STUDY OF VIBRATION TRANSMISSION ON A PAVER'S HAND HAMMER

Uwe Kaulbars[1], Nastaran Raffler[1]

[1]Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA)
(Institute for Occupational Safety and Health of the German Statutory Accident Insurance – IFA, formerly BGIA),
Alte Heerstraße 111, 53757 Sankt Augustin, Germany, ifa@dguv.de

1. INTRODUCTION

Disorders caused by vibrating hand-held power tools and machines have long been known. By contrast, little is known about whether discrete shocks caused in particular by non-power tools lead to comparable exposure. The ISO 5349-1 [1] standard for example states in its scope that its application for repeated shocks is only provisional. A disorder suffered by a paver who for decades had made intensive use of a paving hammer (a special design of hammer) prompted a study of the vibration transmission from the hammer to the hand-arm system. The study was to examine whether the vibration exposure in this particular case was comparable with that of other, power machines or tools. For this purpose, a realistic model workplace was set up in the laboratory, based upon field studies. This guaranteed reproducible test conditions for the subsequent study methods.

The interaction between hand and handle was determined during the discrete impact phases by synchronous measurement of the acceleration at the handle of the hammer and of the coupling forces. The coupling forces were determined by measurement of the pressure distribution on the surface of the handle. The measuring system from the VIBTOOL project [2] was used for this purpose. In addition, the phases of the impact cycle were recorded synchronously by means of a high-speed camera. For further validation of the data, the free vibration behaviour of the hammer handle and peen were determined by modal analysis.

2. STUDY METHODS

2.1 Preliminary studies

Based upon comprehensive studies of the working conditions on construction sites, the laying of paving setts with dimensions of 14 x 16 x 16 cm and a weight of 5.8 kg was selected as a typical work process. Six impacts per sett were measured as the average impact sequence.

2.2 Vibration measurements

Measurements were performed with the same paving hammer originally used by the individual who had suffered the disease. A work process involving an experienced paver was reconstructed in the laboratory for this purpose. The measurements were performed and analysed in accordance with ISO 5349 and the extended requirements of ISO/TS 15694 [3]. The direction of measurement was limited to the impact direction. This corresponds to the primary excitation and to the direction of measurement closest to the direction of the forearm in accordance with VDI 2057-2 [4].

2.3 Measurement of coupling forces

The coupling forces were measured in accordance with ISO 15230 [5] and DIN 45679 [6] synchronously with the vibration measurements. The system developed in the "VIBTOOL" EU project was employed as the measurement chain.

2.4 High-speed camera

A high-speed camera was used to record the work processes synchronously with the vibration and force measurements. The filming rate of 500 frames per second enabled the processes to be resolved at an interval of 2 ms. All signals were synchronized by means of an initial triggering pulse. For technical reasons, only the first few impacts of each work process could be recorded, owing to the limitation of the recording duration to 4 seconds.

3. RESULTS

3.1 Acceleration of the coupling forces

In order to prevent cable movements from causing contamination effects when the hammer was lifted, the vibration exposure was analysed separately for each impact. In order to permit comparison between the individual impacts, each impact was integrated over one second. Altogether, 12 series of measurements were conducted. The results for the energy-equivalent average values over one second were averaged arithmetically over the individual impacts. The resulting average frequency-weighted acceleration a_{hw} was 24.4 m/s². The unweighted acceleration measured at the hammer handle attained peak values of up to 30,000 m/s². The impact event was however very brief, and had already subsided after approximately 20 to 30 ms. The mean value for the push/pull force F_{pu} across all series of measurements was 22.3 ± 8.5 N, and for the grip force F_{gr} 32.8 ± 8.8 N. The coupling force F_{cp} averaged from the individual measurements was 55.1 ± 14.0 N. Since the vibration-free components during raising and lowering of the hammer were included in this average, the forces arising during the impact phase were determined separately.

The summary of all measured values (Figure 1) shows the coupling forces with the unweighted and weighted

acceleration and the position of the hammer during the impact process. For technical reasons, the coupling forces were measured at intervals of 20 ms. The push force is decisive for the force acting outwardly. It acts in the direction of impact, and is oriented in the direction of action of the vibration/recoil. During the impact event, the push force is 17 N and the grip force 49 N. The recordings by the high-speed camera clearly show the transmission of the shock into the wrist, which is accompanied by a rotating/tilting motion.
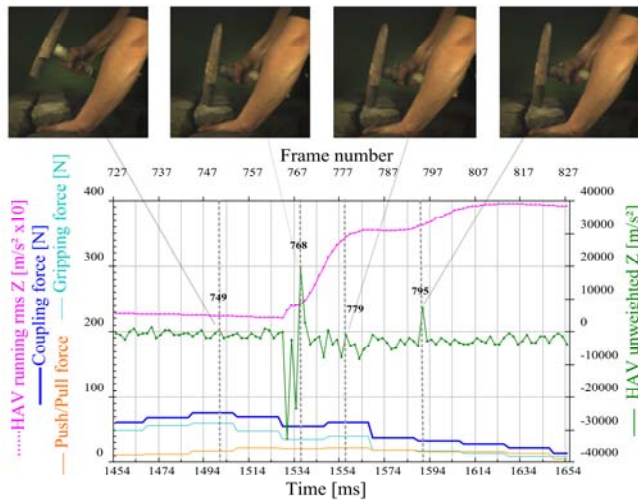

Figure 1: Summary of the measured values in the phases of the impact process (example)

3.2 Modal analysis

A modal analysis of the paving hammer was conducted to determine the free vibration behaviour of the hammer handle and peen. For the purpose of measurement, the direction of impact was defined as the x direction and the axis parallel to the hammer handle as the z direction.

The entire hammer (peen and handle) exhibits a clear tilt movement in the x direction, i.e. in the direction of impact (forearm direction), with values of 9.4 to 17 Hz. The reason for this movement lies in the flexural vibration of the upper part of the hammer peen. This vibration movement is transferred directly to the hammer handle. At 20 Hz - 31 Hz, the movements of the hammer peen and hammer handle are out of phase with the steel body leading. At 31 Hz - 650 Hz, the two components of the hammer are back in phase. At over 650 Hz, the hammer handle is subject to a self-motion independent of the hammer peen. This is a flexural motion.

To summarize, the additional modal analysis confirms the exposure measurements, since free vibration of the paving hammer occurs within the relevant frequency range of the normal frequency of the hand-arm system.

4. ASSESSMENT AND DISCUSSION

The measurement and evaluation method in accordance with ISO 5349 applies in the first instance to periodic, random and non-periodic vibrations. Under what boundary conditions can the method also be applied to repeatedly occurring impacts? If the coupling force is considered to be an essential factor for the interaction between hand and handle in accordance with DIN 45679, the risk can be assessed as follows: If in addition, owing to the particular point of transmission, only the push force is considered, the frequency-weighted acceleration must be weighted (corrected) with the coupling factor c_p of 0.6. The coupling-force-weighted and frequency-weighted acceleration a_{hwF} is then 14.6 m/s². For the specific exposure case of 280 setts per day, the daily dose as a function of the coupling force $a_{hw(8)F}$ is then 3.5 m/s².

For the case under examination, the Social Court upheld the claim of occupational disease. The results also have implications for prevention. They show that consideration should be given in risk assessments to intensive paving work, even where power tools or machines are not also in use.

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