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Active Human Response to a Vibration Environment

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Abstract

Human computer models built with LifeMOD and MSC Adams can be developed to predict human subsystem vibration frequencies for a particular environment, a particular posture and particular interface configuration between the human and the environment. Computer models can also provide detailed information on the joint and muscle forces during the episode as well. By studying an active human model, or one which responds in an active way to the environment, information can be provided on human reaction and vibration adaptation or shielding.

In this study, a multi-axis vibration environment for an off-road heavy vehicle is examined using an active human model. Data for motion of the platform, the seat, and the body segments human test subject is collected using a video-based motion tracking system and used to develop a human model which responds to the vibration environment. The model is used to provide insight on human internal reactions, segment vibration frequencies and human adaptation to the vibration environment.

Introduction

Every day people are exposed to vibration in many ordinary activities such as riding in vehicles, working with vibrating machines, using power tools, etc. Severe or long-term exposure to vibration can affect comfort, safety and health of persons exposed. Since vibration is a common factor in the workplace, it is recognized as an occupation health hazard and should be treated as any other hazard such that it is controlled, eliminated or minimized.

In the construction and heavy mining equipment field two types of human vibration are under investigation including whole body vibration and segmental vibration. Whole body vibration energy enters the body through a seat or the floor; it affects the entire body or a number of organs in the body. Segmental vibration exposure affects an organ, part or "segment" of the body.

Severity of vibration is determined by its magnitude, frequency, duration and direction. Each part of the human body has its own natural frequency of vibration, therefore the extent to which the human body is affected depends on the vibration frequency it is to which exposed.

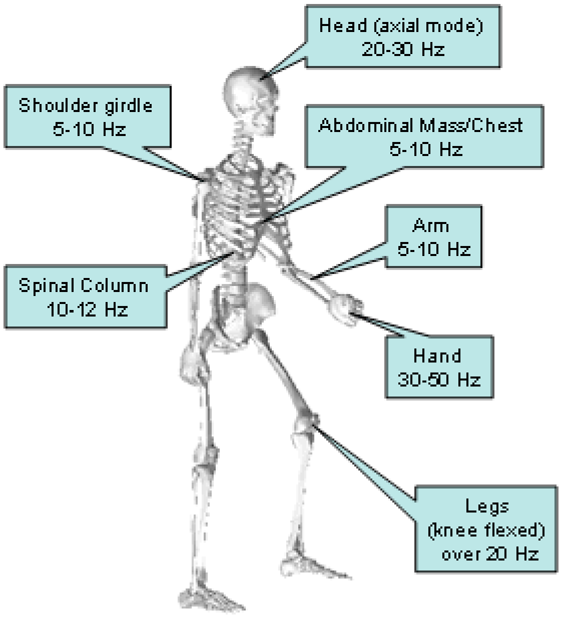

Figure 1. Simplified human body subsystems and vibration frequency resonance band

To understand why human beings are more sensitive to some frequencies than to others, it is useful to consider the human body as having sub-systems, where each sub-system has its own resonance frequency band and the interactions between sub-systems are influenced by the body's position, for example, standing or sitting. Figure 1 displays a simplified human body subsystem classification with the resonance vibration frequency band for each.

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In this study, a multi-axis vibration environment for an off-road heavy vehicle is examined using an active human model. Data for motion of the platform, the seat, and the body segments human test subject is collected using a video-based motion tracking system and used to develop a human model which responds to the vibration environment. The model is used to provide insight on human internal reactions, segment vibration frequencies and human adaptation to the vibration environment.

Data Collection

To study the human response to a vibratory environment of an off-road heavy vehicle a human test subject was instrumented with photo-reflective markers used to track displacement data with a Vicon-Peak (Irvine California) Motion capture system reporting data at a resolution of 100 Hz.

A test cabin, complete with seat with suspension and driver controls was used to simulate the actual vehicle under work loading conditions for periods of several minutes. The test cabin consisted of a 6 degree-of-freedom moving platform driven with data from the actual vehicle during a working activity. Motion data was collected in separate files for the platform, the seat and the human subject. Figure 2 displays the instrumented testing platform, seat, controls and human test subject.

Figure 2. Test rig to simulate actual working conditions of the off-road heavy vehicle. Operator is rigged with photo reflective markers used to capture the motion during the exercise. Input to the rig is through a 6 dof moving platform.

Model Development

LifeMOD was used to develop a model of the operator used in the experiment. Forty seven specific body measurements were recorded from the operator and used in conjunction with the anthropometric library within BRG.LifeMOD to create the 19-segment human model closely approximating the segment dimensions and mass properties of the operator.

A seat model complete with articulating rider controls was created and joined to a virtual model of the articulating platform. Contact forces were created between the human model and the seat, hands and the controls and the feet and the pedals. Figure 3 displays the model positioned in the vibration environment.

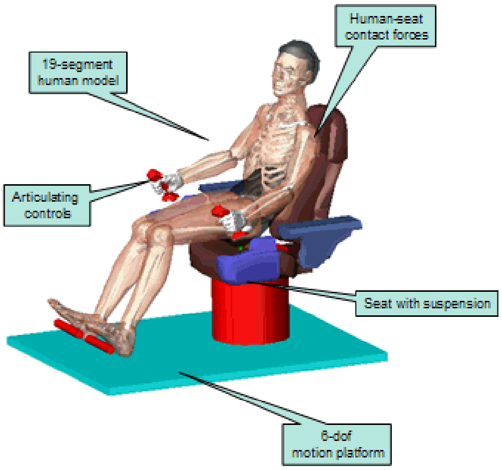


Figure 3. Simulation model complete with articulating platform, seat with suspension, 19-segment human model and forces between the human model and the environment (seat, controls and foot pedals).

LifeMOD™ motion agents are automatically created at each reflective marker location from the data collection experiment. Motion agents are parts which will be driven using the recorded trajectory information from the experiment. Motion agents are created on the human model, the seat and the platform. Each motion agent spring forces is normalized to the relative accuracy of the specific reflective marker, thereby allowing for the most accurate reflective marker to contribute most to the model motion.

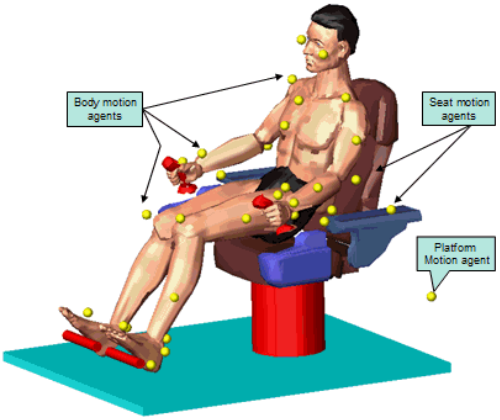


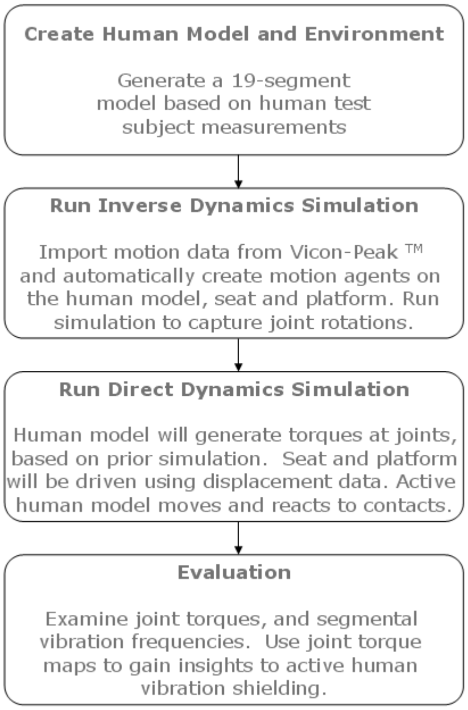
Figure 4. Motion agents are automatically created at the reflective marker locations in the experiment. They will drive the model to capture joint motion patterns to be used in a subsequent forward dynamics analysis

With the human model created and positioned in the seat and the motion agents positioned at each reflective marker location, the model is now ready for inverse-dynamics analysis. During this dynamic simulation, the three-dimensional joint angles at each anatomical joint are recorded.

Next, the motion agents are removed from the human model and proportional-derivative controllers are automatically generated by LifeMOD to create the torques which drive the anatomical joints by minimizing the error between the desired angle and the instantaneous angle. With the torques now driving the joints, the model becomes an active human model.

For the active human simulation, the motion agents on the seat and the platform are still present and will be used to drive the seat and platform using the same data as in the previous simulation. With the motion agents removed from the human model, the human model will be free to bounce in the seat as well as to move via the joint torques.

Figure 5 summarizes the model building and simulation process.



Create Human Model and Environment

Generate a 19-segment model based on human test subject measurements

Run Inverse Dynamics Simulation

Import motion data from Vicon-Peak ™ and automatically create motion agents on the human model, seat and platform. Run simulation to capture joint rotations.

Run Direct Dynamics Simulation

Human model will generate torques at joints, based on prior simulation. Seat and platform will be driven using displacement data. Active human model moves and reacts to contacts.

Evaluation

Examine joint torques, and segmental vibration frequencies. Use joint torque maps to gain insights to active human vibration shielding.

Figure 5. Modeling process flow

Results

Two types of model output were examined: the body segmental vibration and the active human response to the vibration. Figure 6 displays the input motion from the machine and the human model response via head and chest vibration patterns in the horizontal and vertical planes. From the plots it can be ascertained that the vibration frequencies for the head and chest are around 3 Hz and 1.5 Hz respectively or far below the resonance frequencies displayed in figure 1.

Also, the graph indicates that the vibration frequencies of these body segments are much less that the input frequency of the driving platform indicating a large amount of damping or energy release between the platform and the body segments.

The question is: Other than the passive effects, how did the human actively shield his head from vibration and excessive motion?

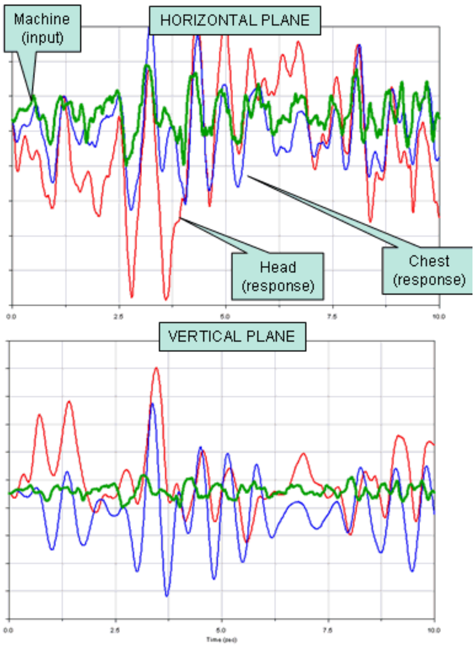


Figure 5. Head and chest vibration in the horizontal and vertical planes.

To gain some insight into the human active vibration shielding it is helpful to examine plots of the vertical plane velocity of the lower torso and the head and relate these to neck torque function. (See Figure 6). It can be observed in this figure, that the pelvis velocity is of a greater magnitude than the head indicating a vibration damping effect or shielding by the human joint reactions. The trends indicate that when velocity of both segments changes the neck torque peaks. This could represent a measure of anticipation of a rotational hyperextension.

This type of analysis was carried out in other planes and other joint combinations to characterize the human response to the environment from an internal reaction perspective.

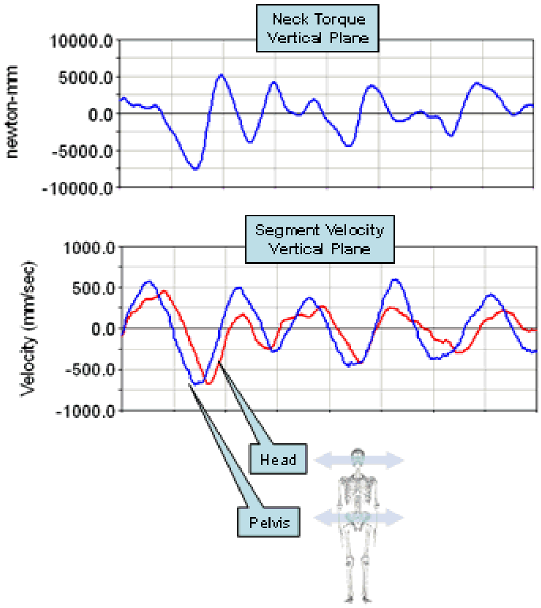


Figure 6. Vertical plane neck torque compared to vertical plane head and pelvis velocities for a specific time slice of the simulation.

Conclusions

This study represents an on-going effort into the study of active human response to vibration. This study will lead to efforts to characterize the response as an measure of comfort and chronic or acute injury potential. New techniques being developed for this project include new data collection methods, and the development of specific modules to enhance LifeMOD's ability to support a general vibration environment.