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IMPROVED OPERATOR PERFORMANCE FROM REDUCED VIBRATION

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ABSTRACT

The ride vibration on agricultural tractors is severe but systems that would substantially reduce this vibration are expensive. The benefits of reduced vibration to driver health and comfort are difficult to place a value on so an economically sound case for including vibration reducing measures on a tractor cannot be made on these grounds alone. The experimental results reported in this paper show that for many normal agricultural tasks a voluntary increase in driving speed occurs when the ride vibration level of the vehicle is reduced by means of a suspension. Reductions in vibration of between 10% and 20% resulted in increases in driving speed of a similar amount. Such results mean that the cost of suspension systems could be justified by the potential for increased work rates in addition to the health and welfare benefits.

INTRODUCTION

The ride vibration on agricultural tractors as they perform routine tasks frequently exceeds internationally accepted levels. It is now widely accepted that such levels of whole body vibration can be the cause of several occupational diseases such as back, stomach and kidney problems (1). Because these effects are long term they are very difficult to measure or even to prove conclusively. Without quantifiable economic benefits or the force of legislation the development of machines with lower levels of ride vibration is likely to be slow. However there are clear economic benefits to he obtained from higher working speeds. There is some evidence that the vibration of agricultural tractors limits the speed at which they are driven (2). If this is the case then the effect of improved ride vibration on working speeds should be readily observable within a relatively short time. This paper describes an experiment which investigated the effect on driver comfort and driving speed of reduced vibration levels.

A conventional farm tractor has been modified at AFRC Engineering to include a suspension system on the front axle. In order to facilitate direct comparisons between the ride vibration characteristics of an unsuspended and suspended vehicle it was designed so that by operating a switch the suspension could be locked out, effectively returning the tractor to its previous unsuspended state. This created an opportunity to assess the effect of reduced vibration on tractor operating speeds under real farming conditions. This experiment was run over two years. In the first year a pilot study using tractor drivers employed by AFRC Engineering was conducted. In the second year a larger experiment was run with the tractor being used on 13 different farms.

EXPERIMENTAL DESIGN

INDEPENDENT VARIABLES. The main variable being evaluated was the tractor condition. In the trials there were two conditions described simply as locked and suspended. Between these two conditions there was a difference in ride vibration levels, however the vibration was affected as much or more by other factors.

Probably the most important factor affecting the vibration was the task being performed. This was also expected to influence the drivers' response to the two different tractor conditions, because while for some tasks the driving speed is clearly governed by comfort and safety, for others, factors such as steering accuracy, and work quality influence the drivers' choice.

The third independent variable was the driver. Different drivers were expected to respond differently to both the tractor condition and to the task.

WORKING SPEED. Working speed has a direct effect on the level of tractor vibration. If comparisons are to be made between different tractor conditions it is necessary to ensure that the driving speed is the same for both trials and is set according to accepted practice for the particular tractor task. Subjective assessments of comfort therefore relate to levels of vibration caused by the predetermined driving speed. However as many drivers are likely to choose different speeds under suspended or locked conditions the relevance of such a closely controlled experiment might be questioned.

An alternative approach might be to allow the drivers a completely free choice of driving speeds. In this case if the driver chose speeds which gave equivalent levels of comfort for the locked and suspended conditions then there would be no difference in the comfort assessments of the two conditions, but there would be a useful indicator of a performance difference.

The method actually chosen was to allow the drivers to select their own working speeds for the first tractor condition which they tried and then to use the same speed for the other condition. By presenting the conditions in random order, half of the drivers chose working speeds for the locked condition and half for the suspended condition. This enabled the effect of tractor condition on both working speed and comfort to be assessed.

OTHER VARIABLES. Many other factors influence either the machine performance or the psychological state of the driver, and may thus affect the the results of the field trials. These include the weather conditions, the time of day, the ground conditions, and the driver's familiarity with the tractor and implement and the time needed for drivers to become familiar with new working speeds. Most of these variables have to be accepted as increasing the variability of any results as they are difficult to control when trials have to be accommodated within the normal timetable of fieldwork.

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MEASUREMENTS. Working speeds were obtained either by timing the tractor over a known distance or by measuring the engine speed and noting the gear which was selected.

Comfort was assessed subjectively. After working for at least twenty minutes the driver was asked to rate the overall comfort by making a mark on a line 100 mm long whose ends were marked as "Very Comfortable" and "Very Uncomfortable". This apparently simple technique has been shown to give consistant results for experiments like this (5). It was used to give rating scores on a linear scale between 0 (very uncomfortable) and 10 (very comfortable), for the overall comfort, the vertical motion, roll and pitch, and for the ease of steering.

As the drivers made these rating assessments the tractor condition was changed. The driver then continued driving for another 20 minutes. He then made an assessment of the comfort of the new tractor condition, without being allowed to see his previous markings. He was also asked to rank the two rides according to which condition he thought was better. These rankings were used in the analysis to check the consistency of the drivers assessments. Any pair of ratings which did not agree with the rankings was discarded from the subsequent analysis.

RESULTS

In the first year six drivers used the tractor for six tasks in a balanced experiment in which all the drivers covered the same or similar ground for any one of the tasks. The experimental variables were reduced or at least controlled, and so that the results could be analysed to show how much variation could be ascribed to tractor condition, task, and driver.

In the second year, 43 drivers were used for 22 different tasks. As these drivers were distributed on 13 different farms the scope for such analysis was greatly reduced, however the results can be ascribed to the general tractor driving population and related to commercial farming conditions with much more confidence than those of the first set of trials.

COMFORT. The distribution of comfort ratings for all tasks and all subjects in the first year's trials are shown in fig 1. Without exception the differences in ratings between the two tractor conditions indicate that the suspended condition was more comfortable than the unsuspended. The mean values of the ratings for the four tasks for which all the rankings and ratings were consistant are given in Table 1. This shows that although there are large variations between drivers, the largest variation in ratings is between tractor suspension conditions.

The comfort ratings from the second year's trials for the 78 consistant pairs of ratings showed that in this case not all the differences were positive. However the two distributions are not likely to have come from the same population (Wilcoxon matched pairs, signed ranks test, probability 1:30000). From these results there were not enough ratings for any one task to differentiate between tasks with any reliability.

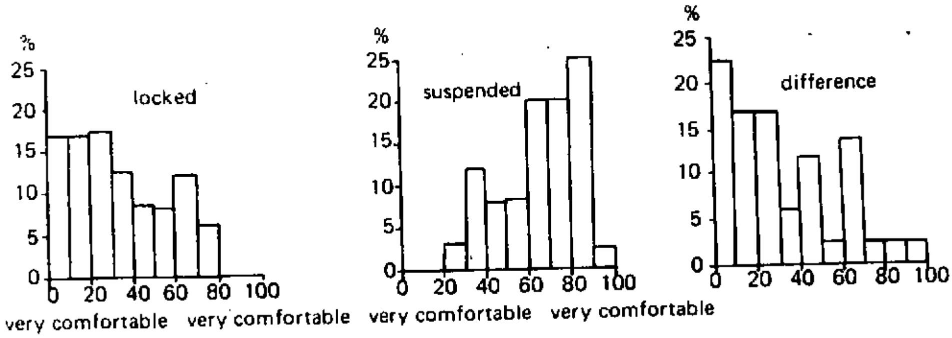

Fig 1 Distribution of subjective comfort ratings, first season

Grand Mean: 4.93

Tractor Condition:

Locked	Suspended
3.26	6.60

Task:

Moving	Plough in Transport	2-Wheel Trailer	4-Wheel Trailer
5.26	5.81	3.86	4.79

Driver:

1	2	3	4	5	6
4.70	4.06	4.29	5.43	6.11	4.46

Tractor/Task:

	Moving	Plough in Transport	2-Wheel Trailer	4-wheel Trailer
Locked	3.36	3.62	2.53	3.58
Suspended	7.16	7.99	5.18	6.00

Table 1 Subjective Ratings of Overall Ride, Table of Means
1 = Very uncomfortable 10 = Very comfortable

MEASURED VIBRATION. In the first year's trials the vibration at the mounting point of the driver's seat was measured in the vertical, longitudinal, lateral, roll, pitch and yaw directions. The vibration in each direction was frequency weighted and combined together according to the human sensitivity as given by Griffin et al (6). These total weighted levels given in fig 2 show differences of up to 50% but generally between 10% and 20% between tractor suspension conditions. The vertical and longitudinal components of the vibration were the two most important components of the vibration.

WORKING SPEEDS. The working speeds observed in the first year's trials are shown in fig 3. These show a wide range from nearly 50% increase to a slight decrease in speed in the suspended condition relative to that in the locked condition. The increase in the overall average was 11.5%, from 12.6 km/h to 14.4 km/h.

The working speeds observed in the second year's trials are shown in fig 4. These drivers often maintained routines already established and did not try other speeds for fear of adversely affecting the quality of work. Differences were observed in only 9 of the 22 tasks, and these ranged from an increase of 3% to 26%, mainly for transport operations.

DISCUSSION

This work has shown that reductions in ride vibration of 10% or 20% are clearly perceived by tractor drivers as improvements in comfort. However it is difficult to put a value on that improvement unless it can be related to some other change in the environment such as noise, or unless it can be related to a change in operating performance. From the trials described it appears that an increase in working speed of a similar proportion to the decrease in vibration may be achieved.

This experiment gives more evidence of a strong link between vibration and working performance. Since tractor operations occupy a significant proportion of almost every farm's operating costs, the economic benefits of reducing vibration ,alone, could justify the introduction of suspensions to some farm tractors.

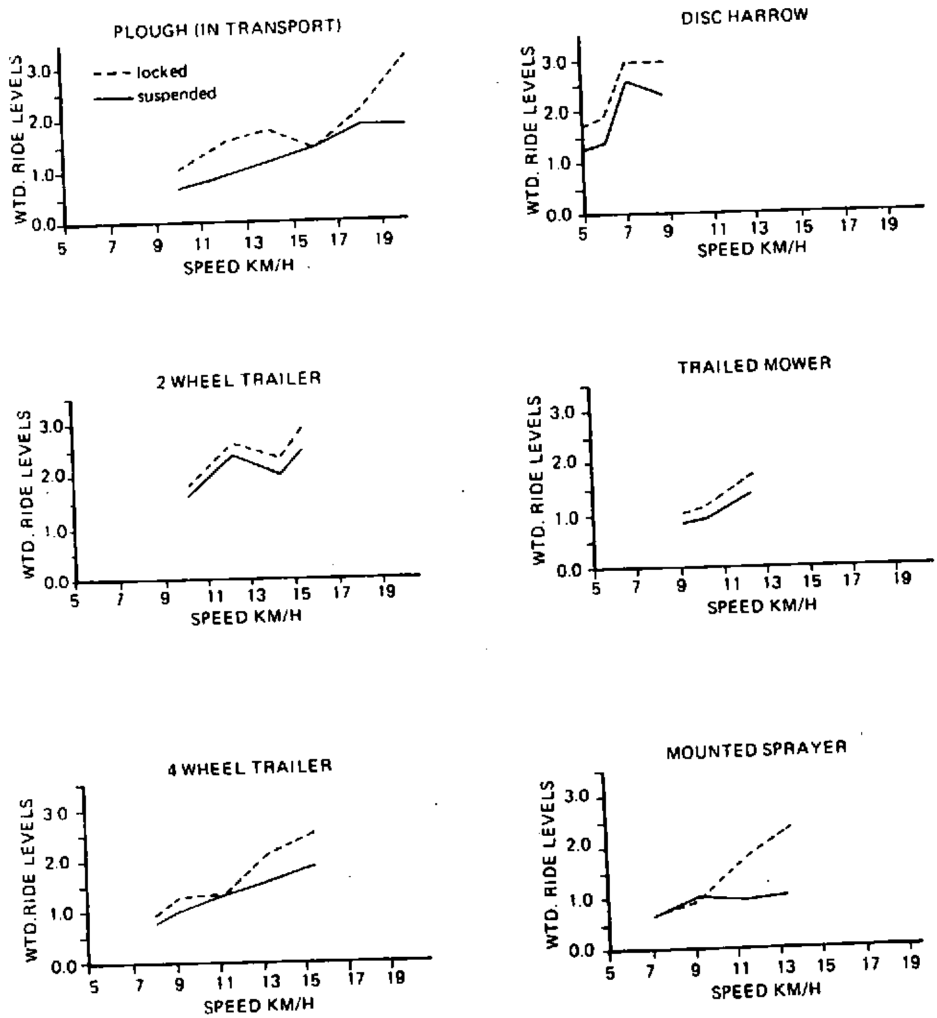

Fig 2 Combined, weighted, rms vibration levels vs driving speed for six tasks

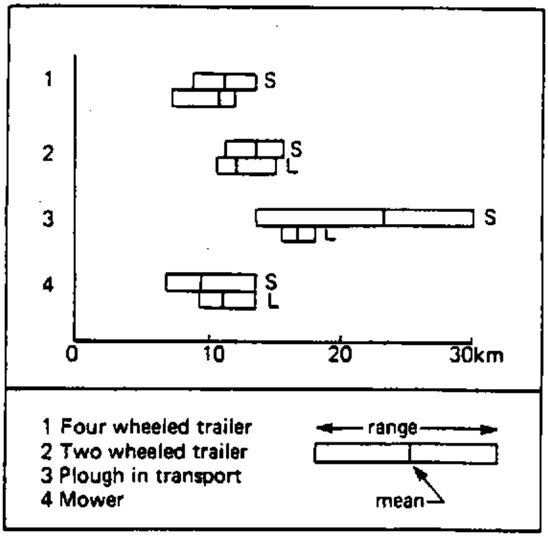

Fig 3 Speeds observed in first season field trials

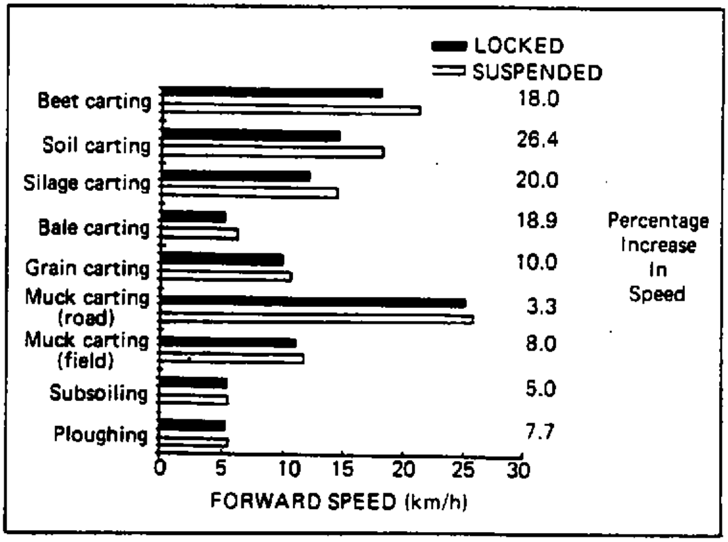

Fig 4 Mean speeds observed in second season field trials

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