We admit that have read this work

and in our view this work was adequate from the scope and quality to the award purpose for

Bachelor of Mechanical Engineering (Automotive).

Signature:.....

Supervisor :.....DR. K. Hudha

Date :.....12/05/2008.....

DEVELOPMENT OF QUARTER CAR TEST RIG FOR VEHICLE RIDE ANALYSIS

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DECLARATION

"I admit this report is done all by myself

Except statement that I have already started on each one of them

Signature: .....

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ABSTRACT

Development of quarter car test rig for vehicle ride analysis is the new idea to support our industry especially in automotive field. The technology that will be used is a not the high technology but the concept to develop the idea and the result of the scope is the main important thing we must consider. Writing in this report is the starting point to introduce about this project. It consists of the introduction, literature review to develop this project and also some methodology to do analysis and drawing to complete the prototype and so on to design the actual drawing. The equations of motion for the quarter-car model are derived in state space as well as a transfer function form that applied at the Simulink programmer of Matlab. Several tests will be run in simulation to investigate the performance and the characteristic of suspension system for quarter car model. By using the acceleration measurements from the quarter-car test rig, a quarter-car parameter and the characteristic optimization for use in the test rig was performed via operation the machine. Based on the operation, the suspension characteristic for quarter car model will be identified. End of this project, we will achieved the result and fulfill the objective of this project that to design of a small scale quarter car test rig, to design an instrument from system for quarter car test rig and to identify the suspension characteristic of the quarter car test rig.

ABSTRAK

Membangunkan mesin uji kaji bagi suku kenderaan untuk analisis kenderaan merupakan satu idea baru yang dihasilkan dalam industri automotif. Ia bukan sahaja di bangunkan dengan menggunakan kecanggihan teknolgi tinggi malah ianya lebih berharga apabila mencapai skop kerja yang diinginkan melalui keputusan uji kaji yang di jalankan. Dalam menghasilkan projek ini, beberapa kajian ilmiah dilakukan bagi memudahkan ianya lebih di fahami dari segi konsep kerja dan juga parameter yang digunakan dalam menghasilkan mesin ini. Ianya bermula dengan melakukan kaji selidik berkenaan mesin uji kaji yang sedia ada serta menentukan parameter yang wujud didalam membangunkan mesin uji kaji seperti ini. Setelah itu, lakaran projek juga amat penting dalam memastikan pembangunan mesin akan mengambil kira factor-faktro sebenar pada sebuah kenderaan, lakaran projek kemudian di kemaskini melalui penggunan perisian yang lebih baik bagi mendapatkan dimensi yang lebih tepat dan jitu. Konsep asal mesin ini di ambil daripada sistem suku kenderaan dan mengambil kira pemboleh ubah yang terlibat bagi mencapai dan mendapatkan keputusan yang lebih baik dan tepat sebagaimana yang berlaku pada sesebuah kenderaan. Akhir sekali, berdasarkan ciptaan dan objektif projek ini, amatlah di harapkan agar ianya dapat di hasilkan dengan sebaik mungkin bagi mencapai kondisi yang sempurna sekali gus dapat mengenal pasti parameter yang digunakan di dalam sistem suku kenderaan.

TABLE OF CONTENTS

TABLE LIST

FIGURE LIST

SYMBOL LIST

SYMBOL	DEFINITION
a	Acceleration, m/s^2
a_b	Body Acceleration, m/s^2
C_s	Damper Stiffness, N/m
C_t	Damping coefficient o tire, N/m
F	Force, N
g	Gravity (9.81)
F_d	Damping Force, N
F_t	Tire Force, N
F_s	Spring Force, N
f	Frequency, Hz
K_s	Spring Stiffness, N/m
Ms	Sprung Mass, Kg
Mu	Unsprung Mass, Kg
Mb	Body Mass, Kg
$\ddot{Z}_b$	Body Acceleration, m/s^2

$\dot{Z}_b$	Body Velocity, m/s
Z_b	Body Displacement, m
$\ddot{Z}_w$	Wheel Acceleration, m/s^2
$\dot{Z}_w$	Wheel Velocity, m/s
Z_w	Wheel Displacement, m
ζ	Damping Ratio

CHAPTER 1

INTRODUCTION

The purpose of this chapter is to provide with an introduction to the research conducted for this project. First the shortcoming of suspension system included the function of the suspension. Also overview about the quarter car test rig and the main objectives of this project that related to develop quarter car rig and the list of scope project will be presented. The end of this chapter is outline of the subsequent for each chapter involved in this report.

1.1 Overview of Quarter Car Test Rig

Automobile frame body is mounted on the front and rear axle not directly but through some form spring, mountings and shock absorber that is called suspension. While the vehicle moving on the road the wheels are thrown up and down due the irregularity of the road. This results in strain on the components of the vehicle and the passengers. To prevent damage to the working parts and also to provide riding comfort, suspensions is used in the vehicle.

Among the function of suspension systems is to prevent road shocks reaching the frame and other units. Suspension also functions to provide good road holding while driving, cornering and braking and at the same times it purpose to maintain proper steering geometry. A quarter car test rig is used to study the behavior of vehicle due to the variation in road profile which is commonly known as ride vehicle analysis. The performance criteria in designing vehicle suspension system are body acceleration, suspension travel and wheel acceleration. Performance of the suspension system is characterized by the ability of the suspension system in reducing those three performances of criteria effectively. The quarter car test rig should be developed in such as way that closely resembles the quarter car part of real vehicle. The quarter car test rig should have the ability to mount several different designs of actual car suspensions, able to perform a wide range of tests which include variation on body loads and the frequency of road disturbance, and still have the ability to expend for future developments.

1.2 Objective

The primary goal for this study is to develop a new modified quarter car test rig for vehicle ride analysis and evaluate technology that can improve the state-of-the-art in vehicle simulation testing on a quarter-car vehicle. Because this is a start-up lab, an additional, necessary objective is to develop a state-of-the-art quarter-car test bed for this research. Currently, the desired functions of a quarter-car rig include the ability to mount several different designs of actual car suspensions, have the ability to perform a wide range of tests, which include body loads on the sprung mass, and still have the ability to expand for future developments. There are several quarter-car test rigs that are currently available. More details about the previous design and comparison of the quarter car rig will be discussed at next chapter. Many of those rigs do not have the functionality desired for the current and future research projects.

The commercially available rigs are quite expensive and yet most still do -not offer the amount of flexibility needed, a commercially developed rig from a company such as MTS or ServoTest would require close development with the researchers. This would prove to be an even more expensive proposition and at the same times it will be develop a new concept of quarter car test rig. Thus, the goal of this research was to develop the new rig in order to achieve the desired functionality at a reasonable expense and ergonomic machine and also to design an instrument from system for quarter car test rig.

With a competed test rig the other goal is to perform a study on the application of a control system to the rig for reproducing test vehicle response. This is not a new concept. In fact, much of the literature suggests that several methods have been attempted, and commercial solutions are available. However, most of the literature is not clear or vague in terms of the technical details.

In summary, a new quarter-car test rig has been designed and built. In an attempt to prove the concept, a well known control scheme, not currently used for this application, is applied to the problem of replicating vehicle response signals. Finally, the last goal is to design an instrument from system for quarter car test rig has been succeed.

1.3 Scope Project

- To developed a new modified full scale Quarter Car Test Rig for vehicle ride analysis
- Identification of the suspension characteristics

1.4 Problem Statement

Today there are several types of quarter car test rig that are currently available. Many of those rigs do not have the functionality desired for the current and the future research projects, whereas the commercially available rigs are quite expensive. In most of the existing quarter car test rig, the tire vertical dynamics are omitted or just represented by a simple linear spring and the effects or the tire rotational dynamics are also neglected. Consequently, the good correlation of the result from the quarter car test with real data from the represented vehicle will be difficult to obtain by this simplification. Prototype of a full scale quarter car test rig has been developed in this research project to overcome the shortcoming of the existing quarter car test rig.

1.5 Approach

To achieve these goals the following approach is taken. Current quarter-car test rigs and the state parameter of quarter car testing in general are first evaluated. The approach is to develop a quarter-car test rig that addresses many of the shortcomings found with the latest design while trying to minimize expense. After determined the parameter of quarter car test rig, the next step is design of the construction concept for the new modified rig by using 3D software that we called CATIA. Having drawn the conceptual design, the next step is built up the prototype with send to manufacture. Finally, a real-time implementation of the application to the quarter-car test is by doing the experiment and testing to validate the control scheme. Actual acceleration response will be reproduced on the sprung and unsprung mass of the quarter-car rig.

1.6 Outline

Chapter 2 was presents information of the literature review that consists of 2DOF (Degree Of Freedom) of quarter car test rig and some of comparisons previous deign quarter car rig with new design. It also provides a literature search that was conducted to investigate the past research done and any of areas relating to this project. Chapter 3 discuses in details about methodology research to complete this project. This chapter also provides a research work flow of development quarter car rig and the result variable to support this research and experimental equipments of quarter car test rig. Another topic that provides in details is the information of controller devices that fix at the quarter car rig. This chapter also presents the experimental setup of the quarter car test rig apparatus. Chapter 4 describes of the results for all the experimental testing and more details about deign and functional work of the rig highlights of machine elements analysis and mathematical model for quarter car test rig. Finally, chapter 5 is conclusions the results of this project and some discussion to improve the design of the rig that identified along time to complete the development of full scale quarter car test rig for vehicle ride analysis.

CHAPTER 2

LITERATURE REVIEW

In this chapter, it begins with a survey of the current test rig technology and some of the issues or deficiencies found with them. This will lay the groundwork for defining the new requirements of the quarter-car rig design presented in this project. The literature review also will conducted to investigate the pass research and design done of quarter car test rig in any of areas that it consider has relation between this project. Among of the areas that provides in this project is quarter car testing and any types of quarter car rig also the parameter of quarter car rig system. ScienceDirect and IEEE Xplore is two databases were used for literature search. ScienceDirect is database for physical science and engineering, life science, health science and social science and humanities while IEEE Explore is a digital library providing full text access to the world's highest quality technical literature in electrical engineering, computer science, and electronics. The purpose of this chapter is to provide 2DOF system of quarter car test rig background and comparison of previous design with a new modified of quarter car rig.

2.1 Vehicle Testing Rig

The main purpose of the vehicle testing rig is to study the behavior of vehicle due to the variation in road profile which in terms of noise, vibration and harshness performance. In other words, vehicle testing rig purpose of a shaker rig regardless of the number of posts are to evaluate noise, vibration and harshness (NVH), perform durability tests, and/or improve vehicle performance [1, 2, 3]. These goals vary slightly depending on the nature of the industry in which they are applicable. The automotive field would primarily be interested in NVH and durability but on some occasions may want to improve the handling performance of their vehicle without spending countless hours on a proving ground. But it contrast to racing industry which they are not as likely to be interested in NVH, however durability and particularly performance metrics, such as handling and suspension tuning, are critical.

For these tests, knowledge of the road input is very important, especially if the desire is to simulate the surface of the track and characterize vehicle response. But for this project the objectives of the experiments is to do observation of probability and operation of the rig and at the same time to define vibration responses between sprung and unsprung mass of the rig. From the responses, it will show the natural frequency of the system and then derive the transfer function. More details about the observation will be discussed at next chapter. The main objective of this project is to determine the acceleration, velocity and displacement of wheel. However, this information is seldom actually known, particularly in the motorsports industry. Even if the road profile is known precisely, it tells the test result nothing about other dynamics the vehicle endures such as inertial and aerodynamic loading. This information is often calculated based on maps, lookup tables, or vehicle models running in software such as ADAMS. These types of software run in conjunction with the simulator [2,3]. This section discusses the current state-of-the-art in vehicle testing rigs. Particularly, a survey of quarter-car test rig technology is presented which details the need for increased functionality of the new quarter-car test rig. Finally, the section closes with the proposed new functional requirements of said test rig.

2.1.1 Complex Shakers

Among the most complex test equipment are the 4-post, 7-post and 8-post shakers and kinematic and compliance rigs. A typical 4-post rig is comprised of 4 servo actuators. If the test rig is tire-coupled, each actuator (post) supports the vehicle under each tire. If spindle-coupled, each spindle on the vehicle is mounted directly to the actuator. Thus, the test rig can input various signals into the vehicle and responses may be measured. The 7-post works in a similar fashion with the addition of three extra actuators (4 extra actuators if it is an 8-post) attached between ground and the sprung mass of the vehicle. These offer increased capability in the form of simulating vehicle response from inputs such as braking, acceleration and cornering as well as aerodynamic loading.

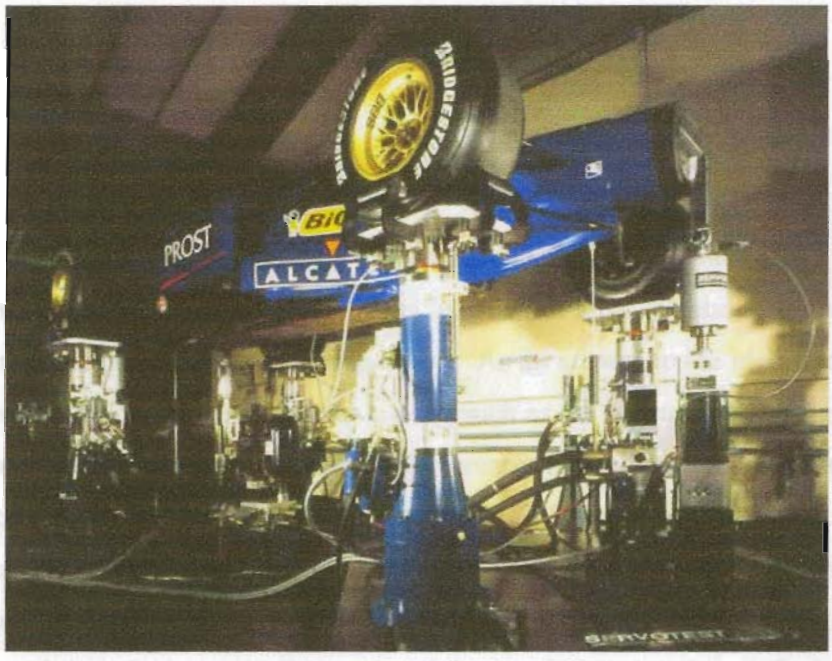

Figure 1: Image of ServoTest 7-post Test Rig

Figure represents a ServoTest tire-coupled 7-post rig with a Formula 1 race car. These complex test rigs offer an immense amount of capability, however they 7 are very expensive to build and maintain. They also present other difficulties. These rigs are very sophisticated muli-input/multi-output (MIMO) systems which require a high degree of control knowledge and understanding to use properly. Often, the complex nature of these multivariable problems requires multi-step iteration to obtain a suitable drive file for commanding each of the actuators. Once converged data is extracted from tests run on these systems, it is often very difficult to interpret and correlate to the real world counterpart. Some reasons for these issues with more complex test rigs are the lack of literature and other available documentation [4, 5]. To the authors knowledge only a handful of papers that discuss multi-post test to any detail exist [6, 1, 7, 8]. It is likely that the lack of available information is partially due to race teams and automotive companies trying to protect their competitive advantage.

2.1.2 Current Quarter Car Rigs

The quarter car test rig should be developing in such away that closely resembles the quarter part of real vehicle. It must have the ability to mount several different designs of actual car suspension. As an answer to the high complexity and expense of these systems, simpler test rig such as the quarter-car test rig are used. A rig such as this reduces the complexity greatly by only focusing on one corner or quarter of the vehicle. These may be considered one-post or two-post systems by means these have considered one or two servo actuators. Often, these systems can be viewed as a single input/ single-output (SISO). This greatly reduces computational time and complexity and often a closed form solution may be reached. This allows for much better understanding of both the problem and results.