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# Study of simultaneous shock and vibration control by a fore-and-aft suspension system of a driver's seat

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ABSTRACT

A single degree-of-freedom simulation model of a seat equipped with a non-linear fore-and-aft suspension system was developed. The performance of a typical fore-and-aft suspension system was analysed using typical vibration and shock acceleration signals measured in loaders while travelling on off-road terrain and while driving the bucket into a heap of soil. Damper modification was suggested to improve the suspension performance in the control of both vibration and shocks. Suspension system performance was analysed using the simulation approach for variations in both mass loading and excitation intensity. A discussion of results obtained and practical suggestions for improvement of the fore-and-aft driver's seat suspension system concludes this contribution.

*Relevance to industry:* The simulations are of use to seat manufacturers in developing improved fore-and-aft seat suspension for wheel loaders. It is shown that a damper with an optimised progressive damping characteristic provides better shock mitigation than is available with either a seat without any suspension or a suspended commercial seat as presently available on the market.



## 1. Introduction

In various land vehicles the isolation of the seated operator from vibration and shock is of considerable importance. Exposure to whole-body vibration in the working environment may lead to fatigue and in some cases to injury. Workplace epidemiological studies (Dupuis et al., 1988; Schwarze et al., 1999; Griffin, 1990) have stressed the need for proper suspension design. This is stressed even more in Europe by the Physical Agents (Vibrations) Directive 2002/44/EC (2002). According to this Directive, a limit is prescribed for the whole-body vibration to which a worker may be exposed. Persistent low-back pain (LBP) caused by the excessive exposure to whole-body vibration is acknowledged in some European countries as a recognisable occupational disease, entitling one to worker's compensation due to the inability to work (Hulshof et al., 2002).

Much attention has been paid to the control of vibration and shock in the vertical direction. There is evidence that besides the vertical vibration the fore-and-aft vibration and shocks also influence worker's health (Sandover, 1998; EN/TS 15730, 2008; Guide to Good Practice on Whole-body Vibration, 2010). As noted by Rakheja et al. (2010), in number of industrial and building vehicles the driver is subjected to fore-and-aft and lateral vibration that are sometimes of the same magnitude as in the vertical direction. In the past, comparatively little laboratory research had been conducted on human body response in the non-vertical axes (Fairley and Griffin, 1990; Holmlund and Lundström, 1998; Mansfield and Lundström, 1999; Mandapuram et al., 2005; Hinz et al., 2006; Mansfield and Maeda, 2007). The aim of the European project VIBSEAT (VIBSEAT, 2010) was to determine how the operators of various vehicle types could be protected from the horizontal and rotational vehicle vibration by the use of suspension seating. The research was based on the development of performance assessment, subjective discomfort evaluation and vibration isolation strategies for multi-axis random excitation, as practically measured in real operating conditions.

Many leading driver's seat manufactures do equip their better seat models with a fore-and-aft suspension system. Hence, there is a motivation to study such suspension system and make predictions concerning improvement in the control of both vibration and shock and, by simulation study, to provide guidance for the improvement of existing designs.

To be able to model the complex interactions of the seated human body and a cushioned seat, it is necessary first to analyse the various interactions in a modern driver's seat with both vertical ($z$-direction) and fore-and-aft ($x$-direction) suspension systems. The interaction with the back support is of particular importance, here predominantly in the fore-and-aft direction.

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