

REDESIGN OF HAND-HELD IMPACT MACHINES TO REDUCE HAND-ARM VIBRATION

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1. INTRODUCTION

Vibration exposure to workers from hand-held impact tools causes considerable injuries in the stone industry. In order to improve the work environment, a project was started with the objectives to redesign the tools to achieve low vibration, as well as improved ergonomics, dust removal and reduced noise while maintaining productivity. Redesign of current hand-held pneumatic impact machines can reduce the vibration level and thereby reduce injuries to workers. Hand-arm vibration injury, often called Hand-Arm Vibration Syndrome (HAVS) is one of the most common reasons for work-related injuries among this group of workers in the stone industry.

Although pneumatic impact machines have been used since the early 20th century, little has changed in their fundamental design. Despite their being robust and efficient, vibration, noise, dust and poor ergonomics cause a large number of injuries to the operators. Previous work has been done to improve these machines, and some results have been patented, e.g. [1], [2]. Yet these improvements seldom reach the market. The main reasons seem to be that the results remained questionable, costly, and reduced the efficiency and robustness of the machines. Another contributing cause could be lack of customer interest.

However, a new generation of impact machines can be developed by approaching the redesign from a user perspective, and by adhering to strict conditions of low vibration, noise and dust as well as good ergonomics. The objective of this study was therefore to develop a user-friendly, low vibration impact machine using a tuned vibration absorber, together with integrated vibration isolation. A tuned vibration absorber combined with vibration isolation has shown to significantly reduce the vibration exposure of the operator. The machine is also designed so that it can be manufactured in small volumes.

2. METHOD

The first part of the project was a survey of vibration exposure to workers in the stone industry. The different working operations were investigated and characterized, and their contribution to the total vibration measured. The results from the survey showed that three work operations contributed to more than 90% of the vibration exposure. These operations are executed using machines that are similar in design, namely pneumatic reciprocating impact machines with a piston that hits the work piece, but with different impact energy for various operations. By

improving this type of machine, a large part of the problem with vibration injuries could be solved.

The second part of the project, the redesign of the tools was carried out using three approaches: analytical calculation, multi-body simulation and experimental study. The machine used in this part of the study was an impact machine used for chiseling oval holes of about 20 x 10 mm wide and 30 mm deep. The machine is a KV434 from Atlas-Copco and has an impact energy of about 25 Joules. Its total weight is 11 kg with a piston weight of 530 grams and a hitting frequency of 35 Hz. The hand-arm filtered acceleration is about 20 m/s², which allows the worker to use the machine for only a few minutes per day before the exposure action value (2.5 m/s², A(8h)) is reached. This time limit is regularly exceeded during a normal 8 hour work day.

The redesigned machine has the same properties as KV434 with respect to total weight, piston weight, impact energy and operating frequency. The vibration reduction was accomplished by using two combined approaches: 1) a tuned vibration absorber that creates a counter force to the reaction forces on the cylinder of the piston, and 2) isolation of the vibration between the impact mechanisms and the housing to which the handles are attached (see Figure 1).

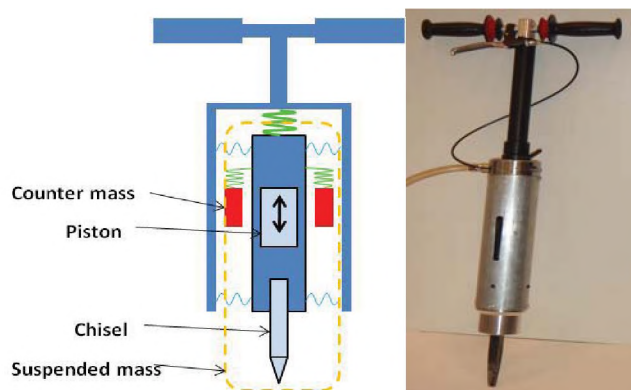


Figure 1. Principle of redesigned machine and prototype

2.1. Tuned Vibration Absorber

Using a tuned vibration absorber is a well known method, frequently described in the literature but not commonly used in products. It has been used in, for example, electric hair clippers, airplanes and cars (see [2] for a description of the theory). An initial problem was the narrow operating frequency range associated with the method; however, successful development of the method at Swerea IVF has resulted in a broader frequency.

The counter mass of the tuned absorber in this study weighs 930 grams and is attached to the suspended mass via a spring. The spring and counter mass are tuned to a resonance frequency of 35 Hz with respect to the suspended mass. Care has been taken to reduce friction in the system as much as possible. The damping coefficient is estimated to be below 2 % of critical damping (see Figure 1). The mass of the suspended system is 4.4 kg and the total weight of the machine is 11 kg.

2.2. Vibration Isolation

In order to achieve effective vibration reduction, the machine has been divided into two functional parts: first a suspended mass that contains the impacting mechanism and the tuned vibration absorber, and second, a housing with the interface to the operator. Vibration isolation between the suspended mass and the housing is applied in the axial, radial and rotational directions in order to handle the vibrations that still remain after the tuned absorber. Care has been taken not to compromise the ability to accurately control the machine.

2.3. Vibration Measurement

The vibrations on the handles of the machines were measured in a test rig, which yielded the same characteristics as described in ISO 8662-5. A three-axis Dytran 3053B2 accelerometer with mechanical filter was used to measure the vibrations. The signals were analyzed in Labview. Vibration measurements on the suspended mass and the counter mass were done with stroboscopic light and a steel scale.

3. RESULTS

In order to test the effect of the vibration reduction measures, three test configurations were set up and compared with the original machine. The test procedure was in accordance with ISO 8662-5, and results are shown in Table 1.

Table 1. Handle vibration

Configuration	Hand-arm filtered vector sum acceleration (m/s^2)
Original machine KV434	20.2
Redesigned machine with counter mass active	2.7
Redesigned machine with blocked counter mass	6.7
Redesigned machine with removed counter mass	8.4

The redesigned machine reduced the vibration by 87%, from 20.2 to 2.7 m/s^2 . The vibration isolation on its own reduced the vibration by 58% from 20.2 to 8.4 m/s^2 ; the tuned vibration absorber produced a further reduction of 68%

from 8.4 to 2.7 m/s^2 . The stability of the operation of the tuned vibration absorber was tested by varying the air pressure to the machine from 3 to 7 Bar, as well as by varying the feed force from -110 N to 450 N. It was found that the vibration level varied between 2.2 and 3.6 m/s^2 .

An analysis of the behavior of the counter mass and how it affects the vibrations of the suspended mass was also carried out. Results are shown in Table 2.

Table 2. Vibration of suspended mass and counter mass

Configuration	Suspended mass, displ. (mm p-p)	Counter mass, displ. (mm p-p)
Counter mass active	1.9	30.4
Blocked counter mass	5.2	5.2
No counter mass	6.4	-

From these results, the generated peak force from the counter mass was calculated to reach 684 N, providing the movement of the mass is sinusoidal.

4. DISCUSSION AND CONCLUSION

This study has shown there is a substantial potential for reducing vibration from hand-held pneumatic impact machines through redesign. This was done by dividing the machine into two functional parts and applying proper vibration isolation between the parts, as well as by adding a tuned vibration isolator. In this case, the vibration level was reduced from 20.2 to 2.7 m/s^2 hand-arm filtered vector sum acceleration.

It was also found that the operation of the tuned vibration absorber was stable over a relative wide range of feed forces and pneumatic pressures to the machine. This means that there is a possibility to substantially reduce the risk for vibration related injuries. In this case, the vibration level was reduced by a factor of more than 7, which would give a reduced risk according to ISO 5349 by a factor of about 50.

During spring 2011 the machine will be field tested in the stone industry.

REFERENCES

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