UNIVERSITI PUTRA MALAYSIA

SIMULATION OF TRANSMISSION MATCHING TO IMPROVE CNG-DI VEHICLE PERFORMANCE

HAMZAH BIN ADLAN

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By

HAMZAH BIN ADLAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATION

Thank you to my wife, Natsue Hieda who is very patient with my ‘job’. Not to forget to my 2 lovely kids, Hana and Hadi who always give me inspiration and ‘disturbance’ to complete the write-up. My parents who always support whatever I am doing. My Rally Team mate who always gives ideas on what I am doing. Lastly thank Almighty to give me strength to finish this study.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: Professor Ir. Barkawi bin Sahari, Ph.D.

Faculty : Engineering

This research presents the process of designing a simulation tool to predict dynamic performance of a vehicle. In this case, PROTON WAJA powered by newly developed CNG-DI CamPro prototype engine was taken as model to be predicted and at the same time to improve vehicle performance. Besides that, the potentials of Natural Gas and Direct Injection technology were reviewed as one of the main elements in this project. However this paper will not cover the design change or modification required to optimize Natural Gas as a fuel. Performance of the CNG-DI engine was simulated to match with the five speed manual transmission. In order to calculate the vehicle performance, combination of gear ratio and final drive selection was carried out. Three gear ratios and final drives combination were selected and compared. The best gear ratio combined with best final drive will decide the best performance. Besides

that, comparison between simulation result and actual test conducted by vehicle manufacturer at the same test basis was also done to verify the accuracy of simulation tool. The tool was design to ease engineers or researchers when comes to transmission selection for a given vehicle.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

SIMULASI KESESUAIAN KOTAK GEAR UNTUK MENINGKATKAN PRESTASI KENDERAAN CNG-DI

Oleh

HAMZAH BIN ADLAN

Januari 2007

Pengerusi: Profesor Ir. Barkawi Sahari, Ph.D.

Fakulti : Kejuruteraan

Penyelidikan ini mempersembahkan proses mereka bentuk sebuah program simulasi untuk meramal prestasi sesebuah kenderaan. Dalam kes ini, sebuah kereta PROTON WAJA yang dikuasai oleh injin CNG-DI yang baru dibangunkan telah dipilih sebagai model untuk diramal disamping ditingkatkan lagi prestasinya. Disamping itu, potensi Gas Asli (NG) dan juga teknologi kaedah suntikan terus (DI) juga diulas sabagai sebahagian elimen penting dalam penyelidikan ini. Walau bagaimanapun thesis ini tidak menyentuh perihal perubahan rekabentuk atau modifikasi injin untuk mengoptimumkan pengunaan Gas Asli. Prestasi injin CNG-DI telah digunakan untuk dipadankan dengan kotak gear manual lima kelajuan. Untuk mengira prestasi kenderaan, beberapa kombinasi nisbah gear dan nisbah pacuan akhir telah dipilih dan dibuat perbandingan. Kombinasi

nisbah gear dan nisbah pacuan akhir yang terbaik akan menentukan prestasi kenderaan yang terbaik. Disamping itu, perbandingan diantara keputusan simulasi dan keputusan ujian sebenar yang dijalankan oleh pengeluar kereta mengunakan parameter yang sama telah dijalankan untuk menguji ketepatan program simulasi. Program simulasi ini direka untuk memudahkan para jurutera atau penyelidik untuk memadankan nisbah gear terbaik untuk sesuatu kenderaan.

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I certify that an Examination Committee met on 11th January 2007 to conduct the final examination of Hamzah bin Adlan on his Master of Science thesis entitled "SIMULATION OF TRANSMISSION MATCHING TO IMPROVE CNG-DI VEHICLE PERFORMANCE" in accordance with University Putra Malaysia (Higher Degree) Regulations 1981. The Committee recommends that candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Azmi b. Dato' Yahya, PhD, Ir.
Assoc. Professor
Faculty of Engineering
Universiti Putra Malaysia.
(Chairman)

Ir. Megat Mohamad Hamdan Megat Ahmad, PhD, Ir.
Assoc. Professor
Faculty of Engineering
Universiti Putra Malaysia.
(Member)

Desa Ahmad, PhD, P.Eng, Ir.
Professor
Faculty of Engineering
Universiti Putra Malaysia.
(Member)

Independent Examiner, Ph.D.
Professor
Faculty of Engineering
University Malaya…….
(Independent Examiner)

_____
HASANAH MOHD GHAZALI, PhD.
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Barkawi Sahari, Ph.D.
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Maged Hamouda, Ph.D.
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Wong Sai Voon, Ph.D.
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

_____
AINI IDERIS, Ph.D.
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 10 MAY 2007

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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HAMZAH BIN ADLAN

Date: 14 FEBRUARY 2007

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LIST OF ABBREVIATIONS

NGV	Natural Gas Vehicle
DI	Direct Injection
OPEC	Organization of Petroleum Exporting Countries
USA	United State of America
UK	United Kingdom
ASEAN	Association of South East Asia Nation
PROTON	Perusahan Otomobil National Berhad
BP	British Petroleum
CNG	Compressed Natural Gas
kW-	kilowatt
rpm	revolution per minute
Nm	Newton meter
ECU	Electronic Control Unit
EMS	Engine Management System
NOx	Nitrogen Oxides
LPG	Liquid Petroleum Gas
BMW	Bayerische Motoren Werke
VE	Volumetric Efficiency

GDI	Gasoline Direct Injection
FD	Final Drive
CVT	Continuous Variable Transmission
AMT	Automated Manual Transmission
MBT	Maximum spark advance for Best Torque
USSR	United Social Soviet of Russia
EUDC	European emission Drive test Cycle
CoD	Coefficient of Drag
N/V	Engine revolution/ vehicle speed
BMEP	Brake Mean Effective Pressure
NA	Naturally Aspirated
DOHC	Double OverHead Camshaft
NVH	Noise, vibration and Harshness

CHAPTER 1

INTRODUCTION

1.1 Background

Lately, due to the escalating demand for gasoline and diesel, the price of this precious commodity has skyrocketed to a new unprecedented level. Hence, the Malaysian government has decided to encourage the development and use of alternative fuels such as natural gas and bio-diesel. The rise in crude oil prices has also shifted the efforts of countries towards enhancing fuel economy. Natural Gas is abundant and cheaper compared to other fuels. Vehicles that have been transformed from using petrol or diesel to compressed natural gas show significant savings in fuel economy and maintenance thanks to clean combustion although there is some performance penalty. Matching the right transmission ratio is one of the strategies that could enhance the performance of a Compressed Natural Gas Direct Injection (hereafter CNG-DI) engine in a Natural Gas Vehicle (hereafter NGV) to be at par with its gasoline counterpart.

Transmission or gearbox in general terms is undeniably one of the most important engineering components in a modern day vehicle. It is the pair of an engine and a perfect match to the engine is always an important

criteria. The core principal of a transmission is to capture the torque available at the rotating engine's flywheel, transfer the torque via a combination of gears, multiply the torque according to the selected gear ratio, and finally transfers the modified torque via its body through the transfer box or drive shaft and finally to the driven wheels, be it front, rear or all wheel drive. In essence, the function of any transmission is to assist the propulsion of a vehicle by varying torque distribution depending on the vehicle linear speed and road gradient.

Product Planning executives and Powertrain engineers all around the world consider many factors during the selection stage of a transmission for their company's model. This is because there are different types of transmission that are priced differently. There is automatic, manual, Automated Manual Transmission (AMT), Continuous Variable Transmission (CVT), to name but a few. Besides budget and cost, the most important criteria in selecting the suitable transmission are definitely the requirement and demand of the intended sales market. For example, 80% of the European prefers manual transmission while 70% of Asian car buyers would opt for automatic transmission. This is probably because in Europe, the fuel cost is so high; the driver would sacrifice comfort by driving the fuel frugal manual transmission. In the other hand, most of the cities in Asian countries are very crowd; furthermore the traffic condition

is not as good as the European that lead Asian people to opt for automatic transmission car.

Whether it is an automatic gearbox or manual gearbox, the fundamental of gear ratio calculation is relatively same. The main reason for this project to concentrate on manual transmission is the simplicity of the structure. Furthermore, they are easy to understand on how it works and relatively carry lesser number of parts compare to any other type of transmission. Manual transmission has better mechanical efficiency due to lesser moving parts. In the other hands, automatic transmission unit has a torque converter that has an impeller to rotate a fluid to convert rotating torque from the engine into the drive shaft, then to the wheel. Thus, more rotating parts and heat losses those lead to less mechanical efficiency. Manual transmission is cheap to produce and easy to package into vehicle, thanks to its smaller size compare to automatic transmission and relatively effective cost solution when it comes into production that it will not reflect high built-of-material overall cost. For example, 4-speed automatic transmission is simply double the price of 5 speed manual transmission. Even in Asia, manual transmission is less popular, but it is still a good option for smaller car that has a small engine to compensate with low engine output. It also has a low maintenance cost and most importantly, a very robust unit that usually ended its life with the vehicle.

There are numerous factors affecting transmission design. For a start, packaging of an engine bay plays a vital role in deciding whether to use four, five, six or even seven speed manual transmission. Most of high performance car that usually has a longitudinal engine configuration (engine is located parallel to the body line) has more gear ratios. High performance car has a high performance engine that needs the power to be divided evenly across the ratios. Engine bay for high performance car has been designed to cater for big engine and transmission, thus allowing the transmission to have more ratios. For example, Lamborghini Diablo has a 7-speed unit inside and similar to Ferrari F40 has 6-speed manual transmission. On the other hands, small car that is targeted for decent people usually has 5-speed manual transmission that located transversely in the engine bay. Another factor that is affecting the design is the cost. Since the cost is the most vital element in the modern automotive industry, it is very clear to choose the right material and manufacturing process to the given budget. Gear and shaft base material selection plus hardening process (usually case hardening) has to be selected in order to produce inner rotating parts. Transmission casing and 'bell' housing that usually made by aluminum is always an option for normal car. But sometime the lightweight magnesium casing is on option for a performance car. The other factor is the torque capacity. The capacity depends on the amount of torque produced by the engine, hence determines the heat treatment process and base material selection. The rest of the deciding factors are

minor but important on how rough or how smooth the gear change depending on the surface finishing, dimensional tolerance and level/ direction of vibration coming from the engine.

For the new PROTON WAJA CNG-DI vehicle, there are five reasons why the drive train engineers need to choose the proper transmission gear ratio and the correct final drive. The first one is the different torque output and characteristic from CNG-DI compare to gasoline engine. The second one is the emission target, which differs by engine load and engine speed that is not discussed in this project. Others are the vehicle weight, which is very important in transmission tuning. Fourth reason is new target for engine revolution to speed ratio (N/V ratio) that might be different based on intended market or topography. Finally is the maximum torque capacity for the internal gears could withstand that should be inline with maximum torque produced by the engine..

The different gear ratios are necessary because the engine develops relatively little power at low engine speeds. The engine must be turning at a fairly high speed before it can deliver enough torque to start the vehicle moving. Transmission torque capacity would also determine the type of heat treatment for the base material of the moving parts. Design tolerances and surface finish would affect the smoothness of gear changing, vibration and road shock dampening. The strategies employed in the transmission

design are various. Among the transmission design considerations are environmental such as the End of Life Vehicle (ELV) regulation compliance, which is to include recyclable parts. Other considerations include collision safety and the use of lightweight materials. The transmission can also be designed to meet the collision safety standard. The engineers can also juggle the option of a lightweight transmission to improve the fuel economy of the vehicle. Finally, the engineers can strategize to reduce the size of the transmission so that it is compact and can be packaged in many vehicles and thus increase the possibility of cross company sales.