proceedings

Proceeding Paper

Evaluation and Damping of High-Frequency Vibrations on a Tightening Tool †

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† Presented at the 15th International Conference on Hand-Arm Vibration, Nancy, France, 6–9 June 2023.

Abstract: Impulse tightening tools can generate high-frequency vibrations that are not taken into account in currently applicable standards. In various publications, it has been suggested that those high-frequency vibrations may cause health issues. In the present study, high-frequency vibrations produced by an impulse nutrunner are evaluated and used to assess the potential damping effect provided by a thin layer of soft rubber.

Keywords: hand-arm vibrations; high-frequency material; damping material

1. Introduction

Hand-transmitted vibrations from power tools are associated with injuries and diseases labeled as hand-arm vibration syndrome (HAVS) [1,2]. In many countries, concerned authorities have thus issued regulations to protect users of vibrating tools [3]. For example, within the European Union, power tool suppliers are required to provide information on vibration emissions that reach or exceed a level of 2.5 m/s^2 measured and reported in accordance with several specific standards [4,5]. While the current methods for vibration declaration solely taking into account frequencies below 1250 Hz [2,5] have been useful in reducing the number of injuries, it is suggested in various studies [6–8] that vibrations at frequencies above 1250 Hz may cause nerve damages to power tool users. Consequently, there may be new requirements emerging from authorities and companies concerning the evaluation and the reduction of high-frequency vibrations.

The present paper deals with an experimental study of high-frequency vibrations measured on a hydraulic impulse nutrunner. In the study, the signals recorded on the nutrunner handle are used to assess the damping effects of a soft rubber layer on high-frequency vibrations.

2. Background and Procedure

In all industries in which productivity is essential, handheld power tools are utilized to perform tightening operations. In particular, hydraulic impulse nutrunners are widely used for assembly work due to rather high productivity and acceptable accuracy. Moreover, this power tool type presents obvious benefits in terms of ergonomics since they generate no significant reaction forces and have low vibration levels according to ISO 28927-2. In hydraulic impulse nutrunners, the torque is actually built up by impacts on a pulse unit containing oil that acts as a damping cushion. Nevertheless, the impacts may imply significant accelerations at high frequencies. Therefore, to investigate high-frequency vibrations and a potential damping method, measurements were performed on a hydraulic impulse nutrunner manufactured by Atlas Copco and designated EP7 PTI55.

The measurement procedure was conducted according to the general guidelines described in ISO 28927-2. However, the procedure was slightly simplified by using one machine run by only two operators. In addition, the time signals that were obtained from

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Citation: Lundin, O.; Haettel, R. Evaluation and Damping of High-Frequency Vibrations on a Tightening Tool. *Proceedings* **2023**, *86*, 18. https://doi.org/10.3390/proceedings2023086018

Academic Editors: Christophe Noël and Jacques Chatillon

Published: 12 April 2023

the triaxial accelerometer mounted on the tool handle by using double-sided tape and a cable tie were acquired with a sampled frequency of 65,536 Hz. The recorded data were then analyzed by applying a low-pass filter at 10 kHz in order to conform to the useable frequency range of the accelerometer. For the measurements, the nutrunner was operated in the appropriate brake device at the maximum rated torque, as shown in Figure 1. Each of the two operators performed five runs of 10 s initially on the nutrunner with a regular handle (new tool from factory) and then on the same machine with a damped handle. The regular handle for this type of nutrunner is made of an aluminum core covered by hard rubber. The dampened handle consists of a 2 mm layer of soft rubber glued to the aluminum core and then covered by the hard rubber.

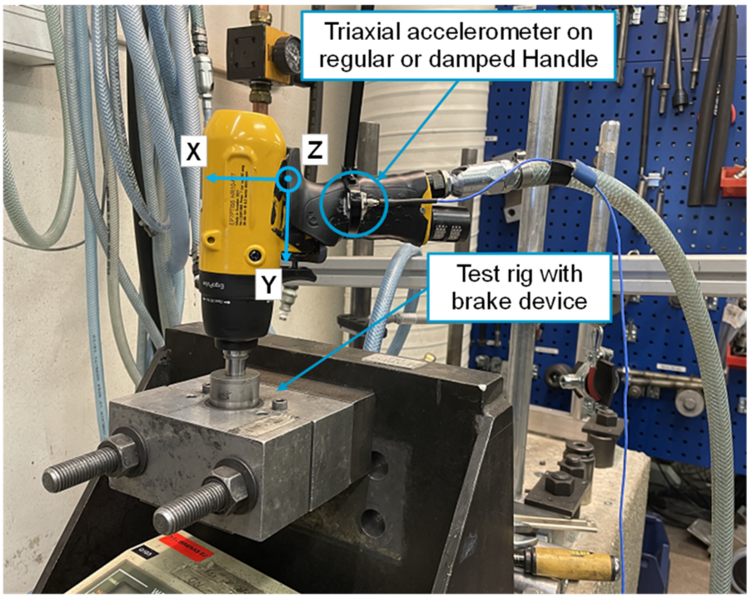

Figure 1. The nutrunner positioned on the brake device that was used for the vibration measurements that were performed with a triaxial accelerometer mounted on the handle.

The data provided by the triaxial accelerometer were used to evaluate the declared vibration emission value a_{hw} for the nutrunner. In addition, the Vibration Peak Magnitude (VPM) was calculated by using the relationship:

$$\mathrm{VPM} = \sqrt{\frac{\sum a^{2+2k}}{\sum a^{2k}}} \tag{1}$$

where the parameter k was set to two.

According to a report on signal processing [9], the value produced by the VPM calculation can be used to quantify the high-frequency content of the vibrations generated, for example, by repeated shocks. In the present study, the VPM value is mainly used to characterize the effect of vibration damping at high frequencies.

3. Measurement Results

In Figure 2, the time signals of the accelerations recorded by the triaxial accelerometer are shown in the X-, Y-, and Z-directions for two runs, where one run was performed on the regular handle and the other run on the damped handle. The signal amplitudes can vary significantly during a triggering sequence. Nevertheless, the signal amplitudes are clearly reduced by using the soft layer of damping material, especially in Y- and Z-directions.

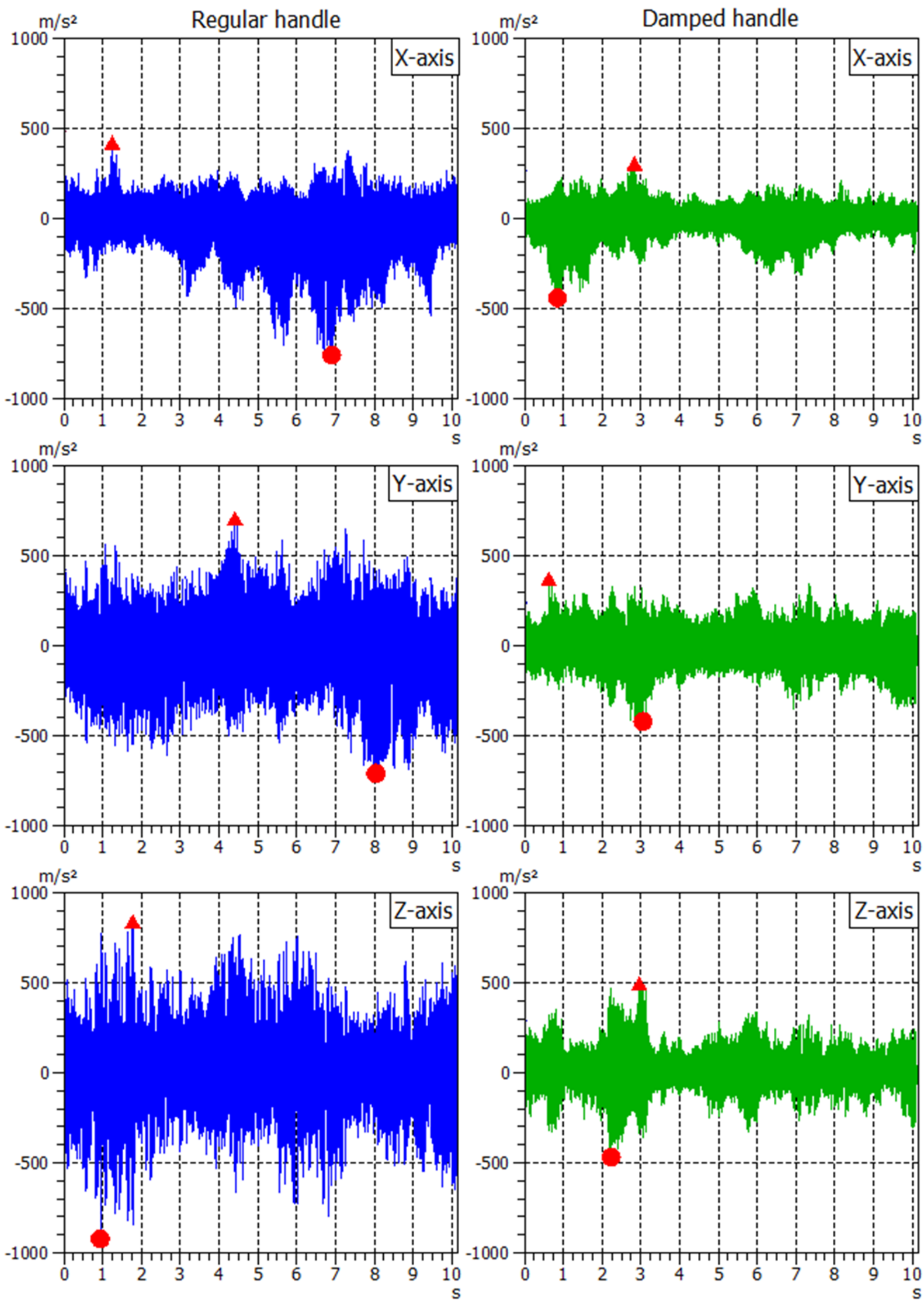

Figure 2. Time signals for two runs, one run performed on the regular handle (plots on the left) and the other run on the damped handle (plots on the right). Measurement direction and max-min values are indicated in each graph (red triangles for max values and red circles for min values).

The acceleration spectra obtained by averaging the vibration data from the ten runs are presented for both tool configurations in 1/24th octave bands in X-, Y-, and Z-directions, as shown in Figure 3. A large reduction of the acceleration amplitudes can be observed at frequencies above 1–2 kHz, whereas an increase in the acceleration levels can be viewed at the frequency range below 1 kHz, particularly in the Y-direction. This increase may be attributed to a resonance that is implied by the mounting of the accelerometer on the handle.

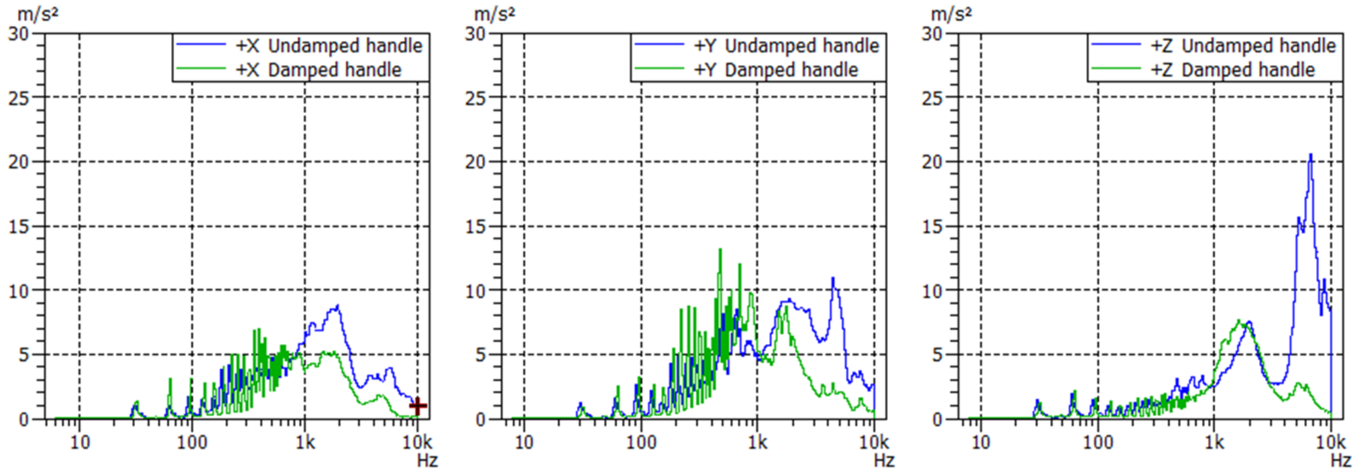

Figure 3. Acceleration spectra given at 1/24th octave bands for both tool configurations in X-, Y-, and Z-directions.

In Table 1, the VPM and a_{hw} values obtained for both tool configurations are given in X-, Y-, and Z-direction and for the resulting vector norm. The soft rubber layer used on the damped handle provides a decrease in the VPM value and a slight reduction in the vibration declaration value a_{hw}.

Table 1. VPM and a_{hw} values are provided for both tool configurations with standard deviation and uncertainty factors. All values are given in m/s^2 and rounded to one decimal.

Tool	Regular Handle		Damped Handle	
	VPM (Std. deviation)	a_{hw} (Std. deviation)	VPM (Std. deviation)	a_{hw} (Std. deviation)
X:	415.1 (77.0)	1.8 (0.1)	253.2 (66.9)	1.5 (0.1)
Y:	458.6 (46.8)	2.0 (0.3)	326.4 (83.2)	1.7 (0.2)
Z:	618.9 (170.0)	1.7 (0.4)	268.5 (52.0)	1.1 (0.1)
Norm (X, Y, Z):	888.6 (113.9)	3.1 (0.4)	500.3 (80.7)	2.5 (0.2)

4. Discussion and Conclusions

The damping effects of a thin layer of soft rubber on high-frequency vibrations are demonstrated by using time signals, acceleration spectra, and VPM values. The slight decrease that was observed for the declared vibration emission value from 3.1 m/s^2 to 2.5 m/s^2 cannot be fully attributed to the added damping. In fact, the official declaration value for the nutrunner is 3.3 m/s^2 with an uncertainty K = 0.9 m/s^2. At least, this shows that the increase of vibrations at frequencies below 1 kHz due to the added soft material does not impact the declaration value. Furthermore, the damping effects at high frequencies, as shown in Figures 2 and 3, are clearly indicated by the decrease in VPM values. This tends to prove that the VPM value can be used as a suitable parameter to quantify high-frequency vibrations.

The use of a thin layer of soft rubber on a nutrunner handle gives a significant damping effect on high-frequency vibrations and provides extra insulation against the cold surfaces generated by a pneumatic tool. For further development, the potential influence of resonances at lower frequencies and material durability should be investigated thoroughly.

Author Contributions: R.H. and O.L. contributed equally to this article. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Atlas Copco Industrial Technique AB.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data are available on request if authorized by company policy.

Conflicts of Interest: There is a potential competing interest as the authors are employed by the tool manufacturer, Atlas Copco Industrial Technique AB.

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