Impulsive and Shock Hand-Arm Vibration

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ABSTRACT

Hand-arm vibrations that are impulsive or single shocks are a challenge in many ways. Previous studies have shown that a basic knowledge or wellfounded assumptions on the occurring vibrations are needed for their measurement. This is due to the wide span of frequencies and amplitudes of possible oscillations requiring the measuring equipment to be chosen accordingly. If this is not considered the measuring results can be distorted. Apart from the aspects regarding measurements, the effect of these vibrations on the human hand-arm system are of interest. Various research has shown that the available knowledge is insufficient to assess their impact and the resulting stress on the system extensively.Taking previous research and pending questions into account, it is being asked in this contribution which solutionapproaches have already been established and what would be conceivable for the future.

1. INTRODUCTION

Evaluation of vibration includes several requirements which extend from knowledge on source and receiver to the measurement execution and the post-processing of the gathered data. In most cases vibration is analyzed regarding its potential harm towards the receiver. Unlike the audible case, the transmisson of the vibration, source and receiver are easily influenced. The source can be influenced by the receiver, as can be the transmission, but also other fators such as temperature may play a role. Studies such as [1] present the difficulties in measuring hand-arm vibration with a impulsive or even shock characteristic. Such vibration are challenging as they combine a short vibrational event with high acceleration amplitudes and a wide frequency spectrum. In [1] the impulse only lasts a few ms and has a peak acceleration value around $10000\,\frac{m}{s^2}$.

2. STANDARDS AND RESEARCH

Several standards have been developed to enable a preferably consistent analysis of hand-arm vibrations. Some of which apply to all types of hand transmitted vibration, such as DIN EN ISO 5349-1:2001 [2] and DIN EN ISO 5349-2:2001 [3]. Then there are standards only applicable to hand-held tools (DIN EN ISO 20643:2005 [4]). Others are more specified with regard to tool or vibraion type, as DIN EN ISO 28927-13:2019 [5], DIN ISO/TS 15694:2004 [6] or DIN ISO/TS 8662-11:2004 [7]. In some regards these standards are in agreement, such as the directions in which the vibration needs to be measured or the fact that the coupling between the sensor and the handle of the tool needs to be as rigid as possible. That a mechanical filter may need or has to be used is part of most of them. Both [5] and [6] include a 3Hz repetition rate of the impacts, if it can be chosen. Yet, [7] demands only an interval larger than 2s between them. And though [5] applies to motorised tools and [7] to pneumaic ones, [6] may apply in both cases. In the latter, a discrete shock is defined as a short acceleration impuls. All of the above standards require the application of the W_h frequency weighting described in [2]. It inludes weighting factors for the $\frac{1}{3}$-octave bands reaching from the center frequency of 6.3 Hz to 1250 Hz that represent the assumed significance regarding damages to the hand-arm system.

Various studies have applied at least one of these standards and analyzed the effect of vibration on the human hand-arm system. In [8] the authors studied the effect of vibration frequency on finger blood flow and found two frequency regions (31.5 - 63 Hz and 250 - 500 Hz) that caused blood flow reduction of up to 50%. Though, the results of other studies referenced here do not neccesarily coincide with regards to these frequencies.

In [9] the temporary changes in mechanoreceptor-specific vibrotactile perception caused by stimuli simulating impact power tools are investigated. Therefor, three carrierfrequencies were applied to address the three different groups of mechanoreceptors individually (4 Hz, 31.5 Hz, 125 Hz). These were used as contiuous sinusoids and as decaying sinusoids. For the latter three different repetition rates were adopted (4 Hz, 16 Hz, 32 Hz). The impact on the temporary changes in perception varied over carrierfrequencies and repetition rates, hence the same frequency-weighted acceleration does not lead to an equal response. The authors found that more weight needs to be given at the frequencies 4 Hz and 31.5 Hz and concluded from the repetition rate of 4 Hz causing the least response that the impact summing according to DIN EN ISO 5349-1:2001 [2] is not appropriate.

In order to analyze the effects of impulsive vibration on the human hand-arm system, in [10] the vibration in z-direction of different hand-held tools, presented at an acceleration level of $6.3\,\frac{m}{s^2}$ was used. The evaluation of the effects included the analysis of the biodynamic behavior of the hand-arm system, of muscle activity, of the skin temperature, in order to check the circulation, and the subject's perception. No significant differences between non-impulsive and shock-type vibration was found for the short exposure time. But it is noted that the resonances of the hand-arm system are in the range of $10 - 25$ Hz and therefore could be a reason for the occurring health effects.

As in [10], [11] analyzed the biomechanical transmissibility of the hand-arm system, the muscle-activity, skin temperature and the subjective perception for stimuli with a weighted acceleration of $6.3\frac{m}{s^2}$. No significant difference in effects of impulsive and non-impulsive vibration was found here as well.

A comparison of the health effects of non-impact tools (e.g. grinders), low-frequency (e.g. chipping hammers) and high-frequency (e.g. impact wrenches) impact tools is presented in [12]. Unlike other studies, here sympoms of workers were analyzed instead of effects after a short exposure time under laboratory conditions. More users of low-frequency impact tools reported symptoms in elbows and shoulders than those who only used non-impact tools. More high-frequency impact tool users declared having symptoms in the wrists than did those using non-impact tools. As a poosible reason for these findings, it is stated that impact vibration or forces create an elastic wave propagation in the bones. For example vibration at a frequency of 50 Hz reaches the elbow almost unattenuated. This may cause an overload in bones and joints.

The influence of the repetitions rate and magnitude of the shocks were analyzed in [13]. Here, different repetition rates (1.3 Hz, 5.3 Hz, 21 Hz, 83.3Hz) were applied and the stimuli scaled to different acceleration levels ($a_{rms,unweighted} = 2.5\,\frac{m}{s^2}$, $5\,\frac{m}{s^2}$, $83.3\,\frac{m}{s^2}$). It was found that at the same $a_{rms,unweighted}$ the stimuli with different repetition rates and peak acceleration values caused similar reduction in blood flow in the hands. No effect in blood flow showed due to grip force without vibration exposure. A repetition rate of 83.3 Hz caused an immediate digital vasoconstriction, indipendet of he applied acceleration level and it showed a greater reduction of blood flow than at lower repetition rates. The blood flow reduction increased with the unweighted r.m.s. acceleration. Yet, the authors reference other studies stating that the damage to cell membranes depends on the peak acceleration and is underestimated by the r.m.s acceleration.

In [14] frequency weightings were compared regarding their suitability to predict vibration-induced white finger (VWF). The weighting given in DIN EN ISO 5349-1:2001 [2] W_h and W_p, the weighting described in ISO TR 18570, were tested. The latter gives greater importance to intermediate and high frequencies and was found to be the better predictor.

3. DISCUSSION

Taking the findings of studies like [14] and [9] into account, the question arises, if in cases of shock-type vibration the W_h frequency weighting is fitting. Giving little weight to the very low frequency components possibly stemming from the repetition rate and to the contained high frequencies may not give an accurate representation of the possible damages to the hand-arm system. Is it neccessary to make a further distiction in the evaluation than just between impact and non-impact vibration taking into consideration the diffence in reported sympoms between high-frequency and low-frequency impact tools [12]?

Additionally, there is a clear difference between those studies done in laboratories, which did not find a difference between impact and non-impact vibrations (as [10] and [11]), and those analyzing symptoms of workers (like [12]) that show a clear difference in health effects. Is the transmission through the bones possibly not detectable by means of accelerometers on the arm or joints? May this be caused at least partially by the vibration traveling through the bones in a direction perpendicular to any possible measurement position?

Aside from the difficulty of measuring the vibration or its effects, studies like [12] and [15] also refer to the ergonomical factors. The weight of the tool can already cause stress on the hand-arm system while working with it. Furthermore, [15] found the body posture, such as having to work over ones head, to be a factor contributing to the health effects. Can those factors be addressed by for example including the mass of the handled machine in the applied weighting or the risk calculation?

4. REFERENCES

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