COMFORT ANALYSIS IN COMMERCIAL VEHICLE'S PASSENGER SEAT

TAM WEE KONG

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechanical)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

AUGUST 2006

To my dearest parents and brother…

ACKNOWLEDGEMENT

First of all, I would like to express my sincere gratitude to my supervisor, Associate Professor Haji Mustafa bin Yusof and my co-supervisor, Professor Dr. Roslan Abdul Rahman, for their assistance, contribution and valuable guidance through this research, as well as great patience I shall not forget.

I want to thank Miss Kartina, Mr. Syam and Mr. Romaizi, for their help with research material collecting, test rig construction, testing and data processing. To those friends who had assisted me as the subjects in all my experiments, thank you for your precious time and tolerance.

I would also like to acknowledge the support provided by the technicians; Mr. Fazli from Strength Lab and Mr. Shamsuddin from Composite Centre.

I wish to express my appreciation to Miss Deborah Lim Shin Fei for providing me with encouragement, understanding and assistance in the completion of this thesis work.

Finally, to my family, especially to my parents who love and believe in me, thank you for all your advice, encouragement and support. I dedicate this thesis to them.

ABSTRACT

A passenger seat is one of the main components to be considered when defining comfort in a moving vehicle. Experience shows that a seat produces different levels of comfort in different conditions. The comfort of automotive seats is dictated by a combination of static and dynamic factors. This research attempts to study the static and dynamic characteristics of a bus passenger seat for comfort through subjective and objective evaluations. The discomfort factors to be studied are the seat structure and pressure distribution at the human-seat interface. Two surveys including a pilot test were carried out to study the subjective evaluation through direct response from local users on seat comfort during their journey on the road. For the objective evaluation, two tests were conducted; SEAT (Seat Effective Amplitude Transmissibility) test and pressure distribution test. An SAE Sit-pad Accelerometer was used to measure vibration on the seat. Whereas, the pressure distribution at the human-seat interface was measured using pressure mapping system. Both tests had been carried out under controlled and uncontrolled conditions. Experimental works in the laboratory were considered as controllable. Uncontrolled condition refers to the road trials or field tests carried out in a moving vehicle which produced random vibrations. The results showed that, besides the postures and size of the passenger, the road conditions also have effects on the pressure distribution and SEAT data. A proposed seat structure with spring and damper properties was used and proved to be more effective in achieving seat vibration comfort. The SEAT values of this proposed seat were lower than the values for the current existing seat. A lower SEAT value means better ride comfort. By improving the seat parameters using the said method, vehicle seats, such as bus seats, could be developed with better ride comfort for local purposes.

ABSTRAK

Tempat duduk penumpang merupakan salah satu komponen yang perlu dipertimbangkan untuk mendefinasikan keselesaan dalam suatu kenderaan yang sedang bergerak. Pengalaman menunjukkan bahawa suatu tempat duduk memberikan tahap keselesaan yang berlainan dalam keadaan yang berbeza. Keselesaan tempat duduk kenderaan terbentuk daripada gabungan faktor-faktor statik dan dinamik. Penyelidikan ini bertujuan untuk mengkaji sifat-sifat statik dan dinamik pada suatu tempat duduk penumpang bas untuk keselesaan melalui penilaian secara subjektif dan objektif. Faktor-faktor ketakselesaan yang ditumpukan ialah struktur tempat duduk dan taburan tekanan pada permukaan antara manusia dan tempat duduk. Dua kajian soal selidik termasuk ujian pandu telah diadakan untuk mengkaji penilaian subjektif secara langsung daripada pengguna tempatan terhadap keselesaan tempat duduk semasa perjalanan mereka. Dua ujian bagi penilaian objektif telah dijalankan, iaitu ujian *SEAT (Seat Effective Amplitude Transmissibility)* dan ujian taburan tekanan. Sebuah meter pecut *SAE Sit-pad* digunakan untuk mengukur getaran pada tempat duduk. Manakala, taburan tekanan pada permukaan antara manusia dan tempat duduk diukur dengan menggunakan sistem pemetaan tekanan. Kedua-dua jenis ujian telah dijalankan dalam keadaan terkawal dan tidak terkawal. Kerja eksperimen dalam makmal dianggap sebagai ujian terkawal. Ujian tidak terkawal dijalankan dalam sebuah kenderaan yang bergerak di mana getaran rawak terhasil. Keputusan menunjukkan bahawa keadaan jalan mempengaruhi data taburan tekanan dan data SEAT, selain kedudukan tubuh dan saiz penumpang. Suatu struktur tempat duduk dengan fungsi pegas dan peredam telah dicadangkan dan dibuktikan lebih berkesan dalam mencapai keselesaan tempat duduk. Nilai-nilai SEAT untuk tempat duduk yang dicadangkan itu adalah lebih rendah daripada nilai-nilai bagi tempat duduk yang wujud kini. Nilai SEAT yang rendah bererti keselesaan duduk yang lebih baik. Dengan memperbaiki parameter-parameter tempat duduk berdasarkan kaedah yang tersebut di atas, keselesaan tempat duduk kenderaan seperti tempat duduk bas dapat ditingkatkan untuk kegunaan tempatan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

$G_{ss}(f)$	-	Seat acceleration power spectra
$G_{ff}(f)$	-	Floor acceleration power spectra
$W_i(f)$	-	Frequency weighting
$H(f)$	-	Transfer function
$a_w(t)$	-	Frequency weighted acceleration time history
T	-	Period of time over which vibration may occur
W	-	Body mass
A	-	Contact area
a	-	Length
g	-	Gravity = 9.81 m/s^2
f	-	Frequency
k	-	Spring stiffness

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, comfortable seating in a vehicle is no longer considered a luxury, but as a requirement. A seat that is comfortable in a showroom may have poor dynamic characteristics that make it uncomfortable whilst on road. What is considered comfortable by a user also depends very much on the way a seat is used and how long it has been used. The optimum seat for one vehicle may not be the optimum seat for another vehicle. It is therefore important to consider both static and dynamic comfort when considering the quality of the in-vehicle experience.

Until now, there is still no local study on seat comfort for vehicles in Malaysia. Most of the automotive seats, especially commercial vehicle passenger seats, were designed not accordingly to the average size of Malaysian. For a long journey ride, the seat is important because it will affect the comfort feeling of the passenger. These are the reasons that the seat comfort need to be studied in detail.

A seat is formed by the seat cushion and the seat structure. The characteristics of the seat cushion can be categorized into three: physical, static and dynamic. The physical characteristics of the cushion include seat contour, softness, and seat inclination. Static pressure distribution is the characteristic to be studied in a static condition (vehicle remains static). Both the seat cushion and structure play important roles in affecting the seat comfort in dynamic condition. Therefore, transmissibility test is necessary for the study on dynamic characteristics of a seat, which will be mentioned in the later chapter. In this research, physical

characteristics of the seat cushion were briefly considered during a survey, whereas the seat static and dynamic characteristics were considered and subjected to the objective evaluation.

Static comfort can be evaluated using postural assessment, interface pressure distribution and other standard ergonomic techniques. Dynamic comfort is usually assessed by making vibration measurement on the surface of passenger seats using method based on ISO2631-1, ISO10326-1 and other international standards. These dictate that vibration on the seat must be measured using accelerometer mounted in a semi-rigid disk originally specified by the Society of Automotive Engineers (SAE Sit-pad).

Besides subjective method, SEAT (Seat Effective Amplitude Transmissibility) test and pressure distribution test had been applied onto the local vehicle passenger seat in this research, by using the subjects of average Malaysian size. The automotive seat aimed for both the subjective and objective analysis is the commercial vehicle (bus) passenger seat. The bus passenger seat was chosen as the commercial vehicles are still the main transportation in Malaysia for the people to travel from places to places. Most of the complaints of body pains after a long journey travel usually come from the bus passengers and not the car passengers.

1.2 Objectives

The objectives to be achieved for this research are:

a. To determine factors affecting seating discomfort through subjective method.
b. To determine human-seat interface pressure distribution and Seat Effective Amplitude Transmissibility (SEAT) values of commercial vehicle passenger seat through objective methods.
c. To determine Seat Effective Amplitude Transmissibility (SEAT) values of a proposed seat structure of commercial vehicle for passenger ride comfort.

1.3 Scope of work

The scope of work for this research includes the following:

a. To conduct surveys among public to gain the subjective evaluation towards the design of current existing bus seat. This subjective assessment would be conducted to gather information on existing commercial vehicle seats from public and to evaluate perceived comfort.

b. To carry out a pressure mapping test to obtain the pressure distribution at the human-seat interface under static and dynamic conditions.

c. To carry out vibration test to obtain the Seat Effective Amplitude Transmissibility (SEAT) values through both laboratory tests and field trials.

d. To conduct road trials onto the proposed seat structure to obtain the Seat Effective Amplitude Transmissibility (SEAT) values.