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POWER ON THE LAND - AN ENVIRONMENTALLY UNFRIENDLY HANDSHAKE

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1. INTRODUCTION

This paper presents some data on the vibration magnitudes and exposure times which the author has observed on machines used on the land during his time as an independent consultant, and before that at the National Institute of Agricultural Engineering (now Silsoe Research Institute). The machines are used in a number of different, but related industries, and the measurements have been made under either of two types of condition. Some have been made in working conditions, for the purpose of establishing an indication of risk of HAVS to a particular employee. Others have been made at the premises of manufacturers or agents to provide values for declaration as required by the Machinery Directive. The state of development of relevant standards for specific machines is reviewed briefly, and some practical details of actual measurements are discussed. The presentation closes with a discussion of common sources of vibration and the possibilities for its reduction. The data is far from complete, and is presented as a basis for gathering further information relevant to this field of activity.

Machines in the categories considered in this paper have been in use for over 70 years, ever since the internal combustion engine became small enough to be used in a pedestrian controlled machine to replace more laborious hand work. However, and notwithstanding the lack of knowledge of HAVS until relatively recently, such machines were generally used only intermittently, and any vibration problem was seen as relating to discomfort and quality. It was only when machines started to be used more continuously that health effects became apparent.

2. INDUSTRY SECTORS

2.1. Forestry

The forestry industry was the first of those considered here in which a power tool was introduced into the virtually industrial conditions of continuous use by large numbers of workers. This tool was the **chain saw**, which increase productivity vastly by replacing hand saws and felling axes. In addition to chain saws, forestry workers use other portable power tools, of which the **brushcutter** is the most common. Also part of the forestry industry are the wood yards, where logs are fed into **sawbenches**.

2.2. Agriculture, Horticulture, Market Gardening

Most farmers use chainsaws, brushcutters and sawbenches similar to those used in forestry, but on only a very occasional basis. People working plots of land which are too small for a normal agricultural tractor have to use **pedestrian controlled tractors** and **powered cultivators**. These are among the earliest applications on the land of powered tools with hand vibration, and for many

years the engines ran at very low speeds, so that the vibrations were in the more sensitive region of the human response curve. However, whereas the tractor is used for many operations on farm scale enterprises, in market gardens and nurseries walking tractors and cultivators are used for only a small part of the complete cycle of operations. Therefore, although they may be used continuously for many hours a day, it would be most unusual to find anyone who used such a machine for more than 5 to 10 days a year.

2.3. Civic Amenities and Sports fields

Local authorities and sports clubs, particularly golf clubs, have a particular task in maintaining large areas of grass. Lawn mowers, having a large "domestic" market, were early in development, and like cultivators at first used low speed engines. However, their use was restricted, and it is only in the last 30 years or so that **mowers** and **strimmers** have been used under "industrial" conditions, i.e. by gangs of workers for many hours a day throughout a long season. Large open areas of grass are cut by ride-on mowers, or tractor-drawn gang mowers. It is the smaller areas which require the use of pedestrian controlled mowers, and areas with steep slopes and difficult access which require strimmers.

In addition to cutting, areas of high quality turf, such as golf and bowling greens, require occasional scarifying and aeration. Whereas larger areas can be dealt with using tractor mounted equipment, the highest quality lawns must be worked with pedestrian controlled machines. Although **pedestrian controlled aerators** and **scarifiers** can have quite high magnitudes of vibration on the handles, it would be unusual for them to be used for extended periods. However, it is likely that the users would otherwise be using grass cutting equipment, and so these machines would also contribute to the workers' overall exposure.

Local authority workers are also called upon to use chain saws, brushcutters, and occasionally powered cultivators and **hedge trimmers**, although it is likely that the latter are mainly sold to the domestic market. Hedgerows of any significant length are usually cut by tractor mounted machinery.

2.4. Public Utilities

Public utilities such as the Highways Agency and the Environment Agency have trees and more particularly grass to maintain. Often the grass is in areas where access, slopes or trees hinder the use of tractor mounted equipment. This again results in gangs of workers using strimmers almost continuously throughout the season from March or April to October.

2.5. Contractors

Changes in the financing and organisation of many of the above industries have led to a considerable increase in the number of contractors whose services may be used across the different sectors. Contractors base their services on the equipment in which they have invested, and as a result they often make longer and more intense use of the machinery than do those directly employed in specific industries.

3. VIBRATION MAGNITUDES AND EXPOSURES

Some vibration magnitudes are shown in Table 1, below. These are either in work ("W") or under test conditions ("T"), and are shown only as indicative ranges for generic machine types. The table also indicates which machines are used for extended periods, and which for only occasional, or short periods. For some, observations have allowed the estimation of a daily L_{eq} or L_{a8} value, but in general this is not the case. The author would welcome any additional information.

Table 1: Vibration magnitudes and exposure times

Machine type handle	Range of vibration ms^{-2} wtd	Industry Sectors Anger time	Daily per or L_{a8}	Days Year
Chain saw (isolated handles)	3.5 - 7 (T)	Forestry Agriculture Amenities Utilities	2 - 3 hrs 1 - 2 hrs 1 - 3 hrs 1 - 3 hrs	>100 <10 ? ?
Brushcutter	7 (W)	Forestry	2 - 3 hrs	50 - 100
Saw benches	4 - 5 (T)	Forestry	6 - 8 hrs	>100
Pedestrian controlled tractors/cultivators	?	Horticulture	6 - 10 hrs	5 - 10
Pedestrian controlled lawnmowers	2.5 - 3 (W)	Amenities Sports fields Utilities	6 - 8 hrs 6 - 8 hrs 6 - 8 hrs	50 - 100 <50 <50
Ride-on lawnmowers	3 - 5 (T)	Amenities Sports fields Utilities	6 - 8 hrs 6 - 8 hrs 6 - 8 hrs	50 - 100 <50 <50
Strimmers (cowhorn)	3.5 - 5 (T)	Amenities Utilities	4 - 6 hrs 4 - 6 hrs	50 - 100 c.100
Hedge trimmers	?	Amenities	?	?
Pedestrian controlled scarifiers	) 1.5 - 11 (T)	Sports fields	6 - 8 hrs	?
Pedestrian controlled aerators	)	Sports fields	6 - 8 hrs	?
Strimmers (loop handle)	3 - 14 (W) 4 - 20 (T)	Amenities Utilities	4 - 6 hrs 4 - 6 hrs	50 - 100 c.100

Although nearly all the machines tested generate vibration in excess of 2.5 ms^{-2}, the potential for HAVS damage is likely to be restricted to those groups of workers for whom the exposure lasts for several hours per day for extended periods. Important among these are contractors.

4. STANDARDS

The basic standard for field evaluation of hand-transmitted vibration is ISO 5349-2, which is presently under development.

The position with regard to type testing of machines for vibration values for declaration is somewhat mixed:

For chain saws there has been a test code for some years, enshrined in a separate document (BS 6916 Part 8 1988; ISO 7505 1986), which involves measurement under the three conditions of idling, cross-cutting and racing. This may be re-evaluated in the light of a recent European research project on chain saw vibration.

For everything else, there are only vibration clauses in more general safety standards:

For brushcutters and strimmers these are under development for BS ISO 14865, and involve a simple measurement under free-running conditions.

For lawnmowers (pedestrian controlled and ride-on) these are in EN 836, and involve free running over smooth grass.

For hedgecutters these are in EN 774.

In general, these vibration clauses at present require tests with only one operator, and there is a shortage of published information to show that results obtained with them are reproducible and are representative of values which would be obtained under working conditions.

5. EQUIPMENT - FIELD EXPERIENCE

The data reported in Table 1 above has been obtained with a variety of measuring systems.

That for strimmers was measured using a dedicated instrument, backed up by DAT recording for investigation of operational speeds and the relative importance of different sources of vibration. This instrument is a single channel device, so that it is necessary to switch between transducers and take sequential readings, rather than simultaneous measurement of three mutually perpendicular components.

Much of the other data was obtained by recording direct frequency analysis of accelerometer signals on a 2-channel fourier analyser. These spectra were transferred into a spreadsheet for frequency weighting and extraction of rms values. Only pairs of components could be measured simultaneously.

A third approach was to record pairs of signals on a DAT recorder in the field and analyse these in the laboratory either using the fourier analyser technique, as above, or using a PC based system (HvLab). A DAT recorder without modification has a reduced response at frequencies of 20 Hz and below, and should not be used for machines which have slow speed sources of vibration, such as the plungers of aerators. In other cases consideration of low frequencies raises concern about the apparent importance of movements made by the operator when weighted by the human response

function. The recording and frequency analysis techniques have the advantage that such components can be identified by the investigator whereas they are not obvious with a direct reading meter.

The PC based HvLab system proved difficult to use directly in the field because of the practical difficulties of screen visibility and of operation when walking over rough ground.

In all cases, checks of the complete measurement/analysis chain, using a laboratory vibrator and reference accelerometer were considered essential. This is particularly important with the DAT recorder because of level changes between recording and playback.

Transducer mounting involved two distinct techniques. Most field measurements were made using an aluminium block which could be readily strapped to any handle without modification, but which would have to be to one side of the hand or the other. A small number of measurements have also been made using moulded mounts which could be fixed under the palm of the operator's hand.

A difficulty, for which no solution has been found, is that on some machines the operators move their hands along handles to cope with changes in ground conditions. As the hand is moved away from the transducer, the measured vibration increases, sometimes by as much as 30%. Controlled checks have shown that the vibration at the new hand position has not increased, so that the reading in work overestimates the vibration to which the operator is exposed.

The types of machine used on the land do not involve such high magnitudes of shock as are likely to cause the "DC shift" effect. However, the conditions, particularly in work, are such that great care is needed to ensure the integrity of any microdot connections so favoured by manufacturers of small accelerometers. This is a simple aspect, but important. Any errors are generally manifested as unusually large values because of the response of the weighting filter, and one of the advantages of the fourier analyser approach, and of continuous recording, is that bad signals are clearly apparent.

6. POSSIBILITIES FOR LOW VIBRATION MACHINES

For most machines in this group, the main source of vibration is the internal combustion engine. These have been improved in recent years, particularly by the introduction of higher speeds, but although mechanical balance can be perfected, single or 2-cylinder engines will always generate vibration in response to combustion forces. For some machines, such as strimmers and brushcutters, there are components which rotate at other than engine speed, and for some, such as aerators, there are reciprocating sources of excitation.

Chain saws have been fitted with anti-vibration systems for about 30 years, and these have been developed to a high level of effectiveness. Anti-vibration mounts have been introduced to some strimmers and brushcutters, but these are relatively new developments, and there is need for more development in these cases.

The problem can be avoided with saw benches when splitting poles by fitting auto-feed attachments, so removing the operator's hands from the vibration. Something similar may be possible for cross-cutting, but has yet to be developed.

7. CONCLUSION

The application of power to operations on the land has resulted in a wide range of machines which are capable of exposing their operators to vibration in excess of 2.5 ms^{-2}. There may be quite large numbers of workers, particularly those using mainly chain saws and strimmers, for whom the annual exposure is extensive in terms of both hours per day and days per year.

The information on several types of machine is incomplete, and the relationship between type tests and exposure levels is often unclear.

Anti-vibration systems for chain saws are well developed, but there is scope for improvement on most of the other types of machine.

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