# IDENTIFICATION OF TEST RIG FOR A QUARTER CAR ACTIVE SUSPENSION SYSTEMS

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*This project report is dedicated to………*

*My beloved mother, Pn Hajjah Fatimah Binti Hussein*
*Who has so much faith in me*
*Love u forever*

*Also to my beloved brothers and sisters; Asha, Meen,*
*Nasri, Sila, Iza, Huda, Syam and Anuar*
*Who always been very supportive and*
*guide me throughout my academic career*

*To all my friends, who have stood by me through thin and thick*
*I treasure you all*

*Thanks for showering me with love and happiness*
*Life has been wonderful colour by you*

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# ABSTRACT

System Identification approach can be used to estimate the models and parameters of the passive system of a test rig for a quarter car active suspension systems. The passive suspension system is consists of sprung mass, unsprung mass, damper and hydraulic actuator. Identification of the system is carried out based on the experimental work of the test rig. The input of the system is an input signal from the LVDT sensor that be controlled by valve and two output signals of the system are the output signals from accelerometers. One output signal is taken from the accelerometer that placed at the body of the car and another one is placed at the tire of the car. Input signal excitation and data acquisition process are controlled by using Simulink. In order to estimate and validate the model and parameters, the data are process using the System Identification Toolbox in Matlab. Since the system is modeled as a linear model, linear ARX model is utilized as a model structure. Model parameter estimation for the passive systems is performed using ARX430 and ARX420 methods respectively. Through the validation process, percentage of the best fit can be reached more than 90% and the smallest LF, PFC and AIC criterions also can be reached. Hence, the model parameters of the system are acceptable.

# ABSTRAK

System Identification dapat digunakan untuk mengira parameter-parameter dan model dari system pasif daripada test rig untuk seperempat kereta dengan sistem aktif suspension. Sistem pasif terdiri daripada jirim, spring, perendam getaran dan pendorong hidraulik. Pengenalan bagi kedua-dua sistem berdasarkan kepada eksperimen yang dijalankan keatas test rig di dalam makmal. Terdapat satu data masukan bagi sistem ini merupakan tanda masukan dari pengesan jarak yang diletakkan pada pendorong hidraulik yang dianggap sebagai permukaan jalan dan data keluaran daripada sistem ini adalah dua tanda keluaran dari pengesan pecutan yang diletakkan pada bahagian badab kereta dan satu lagi di bahagian tayar kereta. Data masukan dan proses perolehan data dikawal dengan menggunakan program Simulink. Oleh itu, untuk mengira parameter dan model pada sistem ini, data akan diproses dengan menggunakan kaedah System Identification Toolbox di dalam Matlab. Setelah sistem ini dimodelkan sebagai linear model, maka linear ARX model dipilih sebagai struktur model. Pengiraan parameter model untuk sistem pasif dilakukan dengan menggunakan jenis model ARX430 dan ARX420 masing-masing untuk pasif sistem. Melalui proses validasi, persen untuk fit terbaik dapat dicapai melebihi 90 persen dan memperolehi nilai terkecil untuk kriteria LF, PFC dan AIC. Dengan memperolahi nilai-nilai tersebut, maka parameter dan model dapat diterima kerana ianya memenuhi kriteia-kriteria yang ditetapkan.

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| *PRBS* | - | Pseudo-random Binary Sequence |
| *DFT* | - | Discrete Fourier Transformation |
| *AR* | - | Auto-regressive Input |
| *ARX* | - | Auto-regressive with Exogenous Input |
| *ARMAX* | - | Auto-regressive Moving Average with Exogenous Input |
| *OE* | - | Output-error |
| *BJ* | - | Box-Jenkins |
| *LC* | - | Lost function |
| *FPE* | - | Akaike’s Final Prediction Error |
| *AIC* | - | Akaike’s Information Criterion |
| *DAQ* | - | Data Acquisition Card |
| *LVDT* | - | Linear Variable Differential Transformer |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| $M_s$ | - | sprung mass (kg) |
| $M_u$ | - | unsprung mass (kg) |
| $k_s$ | - | spring constant of body (N/m) |
| $k_t$ | - | spring constant of tire (N/m) |
| $b_s$ | - | damper coefficient (Ns/m) |
| $Z_s$ | - | displacement of vehicle chassis relative to plain ground |
| $Z_r$ | - | uneven road surface relative to plain groundu |
| $Z_u$ | - | displacement of wheel relative to plain ground |
| $Fa$ | - | output force provided by the servo-hydraulic cylinder |

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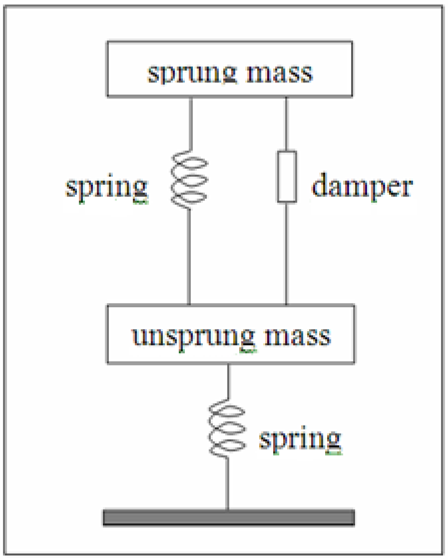
# CHAPTER 1

# INTRODUCTION

## 1.1 Vehicle Suspension Systems

Generally, the objectives of designing vehicle suspension is to minimize the vertical forces transmitted to the passengers for passenger comfort and to maximize the tire-to-road contact for handling and the safety of the vehicle [1, 20]. A high quality suspension system should have capability to reduce the car body displacement and acceleration, and maintain in the right contact between tire and terrain. In order to develop a good suspension system, there are few performance characteristics to be considered. These desired characteristics include the regulation of body movement, regulation of suspension movement and the distribution of force. Ideally the suspension should isolate the body from the road disturbances and inertial disturbances associated with cornering; that cause body roll and braking or acceleration; that cause body pitch [2].

The vehicle suspension system can be categorized into passive, semi-active and active suspension system according to the external power input to the system. Passive suspension system is always a compromise between comfort and safety for any given input set of road conditions and a specific stress. The passive suspension system consists of passive elements; a spring and parallel damper placed between the vehicle body and each of the wheels as shown as Figure 1.1. The semi-active suspension system is the adaption of the damping and/or the stiffness of the spring to the actual demands. Figure 1.2 shows the semi-active suspension system is a similar to the passive one but the dampers are continuously variable or controlled by an on/off signal. While active suspension systems in contrast provide an extra force input in addition to possible existing passive systems and therefore needs much more energy [3, 18]. An active suspension system as Figure 1.3 is one in which the passive components are augmented by hydraulic actuators that supply additional force.



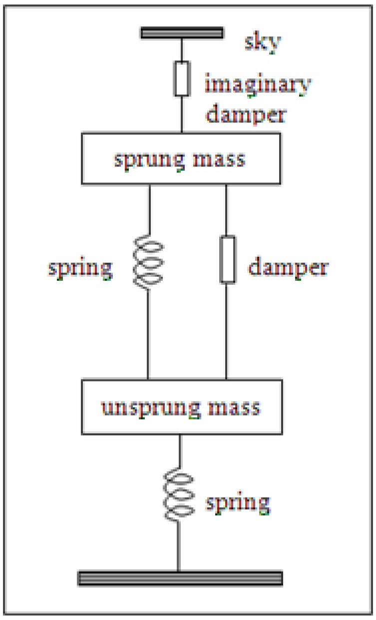




Figure 1.1: Passive Suspension

Figure 1.2: Semi-active Suspension

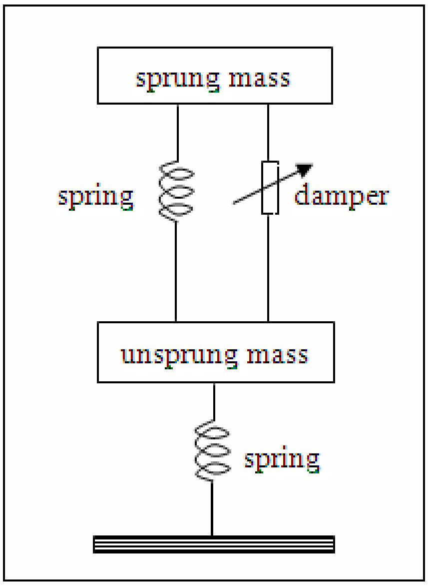



Figure 1.3: Active Suspension

Typically, the acceleration of the body as an obvious quantity of the motion and vibration of the car body and the tire load variation as indicator for the road contact are used for determining quantitative values for driving comfort and safety, respectively. Now, the terms of driving comfort and safety are defined. Driving safety is the result of the harmonious suspension design in terms of wheel suspension, springing, steering and breaking, and is reflected in an optimal dynamic behavior of the vehicle, where as driving comfort results from keeping the physiological stress that the vehicle occupants are subjected to by vibrations, voice and climatic conditions down to as low a level as possible. In order to improve the ride quality, it is important to isolate the body, also call sprung mass, from the road disturbances and to decrease the resonant peak of the sprung mass near 1Hz which is known to be sensitive frequency to the human body. In order to improve the ride stability, it is important to with the road surface and therefore to decrease the resonance peak near to 10Hz, which is the resonance frequency of the wheel also call unsprung mass [3].

## 1.2 Problem Statement

The problem statement for this study is expressed as follows:

"Determine the physical model and parameters of sprung mass and unsprung mass for passive components and choose the best model by comparing between the simulation results and experimental results without controller."

## 1.3 Objectives of Project

The objectives of this project are as follows:

i. To determine the suitable model for the whole passive system in a quarter car active suspension includes sprung mass (body mass) and unsprung mass (wheel mass) physically.
ii. To estimate the parameters of passive component based on the mathematical model by using System Identification Technique.
iii. To validate the actual and the experimental data using a differences model structure.

## 1.4 Scope of Project

The scope of this project are estimating the model and parameters of the passive system includes sprung mass and unsprung mass (spring constant of body, $k_s$, damper coefficient, $b_s$ and spring constant of tire, $k_t$) and choose the suitable model for the system by comparing the simulation and experimental results without controller.

## 1.5 Significant of Project

By using system identification technique, the parameters of the active suspension systems can be obtained and the suitable model can be chosen. Those of the aspects that is parameters and model will be used to control and achieved a good performance of the system.

## 1.6 Project Outline

This thesis consists of six chapters. It begins with the introduction chapter. This chapter gives the brief description of the problem statement and background of the test rig for a quarter car active suspension systems, the objectives, scope and significant of the project.

Chapter two discusses the literature review and the others related works from previous existing modeling paradigm and technique to identify a suitable model and estimate the parameters to achieved a good performance of the test rig for a quarter car active suspension system.

Chapter three includes design and methodology of the project. It contains design of the system, experimental design and procedure and system identification process.

Chapter four is includes preliminary results and discussion of the project for the passive system.

Finally, chapter six describes conclusion and suggestions of the project.