

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

Effect of Vibration on Human Body due to Machinery used in Construction Industry

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ABSTRACT: As per the latest economic survey construction industry is the second largest and rapidly growing sector in India next to agriculture and it contributes 11% of India's GDP. Also the work force in construction sector is expected to surpass 52 million by 2022. As per International labor organization (ILO) India has the highest accident rate in construction sector and 165 out of every thousand workers are injured on the job. Employees are involved in handling of various machineries through which vibration is transmitted to them. Employees are exposed to vibration while handling heavy duty equipment in the construction industry which leads to acute and chronic health effects. The major machineries employed in construction industry which transmits vibration to human body are excavators, bulldozer, backhoe loader, forklift, mobile cranes etc. The vibration causes several ailments depending upon several factors like duration of exposure, frequency of vibration, amplitude of vibration etc. This review study is based upon the data collected during the operation of vibration generating machineries using accelerometer which produces electrical signals proportional to the vibration generated. Further the amplitude and frequency are obtained by connecting the accelerometer to Lab View software with help of the data acquisition card. The graphical data during testing from several machineries is compared with standard values and control measures are recommended to minimize the impact of vibration on equipment operator.

KEYWORDS: Construction machinery, health effects, vibration, amplitude, frequency

I. INTRODUCTION

Vibration is a major physical hazard that prevails in several sectors like mining, agriculture, industrial operations, public utilities, but it is predominant in construction sector. The construction sector majorly comprises of forced vibrations whose damping occurs over a long period. Whole Body Vibration (WBV) and Hand-Arm Vibration (HAV) are the two types of vibration found. When the human body is over a vibrating surface, the Whole Body vibration occurs, e.g. transportation by any means, working amidst industrial machineries. Hand-Arm Vibration occurs when the vibrations transmit through the hands and arm of the individual, e.g. rotatory or vibrating equipments are held by hand during operation. The factors that determine the human response or the effect on humans are frequency, magnitude, duration of vibration, direction. Magnitude of vibration is measured in terms of acceleration (ms^{-2}), velocity (ms^{-1}) and displacement (m). For convenience, in practice, the root mean square value of the acceleration is taken (ms^{-2} r.m.s) which is the average value of the acceleration of the vibration. Average values or RMS values of acceleration for mobile cranes, tractors, dumpers, forklifts and excavators are 0.67 ms^{-2} , 0.72 ms^{-2} , 0.73 ms^{-2} , 0.82 ms^{-2} and 0.91 ms^{-2} respectively [2]. The frequency of vibration is measured in terms of Hertz (Hz) which is cycles per second. Studies state the Whole Body Vibration with frequency as low as 0.5 to 80 Hz and Hand-Arm Vibration with a frequency range of 6.3 to 1250 Hz can cause health effects [3]. Long term exposure to WBV leads to disorders relating to lower back pain, motion sickness, reproductive organ damage, etc. The ailments that can be caused due to HAV are White finger where the individual suffers inadequate flow of blood to the fingers, carpal tunnel syndrome where the worker experiences contraction of nerves in the wrist, muscle and joint damage in hands and arms. These chronic effects can be minimized by shortening the duration of exposure, usage of vibration resistant protective equipment and job rotation of the employee. The International Standard provides an exposure limit of $40\text{-}80 \text{ ms}^{-2}$ for duration of 8 hours. Research is

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done to assess the factors of vibration in Indian scenario and compare them with the standard values. The result obtained will be helpful in determining the control measures and reduction procedures of the vibrations in construction machineries to an allowable limit.

II. REVIEW OF LITERATURE

Whole body vibration was experimentally verified in the year 2010 in the excavators employed in rock breaking operation. Questionnaires were distributed to the operators to know the health effects during operation of excavators. It was very clear that most of the operators suffered from chronic lower back pain in the rock breaking work using excavators. It was revealed that operators were exposed to vibration for extended periods. Vibration was measured by mounting sensors such as accelerometer in the operator's seat, back-seat and the feet during rock breaking job. Vibration exposure value was found to be 62.1cms^{-2} to 193.2cms^{-2} and it was proved that there is higher chance of suffering from lower back pain in the rock breaking operation using excavators as the vibration exposure limit is greater than the International standard ISO 2631.

In the year 2015 Adam P. Cann conducted a study in heavy duty equipment employed in construction sites. Fourteen types of equipment's were selected and they are divided into two categories viz., stationary and mobile. Accelerometer was mounted on three different axes to measure the vibration and exposure of vibration was tested in different soil condition such as hard, soft and muddy. Eight out of 14 types of heavy duty equipment exceeded the vibration dose value and it has higher risks of developing chronic health effects.

III. EFFECT OF VIBRATION

Human is exposed to whole body vibration via.

- Feet
- Back and seat
- Supporting surface

Operators are at risk due to whole body vibration and often suffer back ache due to shock and jolts. Other causes of whole body vibration are poor design, posture, and longer duration in seat, manual handling, improper access and non-occupational causes. Approximately 20,000 people are exposed to vibration beyond Exposure limit value in the construction sector. The consequence of exposure to random or transient vibration is degradation of health, impaired activity, high level of discomfort and motion sickness. The prolonged exposure of vibration weakens internal organs, lower back pain, affects digestive and reproductive system. Exposure to high levels of HAV ruins blood vessels, decreases blood supply, and it may also affect bones and muscles leading to arthritis.

IV. MATERIAL REQUIRED FOR VIBRATION ANALYSIS

Hardware such as accelerometer or vibration sensor or transducer, DAQ processor, to convert the digital to analog signal & prototype of heavy duty equipment or actual construction machineries are required for the study of whole body vibration. DAQ has different modules and it has four different channels in which the transducer is connected and it is further connected to the PC consisting of Lab VIEW programming (Software). Real time vibration can be measured using Lab VIEW and interpretation of the result is easier with the graphical output.

V. EXPERIMENTAL

Vibration in the construction machinery can be studied by the usage of virtual instrumentation software such as Lab VIEW, MATLAB, etc., Lab VIEW is chosen for the study as the interface is far better than other virtual instrumentation software and it is more accurate for the condition monitoring of the equipment. Accelerometer is mounted on the operator's seat of heavy duty equipment such as excavator, scraper, etc., and vibration measured. The Accelerometer is connected to the NI DAQ card which further connected to the PC to interface with Lab VIEW.

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Accelerometer which acts as a vibration sensor is placed on specific location such as operators' seat, Operators' foot and the back seat. The output is obtained both in terms of velocity and acceleration in the software in time domain. By the use of the FAST FOURIER TRANSFORM analyzer option in the Lab VIEW software it is possible to convert the time domain values to frequency domain. Hence the peak RMS acceleration can be obtained at particular frequency at different locations. Vibration transmission is higher from the floor of the equipment to leg compared to the vibration transmission from the seat to the operator. The seat with better cushioning dampens the vibration to a large extent and reduces the lower-back pain to the operator. The peak frequency domain graph in the Lab VIEW software indicates the vibration amplitude on the floor to the equipment is higher than the vibration on the seat back due to the presence of cushioning which helps in reducing the adverse health effects.

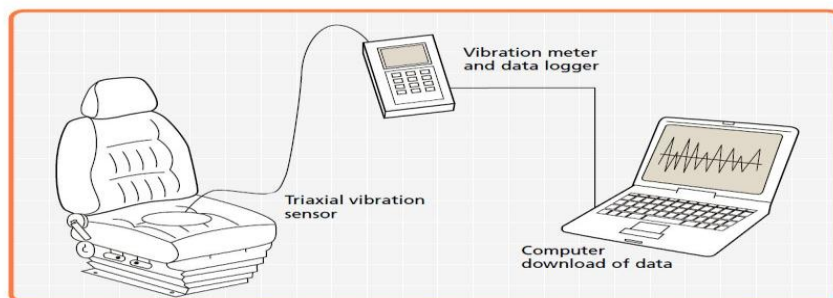
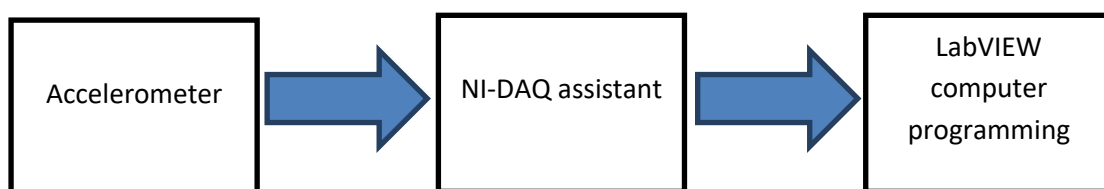


Fig. 1 Experimental setup



VI. RESULTS AND DISCUSSION

Vibration can be reduced by referring the heavy duty equipment manufacturer manual or handbook where the exposure limit is specified. Job rotation could be a basic solution to reduce the adverse health effects due to vibration. Since most of the equipment is hydraulically operated, chance of vibration is high due to the continuous retraction in the hydraulic system. Predictive maintenance is the only solution to control the health effects due to vibration from the rotating and reciprocating part of the construction machinery. Portable vibration meter can be used to check the vibration generated from the machineries. The exposure action value of 0.5ms^{-2} should be monitored in the construction machineries and action such as extra cushioning to increase the damping capacity, lubricating of the rotating part in the machinery, using of proper PPEs, job rotation etc. must be deployed to avoid the health risks due to vibration. Exposure limit value should be 1.15ms^{-2} , which is the maximum amount of vibration a person may be exposed in a single day. Besides the above measures, risk assessment should be carried out based on the task to be done using construction equipment. Finally the health of the employee shall be monitored periodically to detect the health effects due to vibration.

Reduction of whole body vibration

When the latest model of construction machineries is bought ensure that the vibration emission for a given performance is lower. Construction machineries has to be employed in smooth road surface rather than using it in an

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uneven surface. This will have a greater effect in reduction of vibration transmission to the human body during operation of the equipment. The construction machines should be provided with suspension seats to reduce the vibration to a minimum level. Seating information must be gathered from the manufacturer before it is installed. Following are the instances of time to reach the EAV and ELV for various magnitude of hand arm vibration. When the vibration exceeds the EAV necessary steps has to be taken to lessen the exposure to the operator's by introducing vibration damping material in the equipment or by aligning the assembly offset in case of rotating machineries. Also the exposure limit value should never exceed the standard value specified.

Table 1 Examples of time required to reach the EAV and ELV for HAV [7]

Vibration magnitude (cms ⁻²)	250	350	500	700	1000	1400	2000
Time to reach Exposure Action Value (min)	480	240	120	60	30	15	7.8
Time to reach Exposure Limit Value (min)	<1440	960	480	240	120	60	>30

VII. CONCLUSION

The study comprised of vibration tests to determine the WBV in the field from several equipment's like excavators, crawler loaders, scrapers, backhoes, off-road dump trucks, skid steer vehicles, wheel loaders, ride-on power trowels, bulldozers etc. Results indicate that the mobile equipment have a greater part in WBV exposure than the stationary equipment. This gives a possibility for presence of lower back ache and other muscular-skeletal injuries like joint ache, leg ache, etc. The present scenario confirms the study that huge numbers of construction machinery operators are susceptible to vibration.

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