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Application of Artificial Neural Network Model to Human Body Vibrations in Large Haul Trucks

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The working conditions in oil sand mines in Northern Alberta, Canada, are greatly affected by the climate and geology. The ground is very hard and competent in winter but very soft during summer [1]. This changing behaviour of the ground has a great impact on the truck's frame and the health of the operator because he is exposed to large Whole Body Vibrations (WBV). When the human body is exposed to large WBV for prolonged periods, it begins to have chronic back problems resulting in diseases of the lumbar spine, disc degeneration and other pathological effects to the spine and skeletal structure [2]. Many of these health effects are irreversible and people suffering from WBV disorders can experience pains for the rest of their lives. Studies carried out to correlate WBV to health problems have resulted in the setting of standards with the help of various government agencies, physiologists and industry experts. The main WBV standards that the mining industry has to observe are those of International Standards Organization (ISO) and the British Standards Institute [2]. ISO 2631-1 uses a three dimensional coordinate system where the axes are orthogonal to each other as shown in Figure 1 [3]. The standards require that the measuring device (accelerometer) should be placed at a point where vibrations are entering the body. In this study the data was collected for the seat accelerations in X, Y and Z directions by installing the accelerometer on the seat pan of a CAT 797 haul truck. An Artificial Neural Network (ANN) model was developed to predict the seat vibrations in very large capacity haul trucks in the X and Y directions. The study was done to find if the vibrations in the truck and their effects on the operator can be correlated to the truck's operational parameters like speed, payload and strut pressures.

There is a need for an onboard monitoring system on large haul trucks to alert the driver when he exceeds specified speed limits at certain locations along the haul road which are unsafe for him. Caterpillar 797 trucks use Vital Information Management System (VIMS) to track the truck's behaviour when driven along a haul road. It includes onboard truck measuring equipment and off-board VIMS software which enables data logging and downloading into a computer. A record of real time parameters gives a detailed view of what happens to the truck body while performing the various functions [4]. The disadvantage of using a piezo-resistive accelerometer to collect the data collection is that it has a limited high frequency response [5]. Thus, it is necessary that the data be collected at higher frequencies to obtain a better model that can give more accurate predictions. In this work the accelerometer was replaced with an ANN model. The ANN model is developed for the dump truck such that it models the seat vibrations in the truck in response to the truck's speed, payload, changing ground stiffness and profile.

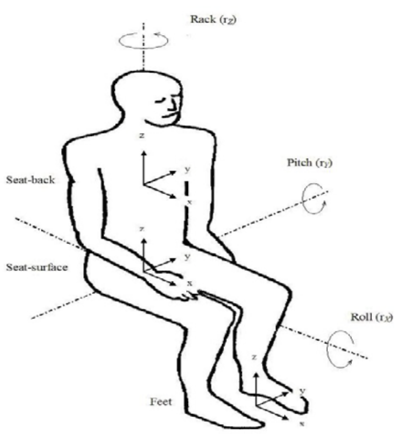

Figure 1: ISO 2631-1 Coordinate System [3].

These truck parameters can be estimated from the strut pressure responses measured in terms of machine rack, machine roll and machine pitch. The machine's roll, rack and pitch give an idea of the truck's response to the changing ground conditions and operator's driving skills. These values are calculated using the changing pressures of the four struts on which the whole truck frame is resting. These parameters were used as input variables during the development of the ANN model. This study focused only on the seat accelerations in the X-direction and Y-direction as output variables, as these are more important than the accelerations in the Z-direction. The ANN model is very efficient for non-linear processes and tends to improve its performance as it learns more and more about the system. Thus when the ANN model is used, very accurate acceleration values can be predicted. This is important for the health of the operator and also for the lifespan of the truck as the high amplitude vibrations are detrimental to truck's structural components.

Using the NeuroShell® 2 software, a multilayer perceptron ANN was trained with the back propagation algorithm. The model's performance was optimized following the systematic approach developed by [6,7]. This is done by looking for the simplest network architecture that can converge. During the development of the ANN model for Seat X acceleration, the number of hidden layer neurons was increased from 10 to 70 while keeping the number of learning epochs constant at 50. The number of neurons which gave the best value for R^2 (Validation) were found to be 39. This value was considered to be the optimum for the model. Then the number of epochs was increased from 50 to 2000 at intervals of 50 epochs till the best R^2 corresponding to 450 epochs was obtained. The same procedure was followed for the Seat Y acceleration model development and the optimum number of hidden neurons and epochs were found to be 24 and 800 respectively. The best candidate models which were developed for predicting the Seat X acceleration and Seat Y acceleration gave the highest values of R^2 as 0.58 and 0.78 respectively. Figure 2a and 2b show that the model developed for the

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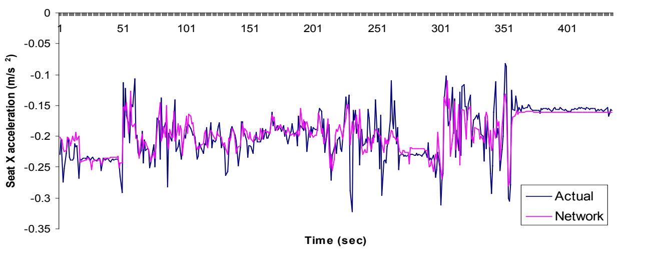

Figure 2a: Actual and Predicted Seat X Acceleration Values.

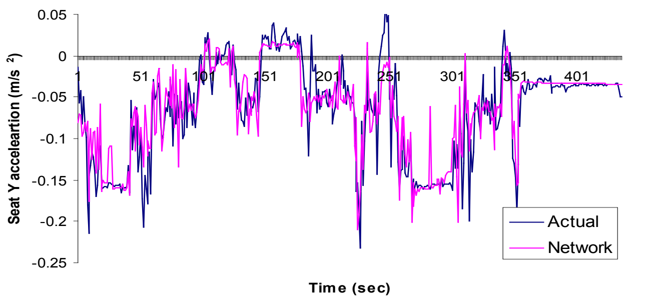

Figure 2b: Actual and Predicted Seat Y Accelerations Values.

Seat X acceleration is inferior to Seat Y acceleration model in terms of catching the peaks and troughs of higher magnitude.

The results of studies conducted on the effect of ground speed, payload, pitch, machine rack and machine roll on seat vibrations in the X and Y directions show that machine roll has the highest effect on seat vibrations in both X and Y directions while the payload has the least effect in the development of the seat vibrations in both X and Y directions. This shows that the haul road profile is very important in preventing the generation of high magnitude vibrations in the moving trucks.

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