simulation. It provides a detail explanation on how to design various cam profiles and how to investigate its effect on engine performance curve.

In chapter 4, it provides all the obtained results for different cam profiles and the improvement of the engine performance curve so that to investigate the consequences of cam profiles to the performance of MODENAS CT115S engine. Every single aspect that is related and contributes to the result is discussed in detail.

Chapter 5 presents the summary of overall research which includes research conclusion and the future work for further development.

CHAPTER 2

LITERATURE REVIEW

This chapter represents the literature reviews associated with internal combustion engine. The latest findings related to the research question are listed, reviewed and scrutinized in this chapter. Reading materials like book chapters, journal and articles are reviewed first before the useful and important information contributing to research flow was accumulated. The information is needed with the significantly modernized knowledge for much better understanding and upgrading the current knowledge regarding research topics.

2.1 Fundamental of Engine Cycle

Nowadays, the automotive sectors have experienced rapid growth in remarkable trend. State of the art technology and innovation ideas assisted in conceiving the new design and upgraded technology for engines. From the basic principle engine cycle, the internal combustion was introduced in the year 1876 until now considering enhancement of the engine technology. Internal combustion (IC) engine consists of the fuel, which entered the combustion chamber after mixing together with the air for the combustion process and the power stroke was generated in the combustion chamber in the cylinder block (Johanson, 2009).

Currently, there are two major categories of IC engine; an ignition engine and compression engine which operate at four cycles or two cycle engines. The spark ignition (SI) engine requires spark plug which is the indispensable piece to ignite the air fuel mixture, whereas the compression ignition will apply the auto ignition process to set up the engine (Pulkrabek, 2013). Diesel engine provides higher efficiency in term of consistency and power compared than a gasoline engine, with 45% conversion of fuel energy into the actual power, meanwhile gasoline engine converts 30% of fuel energy into the actual power output (Rabault, Vernet, Lindgren, & Alfredsson, 2016).

Normally in small capacity motorcycle, the small spark ignition (SI) engine was applied and installed. This kind of engine normally operates with a single cylinder engine. The main aims in producing this kind of engine are low cost, light weight and small size, besides the other aspects such as fuel consumption, engine vibration and engine robustness. Consequently, the torque improvement is widely spaced, and the smoothness and engine vibration shuddering are significantly complicated (Heywood, 1988).

These kind of fundamental cycles are commonly standard for all those applications. In a four stroke motor, the first stroke is called as an intake stroke. At this stage, cylinder at the inside burning will go to bottom dead center (BDC) from the top dead center (TDC) which is parallel with the intake valve open and exhaust valve will completely shut when the cylinder reaches the BDC (Noor et al., 2008).

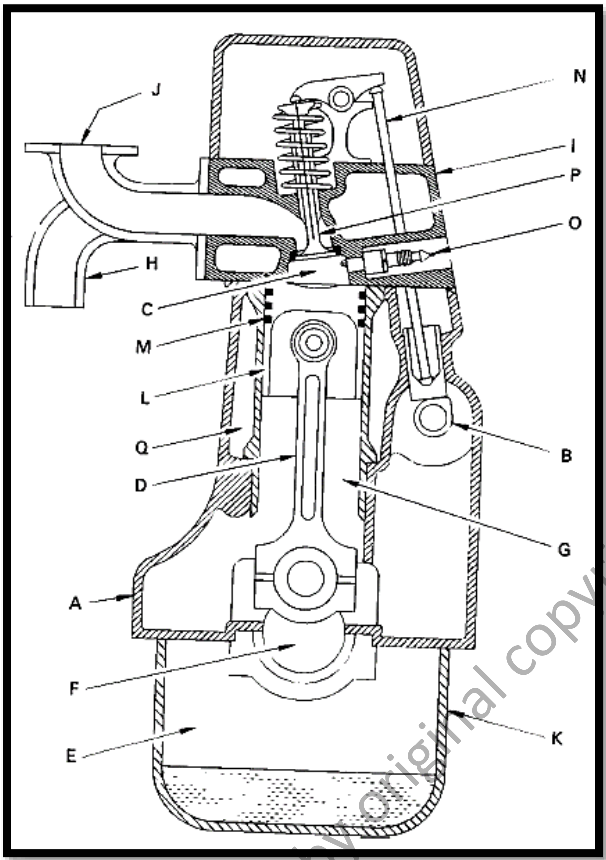

Figure 2.1: Cross-sectional components of engine components (Pulkrabek, 2013).

Table 2.1: The components of the engine (Pulkrabek, 2013).

Components	**Components Name**
A	Block
B	Camshaft
C	Combustion Chamber
D	Connecting rod
E	Crankcase
F	Crankshaft
G	Cylinder
H	Exhaust manifold
I	Head
J	Intake manifold
K	Oil pan
L	Piston
M	Piston rings
N	Push rod
O	Spark plug
P	Valve
Q	Water jacket