Comparison of Vibration Impact of an Impact Drill on the Human Body under Different Working Conditions

Bartosz JAKUBEK
Poznan University of Technology, Institute of Applied Mechanics
24 Jana Pawła II Street, 60-965 Poznan, bartosz.jakubek@put.poznan.pl

Wojciech RUKAT
Poznan University of Technology, Institute of Applied Mechanics
24 Jana Pawła II Street, 60-965 Poznan, wojciech.rukat@put.poznan.pl

Abstract

Currently there is a wide range of different kinds of power tools on the market. In the case of impact drills the major threat to the user's health are vibration and acoustic impacts. Knowing that the actual drilling conditions may vary significantly from standardized conditions. It is important to determine the actual maximum level of dangerous factors present during drilling. Furthermore, it is also very important to link that factors to the conditions in which they occur. Among many factors affecting the level of vibration of an impact drill, change of the working position, the length of the drill bit and the diameter of the drill bit were verified in this paper. Verification was based on a comparison of vector-weighted mean values of acceleration of vibrations $\bar{a}_{RMS}$ registered on the handles of the impact drill, while drilling in concrete, under different working conditions.

Keywords: impact drill, local vibrations, concrete drilling, drill bit, different working conditions

1. Introduction

Impact Drills are one of the most common power tools used both professionally and at home. The manufacturer's declaration of levels of vibration and noise are taken into account in industrial conditions for legal reasons [1]. However, in the case of private use, the lack of awareness of safe use can be observed or the threats are just ignored.

Vibration levels declared by the manufacturers are determined in the specific standardized conditions. According to EN 60745 the procedure requires a drill bit diameter of 8 mm and a working length of 100 mm. While drilling vertically, downward the force acting on the device must be between 120 N and 180 N. [2]. However, the actual drilling conditions often significantly differs from the standardized conditions, which are the basis of manufacturers' declarations of vibrations. Therefore, the value of acceleration of vibrations given by the manufacturer should be treated with caution. Due to the harmful impact of vibration on human health [3,4] the proper selection of personal protective equipment, determination of allowable time of exposure or even the decision to stop using the device is vital.

There are a number of factors affecting the level of vibrations emitted by an impact drill. These factors can be divided into three groups associated with:

- machined material and the way of its foundation (concrete, brick, stone, etc.),
- operator's personal features (physique, experience),
- device and tool (build and additional equipment).

The factors affecting the level of vibration emitted during drilling were discussed in many publications [5-10]. But there is no information about the influence of different diameters and working lengths of the drill bit in terms of the measurement of acceleration of vibrations.

2. Measurements

A series of holes was drilled in reinforced concrete beams (vibration-compacted concrete) in the experiment. Drilling was done vertically, downwards and horizontally. The operator's positions are shown on Figure 1.

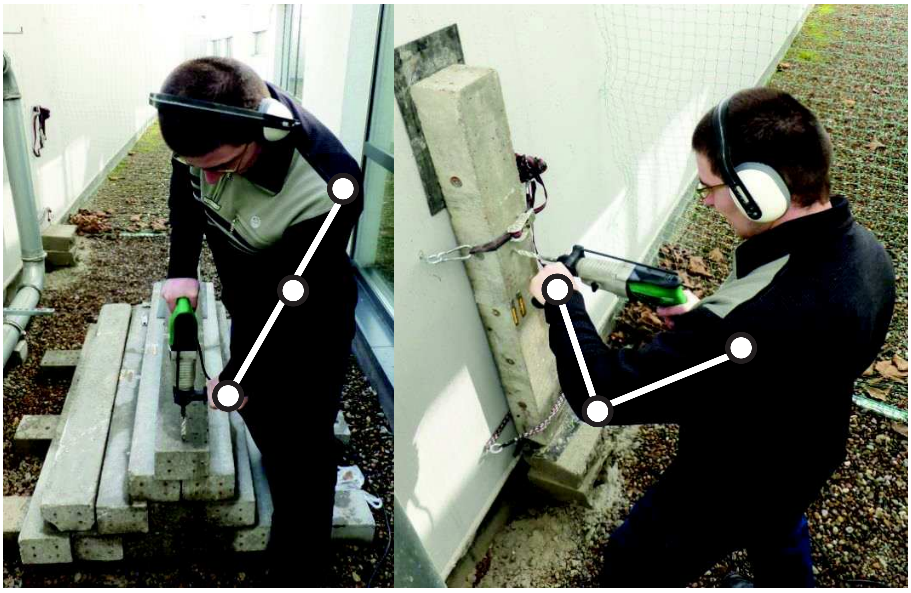

Figure 1. The stand and the operator while drilling vertically – on the left, while drilling horizontally – on the right

Triaxial vibration transducer ICP 604B31 and SVAN 911A analyser were used to register the vibration signal. Spatial orientation of the measurement directions, related to a tool, is following:

- the X direction (axis) corresponds to the longitudinal axis of the spindle of the drill,
- the Y direction (axis) corresponds to the longitudinal axis of the rear handle of the drill (a handle rigidly connected with the tool's body),
- the Z direction (axis) is mutually perpendicular to the other two [11].

During the tests 620W impact drill HITACHI DH 22 PH was used. To determine the impact of the forced change of the operator's position Ø12mm drill was used. In order to determine the effect of the diameter of the drill bit the following tools were used: Ø8mm, Ø12mm, Ø16mm and Ø20mm. Examination of the effect of drill bit's diameter on the vibration was carried out in the vertical direction, downwards. To determine the effect of the length of the drill bit on the values of vibration a set of Ø12 mm drill bits was used. The set includes the following bits: 125/165mm, 250/315mm, 400/460mm, 520/600mm and 900/1000 mm (working/total length). In this case drilling was done only in the horizontal direction.

Each comparison required as constant conditions as possible. One experienced operator drilled in a single beam (one for each comparison). The operator was 27-year old, 175cm tall and 78kg weight male. The maximum power of the device was used. The drilling direction was controlled by laser. In order to eliminate the influence of temporary changes in the downforce, the average of multiple measurements was adopted as the result. The total measurement time was approximately 300s in the comparison of drilling directions, and 180s for the rest. Transient states were omitted in the measuring sequences.

3. Research results

The results of the measurements are presented below. The following charts show the impacts of: forced change of the operator's position, the length of the drill bit and the diameter of the drill bit on the values of vibrations.

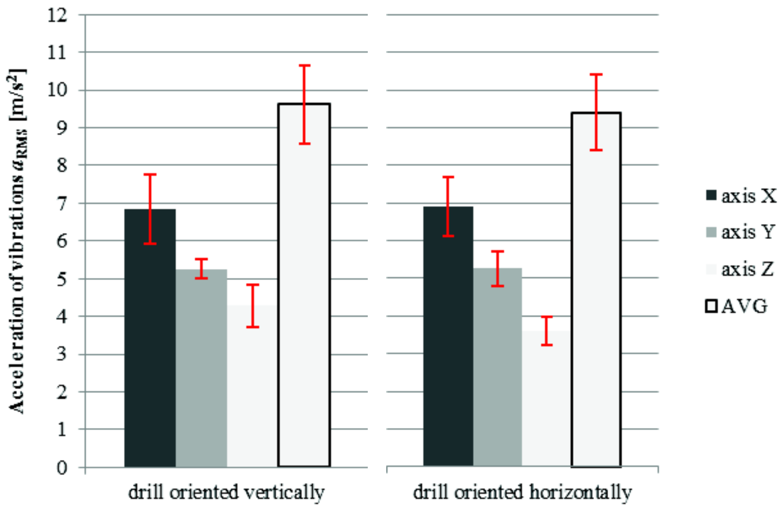

Figure 2. Acceleration of vibrations of the front handle of the impact drill deepening on drilling direction

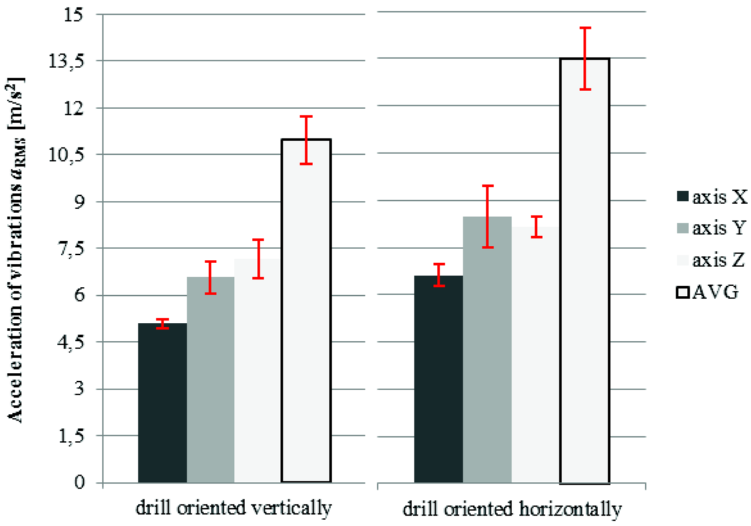

Figure 3. Acceleration of vibrations of the rear handle of the impact drill deepening on drilling direction

As it can be seen in Figure 2. the change of operator's position due to change of drilling direction has no impact on the value of acceleration of vibrations measured on the rear handle. The highest vibrations were measured along the x-axis. The repeatability of the results determined by the formula (1) equals 97.7%.

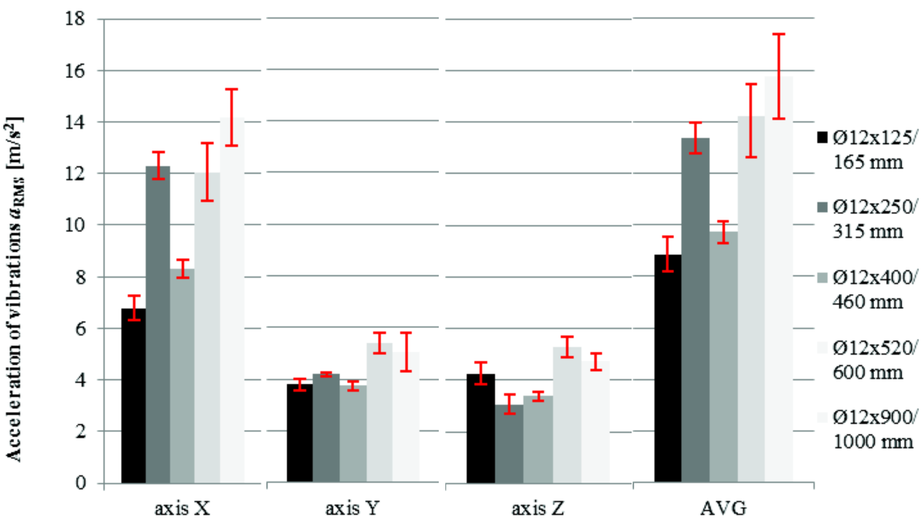

Figure 4. Acceleration of vibrations of the front handle of the impact drill deepening on drill bit length

$$\frac{\bar{a}_{\mathrm{RMS}} - \left| a_{\mathrm{RMS\_H}} - a_{\mathrm{RMS\_V}} \right|}{\bar{a}_{\mathrm{RMS}}} \cdot 100\%, \tag{1}$$

Where $\bar{a}_{\mathrm{RMS}}$ is the arithmetic mean of $a_{\mathrm{RMS\_H}}$ and $a_{\mathrm{RMS\_V}}$,

$a_{\mathrm{RMS\_H}}$ is vector-weighted mean value of acceleration of vibrations measured while drilling horizontally,

$a_{\mathrm{RMS\_V}}$ is vector-weighted mean value of acceleration of vibrations measured while drilling vertically.

In the case of the front handle, an increase of acceleration of vibrations was observed, what confirms the conclusions of other work [10]. This is caused by the change of the angle between the arm and the forearm of the operator’s left hand. In the case of vertical drilling the arm is straight. During horizontal drilling, the left arm is bent at the elbow (see Figure 1.). The repeatability of results in the case of front handle equals 79.3%.

With the increase of the length of the drill bit an increase of the acceleration of vibrations of the rear handle is observed. Maximum vibration values were measured along the x-axis.

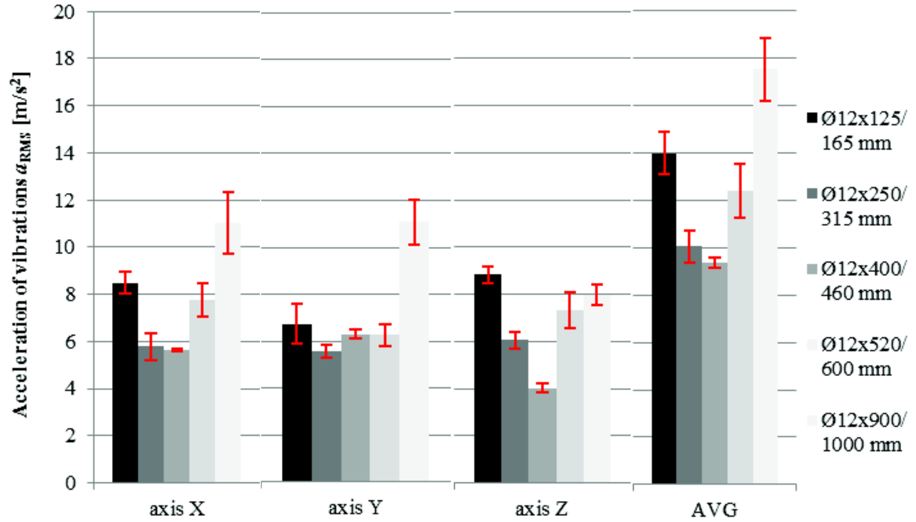

Figure 5. Acceleration of vibrations of the rear handle of the impact drill deepening on drill bit length

It is impossible to describe the nature of the dependence between the length of the drill bit and the values of acceleration of vibrations of the front handle. Initially the values of acceleration of vibrations tend to decrease, followed by their increase. In the case of the longest drill bits, such high $\bar{a}_{\mathrm{RMS}}$ values were caused by the buckling of the drill bit. The buckling was probably triggered by the action of the downforce, which was misaligned with the drill bit's axis [12,13]. Verification of exceeding the critical buckling force was not possible.

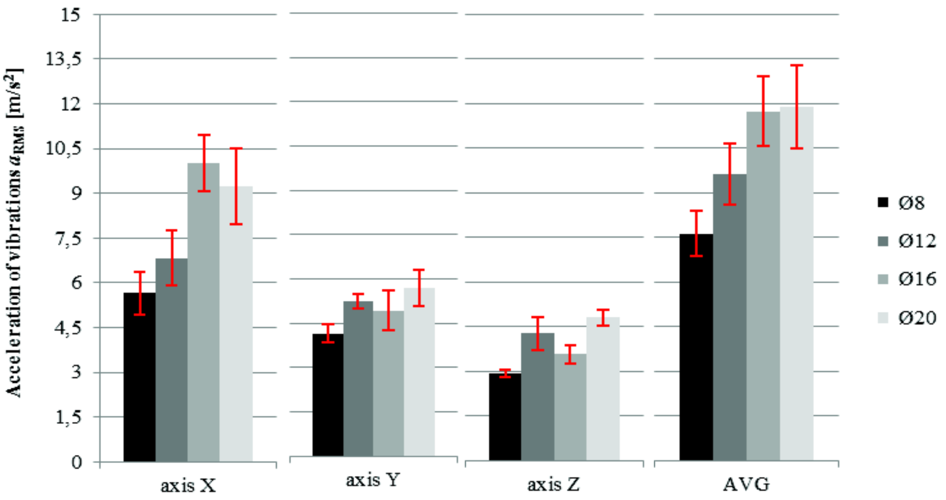

Figure 6. Acceleration of vibrations of the front handle of the impact drill deepening on drill bit diameter

With the increase of the drill bit diameter an increase of the acceleration of vibrations of the rear handle is observed. Maximum vibration values was measured in the X axis. In this case, the coefficient of determination R^2 equals 0.91 which indicates a very strong dependence between the level of vibration of the rear handle and drill bit diameter.

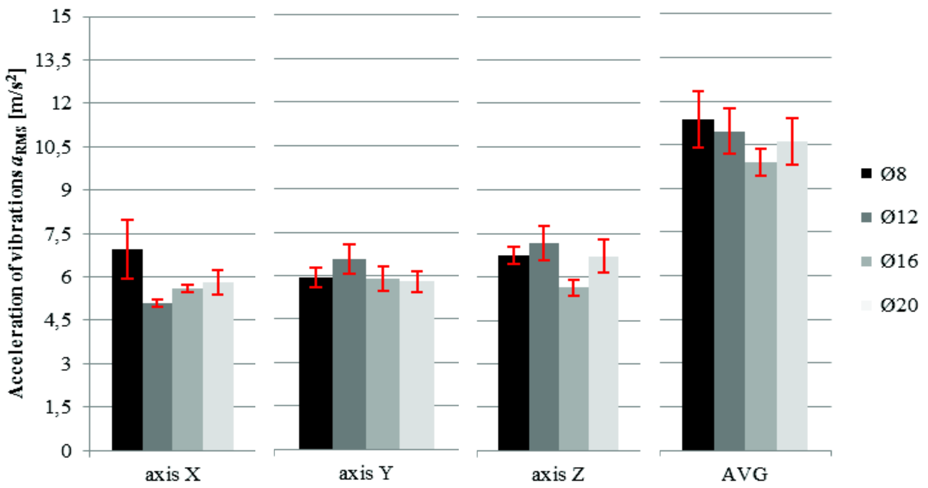

Figure 7. Acceleration of vibrations of the rear handle of the impact drill deepening on drill bit diameter

On the basis of Figure 7. it can be stated that the vibration level measured on the front handle does not change with increasing diameter of the drill bit. Vibration values are similar in different directions. The measurement results are consistent with previous work. [11].

In order to meet the paper fundaments the drill bit Ø12×125/165mm was used three times (three different beams). The convergence of the results were calculated with the use of additional data. Percent convergence of results determined on the basis of formula (1) equals 96.41% for the rear handle, and 94.02% for the front handle. The average absolute error of the vector-weighted mean value of acceleration of vibrations $\overline{a}_{\mathrm{RMS}}$ is 0.9 m/s^2, and the average relative error is 7.88%.

Table 1. The time limit for drilling in different working conditions

Handle	direction of drilling	Drill bit description							
		Ø8 mm	Ø12× 125 mm	Ø12× 250 mm	Ø12× 400 mm	Ø12× 520 mm	Ø12× 900 mm	Ø16 mm	Ø20 mm
right	vertical	65.0 min	40.6 min	-----	-----	-----	-----	×	×
	horizontal	-----	42.6 min	×	39.7 min	×	**×**	-----	-----
left	vertical	×	31.3 min	-----	-----	-----	-----	38.5 min	33.5 min
	horizontal	-----	×	37.2 min	42.9 min	×	**×**	-----	-----

The table above shows the time limit for drilling in different working conditions in relation to Exposure Limit Value (ELV) [1]. The symbol × indicates conditions that do not allow the use of the drill without personal protective equipment. In two cases that are in bold, $\overline{a}_{\mathrm{RMS}}$ of drill's handle exceeded the manufacturer's declaration (13.2 ± 1.5 m/s^2) with maximum uncertainty included.

4. Conclusions

There were no changes in the acceleration of vibrations on the rear handle associated with the change of the operator's position and direction of drilling observed. At the same time an 30% increase occurred for the front handle. This is connected with forced bend of elbow joints in left arm.

Vibrations of the drill's handle depend on the length of the drill bit but the nature of this dependence is not clear. Vibration levels dangerous for operator and exceeding the ELV were observed for the longest drills and it was caused by the buckling of the drill bit.

The change of the drill bit diameter has no effect on the level of vibration of the front handle. Yet, the dependence between the change of the drill bit diameter and the level of vibration of the rear handle is increasing.

The increase of the diameter of the drill bit, as well as the change of drilling direction and the change of operator's position from vertical to horizontal extend the time of drilling and cause a loss of productivity of the process – both are connected with power demand.

In practice there may occur a combination of factors at the same time, which will result in vibration emitted by the device exceeding the ELV as well as the occurrence of health hazard to the operator, despite secure level of vibration declared. In one case the acceleration of vibrations of both handles significantly beyond the manufacturer's declaration were measured.

Acknowledgement

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References

1. J. Skowroń, *Weryfikacja wartości NDN dla drgań mechanicznych o działaniu ogólnym i miejscowym*, Bezpieczeństwo Pracy Nauka i Praktyka, **6** (2000) 22 – 23.
2. EN 60745-2-1:2010, *Hand-held motor-operated electric-tools – Safety; Part 2-1: Particular requirements for drills and impact drills*.
3. G. Björing, L. Johansson, G. Hägg, *Surface pressure in the hand when holding a drilling machine under different drilling conditions*, International Journal of Industrial Ergonomics, **29** (2002) 255 – 261.
4. B. Harazin, *Occupational exposure to whole-body vibration in Poland*, Occupational Medicine (Medycyna Pracy), **6** (2002) 465 – 472.
5. B. Huang, J. Kuang, P. Yu, *Effect of crack on drilling vibration*, Journal of sound and vibration, **322** (2009) 1100 – 1116.
6. S. Keith, A. Brammer, *Rock-drill handle vibration: measurement and hazard assessment*, Journal of Sound and Vibration, **174**(4) (1994) 475 – 491.
7. G. Neely, L. Burström, M. Johansson, *Subjective responses to hand-arm vibration: implication for frequency-weighting and gender differences*, Proceedings of the 7th Annual Meeting of the International Society of Psychophysics, (2001) 553 – 558.
8. R. Oddo, T. Loyau, P. Boileau, Y. Champoux, *Design of a suspend handle to attenuate rockdrill hand-arm vibration: model development and validation*, Journal of Sound and Vibration, **275** (2004) 623 – 640.
9. D. Rempel, D. Star, A. Barr, I. Janowitz, *Overhead drilling: Comparing three bases for aligning a drilling jig to vertical*, Journal of Safety Research, **41** (2010) 247 – 251.
10. E. P. Shanks, S. M. Hewitt, P. M. Pitts, *Investigation of the relationship between vibration emission and in-use vibration for electrical tools*, Health & Safety Laboratory, Canadian Acoustics (Acoustique Canadienne), **39**(2) (2011) 104 – 105.
11. B. Jakubek, W. Rukat, *Influence of a tool's working diameter on the level of handle vibrations of an impact drill*, Vibroengeineering PROCEDIA, **6** (2015) 288 – 291.
12. J. Łabędź, P. Rusek, *Ocena niebezpieczeństwa wyboczenia narzędzia przy obróbce otworów a stali 40H wiertłami długimi o małych średnicach*, Przegląd Mechaniczny, **9** (2008) 25 – 28.