Strategies for the reduction of high hand-arm vibration levels with reference to the example of vibrating screen removal tools

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Abstract
Vibrating screen removal tools are used for the removal of vehicle screens during repair work in automotive repair shops and during the recycling of end-of-life vehicles. The method is highly efficient, but results in exposure to high levels of vibration; the exposure action and limit values as defined in the German Ordinance on noise and vibration protection are exceeded after only a few minutes.
Manufacturers do not yet have a harmonized laboratory measurement method at their disposal with which data can be obtained under industrial conditions. Their data therefore differ, in some cases considerably, from the actual exposure in the field, with the result that the hazard is frequently underestimated.
The article describes the hazard-reduction strategies adopted in the various spheres of occupational safety and health.
In the standardization sphere, a harmonized laboratory measurement method is currently being developed.
Among users, Carglass (France) has developed a handle mount which provides insulation against vibration. Studies involving a prototype antivibration handle developed by the IFA and further developments by users reveal considerable scope for reduction of the vibration: measurements conducted jointly by the IFA and the INRS revealed reductions of up to 91% in the vibration exposure.
Equipment manufacturers are currently developing a vibration-free working method. This is described, as are the first steps being taken in development by automotive manufacturers in the area of vehicle design.
The accident insurance institutions are currently drawing up a guidance document for hazard-reduction measures in the area of work organization.
The English version you will find www.dguv.de/ifa, Webcode e162139
1. Introduction

A need for vehicle windscreens to be removed arises both in automotive repair work and during the recycling of end-of-life vehicles. In the past, steel wire was used to separate the screen from the rubber seals. This method generated no vibration. In modern vehicles, including buses and coaches, however, the windscreen is bonded firmly to the rubber seal and the frame, for reasons of stability. The power windscreen removal tools that have been used for some years to replace windscreens, for example following damage to the glass, subject the user to a high level of vibration [1].

Vibration total values $a_{	ext{tv}}$ of 22 m/s² and in exceptional cases of up to 30 m/s² have been measured for this very efficient procedure. Since at these high exposure levels, the exposure action and limit values as defined in the German Ordinance on noise and vibration protection [2] are exceeded after only a few minutes, employers are obliged to take measures.

According to the German Federal Office of Statistics [3], 47,000 persons were employed in 2011 in the occupational group of vehicle and coachwork construction. The various strategies for reducing the hand-arm vibration levels encountered in the relevant occupational group are described below with reference to the example of vibrating screen removal tools.

2. Determining and assessment of the hazard

Initial industrial measurements of vibration on pneumatic screen removal tools were reported on, with reference to the combined influence of hand-arm vibration and unfavourable body posture, at the fourth conference on human vibration in 2010 [4]. Since complaints among employees increasingly also arose in other workshops (such as those for trams and underground railways), further vibration measurements were performed in practical application on both pneumatic and electric tools from a number of manufacturers. The measurements were performed in accordance with EN ISO 5349 [5] and VDI 2057-2 [6]. Typical tools are shown in Figure 1.

If the exposure values measured under industrial conditions are compared with the manufacturers' data (see Figure 2), the latter are seen to be lower for all tools studied. This was also the case where the values had already been adjusted in accordance with DIN V 45694 [7] and the TRLV technical rules concerning vibration [8].
Assessment based upon the manufacturers’ data consequently results in the hazard being underestimated. Since no harmonized laboratory method exists for measurement of vibration emission under realistic conditions, comparable to the methods available for many other tools (such as drills and demolition hammers), standardization is urgently required.

At a high exposure value of $a_{hv} = 22 \text{ m/s}^2$, the action and limit values for exposure in accordance with the German Ordinance on noise and vibration protection are formally observed for exposure durations of 6 and 25 minutes respectively. Knowledge of very high vibration exposure levels remains limited, however. VDI 2057-2 [6] states for example, in a comment on the curve for the risk assessment (Figure 3), that little knowledge is available concerning exposure durations of less than 30 minutes and over 300 minutes; the reference-value curve for these ranges is therefore shown dashed.
3. Harmonized measurement method

EN ISO 20643 [9] is the basic standard for the specific measurement standards of the group of machines concerned. Whereas the focus previously lay upon comparison between the vibration emissions of the machines within a machine group, the EU Vibration Directive has added the aspects of determining the state of the art and the use of the emission values for the purpose of risk assessment.

Besides a series of parameters for improved reproducibility of the measurement results, the measurement standards also set out the operating conditions which are decisive for the vibration value. The operating conditions relate to the highest probable vibration values anticipated during typical and usual use of the machine. Satisfying this requirement is difficult in the case of vibrating screen removal tools, since they are used under exceptionally varied operating conditions and with wide variation in material and tool combinations. It is therefore advisable for the operating conditions to be subdivided for groups of applications. This enables the manufacturer to provide the user with guidance on selecting the correct emission value for the application concerned.

4. Measures for the avoidance and reduction of exposure

Part 3, Table 3 of the TRLV technical rules concerning vibration provides specific guidance on selecting and prioritizing protective measures. The use of alternative procedures and low-vibration tools takes priority over other measures such as the use of clamping jigs or vibration-damping handles.
4.1 Reduction of the duration of exposure

The use of different blades and optimization of the cutting technique and sequence of cuts may reduce the duration of exposure for a particular working task and thus also reduce the overall exposure to vibration.

This will be illustrated with reference to the use of an electric vibrating screen removal tool for removal of the front screen of an overhead railway carriage. Table 1 shows the tasks and the relevant blade type, the exposure portions and their respective durations of exposure. Calculation from the mean values yields a daily dose $A(8)$ of $2.47 \text{ m/s}^2$ for the task.

Table 1:

<table>
<thead>
<tr>
<th>Tool</th>
<th>Task</th>
<th>Tool insert/blade</th>
<th>Total vibration value $a_{hv}$ in m/s²</th>
<th>Duration of exposure</th>
<th>Daily exposure $A(8)$ for the task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dedicated vibrating screen removal tool produced by C. &amp; E. Fein GmbH, Stuttgart, FSC 2.0 X</td>
<td>Cut into the rubber seal</td>
<td>A</td>
<td>$20.89 \pm 2.22$</td>
<td>2 min 51 s</td>
<td>Summarized $2.47 \text{ m/s}^2$</td>
</tr>
<tr>
<td></td>
<td>Separation of the joint</td>
<td>B</td>
<td>$24.88 \pm 6.00$</td>
<td>1 min 31 s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cutting round the back of the joint</td>
<td>C</td>
<td>$10.12 \pm 1.65$</td>
<td>5 min 7 s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Removal of seepage residue</td>
<td>D</td>
<td>$11.39 \pm 1.65$</td>
<td>1 min 46 s</td>
<td></td>
</tr>
</tbody>
</table>

4.2 Fitting of supplementary vibration-damping handles

Vibration-damping handles may be used as a measure for reducing the transmission of vibration to the user. In this context, VDI 3831 [10] states that retrofitted handles of this kind may also have an influence upon the handling of the tool and upon its ergonomics, and that their effectiveness must be demonstrated on a case-by-case basis. It must also be considered that modifications to the tool invalidate the manufacturer's declaration of conformity. Accordingly, the EU HAV guide [11] states that only handles approved by the tool manufacturer may be used. The results shown below for a number of handle types are therefore intended to illustrate the options and scope offered by technical measures for reducing vibration.

Figure 4 shows the handle developed by Carglass France, which served as the prototype for the further handle variants. The handle developed by the IFA (Figure 5) was studied both with and without the auxiliary handle with damping. Since the front (main) handle is decisive for the vibration exposure on all handle variants, subsequent discussion relates to this transmission point.
Figure 4: Vibrating screen removal tool with AV handle, produced by Carglass France

Figure 5: IFA vibrating screen removal tool with AV handle

Figures 6 and 7 show two further handle variants developed by FFG (a vehicle workshop and user of the tool in Falkenried, Hamburg). Besides decoupling of the frame, the handle shown in Figure 6 also features resilient mounting of the main handle.

Figure 6: Vibrating screen removal tool with AV handle, produced by FFG
The measurement results are shown in Figure 8 in the form of mean values with standard deviation. The measurements for the tasks of "side window" and "windscreen" were performed separately and are comparable only within the relevant task under identical operating and measurement conditions. Owing to the space constraints within the bus, the values for the "side window" task exhibit greater scatter and higher mean values.

The vibration exposure with consideration for the scatter is below 10 and 5 m/s² respectively for all handle variants. This permits a duration of exposure of 2 and 8 hours respectively before the exposure limit is reached.
4.3 Use of alternative procedures

4.3.1 Developments by vehicle manufacturers

Up to now, vehicle screens have been removed by cutting of the adhesive bead between the bodywork and the screen.

To obviate the need for this cutting process, prospective tests have been performed by manufacturers involving embedding of a metal strip in the adhesive bead. The strip is heated inductively externally in order to release the material (see Figure 9).

![Inductive heating of a metal strip embedded in the adhesive bead](image)

This method is vibration-free but is associated with other problems which are yet to be resolved. These include the difficulty of controlling the induction current, strong generation of smoke, difficulties with handling, and continual following of the separation point by means of wedges.

4.3.2 Developments by tool manufacturers

In older vehicles in which the rubber seals were not bonded, the rubber seal was cut by means of a cutting wire. This wire featured handles at each end and was moved backwards and forwards.

Although also vibration-free, this method entails considerable force, and cannot be used for thicker adhesive beads or on screens with special geometries. This older procedure forms the basis of screen assembly arrangements in which suction cups are placed on the screen and a crank system is used to reduce the force to be exerted by the user.

A further development of this system employs a battery-powered motor (see Figure 10). This enables the user to move outside the danger zone (presented for example by the risk of wire breakage). Use on the windscreens of buses or overhead railway carriages has however yet to be trialled.
4.4 Use of low-vibration tools

If the existing procedure is to be retained, exposure to vibration can be reduced by the use of a low-vibration tool. Low-vibration tools generally have a different principle of operation or an improved damping system.

Tools that execute a purely linear movement for example give rise to lower vibration than do those employing oscillating movements in which the blade moves back and forth around a rotary axis.

Figure 11 shows a low-vibration tool for which the manufacturer (BTB) recommends the use of a lubricant. Lubricants may however adversely affect the adhesive bond.

Figure 12 shows the results of measurement in the form of mean values and standard deviations for the BTB tool with and without the use of lubricant, compared to the results for the vibrating screen removal tool with and without vibration damping handle. The higher values measured by the HHA (Hamburger Hochbahn AG) for the BTB tool are attributable to the curved blade with which it was used.
Manufacturers of vibrating screen removal tools are expected to develop tools with vibration damping in the near future.

5. Information and guidance
Information on the hazards associated with the use of vibrating screen removal tools has been available since October 2009 on the IFA's website in No 294 of the "Focus on IFA's work" series of publications [1].
A guidance document concerning exposure to hand-arm vibration during the removal of vehicle screens [13] is in preparation. This information, which is geared to application in the field, will be made available to manufacturers. The topics it addresses include occupational safety and medical support, personal protective equipment and the provision of instruction.

6. Summary
For tasks associated with very high levels of vibration exposure, the various OSH strategies for reducing hazards were described with reference to the use of vibrating screen removal tools for repair purposes.
Based upon the identification and assessment of hazards, deficits were identified in the body of standards and regulations.
The options available to users of equipment for reducing vibration by means of reduced durations of exposure and by the use of handles with a damping action were described. The
measurements performed in the field show that the vibration-damping handles are effective in reducing the exposure.

Despite the need for further improvement, low-vibration tools also already present a means of reducing exposure.

New developments involving alternative procedures which do not generate vibration were presented by both vehicle and tool manufacturers.

Guidance documents and information from the accident insurance institutions are available for implementation of the measures.

Literature


