Mansoura Engineering Journal

Volume 20 | Issue 4 Article 8

12-1-2021

The Effect of Vehicle Suspension System Components on the Ride Comfort due to Road Roughness.

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Recommended Citation
Shaaban, Ashraf; Abo-Mossalam, Yousef; Abed, Kamal; and El-Chazly, Nihad (2021) "The Effect of Vehicle Suspension System Components on the Ride Comfort due to Road Roughness.," *Mansoura Engineering Journal*: Vol. 20 : Iss. 4 , Article 8.
Available at: https://doi.org/10.21608/bfemu.2021.162617

Mansoura Engineering Journal, (MEJ), VOL.20, No 4, December 1995

The effect of Vehicle Suspension System Components on the Ride Comfort due to Road Roughness

تأثير مكونات نظام التعليق فى المركبات على راحة الركوب نتيجة عدم إستوائية الطريق

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الملخص العربى

إن الهدف الرئيسى من إجراء هذا البحث هو عمل دراسة نظرية لخصائص مكونات نظام التعليق فى سيارات الركوب ومدى تأثير تغير هذه الخصائص على تلك المركبة إضافة إلى جسمها. من أجل تحقيق هذا الهدف فقد تم بناء وتحليل النموذج الرياضى المقترح والذى يمثل السيارة والسائق معا إضافة إلى العجلتين الأمامية والخلفية للسيارة واضعا فى الإعتبار مكونات نظام التعليق للسيارة. وقد إعتمد على الحاسب الآلى فى تحليل هذا النموذج المقترح وذلك ببناء برنامج للحاسب الآلى معتمدا على مفهوم محددات الإنتقال. وهذا البحث يعتبر واحدا من الأبحاث التى تسعى للوصول إلى بيانات فنية دقيقة للإقلال من التأثير الضار للإهتزازات الميكانيكية على الجسم البشرى إضافة إلى حماية جسم السيارة. ولقد دلت نتائج هذا البحث على أن راحة الركوب تتأثر تأثرا ملحوظا بمدى التغير الحادث فى خصائص نظام التعليق الأمامى والخلفى للسيارة.

ABSTRACT

The aim of the present work is to investigate theoretically the vibration characteristics of the driver body components due to road surface irregularities, when changing the characteristics of suspension system components. A mathematical model representing the vehicle and the driver, and contains five degrees of freedom, has been built-up and analyzed. A computer program has been written based on the transfer matrices concept, and used in the frequency range up to 15 Hz. Finally, this work is considered a step towards obtaining useful technical protection data against vibration. The results indicate that the vibration characteristics of the driver body (ride comfort) are influenced by the characteristics of the vehicle suspension system components.

Key Words,

Vibration, Paved road, Roughness, Human being, Driver, Vehicle body, Suspension system.

INTRODUCTION

Most of the available literature on studying the vibration problem in vehicle/driver has been devoted to stabilize the responses over the vehicle sprung mass without representing the driver as a human being which has a rather complex vibration system.

On the other hand, only simple models representing the vehicle and the driver separately, have been used in the analysis[1].

A Computer - Automated approach for studying the human body vibration is given by Amirouche [2]. This paper presented the transient response of different parts due to a sinusoidal forcing function as well as an impulse function applied to the lower torso in the vertical direction. The simulation closing fits the experimental findings for the sitting relaxed posture, with the maser peak at 4.85 Hz having an acceleration ratio slightly greater than two. At highest natural frequencies of the model in the range of the peaks are not observed due to the high damping coefficient used. In addition, Pope, et al [3] investigated the response of the spring to both impact and sinusoidal excitations in either a relaxed or erect seated posture. Ten subjects (5 males,5 females) were tested using both methods. The models could then be used for designing seating environments, for instance, which would optimize or minimize response of a truck driver to road condition. Troup [4] studied the relationship between human body vibration and shock on the back pain and explained by epidemidegical studies. It was suggested that the impulse character of vibration must be taken into account, and, that for future studies, a method of determining and evaluating vehicle vibration through frequency- response functions was described by Lines [5]. Human transfer function and the absorbed power are used to investigate the effects of vibration on the human being. On the other hand, El-Madany, et al .[6] performed an analytical and simulation study of a tractor-semi-trailer vehicle incorporating active dampers, semi-active dampers and high gain load levers. The potential ride performance improvements offered by different advanced suspension systems, based on the use of active control techniques, are evaluated and compared with the performance of the connection passive suspension.

Three wheels belong to a class of system which are non-holonomic in nature. A mathematical model for such a vehicle has been formulated to investigate the dynamics and the directional stability. A very simple modification, suggested by Hatwel, et al,[7] helped to avoid instability. The steering becomes much smoother with such modification of the drive. In the same direction, Petersen [8] dealt with measurements and calculations of the dynamic behavior of the vehicle to explain the test rig and reports on accuracy of the simulation. The test rig is able to provide earlier, aster and qualitatively better results when testing the strength of chassis/ suspension and body components than by the normal method of testing prototypes on factory proving grounds. The problem of the interaction of the vehicle with road surface was discussed by Abuel-Seoud [9], in vertical direction only. The proposed mathematical models are presented, and the road surfaces irregularities are presented as stationary random excitations. Fore that, the main aim of this paper is to investigate the variation of the damping coefficient, and stiffness factor for the front and rear suspension systems of the passenger vehicles on the ride comfort when these vehicles move on the paved road surface.

VEHICLE/ DRIVER MATHEMATICAL MODEL IDEALIZATION

The difficulties in solving the problem of vehicle /driver vibrations are due to the fact that both vehicle and driver in their mechanical aspects are non-linear and unstable systems with infinite number of degrees-of-freedom.

When constructing the model of the driver, using a mechanical vibration system, one cannot take into account all the factors reflecting the dynamic characteristics of the driver, and should only consider the essential ones. The number of degrees-of-freedom considered, the resonance state and the linearity must be defined. The simulated mathematical model for the vehicle/driver elements according to the standard coordinates system is shown in Fig. 1.

The formulation of the mathematical model of a linear problem, which will be used in this work, considers the vehicle body is connected to the rest of vehicle units through linear spring and viscous damping elements. The vehicle model itself is based on the model and analyses utilized in the discretion of the dynamic behavior of the vehicle body. Therefore, the natural frequencies of the dynamic model used in the analysis are examined briefly. The following assumptions were made in the course of analyzing vehicle/driver performance.

1- The vehicle body, driver body and wheel/hub masses are considered as lumped masses.
2- The tyre never leaves, the ground.
3- The suspension systems, driver body elements and tyres damping values were assumed to be a viscous damping.
4- The suspension working space of the suspension systems is large enough to prevent the possibility of contact between suspension system elements and bumper.
5- The road profile is considered to be the same under the front and rear wheels.

The power spectrum density function of the ground profile is [10]

$$\bar{\delta}r\,(\omega) = (\,R\ (\omega).\ \omega/2\pi)^{0.5} \quad \text{and}$$

$$R\ (\omega) = C/V\,.\,(\omega.V/2\pi)^{-E}$$

where

V is vehicle forward speed

C =3.1 E - 6 and E = 2 , for a paved road surface

RESULTS AND DISCUSSIONS

Damping Coefficient Variation for Front Shock Absorber

In this section the study of the effect of variation of damping coefficient of front shock absorber of suspension system, on the vehicle and the driver in terms vertical and pitching motions, when the vehicle moves on paved road surface at a forward car speed of 60 km/hr is presented. Figs. 2 to 5 indicate that the increase in the damping coefficient above the reference value (384 N.S./m) by 20%, tends to decrease the driver and vehicle body responses in vertical direction, while the increase of the damping coefficient in pitching motion doesn't affect the vibration response. In addition, if reference value is decreased by 20%, the contrary happens in vertical direction, while in pitching motion nothing has changed. Finally, from Figs. 2 to 5 three facts can be deduced, the maximum response values or maximum accelerations vibration responses change when changing the dash-pot (shock absorber) damping coefficient, the frequencies at which these maximum occur have been altered, and the number of acceleration peaks has changed. The figures indicate also, the resonant frequencies of the passenger vehicle which occur at the frequencies corresponding to the peaks. In designing procedure, those speeds must be suppressed or avoided as possible.

Damping Coefficient Variation for Rear Shock Absorber

Figures 6 to 9 show the effect of variation of damping coefficient of shock absorber for rear suspension system on the driver and vehicle body in vertical and pitching directions. These figures indicate that increasing the damping coefficient value (782 N.S./m) by 20%, increases the discomfort of the driver and vehicle body responses, while the decrease of the damping coefficient tends to decrease the vehicle body response, and increase the ride comfort. generally speaking, the increase of the damping coefficient of the rear shock absorber of the suspension system, accomplishes more comfortability for the driver and less vibration effect on the vehicle body. Decreasing of the damping coefficient of the rear shock absorber of the suspension system has the same effect on the comfort ability of the driver and less effect of vibration on the vehicle body. These results are valid for the scope of this invertigation but beyond it, the results may be changed because the relationship between damping coefficient and vibration response is having a parabolic shape.

Stiffness Variation for the Front Suspension System

In this section, the effect of the variation of stiffness of front suspension system is studied on a paved road, and at forward vehicle speed of 60 km/hr. Figures 10 to 13 show the vibration responses of the driver in vertical direction and vehicle body in vertical, pitching directions, and vertical vibration acceleration response on front wheel/ hub mass From these figures, a bad effect on the vehicle body is noticed when increasing the stiffness above its reference value (12480 N/m) by 20% and increases also the number of worst speeds This effect leads to increase the depreciation of the vehicle. On the other hand, the decrease of the stiffness of the front suspension system in vertical and pitching directions below its reference value by 20%, has no effect.

Stiffness Variation for the Rear Suspension System

In this section the effect of the variation of the stiffness of rear suspension system is studied on a paved road and at forward car speed of 60 km/hr Figures 14 to 17 represent the vibration acceleration responses of the same driver and vehicle body components These figures indicate that, the increase of the stiffness value of the rear suspension system above its reference value (15730 N/m) by 20%, has no effect on the vehicle body in vertical and pitching directions. But the decrease of the rear stiffness value of suspension system below its reference value by 20%, has slightly bad effect on the driver and vehicle body in both directions These results are valid in the range of frequency of 0 - 15 Hz, but beyond it this may be change under other consideration

CONCLUSIONS

1- The variation of the damping coefficient of the rear shock-absorber above or below its reference value causes decrease and increase the driver comfortability, respectively

2- The variation of the stiffness value of the rear and front suspension systems have slightly bad effect on the responses of drive and vehicle body

3- The resonant frequencies of the driver/vehicle combination occur at the frequencies corresponding to the peaks at 1.8, 2.3, 8.4, 14 Hz However, in designing procedures these frequencies must be suppressed or avoided as possible

4- Active dampers are very important to be used in vehicle to modify its self depending on road roughness and vehicle forward speed.

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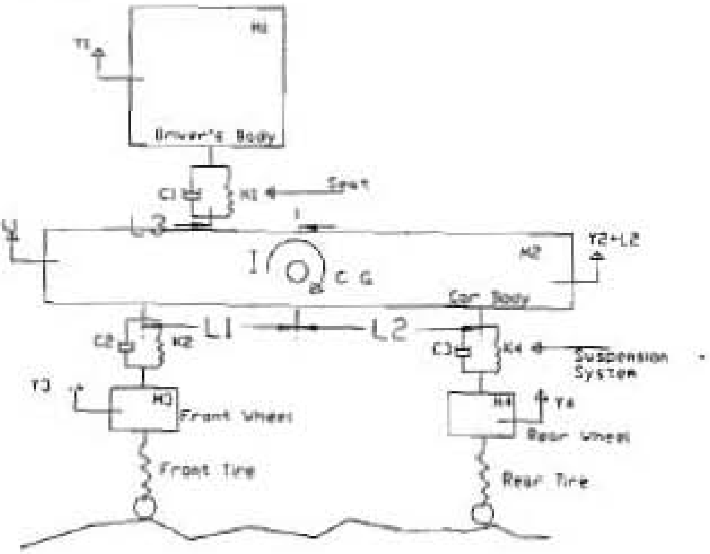

Fig. 1 : A Simulated Mathematical Model For Vehicle/Driver Elements Combination

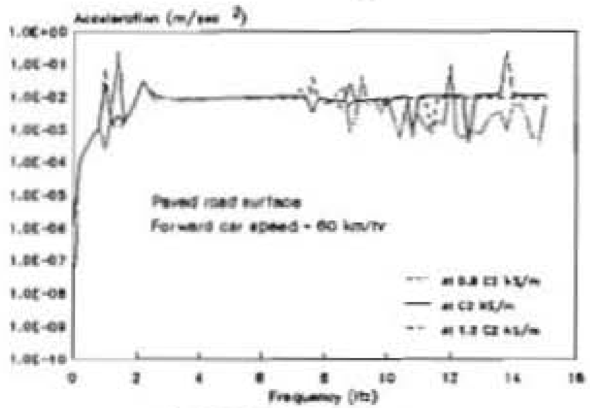

Fig. 2 Vertical vibration responses for different damping coefficient of the front suspension system on driver's body

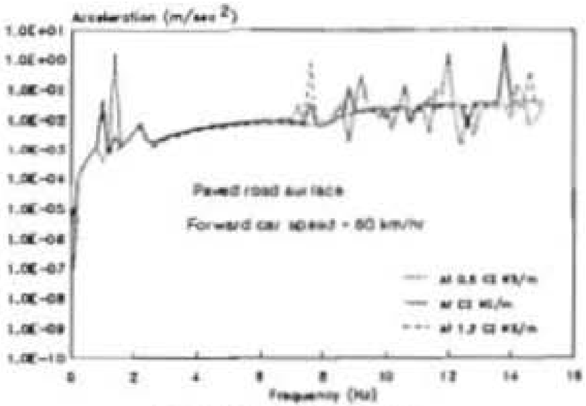

Fig. 3 Vertical vibration responses for different damping coefficient of the front suspension system on car body

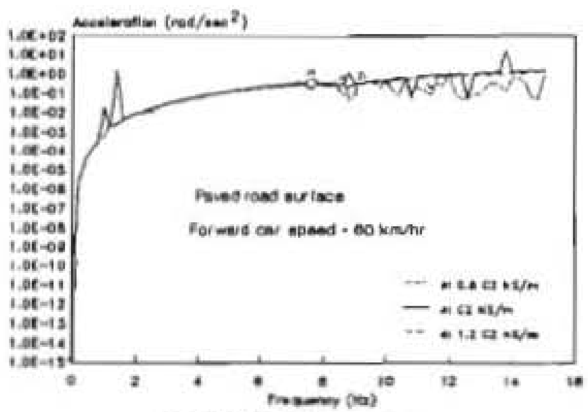

Fig. 4 Pitching vibration responses for different damping coefficient of the front suspension system on car body

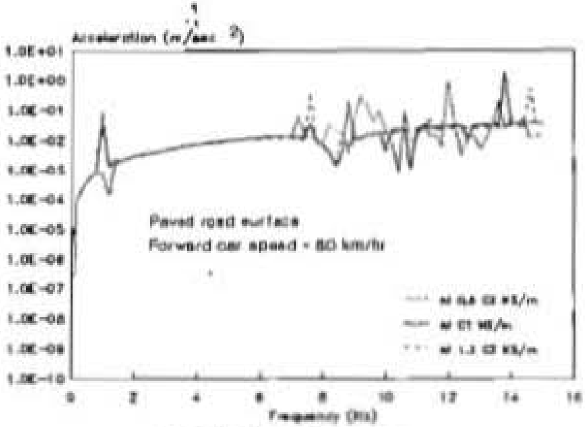

Fig. 5 Vertical vibration responses for different damping coefficient of the front suspension system on Front Wheel

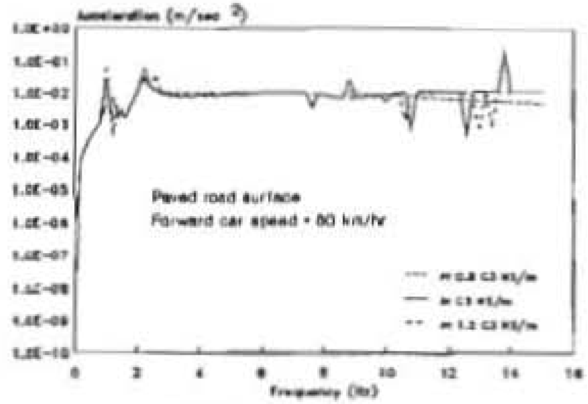

Fig. 6 Vertical vibration responses for different damping coefficient of the rear suspension system on driver's body

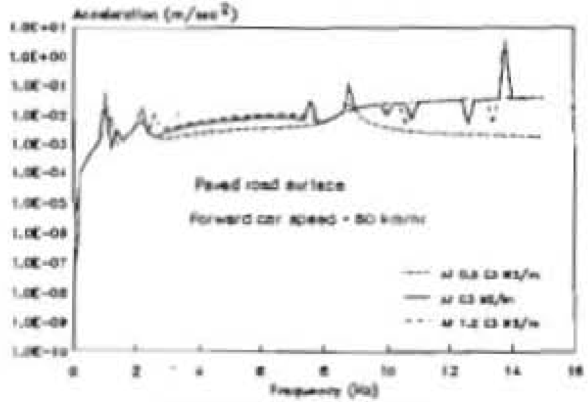

Fig. 7 Vertical vibration responses for different damping coefficient of the rear suspension system on car body

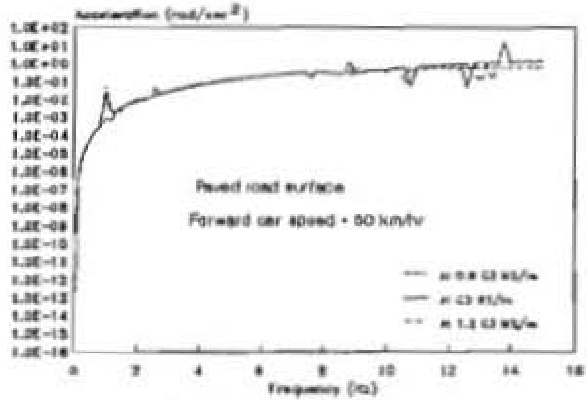

Fig. 8 Pitching vibration responses for different damping coefficient of the rear suspension system on car body

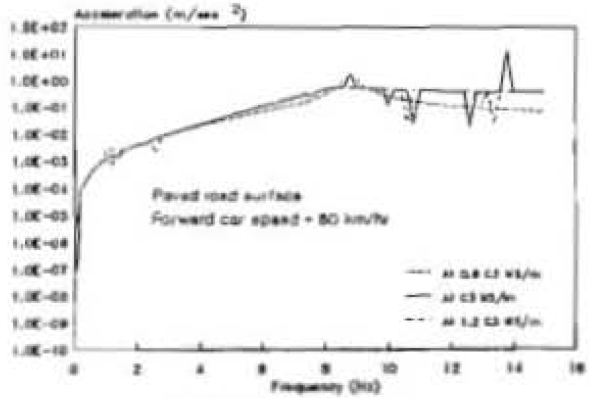

Fig. 9 Vertical vibration responses for different damping coefficient of the rear suspension system on rear Wheel

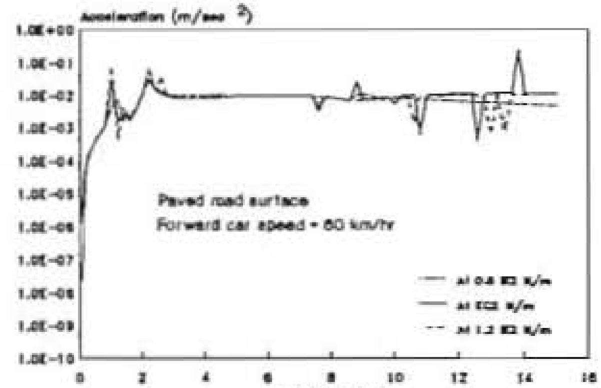

Fig. 10 :Vertical vibration responses for different stiffness factor of the front suspension system on driver's body

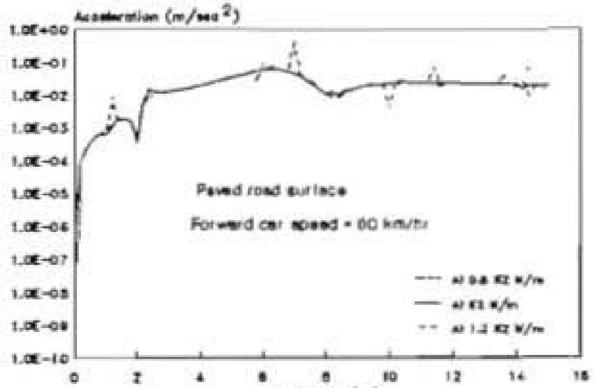

Fig. 11 :Vertical vibration responses for different stiffness factor of the front suspension system on car body

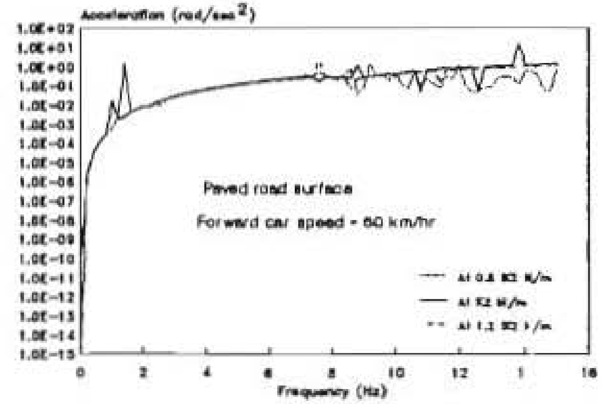

Fig. 12 :Pitching vibration responses for different stiffness factor of the front suspension system on car body

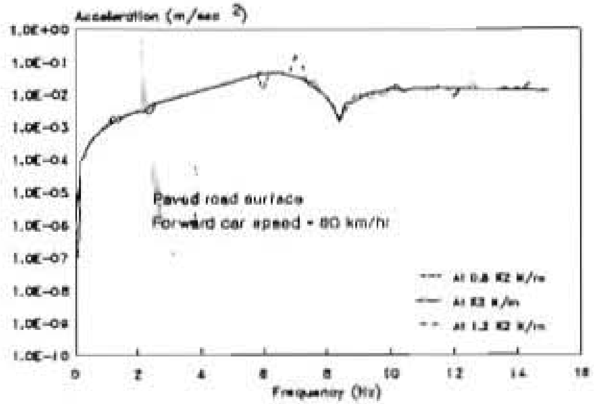

Fig. 13 :Vertical vibration responses for different stiffness factor of the front suspension system on Front Wheel

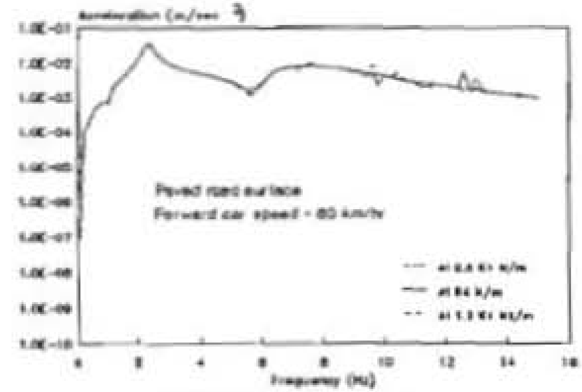

Fig. 14 Vertical vibration responses for different stiffness factor of the rear suspension system on driver's body

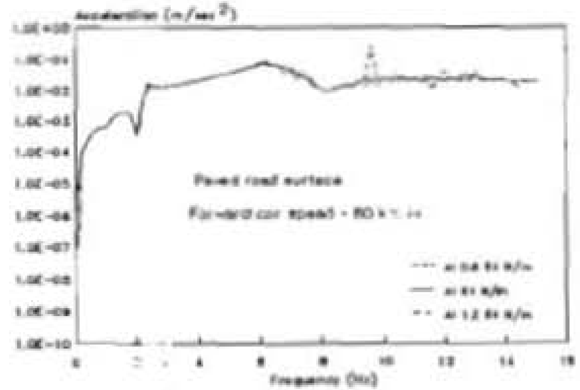

Fig. 15 Vertical vibration responses for different stiffness factor of the rear suspension system on car body

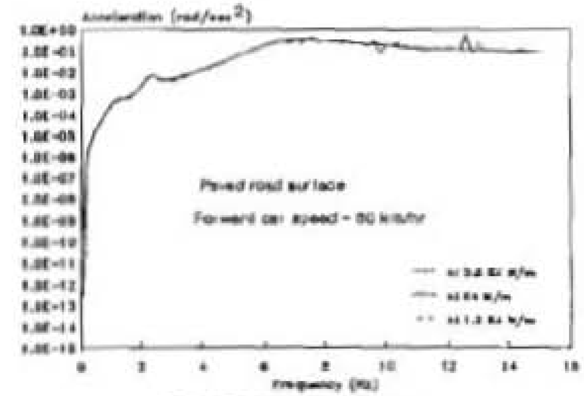

Fig. 16 Pitching vibration responses for different stiffness factor of the rear suspension system on car body

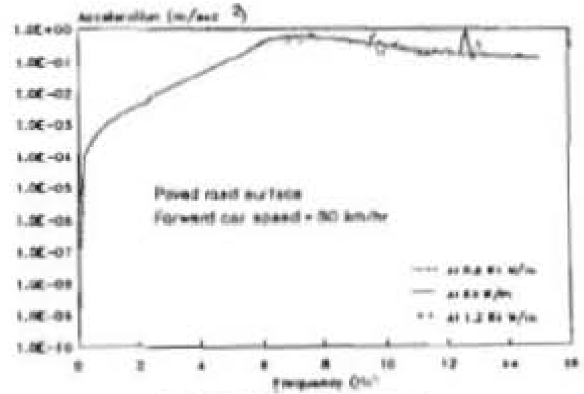

Fig. 17 Vertical vibration responses for different stiffness factor of the rear suspension system on Rear Wheel