ENGINE QUALITY SCREENING SYSTEM USING VIBRATION TECHNIQUES

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Specially dedicated to my beloved family, my project supervisors, fellow laboratory technicians, and the client Proton for your sincere encouragement, guidance, efforts and financial support in making this research a success.

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ABSTRACT

Engine Cold Test is the current trend being pursued by automobile makers to improve on the quality control of their engine. This project looked into the development of an engine screening system (EQS) using vibration technique as part of the Engine Cold Test. The core of this project involved the development of the whole system from conceptual design upon agreement by the client. The EQS system implemented electric motor coupled with a motor driver to drive the engine provided by client. The project also developed the necessary software algorithm and data acquisition (DAQ) system, complete with test bench setup that includes fabrication of test stand and connecting shaft. Transducer such as accelerometers and cam sensor were used to take measurement from the engine during the test run. The outcome of the project includes a user interface that allowed for the control of the motor driver, data acquisition on the motor driver for the feedback related to operating condition of the motor, data measurement and analysis from accelerometer, and signal conditioning for the cam shaft sensor. The Fast Fourier Transform (FFT) data was plotted in 3D to allow for future identification of engine components' vibrating frequency upon further details of engine provided by the client.

ABSTRAK

Engine Cold Test merupakan trend sekarang yang banyak dipelopori oleh pengeluar automatif untuk meningkatkan pengawalan kualiti ke atas engin mereka. Project ini akan menkaji secara mendalam pembangunan sesebuah Sistem Pemeriksaan Engin *(Engine Screening System, EQS)* melalui teknik getaran sebagai salah satu process dalam *Engine Cold Test.* Teras projek ini membabitkan pembangunan system keseluruhan daripada konsep reka bentuk selepas mendapat kelulusan daripada pelanggan (Proton). EQS system mengimplimentasikan elektrik motor yang dikawal oleh *motor driver* untuk menghidupkan engine yang dibekalkan oleh pelanggan. Project ini juga menyediakan algoritma perisian dan sistem pengambilan data (*Data Acquisition System, DAQ*), selain daripada tempat menguji engine yang termasuk process sokongan engine dan shaft penyambungan. Transduser seperti *accelerometers* dan *cam sensor* digunakan untuk mengambil data apabila pengujian engin dijalankan. Hasil daripada projek ini termasuk *user interface* yang membolehkan pengawalan motor, pengambilan data daripada *motor driver* tentang keadaan operasi motor, pengambilan data dan data analisis untuk *accelerometer*, dan pemprosesan isyarat daripada *cam sensor*. Data daripada *Fast Fourier Transform (FFT)* juga disediakan dalam graf 3D untuk tujuan menentukan frekuensi komponent-komponent engine apabila data diberikan oleh pelanggan pada masa depan.

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LIST OF ABBREVIATIONS

Nomenclature

EQS	Engine Quality Screening
DAQ	Data Acquisition
RPM	Rotational per Minute
OP-AMP	Operational Amplifier
FFT	Fast Fourier Transform

Unit

N/m	-	Torque
g	-	Gravitational Acceleration
m^2/s	-	acceleration
hp	-	Horse Power
s	-	Time in Second
W	-	Wattage
V	-	Voltage
A	-	Amperage
Pa	-	Pressure

CHAPTER 1

INTRODUCTION

1.1 Research Background

The development of internal combustion engine for the use of automotive industry has gone rapidly since mid-Karl Friedrich Benz and Gottlieb Wilhelm Daimler introduces them in the 1880s. To ensure minimal production cost and customer satisfaction, automotive industry not only requires innovative concepts in engine design, manufacturing and assembly process [1], the need to ensure the engine quality also arises. Thus, engine fault detection becomes a fundamental process in the production line of automotive engine. Fault detection is about diagnosing the running condition of engine by recording and analyzing relative information to recognize and indicate any anomalies of its operation condition [2].

To achieve fault detection, engine testing is the most straightforward method, whereby the process involves analysing and monitoring all the static and dynamic parameters of an engine under actual conditions. A good engine will have all four working strokes – intake, compression, expansion and exhaust working in tandem and in optimum condition to produce power and torque for the automobile. The four processes demand that various parts of the engine to function as desired on top of a properly assembled engine to perform optimally [3].

Most automobile manufacturers make use of a process called hot test to test their engine, where the engine is fired up during the testing and the engine performance is identified [2]. In a hot test, the conditions are kept similar to what is observed on the vehicle, where the engine is supplied with fuel, coolant and air with

sufficient engine oil to keep the engine lubricated [3]. Recent trend saw a shift by automobile manufacturers to incorporate cold test in their engine testing, to diagnose engine assembly defects that cannot be easily detected through the hot test technique. The cold test involves having an unfired engine rotated externally through the implementation of an electrical drive and a drive line. The measured signal characteristics will be analysed at various engine speeds to diagnose faults [4].

Malaysia's national automobile manufacturer, Proton took an interest in the engine cold test and looked into the possibility of having the system incorporated in their production line. Their team approached University Technology Malaysia to come up with a proposal and a design. The focus of this research will be developing an engine quality screening system, focusing on engine cold test. The methods used in the research will involve acoustic emission and vibration technique, along with pressure and torque measurement.

1.2 Problem Statement

The Malaysia national automobile manufacturer, Proton is currently utilising hot test to verify the performance of the engine. As demonstrated to the UTM team during our industrial visit to Proton's Shah Alam production plant, Proton has multiple hot test stands that are handled by skilled operators. The fully assembled engine will be sent to these hot test stands to be tested as part of the quality assurance program prior to being sent off for installation in the car chassis. Despite having the hot test in place, Proton is facing after-sales engine issues such as overheat, abnormal noise, knocking noise, coolant leak and so on.

To further bolster on the quality assurance of the manufactured engine, and to prevent some of the engine issues which the client gathered from customers' complaint, Proton decided that there is a need for a new testing system. The new testing system must be capable of identifying faults of engine that the current engine hot test is not capable of. Engine cold test appeared to be a promising method from

Proton's review, and Proton is hoping that, through the implementation of engine cold test, the issues will be minimized with a subsequent reduction in warranty claim to increase revenue. For that purpose, Proton is collaborating with UTM to develop the engine cold test, and eventually implement the engine cold test as part of the production line to compete in the highly competitive market.

1.3 Research Objectives

The research is intended to develop an engine screening system in collaboration with Proton that is capable of fault detection that engine hot test is unable to. The core of the research will be:

i. To develop an engine quality screening (EQS) system through vibration technique as part of the engine cold test.
ii. To evaluate the accuracy of the EQS system.

The main objective will be further guided by the following scope:

i. Conceptual design of EQS system based on client's requirements.
ii. LabVIEW algorithm development for EQS.
iii. Signal conditioning and data acquisition (DAQ) system design.
iv. Integration of hardware and software to produce test bench as per client's requirements.
v. Test bench performance testing and analysis based on Proton NFE 1.6 Engine for Proton Iriz.

1.4 Research Question

The project will be guided by the following research questions:

i. What are the criteria for engine cold test?
ii. What is the hardware required for the EQS as part of the engine cold test?
iii. How to develop the software for data acquisition and data analysis?
iv. How to integrate relevant hardware and software to implement the EQS?
v. How to benchmark good engine performance and how to simulate engine defect?

1.5 Significance of Study

This research will lead to progressive development of engine cold test system to match those of industrial standard in developed countries like Germany and Japan. Current available resources on this subject is mostly trade secret of respective automobile manufacturers and consultants, and through this research the knowledge for this particular engine testing method will be made available to local industries.

1.6 Limitation of Study

The research will be limited to designing the engine cold test to cater for spark ignition engine, and in more particular, the Proton's NFE 1.6 Engine. Each type of engine is unique with different output signal from benchmarking and fault simulation, on top of different position for sensors' placement. Designing a suit-all engine cold test will not be feasible from the budget and time constraint.

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