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Effect of vibration while a human subject comes in contact with vibration conditions

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Abstract : Most of the passengers travel in standing postures by industrial vehicles. To reduces the discomfort that is experienced by the human body when exposed to vibration conditions with different magnitude of frequencies and acceleration generated during traveling, walking, reading, working, etc. and also, it has been found that standing posture of the human body is very sensitive. In this study, conversion of complex Indian male human subject of mass 76 kg in standing posture into 3-D CAD model of the human subject, that has been prepared using physical dimensions by Solid Works 2016 to perform harmonic response analysis using FEM when exposed to acceleration with frequency range 2-20 Hz. In boundary condition, no external load has applied on straight human body and feet have as fixed support in ANSYS 16.0 software as feet have assumed to be in complete contact with a ground. It has been observed that maximum transmissibility in the human body is exposed in a vertical direction at acceleration of 1 m/s^2 with a soaking ratio of 0, 0.2, 0.3 and 0.5. The resonance frequency obtained is 6 Hz, which is in validation with existing literature. Then the effect of vibration seems to be more in fore-and-aft direction i.e. at natural frequency of 4 Hz with the transmissibility of 1.90. Results also help to design the comfortable supports for day-to-day use of human subject and it will also help to predict injuries or discomfort that will be experience by the human subject. The results found to be in good relation with existing literature and will also, help reduce the effect of resonance.

***Index Terms* - Standing Posture, FEM, Harmonic Response, Frequency, Damping, Transmissibility**

I. INTRODUCTION

The human body is normally subjected to WBV most commonly at workplace and daily activities. Most of the passengers travel in standing postures by industrial vehicles, public transport system such as tram, commuter train, city buses etc. While travelling, passengers spend their valuable travel time in different activities such as working with laptop, operating mobile communicating device, chatting, reading etc. (Shibata, 2015). And also, power hand tools used by an industrial persons have significant vibration effects. The prolonged exposure to vibration causes different type of industrial illness such as undue stress, injuries and discomfort (Randall et al., 1997). Supported structure that are designed for daily use of human body excites the dynamic response and driving point dynamic response such as apparent mass & mechanical impedance influences the dynamic interaction of standing human subject with the supported structure (Matsumoto and Griffin, 2011). To control discomfort caused by vibration of standing human body it becomes necessary to understand the sensitivity of human body to vibrations (Thuong and Griffin, 2011).Number of studies have been contributed by researchers to observe biodynamic response of human body when exposed to different vibration conditions in different postures by considering variant anthropometric data.

(Randall et al., 1997;Matsumoto and Griffin, 2000; Matsumoto and Griffin, 2003;Kiiski et al., 2008; Matsumoto and Griffin, 2011) worked on human subject vibrations using variant biodynamic models.(Thuong andGriffin, 2011;Thuong and Griffin, 2012;Tarabini et al., 2014;Shibata, 2015) determined the discomfort of human subject in standing posture. (Goggins et al., 2016;Xu et al., 2017; Marchetti et al., 2017;Zhang et al., 2015) measured transmissibility of human subject when exposed to vibrations. (Zheng and Brownjohn, 2001;Baker and Mansfield, 2010;Griffin, 2004;Rahmatalla and Meusch, 2014; Muir et al., 2013; Dong et al., 2013) studied the response of human subject when exposed to WBV. (Paddan and Griffin, 1993; Nigam and Malik, 1987; Singh et al., 2014;Subashi et al., 2008; Bartz, 1975)studied a response of human subject using LPM. (Zhang et al., 2015) hasmodelled Seat and human subject using FEM and transmissibility has been found. (Dutt, 2015) has analysed mesh effect on result for a cantilever beam using FEM. (Kitazaki and Griffin, 1997) used FEM to develop 2-D model of human. (Singh et al. 2016) presented an experimental study, and twelve humansubjects in sitting posture have been exposed to vertical harmonic vibrations.

Lot of work has been performed as per available literature regarding biodynamic response of human subject using different anthropometric data and vibration conditions. Researchers have worked in this area using experimental and analytical approach as compared to FEM. Taking this case into consideration, a harmonic response analysis has been performed using 95th percentile anthropometric data of Indian male population using FEM and results obtained are in validation with experimental results.

II. METHODOLOGY

A harmonic response analysis using FEM has been performed on Indian male subject of 76 kg mass that corresponds to 95th percentile anthropometric data of Indian male population. Acceleration has been applied at feet of human subject (i.e. base excitation) its effects observed at head. A response of human subject has been observed at acceleration of 1 m/s^2(Singh et al. 2016) applied in different directions i.e. fore and aft, vertical and lateral directions. Transmissibility (i.e. the transmission of vibration from feet to head) is calculated for each direction and damping ratios i.e. 0.2, 0.3 and 0.5 (Kitazaki and Griffin, 1997). Transmissibility isdefined as a ratio of any of accelerations, forces, velocities or displacements (Griffin, 1990).A 3-D CAD model of human subject has been modeled using physical dimensions available in existing literature (Chakrabarti, 1997) using Solid Works 2016. A complex structure of mass 76 kg male human body have been modeled in 3-D CAD model using physical dimensions available in exiting literature i.e. 95th percentile anthropometric data of the human subject.

Some assumptions has been considered in performing the study that is available in existing literature (Singh et al., 2014), as human body is a complex and dynamic system so attempt has been made to convert complex structure into a simple model to measure response of human subject using FEM. In standing posture, mostly an effect of vibration is observed maximum at head as per reference to mode shapes observed during modal analysis of same human subject under same conditions. A resonance frequency i.e. frequency where maximum effect of vibration is observed also been evaluated at applied acceleration in different direction i.e. fore-and-aft, lateral and vertical.

2.1 Harmonic Response Analysis of Human Model

A response of human subject has been observed by performing harmonic response analysis using FEM. Characteristics of human subject considered as per exiting literature (Nigam and Malik, 1987; Singh et al., 2014).

2.2 Meshing of Human model

Due to complexity of a structure i.e. human body, tetrahedral mesh element has been considered. During this study,a solid meshing element i.e. tetrahedral element of size 4 mm has been used for meshing of human model. Accuracy in results of FEM depends upon size of element, as smaller the element size, more accurate will be the results. For element size of 2 mm error percentage has found 0% in existing literature and with increase in value to 4 mm error increases approx. to 0.0083% and further increases to element size of 6 mm for tetrahedral element error increases to 0.02359%.

Number of nodes & elements obtained during meshing is 41020 and 23264. Different parameters of meshing have been evaluated as per literature (Gokhale et al., 2008) and the values of meshing parameters lie within permissible limits. The results of FEM vary with a change in mesh elements and found to be fine when meshing lies within permissible limits with element size to be 4 mm.

2.3 Boundary conditions

A human subject has been considered to be in standing posture and backbone is in erect position i.e. body is in straight position perpendicular to the floor. It is considered that no external load is applied on human subject. The arms and hands have been considered to be straight and parallel to thigh; also they have no contact with any part of a human body. Feet have been considered to be straight, parallel to floor and perpendicular to the legs. Both legs (upper and lower) are assumed to be straight without any bend. Feet have been considered as a fixed support in ANSYS 16.0 software as feet are assumed to be in complete contact with a ground.

III. RESULTS AND DISCUSSION

To perform this study, harmonic response analysis has been performed using FEM approach when exposed to vibrations at acceleration of 1 m/s^2 (Singh et al., 2016) and frequency range of 2 to 20 Hz in two-axial direction i.e. fore-and-aft and vertical directions. The output in the form of transmissibility from feet to head has been evaluated at each frequency of vibration applied. Different damping conditions have also been considered in calculating transmissibility with damping ratios of 0.2, 0.3 and 0.5 (Kitazaki and Griffin, 1997) to accommodate the complexity of human body.The response of human subject when exposed to vibration applied in different direction with constant value of acceleration along with varying damping ratios has been discussed below:

1.1 Response of Human subject when Exposed to Vibration in Fore-and-Aft Direction

When a human subject is exposed to vibration given at the base of an excitation floor with the magnitude of vibration acceleration 1 m/s^2 and a defined frequency range from 2 to 20 Hz. Where, D_0, D_1, D_2 and D_3 represents damping value of 0, 0.2, 0.3 and 0.5 respectively in Figure 1.

When human subject is exposed to vibrations given at the base of an excitation floor with the magnitude of vibration acceleration 1 m/s^2 and a defined frequency range from 2 to 20 Hz.

A human subject under un-damped vibration, it has been observed from results of harmonic analysis as shown in Figure 1 that a maximum value of transmissibility (i.e; flow of vibrations from feet to head) is 1.90 at 4 Hz and its transmissibility has reduced up to 0.23 at 6 Hz. With the further increase in frequency of vibration, an increase in value of transmissibility has observed with value of 0.57 at 12 Hz and further reduced up to 14 Hz (0.23). At 16 Hz a value of transmissibility is 0.37 and beyond 18 Hz transmissibility increase up to 0.78 at 20 Hz.

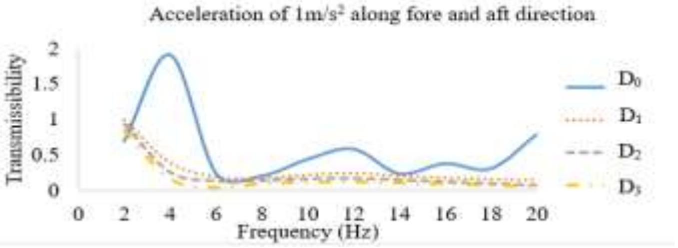

Fig 1:Transmissibility obtained at acceleration of 1 m/s^2 along fore-and-aft direction

With the change in value of damping ratio as 0.2, it has been observed from Figure 1 that at 2 Hz there occurs a maximum value of transmissibility i.e. 0.99. With the decline in value of frequency up to 4 Hz, it found to be 0.38, and with the increase in frequency, transmissibility increases up to 12 Hz gradually with very less change and then starts decreasing up to 20 Hz. At damping ratio of 0.3 and 0.5, a magnitude of transmissibility with maximum value i.e. 0.93 and 0.84 Hz respectively occurs at 2 Hz and beyond this frequency, a very less change in transmissibility has been observed as seen with damping ratio of 0.2.

1.2 Response of Human Subject when Exposed to Vibration in Vertical Direction

When harmonic response analysis is performed while exposure to vibrations in vertical direction. From Figure 2, it has been observed that in case of no damping ratio applied on human model, maximum transmissibility with magnitude of 4.7 is found at frequency of 6 Hz. And it starts increasing beyond 10 Hz up to 12 Hz, with value of transmissibility the further decline up to 0.30 at frequency of 15 Hz. Beyond 15 Hz, transmissibility remains approximately constant up to 20 Hz.

With the increase of magnitude of frequency at same damping ratio (no damping condition), transmissibility decreases after 6 Hz up to 10 Hz. At damping ratio of 0.2, it can be observed from Figure 2 that maximum transmissibility occurs at 6 Hz with the value of 2.5 as with the increase in damping, the effect of vibration magnitude decreases. And with the increase in frequency beyond 6 Hz, a decline in the value of Transmissibility has been observed.

Considering a damping ratio of 0.3, it has been observed from Figure 2 that maximum value of transmissibility 1.9 is obtained with further decline gradually up to 20 Hz.

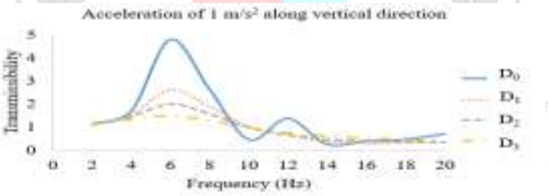

Fig 2: Transmissibility obtained at acceleration of 1.0 m/s^2 along vertical direction

IV. CONCLUSION

In current study, harmonic analysis of Indian male human subject of mass 76 kg has been performed using FEM at acceleration of 1 m/s^2 in two-axial direction at different value of damping ratios i.e. 0.2, 0.3 and 0.5. A 3-D CAD model has been modelled and harmonic response analysis of 3-D CAD model has been performed using FEM. After evaluating transmissibility for all of axis, it has been observed that maximum effect of vibrations on the body of human subject in vertical direction at 6 Hz having transmissibility of 4.7. And then, effect of vibration seems to be more in fore-and-aft direction i.e. at natural frequency of 4 Hz with transmissibility of 1.90. The results have been validated successfully, and results obtained in current study can be used for validation with future results. Results also help to design the comfortable supports for day-to-day use of human subject and it will also help to predict injuries or discomfort that will be experienced by human subject.

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