DIMENSIONAL ANALYSIS OF 17 DOF RAILWAY VEHICLE SUSPENSION MODEL

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DECLARATION

I declare that this project report entitled “Dimensional analysis of 17 railway vehicle suspension model” is the result of my own work except as cited in the references

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	:	…………………….
Supervisor's name	:	Mohd Hanif bin Harun
Date	:	…………………..…

DEDICATION

To my beloved parents, supervisor and friends

ABSTRACT

Dimensional analysis is method that used to convert one unit to another unit. It is very important to understand the physical nature of the problem. In the railway vehicle lateral model, dimensional analysis is described as one of the best way to analyze the performance of the railway vehicle in the real and small scale. On the first part of the study, the dynamic modelling of full railway vehicle is used to perform the dimensional analysis in order to observe the acceleration, roll and yaw of the railway vehicle. The full railway vehicle model consist of 17 degree of freedom were described. In particular, one of the objective of the study was to determine the dimensional analysis based on the scaling method. The simulation software, MATLAB Simulink also were studied as one of the medium to analyzed several graph from the simulation work such as body displacement, body acceleration, body yaw angle and body rolling angle. For the second part of the study, the validation between the simulation models were done. To achieve this, the experimental result for the railway vehicle behavior were applied using a simple mechanism to study the pattern and also the performances of both simulation and experiment model. The discussion were including the analysis of the validation and the behavior of the railway vehicle.

ABSTRAK

Kajian kepada dimensi merupakan salah satu cara untuk menukarkan satu unit kepada unit yang lain. Ia sangat penting untuk memahami sifat fizikal kepada masalah. Dalam model sisi kereta api, analisis dimensi digambarkan salah satu kaedah yang terbaik untuk menganalisis prestasi model kereta api dalam skala yang sebenar dan kecil. Dalam bahagian pertama kajian PSM ini, model penuh kepada dinamik kereta api digunakan untuk melakukan dimensi analisis untuk mengkaji pecutan, gulingan dan ayakan model kereta api. Model kenderaan kereta api yang terdiri daripada 17 darjah kebebasan diterangkan. Khususnya, salaha satu objektif kajian ini adalah untuk menentukan analisis dimensi berdasarkan kaedah skala. Perisian computer yang dikenali sebagai MATLAB- Simulink juga dipelajari sebagai salah satu medium untuk menganalisis beberapa graf dari kerja simulasi seperti sesaran jasad, pecutan jasad, sudut ayakan badan dan sudut gulingan badan. Untuk bahagian kedua kajian, pengesahan antara model simulasi telah dilakukan. Untuk mencapai matlamat ini, keputusan eksperiment untuk tingkah laku kenderaaan kereta api telah diambil menggunakan mekanisma yang mudah untuk mengkaji corak dan juga prestasi untuk kedua-dua simulasi antara eksperimen dan simulasi. Perbincangan termasuk analisis pengesahan dan tingkah laku kenderaan kerata api.

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TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

LIST OF ABBREVATIONS

DOF	-	Degree of freedom
RCF	-	Rolling Contact Fatigue
FE	-	Finite Element
LRT	-	Light rail transport
FLC	-	fuzzy logic control

v

LIST OF SYMBOLS

M	-	Car body mass
J_{ψ}	-	Yaw inertia of car body
J_{θ}	-	Roll inertia of car body
Y	-	Lateral displacement of car body
ψ	-	Yaw angle of car body
θ	-	Roll angle of car body
M_1	-	Bogie mass
$J_{1\psi}$	-	Yaw inertia of bogie
$J_{1\theta}$	-	Roll inertia of bogie
Y_{1-2}	-	Lateral displacement of the frontal and back bogies
ψ_{1-2}	-	Yaw angle of the frontal and back bogies
θ_{1-2}	-	Roll angle of the frontal and back bogies
m_0	-	Mass of wheel sets

$J_{0\psi}$ - Yaw inertia of wheel sets

Y_{m1-m4}- Lateral displacement of wheel sets

ψ_{m1-m4}- Yaw angles of wheel set

K_{1y} - Primary lateral stiffness per wheel set

$K_{1\psi}$ - Primary yaw stiffness per wheel set

$K_{1\theta}$ - Primary roll stiffness per wheel set

C_{1y} - Primary lateral damping per wheel set

$C_{1\psi}$ - Primary yaw damping per wheel set

$C_{1\theta}$ - Primary roll damping per wheel set

K_{2y} - Secondary lateral stiffness per bogie

$K_{2\psi}$ - Secondary yaw stiffness per bogie

$K_{2\theta}$ - Secondary roll stiffness per bogie

C_{2y} - Secondary lateral damping per bogie

$C_{2\psi}$ - Secondary yaw damping per bogie

$C_{2\theta}$ - Secondary roll damping per bogie

ξ_{1-4} - Lateral irregularity of track under wheel sets

ρ_{1-4} - Horizontal irregularity of track under wheel sets

F_1, F_2 - Damping force of MR dampers

F_{11}	-	Longitudinal creep coefficient
F_{22}	-	Lateral creep coefficient
W	-	Axle mass
λ	-	Wheel set tire slope ratio
r_0	-	Wheel set radius
b	-	Semi wheel set spacing
b_1	-	Lateral semi-spacing of the damper
b_3	-	Second vertical semi-spacing of the damper
b_4	-	Second longitudinal semi-spacing of the damper
L	-	Distance between the central line of the bogie and vehicle body
L_1	-	Semi wheel-wheel spacing
h_1	-	Height from center of body mass to the upper line of second spring
h_2	-	Height from center of the body mass to central lateral damper
h_3	-	Height from the upper line of second spring to center of sprung mass of the bogie
h_4	-	Height from the center of the sprung mass of bogie to the center line of wheel set
h_5	-	Height from the center of sprung mass of bogie to central lateral damper

CHAPTER 1

INTRODUCTION

The introduction is including background of study, problem statement, project objective, project scope, project Gantt chart, and project outline

1.1 Background of Study

The railway vehicles that run along a track are one of the most engineering studies in the world (Polach & Iwnicki, 2006). The track irregularities caused during the operation of high-speed railways deepen the vibrations of the track and the surrounding soil. The objective of this project was to improve the control of the vibration of different track irregularities in railway vehicles.

In England, the first such system was designed to perform locomotive testing (Shen & Yin, 2006). The Test Rig has a high- power electric motor that moves the rig and it was a rather expensive system. The control and measurement system are also particularly in details. Trains running at high speed (300-350 km/h) placed a high demand on the alignment of the rail lines and in order to improve the alignment and the stability of the tracks, the other option such as the structure of the stiffness and the track had been decided (Bian et al 2015). The effect of vibration propagation is studied and mention in (Kouroussis, 2014). It mentions that different type of trains and various modelling approaches are presented for the evaluation of dynamical 1characteristic caused by the wheel/rail irregularities. It computationally to measure and studying the behavior of the rail and the vehicle itself. For the economic reason, suggestion for field test had been made for test on the moving train but it will demand a high cost for the test.

The track irregularities generated during the running service of high-speed railway aggravate vibrations of the track and the surrounding ground environment. The problem of mechanical vibration control is generally caused by placing the suspension system between the source of the vibration and also the structure that need to be protected. All type of the moving vehicle like car, motorcycle, train and others produce vibration when moving. These vibrations reduce ride and handling and also dealing with the safety and driving comfort. The Test Rig concept were implemented to observe how the performance of the railway can reduce the problem. The Test Rig with a similar dynamic behavior in term of the damping, resonance of the chassis, wheel mass and nonlinearities were used as one of the instrument to see the real behavior of the railway vehicle.(Koch et al. 2010)

1.2 Problem Statement

One of the most complex dynamical system in engineering is the railway vehicle running along a track. The interaction between the non-conservative forces generate by the relative motion in contact area and also the wheel and rail involve both geometry of wheel tread and rail head makes the system more systematic and most complex. Usually the experiment/simulation that used to carry out for the railway is based on mathematical model. The model used were a full-scale model. That means an experiment that carried out were used a real parameter for the railway vehicle. It's computationally to measure and studying the behavior of the railway vehicle itself. The real scale model also demands a high cost for the test. Besides that, the operation for the test also need more workers as the real-scale were a big operation and the system must be handled with skills. The safety also become one of the important parts when to handle a test especially with the changing of the control such as damper and also the rail of the railway vehicle.

Due to the problem stated, the scaling strategy were developed to make sure the experiment/ simulation can be done without harming anyone. 17 degree of freedom (DOF) were used based on mathematical model that consider ride performance of vehicle body. Based on that, a scaled model using scaling strategy were used as the Test Rig to represent the real measurement of the railway vehicle but in a small test to achieve the minimum parametric represent the real physical of the model.

1.3 Project Objective

The objectives of this project are:

i. To describe a full railway vehicle model with 17 degree of freedom (DOF).

ii. To determine a dimensional analysis of railway vehicle model based on Jaschinski, Iwnicki, Pascal, and Jaschinski modified methods.

iii. To validate a simulation model with experimental model available in the laboratory

1.4 Project Scope

The scope of this project is to described a full railway vehicles parameter that are selected to represent the parameter of the railway vehicle suspension model and only ride analysis is performed in this study. A 17 degree of freedom scale railway vehicle model will be used to represent the railway vehicle lateral model. The study will use a MATLAB-Simulink for simulation work. MATLAB-Simulink is a computer design tools that are used to simulate the dynamics behavior and also evaluate the performance of the structure. The simulation study will be performed to study lateral performance of the full railway vehicle. Besides that, the experiment will be carried out using a Test Rig that available at the laboratory to study the performance of the actual railway vehicle based on scaling method. The simulation model and experiment model will be validate.

1.5 Project Outline

Chapter 1: The introduction including background, problem statement, project objective, project scope, and also project outline.

Chapter 2: the literature review consists of introduction, the history of small-scale railway vehicle, scaling strategy for 4 method used, pascal, iwnicki and jaschinski method, and also simulation model of railway vehicle for quarter car model, half car model and full car model.

Chapter 3: the research methodology is including development of 17-degree of freedom (DOF) of the full railway vehicle model, equation of bogie dynamic, wheel set dynamic and also vehicle body dynamic. The briefing about MATLAB Simulink is used as the additional study in this research. The briefing also about the experiment that carried out with the mechanism and also the sensor used.

Chapter4: in result and analysis, the PSM work will cover on the simulation result for the real scale of the railway vehicle and also the method used which is the small scale of the railway vehicle. The simulation work is done by using the MATLAB Simulink software. From the simulation, the graph of the displacement, acceleration, yaw and roll of the railway vehicle had been studied and analyzed. The validation result of the simulation and the experiment also analyzed and studied.

Chapter 5: the conclusion, summary and the recommendation for future study of the PSM work.

1.6 Summary

The main objectives of this study are to describing a full model of scale model with 17 DOF that consider ride performance of the vehicle. The study also proposes to select a scaling strategy through a simulation studies using MATLAB Simulink and determined the dimensional analysis using the scaling strategy. Lastly, the study will validate the simulation and the experiment model.

CHAPTER 2

LITERATURE REVIEW

The literature review consist introduction, the history of the small-scale vehicle, scaling strategy, Jaschinski method, Pascal method, Iwnicki method, Jaschinski modified method, and overview of simulation model of railway vehicle.

2.1 Introduction

The movement or vibration of all components in the vehicle is linked to the railway vehicle's dynamic behavior. This behavior was influenced by the design of the vehicle, in particular the suspension and the route on which the vehicle operates (Iwnicki & Wickens, 1998). It has indication for the relief of passengers or damage to things, for wheel and rail wear and noise era and for the protection of the railway device. One of the complex studies in engineering was the railway vehicle that running on the track. It is because the interaction between railway vehicle wheel and rail involves both complex geometry of wheel tread and rail head and also non-conservatives forces that generated by relative motion in the contact area. Improvement in rail material results in mitigating maintenance expenses and preventing the rail degradation triggered via rolling contact fatigue (RCF), which is occurred with the aid of the repeated rolling contact of wheels on rail (Naeimi et al. 2014). As claim by (C. Esveld, 2001), the highest stress level occurs at the running surface of the rail.

The track and the switches need to enable easy passage of the trains. If the track is no longer perfectly levelled and aligned, oscillation or vibration of the train will happen because of the irregularities of track (Dahlberg, 2006). Environment, Oscillations, vibrations, and noise can also grow to be disagreeable for the train passenger. Baiasu et al. (2013) mentioned that from (Sebesan et al. 2011) say that in view of the study of the vehicle's response in a horizontal plan, a mathematical model was developed that simulates the lateral dynamics of a four- axle railway vehicle. Zhou explained in his paper that he evolve the tilting control system that provide a comfortable response during curve and maintain the straight track ride (Zhou et al, 2011) but his method only for a real scale of the railway vehicle. The test rig is advantageous because its cost is not very high and its size is quite small. Generally speaking, all tests carried out on a bench are influenced by real behavior differences (Politecnico, 2000).

Figure 2. 1 : The test Rig (Guchi and Metin, 2009)