Effect Of Vehicle Vibration On Human Body – RIT Experience

Katu U.S., Desavale R.G. and Kanai R.A.

Department of Mechanical Engg.
Rajarambapu Institute of Technology
Sakharale-415414.

Abstract:

Vibration has become an important consideration in engineering. Development of industries and vehicles make the subject even more important. In today's world every family has a car. There for it becomes essential to study the phenomenon of vehicle vibration and it's effects on humans.

Man, as a mechanical system, is extremely complex and his mechanical properties readily undergo change. Effect of vibration on human body as a mechanical and biological system is very complex phenomenon. There is limited reliable information on the magnitude of the forces required to produce mechanical damage to the human body. To avoid damage to humans while obtaining such data, it is necessary to use experimental animals for most studies on mechanical injury. However the data so obtained must be subjected to careful scrutiny to determine the degree of their applicability to human, which differs from animals not only in size but in anatomical and physiological structure as well. It is very difficult to obtain reliable data on the effect of mechanical forces on the performance of various tasks and on subjective responses to these forces largely because of wide variation in the human being in both physical and behavioral respects. Measurement of some of the mechanical properties of men is however often practicable since only small forces are needed for such work.

In the present paper, vehicle vibration analysis is carried out. For this analysis it was proposed to perform vibration tests for different vehicle models. Vibration data for each model at three different road and speed conditions were taken by using Fast Fourier Transform (FFT). The spectrum obtained is used for further analysis for determining acceleration levels at different frequencies. The readings obtained from Fast Fourier Transform (FFT) are used to draw the graphs of frequency Vs acceleration. Firstly the effect of road condition on acceleration level of vibration is predicted with the help of these graphs. The effect of speed condition on acceleration level is also studied. By referring ISO 2631, human comfort charts, the comment is made regarding the acceleration level. Mostly lower frequencies of vibrations ranging from 0 to 80 Hz are affecting on human body. From the results, optimum relationship between acceleration level of vibration and human comfort is drawn.

Keywords: vibration analysis, ergonomics, and tolerance criteria.

INTRODUCTION

The vibrations generated in vehicle produce Mechanical Damage, Physiological Response, & Subjective Responses to humans. Human Engineering deals with various effects of vibrations on the different parts of human body. The present paper highlights the

effect of vehicle vibration on human body. This data is also useful in vehicle design & dynamic analysis of vehicle.

The vehicle vibration produces physiological effect on humans. The evidence suggest that short time exposure to vibration causes small physiological effects such as increase in heart rate, increase in muscle tension long term exposure to vibration causes effects such as disk to spine & effects on digestive system peripheral veins & the female reproductive organ.

When spring supported mass such as that of a motor vehicle chassis is given an impulse, it is set in to vibratory motion & it keeps on vibrating until the energy of the impulse completely dies out in overcoming damping forces. There are different sources of vibration of vehicle i.e. road roughness, the unbalance of the engine, whirling of shafts the cam forces & tensional fluctuations etc [1].

Depending upon the cause the vibration may be free or forced. The free vibration may occur when the vehicle passes over an isolated irregularity in the road surface, which may die off as a result of dissipation of energy in damping. Then the forced vibration may result when disturbances occur persistently such as passing over obstacles on a proving road. In this case even if there may be damping, the vibration may persist & build up an undesirable level.

In reality an automobile in its conventional form represents a very complicated vibration system. It is we known that a rigid mass free in space has a six degrees of freedom; three translation, such as 1) Bobbing up & down 2) Swaying back a form 3) Moving forward & backward & Three rotational such as 1) Rolling about longitudinal axis, 2) Pitching about a lateral axis & 3) Yawing about vertical axis, since automobile has three such masses A) The body B) The trot & rear axles & C) Eight distinct spring (Four spring & Four tyers), therefore it has eighteen degree of freedom [1].

PREDOMINANT SOURCES OF VEHICLE VIBRATION

Road Roughness

Depending upon cause, the vibration may be free or forced, the free vibration may occur when the vehicle passes over an isolated irregularities in the road surface, on the other the forced vibration may result when disturbances occur persistently such as passing over obstacles on a proving road.

The road roughness, causes vertical acceleration of vehicle because of which passenger gets the proving and this adds to their discomfort, when a vehicle is being drive over the road, the oscillations of its spring have frequencies which has not only dependant on the frequency at which road impulses or bumps are encountered but also on the relation between the spring stiffness and the mass of the spring part of vehicle, the real description of road is random in nature. Therefore the statistical description of the track will be more appropriate.

Vibration Due To Engine Unbalance

The reciprocating parts of the engine may cause vibration of an automobile due to the periodic disturbances.

Whirling of Shafts

In actual practice, a rotating shafts carries different mountings and accessories in the form of gears, pulleys etc. The center of gravity of pulley or gear is at a certain distance from the axis of rotation and due to this the shaft is subjected to centrifugal force. This force will bend the shaft, which will further increase. The distance of center of gravity of pulley or gear form the axis of this correspondingly increases the value of centrifugal forces which will further increase the distance of center of gravity from the axis of rotations. This effect is cumulative and ultimately shaft fails.

EFFECT OF VEHICLE VIBRATION ON HUMAN BODY

While dealing with the effects of vehicle vibration on humans it is necessary to study the physical characteristics of body. The effect on body due to vibrations is mechanical, physiological & subjective responses. It also affects on the performance of human [2].

Mechanical Damage

Damage is produced when the accelerative forces are of sufficient magnitude. Chronic injuries may be produced by vibration exposure of long duration. In practice such effects are usually found after exposure to repeated blows or to random jolts shaking in vehicle on rough surface, give rise to irregular jolting motion, acute injuries from exposure to these situation are race but have resulted from repeated impact injuries to the spinal column, including fracture of vertebrae are reported due to vehicle vibration pathological changes have been observed in the spine of operators of cars & on the rood trucks & other occupations involving chronic exposure to whole body vibration such exposure to whole body vibration, such exposure is also accepted as a risk factor in the development of low back pain minor kidney injuries are occasionally suspected & rarely to act of blood may appear in urine due to the vehicle vibration.

Physiological Responses

It is difficult to separate out effects due to vibration from effects due to sitting all-day or manual loading & unloading. The vibration of frequency range 4 to 10 Hz procures pain in the chest after backaches seem to occur very particularly at 8 to 12 Hz Headaches, eye strain & irritations in the intestines and bladder are usually associated with frequencies between 10 to 20 Hz.

Subjective Responses

The subjective response most often assessed in the vibration studies is comfort; Comfort of course, is a state of feeling & so depends in part on a person experiencing the situation.

People are most sensitive for vertical vibrations between 5 & 16 Hz & to the lateral vibration between about 1 & 2 Hz. Women are more sensitive than men to vertical vibration above about 10 Hz. Most responses of seated subjects implicated the lower abdomen at 2 Hz moving up to body at 4 & 8 Hz, with most responses implicating head at 16 Hz. At 32 Hz the responses are divided between the head & lower abdomen.

PERFORMANCE EFFECTS OF VIBRATION

Vibration appears to affect mainly visual & motor performance.

Visual Performance

Visual performance is generally impaired most by vibration frequencies in range of 10 to 25 Hz .The amplitude of vibration seems to be key factor & the degradation in performance is probably due to movement of image on the retina, which causes image to appear blurred, for frequencies below 3 Hz. At these frequencies a person can engage in compensatory head & eye movements that stabilize the image on the retina. The characteristics of material being viewed have significant effect on performance in the vibrating situation [3].

Motor Performance

The research has demonstrated that vibration has effects on tracking performance & seated subjects. The effects of vibrations are somewhat dependant on difficulty of the tracking task, type of display & type of controller used. For example the use of side stick & arm support can reduce vibration induced error on by as much as 50 percent compared with the conventional centre mounted joysticks. Detrimental effects of vertical sinusoidal vibration generally occur in the 4 to 20 Hz range with the acceleration exceeding 0.2 g. These conditions can produce tracking errors up to 40 percent greater than under no vibratory control conditions.

Neural Processes

Tasks that involve primarily central neural processes, such as reaction time, monitoring & pattern recognitions, appear to be highly resistant to degradation during vibration. Vibration between 3.5 & 6 Hz can have an altering effect on subjects engaged in boring vigilance tasks. Within this frequency range tensing the track muscles attenuates the amplitude of shoulder vibration [4].

EXPERIMENTAL FACILITIES AND PROCEDURES

In this present paper, it was decided to select four different cars, which are Maruti 800, Indica (Diesel), Fiat uno & Maruti Zen (vx). For each car, three different road conditions were selected and for each road condition three different speed conditions were selected. The road conditions selected are Rough Road, State Highway, National Highway and three speed conditions are 40, 60 and 80 kmph. For these speed conditions the readings were taken with the help of FFT Analyser

EXPERIMENTAL SETUP

For experimental setup metal disk, FFT, and accelerometer were taken. For each car model metal disk is mounted at the center of front seat (near the drivers seat) as shown in Fig. 1. The metal disc is rigidly fixed on the seat with the help of adhesive material.

Location of Measuring Point

As per ISO 2631 [5] transducer should be located so as to indicate the vibration at the interface between the human body and the source of its vibration. Vibration, which is transmitted to the body, should be measured on the surface, between the body and that surface.

ISO 2631 uses three principle areas for seated person supporting seat surface, thus its back and the feet. In this present work, accelerometer is mounted at the supporting seat surface.

EXPERIMENTAL PROCEDURE

Firstly metal disc is fixed on front sheet and with the help of wax accelerometer is mounted on it. Out of three road conditions firstly rough road is selected on each road; three speed conditions are selected (40 Kmph, 60 kmph, 80 Kmph). Then on rough road the car is run for constant speed of 40 Kmph and then readings are taken. After this the readings are taken for 60 kmph & 80 Kmph. Then next road condition is chosen i.e. state highway. Again readings are taken for three speed conditions i.e. 40 Kmph, 60 Kmph and 80 Kmph Lastly next road condition is selected i.e. National highway. At this road condition the readings are taken for three-speed condition. This procedure is repeated for other three cars. The data obtained from FFT analyzer is translated by using RT utility software. The data contains frequency & acceleration of vibration at particular time span. The frequency of vibration is taken on x-axis & acceleration level of vibration is taken on Y-axis. The acceleration is in dB. The data for particular time span is selected and graphs are plotted with the help of MS – excel Software. Finally these graphs are used for analysis work.

RESULT AND ANALYSIS

The data obtained from the FFT is then translated with the help of R- utility 32 software. The translated data is in the form of the frequency and corresponding accelerations of vibration at that particular time span. Then readings at particular time span 0.96 sec were taken for plotting graphs. The graphs were plotted in Ms Excel software. The Frequency is taken on x-axis in Hz and acceleration is taken on y- axis in dB.

1. Effect of Road Condition on Acceleration Level of Vibration

Mainly lower rang frequencies are affecting on the humans. In the present analysis, it was decided to consider frequencies up to 25 Hz. Then the acceleration is averaged up to frequency 25 Hz. The graph of average acceleration *vs.* road conditions is plotted. While plotting graph the speed condition remains constant, which are 40 kmph, 60 kmph, 80 kmph.

By observing fig. 2, for Maruti-800, and for smooth road at 60 kmph, acceleration level is minimum & is increasing towards the rough road. For Indica for smooth road acceleration level is minimum & it increases as roughness of road increases. For fiat-Uno, acceleration level increases from smooth road to rough road. Acceleration level for rough road is maximum than other cars. For Zen, acceleration level increases as roughness of road increases. By observing fig. 2, it is clearly indicated that as road smoothness increases acceleration level decreases at 60 kmph. The actual vibration spectrum is shown in fig. 4.

2. Effect of Speed Condition on Acceleration Level of Vibration

For analyzing effect of speed condition on acceleration level, speed condition of vehicle is taken on x-axis & average acceleration level corresponding to that speed is taken on Y-axis & then graphs are plotted.

By observing fig. 3, it is clear that the acceleration level for of all cars increases form 40 to 60 kmph & then decreases as speed increases for state highway. For Uno,

change in acceleration level is rapid & for Maruti the change is small. For Zen acceleration increase rapidly from 40 kmph to 60 kmph & it slowly decrease as speed increases.

3. Effect of Acceleration Level of Vibration on Humans

It is observed form ISO 2631 (Human comfort chart) and Table 2 that the critical range-affecting humans is within 4 to 8 Hz. For analyzing the effects of acceleration levels of vibrations on humans, it is decided to take the acceleration levels at the frequencies 4 to 8 Hz. Fig. 5 gives the acceleration level for rough road at speed 60 kmph.

Table 3 shows the acceleration level for different car models for state highway. For medium roads the acceleration levels are from 0.07 to 0.4 therefore the man sitting in car feels fairly uncomfortable. It is observed that Zen is more comfortable for medium roads. For is smooth roads the acceleration levels are from 0.06 to 0.1, therefore the man sitting in car feels a little uncomfortable.

4. Effect of Acceleration Level on Humans Depending Upon Exposure Limit

Observing the acceleration levels for frequencies 4 to 8 Hz & comparing it with the standard human comfort chart it is observed that, for rough road the overall acceleration level is 0.3g hence after 30 to 35 min exposure the driver in car will feel uncomfortable. For medium road (state highway) the overall acceleration level is 0.2g; therefore driver will feel comfortable. For smooth road (National Highway) the overall acceleration level is o.1 g therefore it is observed that after 90 min to 2 hrs the driver in car will fell uncomfortable.

CONCLUSIONS

This present paper the experimentation is carried out to study effects of vehicle vibration on humans through vibration analysis and feasibility of it, practically investigated. The vibration Spectrum obtained for different cars at different speed are presented in previous chapter based on which following conclusion are drawn

1. As road condition varies rough to smooth the acceleration level decreases, for Zen acceleration level increases.
2. As speed increases acceleration level also increases up to certain limit (i.e. from 40 to 60 Kmph) then the acceleration level decreases (from 60 to 80 Kmph)
3. For rough road the acceleration levels are higher (0.2 to 0.7 g) therefore the man seating in vehicle feels very uncomfortable & fiat – Uno is more comfortable in rough roads.
4. For medium roads (state highway) the acceleration levels are from 0.07 to 0.4 the driver seating in vehicle feels fairly uncomfortable & Zen is more comfortable in medium roads.
5. For smooth roads the acceleration levels are from 0.06 to 0.1, therefore the driver in car feels a little uncomfortable.
6. For rough roads if the driver is exposed more than 30 to 35 minutes he will feel uncomfortable.
7. For medium roads if the driver is exposed more than 30 to 35 minutes he will feel uncomfortable.
8. For smooth roads if the driver is exposed more than 90 to 120 minutes he will feel uncomfortable.

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3-4 Hz	Resonance in cervical vertebrae (neck).
4 Hz	Peak resonance in lumbar (upper torsos) vertebrae
5 Hz	Resonance in shoulder girdle
20.3 Hz	Resonance between head & shoulders
60 Hz	Resonance in eyeballs.

Table 1: The resonant frequencies of various body structures for a sitting person

Vibration	**Reaction**
Less than 0.315 m/s^2	Not uncomfortable
0.315 to 0.63 m/s^2	A little uncomfortable
0.5 to 1 m/s^2	Fairly uncomfortable
0.8 to 1.6 m/s^2	Uncomfortable
1.25 to 2.5 m/s^2	Very uncomfortable
Greater than 2 m/s^2	Extremely uncomfortable

Table 2: Range For Comfort

ACCELERATION OF VEHICLE(g)			MARUTI- 800					INDICA				
ROAD	SPEED	FREQ. (Hz)	4	5	6	7	8	4	5	6	7	8
STATE HIGHWAY	40		0.09	0.12	0.17	0.22	0.31	0.08	0.08	0.11	0.17	0.34
	60		0.07	0.1	0.16	0.25	0.4	0.12	0.17	0.25	0.3	0.5
	80		0.05	0.09	0.17	0.28	0.44	0.11	0.14	0.2	0.31	0.4

ACCELERATION OF VEHICLE (g)			FIAT- UNO					MARUTI-ZEN				
ROAD	SPEED	FREQ. (Hz)	4	5	6	7	8	4	5	6	7	8
STATE HIGHWAY	40		0.07	0.1	0.17	0.2	0.4	0.05	0.06	0.08	0.13	0.2
	60		0.09	0.1	0.14	0.22	0.4	0.09	0.1	0.22	0.38	0.4
	80		0.13	0.16	0.2	0.36	0.5	0.09	0.08	0.09	0.13	0.3

Table 3: Comparison of Acceleration Levels for different car models

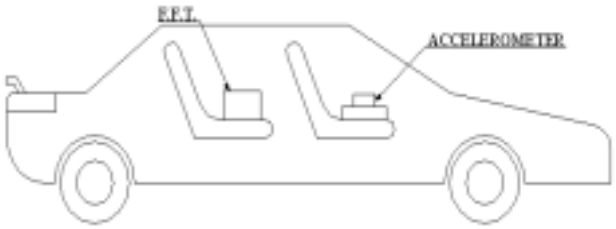

Fig 1 Experimental Set up

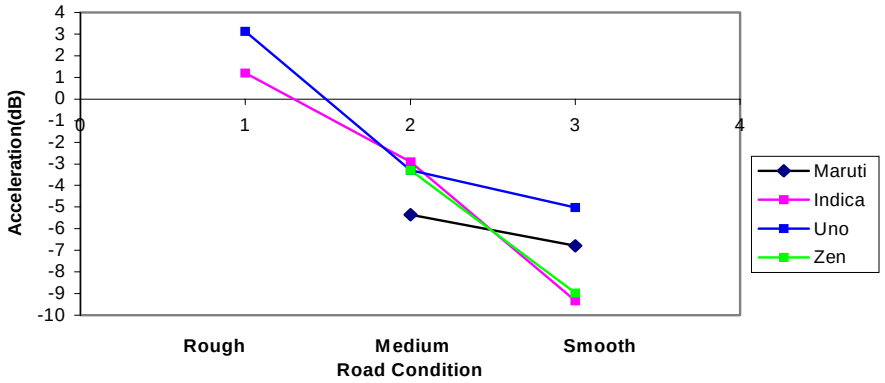

Fig. 2 Graph of road condition vs. avg. acceleration at speed 60 Kmph.

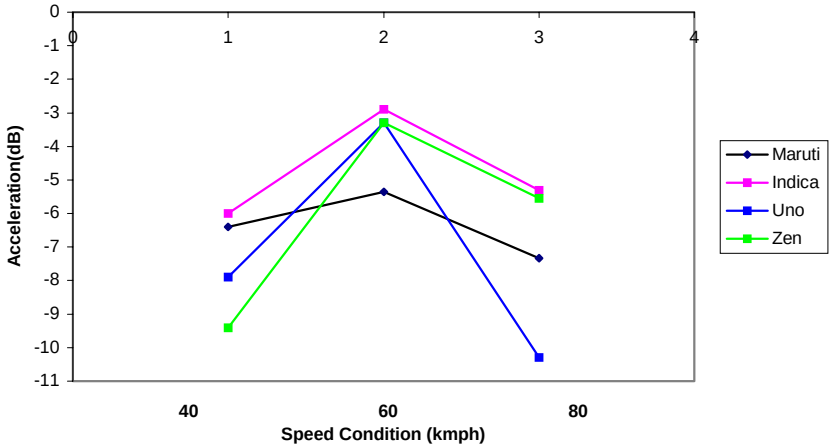

Fig. 3 Graph of speed condition vs. avg. acceleration at state highway

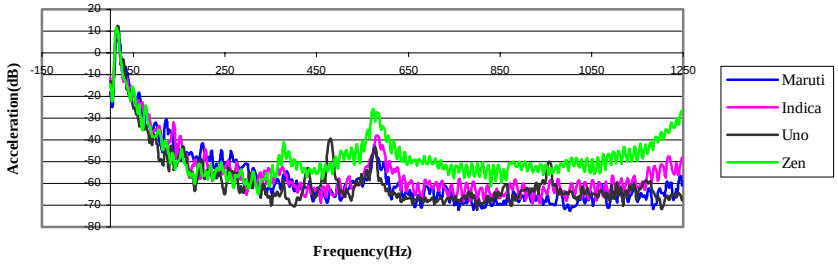

Fig. 4 Acceleration Levels for State Highway at Speed 60 kmph

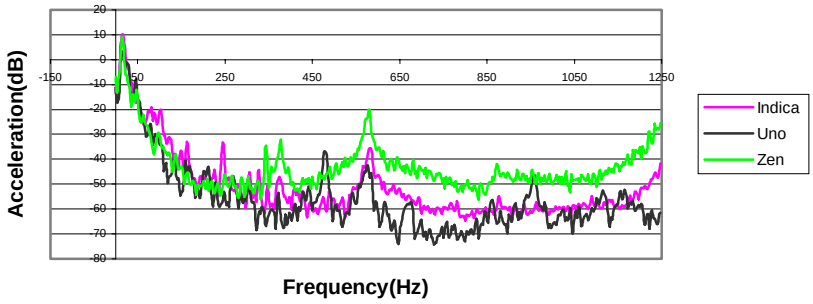

Fig .5 Acceleration Level for Rough Road at Speed 60 Kmph