THE SELECTION OF A CRITERION TO EVALUATE RIDE-DISCOMFORT IN OFF ROAD VEHICLES

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1. INTRODUCTION

As the operational duty of the off-road vehicle diversifies, the human factor becomes increasingly important in maintaining a safe and comfortable working environment for crew members. To allow designers to evaluate ride-comfort in off road vehicles, computer simulation techniques are being increasingly used. Models of a dump truck and a military tank have been developed (8) to predict vibration levels as these vehicles travel over typical terrain.

However, at present, there is no widely accepted criterion to quantify the level of discomfort that such vibration levels and frequencies are likely to cause in operators of off road vehicles. Five criteria (developed primarily for other forms of transport) have been applied to the vibration levels predicted by the computer simulation models of the two vehicles. The levels of discomfort suggested by each criterion have been compared and the most applicable criterion for off road vehicles identified.

1.1 The Vickers main battle tank Mk 3b/3

The tank is a 38 tonne armoured fighting vehicle capable of travelling at over 30 mph. The vehicle suspension consists of independent steel torsion bars with trailing arms to rubber tyred road wheels. The wheels (six on each side) run in two 96 segment tracks. Suspension units 1, 2 and 6 possess secondary torsion bars and hydraulic shock absorbers (Fig. 1).

1.2 The Artix D25 dump truck

The truck is a multi-purpose off road articulated tractor-trailer combination designed primarily for materials haulage in the civil engineering environment. The articulated joint provides steering and roll freedoms, thus reducing twisting stresses that would be present in a rigid chassis vehicle. The front and rear suspension is provided by independent oil/nitrogen systems. The vehicle is capable of carrying a 25 tonne payload at speeds up to 25 mph. (Fig. 2).

2. RIDE DISCOMFORT IN OFF-ROAD VEHICLES

The discomfort experienced by personnel during off-road vehicle operation is considered to result mainly from vibration in one or more axes generated by variations in the ground contact forces. Other physiological effects such as noise, required task etc. can contribute to human discomfort.

Specialist off-road vehicles pose a unique and extreme problem for a number of reasons. Firstly the highly irregular terrain produces random accelerations of large magnitude. These accelerations are often interspersed with high crest factor shock loads, which are not only uncomfortable, but have been shown to encourage spinal damage in the lower
back area (1). The shock loads are therefore thought to be more damaging than the background level of vibration.

Because of the nature of off-road operations it is difficult to predict actual discomfort resulting from accelerations of the body support points because the operator may move relative to the seat, often losing contact with it altogether. This makes it impossible to use seat transfer functions effectively. Also discomfort is unique to each operator due to posture, muscle tone, body weight, clothing, age, sex, etc.

Discomfort is also influenced by noise, humidity, smell, light intensity, ventilation, ease of control operation and health of operator. Some of these factors may also act as a catalyst to motion sickness. Taken altogether, these factors produce broad subjective responses to any given vibration. The present study was restricted to consideration of the effects of physical whole body vibration.

2.1 Ride comfort criteria

The five criteria considered in this study were:
(a) ISO 2631 "Guide for the evaluation of human exposure to whole body vibration" (2).
(b) Vibration dose value (4).
(c) Absorbed power method (5).
(d) DISC rating (3).
(e) Comparison to vibration while walking (6).

2.1.1 ISO 2631. ISO 2631 2nd edition 1978, covers vibration in the frequency range from 1 to 80 Hz. Addendum 2 1980 extends this to the kinetosis region between 0.1 and 0.7 Hz. The original crest factor limit of 3 has been raised to 6 in an attempt to make the criterion more applicable to shock loading. The effects of vibration in the A_z, A_x, or A_y axes may be considered individually or together in the form of an equivalent vibration level. The criterion was developed from subjective human response and predicts duration limits to reach the following levels of discomfort:
(a) Reduced comfort boundary.
(b) Fatigue decreased proficiency boundary.
(c) Exposure limit.

The limits are specified on the 1/3 octave spectrum of the vibration and commonly shown in the form of graphical output.

2.1.2 Vibration dose value. The VDV method provides a single numerical descriptor to represent the vibration dose accumulated by the human body. The vibration dose for each axis is the integral with respect to time of the 4th power of the frequency weighted acceleration time history. The vibration dose due to multi-axis vibration is the sum of the vibration dose from each axis. The vibration dose calculated in this manner is usually numerically large so the vibration dose value, which is the 4th root of the vibration dose has been proposed as the criterion. A value of 15 m/s^1.75 is considered to cause severe discomfort (4).

2.1.3 Absorbed power method. This criterion considers the power that is absorbed by the human body subjected to vibration. The absorbed power is derived by summing the product of the power spectrum (acceleration magnitude squared) and a frequency dependant weighting (Fig. 5) over the discrete frequency spectrum. Typical absorbed power values for off road vehicles lie between 5 and 15 watts. The absorbed power in each axis can be summed to produce a multi-axis absorbed power value.

2.1.4 DISC rating. In this method a numerical rating is calculated from a range of equations based on such parameters as peak vibration level, centre frequency, r.m.s., duration etc. (3). A DISC value of 1 is