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Zero Vibration Injuries—A Swedish Holistic Approach to Reduce Vibration Injury †

Carolina Pettersson *, Hans Lindell and Snævar Leó Grétarsson

RISE Research Institutes of Sweden, 431 53 Mölndal, Sweden; hans.lindell@ri.se (H.L.); snaevar.gretarsson@ri.se (S.L.G.)

* Correspondence: carolina.pettersson@ri.se

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Abstract: Vibration injuries cause significant costs for society, great personal suffering, and often the relocation of personnel within a company. The project "Zero Vibration Injuries" is a Swedish initiative with the objective of taking a holistic approach to the problem, involving all stakeholders. The project's vision is "Zero Vibration Injuries". This is achieved by addressing the source of the problem by reducing the vibration levels in hand-held machines and applying the solutions in industry to the benefit of the users.

Keywords: vibration injuries; hand-held machines; preventive measures; vibration reduction

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1. Introduction and Background

Every day, more than 400,000 people in Sweden are exposed to vibrating machines for at least two hours per day. Injuries due to the effects of vibrations were the most common occupational injury for men during 2016–2020 [1]. If carpal tunnel syndrome, which often is related to vibration injuries, is included in this, the percentage of occupational injuries linked to vibrations is almost 60 percent among men and almost 20 percent among women. Currently, several industry sectors do not comply with EU directives [2,3] for vibration exposure, often due to no availability of machines with low vibration levels. Even in areas where there are effective technical solutions, the lack of knowledge is an important factor leading to constant or increasing numbers of vibration injuries.

Since the work within the project Zero Vibration Injuries started in 2014, the purpose has been to reduce vibration injuries by addressing the source of the problem and developing low-vibration machines. The objective is to take a holistic approach to the problem, with all stakeholders in society participating in the project, i.e., machine manufacturers, a comprehensive range of machine users, the Swedish work environment authority, employer and labor organizations, and occupational medicine and vibration researchers.

The strategy has been to develop low vibration concept prototypes, representing the main research area. It has been shown for a broad range of types of machines that machines do not need to vibrate and thus injure people, and this is also our motto within the project. At this stage of the project, lab-scale prototypes and concepts are being scaled up to establish replacements for new and existing hand-held machines, with the goal to make them accessible on the market.

In this project, vibration regulated with ISO 5349-1 with an upper frequency limit of 1250 Hz has been addressed, but also higher frequency vibrations, so-called ultravibrations, have been reduced. Ultravibrations are vibrations with a frequency higher than 1250 Hz, which is beyond the human perception threshold. Precautions against high frequency shock vibration are important, since there is a substantial risk for vibration injuries [4–7]. Reducing ultravibrations is, from a technical perspective, generally much easier than those at lower frequencies due to the laws of physics. Regrettably, currently there is no incentive for machine manufacturers to reduce these vibrations since there is no standardized

method to measure and quantify ultravibrations. However, work from the International Organization for Standardization, ISO, is ongoing in order to include high frequencies and transients/shocks.

2. Method

The project has, since the start 2014, been divided into three stages, and these are:

1. It can be done!Representative machine types have been redesigned and tested in the laboratory.
2. It can be done in real production!The solutions from stage one have been upscaled and set into industrial production in the relevant areas.
3. Make it happen!The developed solutions will be implemented for the project participants, leading to the manufacturing of low-vibration machines as requested by the users, which results in lower vibration exposure and injuries.

In the current stage 3, the work is being conducted in real industrial environments with participating parties representing the automotive, construction, stone, and dental sectors.

2.1. Activities

The work is based on three main activities:

- Information on low-vibration alternatives;
- Facilitating the selection of low-vibration machines;
- Establishing a culture change.

Information on low-vibration alternatives: We have shown that vibrations can be reduced with new techniques on the lab scale and in prototypes. Now, scaling up the vibration-reducing solutions to system solutions for new and existing hand-held machines and machine groups is the next step. One example of doing this is through the newly formed company, ATVA License Group, which has been established for commercializing the ATVA technology worldwide (see more about ATVA below in Section 2.2).

Facilitating the selection of low-vibration machines: In order to enable machine users to require, assess, and purchase low-vibration machines, measurement and assessment of vibrations, including the peak vibrations in the high frequency area, are needed. Ultravibrations are not measured in vibration instruments used in the field today. However, in this project, RVM10, a measurement system for hand-arm vibrations capable of simultaneously measuring vibrations according to ISO 5349-1 and ultravibrations up to 30 kHz is being developed. The system is a scientific prototype, with the goal to make it available for purchase.

Establishing a culture change: This concerns company behavior regarding vibrations and vibration injuries, also including ultravibrations, and minimizing the problem by choosing low-vibration machines. Knowledge and information dissemination of vibration-reducing solutions, understanding and acceptance throughout the organization of the vibration problem, and raising awareness about the risks of injury from ultravibrations are important in all levels of organizations, e.g., machine users, managers, purchasing departments, occupational health care, labor organizations, employers, and so on.

2.2. Methods to Reduce Vibrations in Hand-Held Machines and Tools

Vibrations are reduced in machines by design solutions based on (a) balancing rings, also called autobalancers, for vibrations originating from imbalance and rotational forces in, e.g., grinders, (b) Auto Tuning Vibration Absorbers (ATVA), which reduce reciprocating forces in, e.g., rockdrills, and (c) traditional vibration isolation and conceptual redesign. These solutions, alone or in combination, can be used for the vast majority of hand-held vibrating machines.

The balancing ring is in principle a ring containing balls and a dampening lubricant. The balls will automatically adjust themselves and compensate for the imbalance in a frac-

tion of a second and keep the system continuously in balance. As soon as new imbalances are created, the balls immediately readjust [8].

The Auto Tuning Vibration Absorber (ATVA) technology [9–11] is a vibration absorbing unit that is integrated into a machine with reciprocating vibrations. The ATVA unit creates a counter force to the excitation force from the piston of the machine, which reduces the vibrations.

Traditional techniques, e.g., vibration isolation of handles and conceptual redesign, are also used to reduce vibrations in machines and tools when applicable.

3. Results

Several machines and tools have been re-built within the project, according to the methods mentioned above (Section 2.2). A few examples, which represent a vast proportion of machines that cause vibration injuries, are given in Table 1 below. The project also includes dental tools.

Table 1. Summary of some machines and tools, the reduction methods, and the consequent reduction in vibration levels.

Machine	Reduction Method	Vibrations Before (m/s^2)	Vibrations After (m/s^2)	Reduction
Round vibratory plate	Optimized vibration isolation	11.1 [1]	5.5 [1]	51%
Chisel machine	ATVA, optimized vibration isolation	20 [1]	2.7 [1]	87%
Rock drilling machine	Isolating handle	27.3 [1]	8.6 [1]	68%
Rammer	ATVA, isolating handles	25–32 [1]	5–8 [1]	75–80%
Anvil	Vibration isolation	13 [1] 8000 [2]	6 [1] 150 [2]	54% 98%

[1] Vibrations measured according to ISO 5349-1; [2] Ultravibration, VPM, average peak measured up to 30 kHz.

Peak ultravibrations were measured up to 30 kHz. An average level was estimated by visual assessment; however, it is recommended that peak ultravibrations should be calculated according to the VPM algorithm [12].

4. Discussion and Conclusions

It has been shown that machines and tools can be re-built or re-designed in order to minimize harmful vibrations, often at a low cost and potentially enabling additional improvements at the same time. It is important to spread the knowledge about the problem and the solutions in order to reduce vibration-related injuries.

Some of the re-built machines and tools are in serial production. The newly developed, low-vibration machines meet the specific requirements of users. Demand from workers and companies are necessary for the manufacturers to start producing more low-vibration machines. The prerequisite is standardized methods for vibration measurements, which also includes ultravibrations and shocks. A leap forward could come from the suggested revised European Machinery Regulations, planned to come into force from Q1 2023, requiring manufacturers to declare these vibrations. This will hopefully lead to an increased drive from the machine user to demand low-vibration machines and an incentive for the machine producers to reduce them. It is necessary that low vibration machines are demanded, manufactured, and purchased. Machines do not need to vibrate and injure people!

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