MITIGATION OF HAND-ARM VIBRATION IN WORKERS ON A PNEUMATIC NAIL GUN ASSEMBLY LINE

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1. INTRODUCTION

A pneumatic nail gun company has an assembly line on which operators have high rates of musculoskeletal complaints. The standard assembly procedure with highest complaint rate requires an operator to hold the handle of an assembled nail gun by one hand and install a screw top at the handle butt by the other hand (Figure1a). Inspectors interviewing operators found that a task involving the use of a pistol-grip air impact wrench to tighten the screw top also caused high hand-arm vibration (HAV) to both hands of the operator (Figure1b). Job rotation was adopted onsite to prevent operators from suffering numbness of the fingers.

In this preliminary study, a wooden fixture was developed to reduce the exposure of assembly line operators to HAV caused by the impact wrench. Experienced operators were recruited to assess the effectiveness of the fixture in reducing their HAV. Experimental findings and operators' subjective responses are reported in this paper.

(a) (b)

Figure 1. Work postures of an assembly operator while - (a) installing a screw top at the handle butt, and (b) tightening the screw top using an impact wrench

2. METHOD

2.1. Apparatus

Vibration is transmitted to operators' hands during the use of a pistol-grip air impact wrench. Vibration was measured using three piezoelectric accelerometers (model 4374L, Brüel & Kjær, Denmark). These accelerometers had a frequency sensitivity range of 1–26,000Hz, and were pre-calibrated using an excitation of 10 m/s^2 (r.m.s.) at 159.2 Hz, with a hand-held calibrator (model 4294, Brüel & Kjær). The three accelerometers were mounted on a lightweight adapter, which was held in contact with the handle-hand interface by the operator, to measure the vibration level in three orthogonal axes (X, Y and Z). Accelerometer outputs were connected to a 3-channel amplifier (Model 2693, Brüel & Kjær) with a signal conditioning gain of 31.6 mV/G. Outputs of the amplified signals were recorded on a portable data logger at a rate of 5000 samples/s per channel. The logger stored collected data on a compact flash memory card. The logged data were downloaded onto a personal computer using a card reader for further data processing (Chen et al., 2006).

A simple wooden fixture, which fastened the impact wrench to a worktable and held the assembly part of nail gun, was designed to reduce the vibration at the operators' hands by supporting the impact wrench and incorporating shock absorbing polyurethane material (Figure 2).

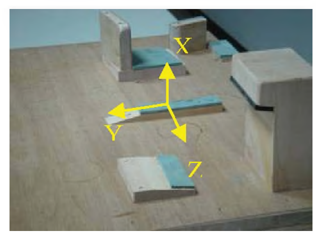


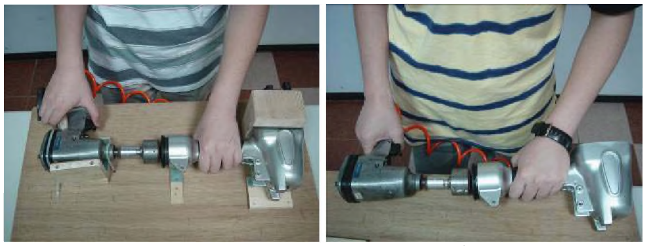
Figure 2. The designed wooden fixture, and directions of the measurement coordinate system for HAV measurement.

2.1. Subjects

Six experienced operators (three males and three females) were recruited as subjects from the assembly line for HAV tests. All subjects were informed about the purpose of the study and signed a consent form before participating in the experiments. All subjects were asked to complete two assembly tasks of fastening the screw top, with and without the wooden fixture (WF/WOF), with a 5-minute rest break between each task. For the task with the wooden fixture plate, each subject capped the screw top, held the assembled nail gun and lodged it in the L-shape hook of the fixer, then triggered a fastened impact wrench to tighten the screw top (Figure 3a).

For the task without the fixture, subjects performed the assembly task by holding the assembled nail gun on the worktable with their left hand while tightening up the screw top using an impact wrench in their right hand (Figure 3b).

Each operator repeated six trials, with HAV measured three times in each hand. Each trial included 10 seconds of data.



(a) (b)

Figure 3. Subjects' typical posture in performing screw top fastening task (a) with, and (b) without the fixture use

2.3. Data Analysis

The HAV levels, frequency-weighted root mean square acceleration, with and without the fixture plate were evaluated according to the ISO 5349-1 (2001) and ISO 8041 (2005) standards using Viewlog software (Chen et al., 2009). The results for the two procedures were compared using the Wilcoxon test. The difference was considered significant at a level of $p<0.05$.

Table 1. HAV levels (mean±SD, unit: m/s^2) With fixture (WF) and without fixture (WOF). ** p<0.05 for significant task difference by Wilcoxon test

Direction	Task (n=5)		Difference
Part-holding hand	WF	WOF	
X**	8.880 ±0.528	4.667 ±0.198	47.4%
Y**	4.857 ±0.253	2.208 ±0.459	54.5%
Z**	2.709 ±0.156	1.275 ±0.583	52.9%
Tool-grip hand			
X	2.237 ±0.585	1.563 ±0.387	30.1%
Y	0.981 ±0.445	0.627 ±0.106	36.1%
Z**	4.144 ±0.361	1.102 ±0.348	73.4%

3. RESULTS

Measurements indicate that using the fixture resulted in the dominant HAV levels being significantly reduced in both hands. The results given in Table 1 show the greatest mean HAV level to be 8.88 m/s^2, for the palmar direction (X-axis) in the part-holding hand. The greatest mean HAV level in the tool-gripping hand was 4.14 m/s^2, in the bushing spinning direction (Z-direction). The dominant frequency-weighted root mean square acceleration was reduced by 73.4% (from 4.14 to 1.10 m/s^2) in the tool-gripping hand and by 47.4% (from 8.88 to 4.67 m/s^2) in the part-holding hand. All subjects reported a recognizable reduction of HAV in the task when using the fixture.

4. DISCUSSION

Significant reductions were achieved in frequency-weighted accelerations using the fixture plate. However, only 30% reduction (from 2.237 m/s^2 to 1.563 m/s^2) was obtained in the palmar (X-axis) direction in the tool-gripping hand. This may because the plastic fastener, which fixed and restricted vertical movement of the impact wrench, could not diminish the vertical vibration effectively. Metal fasteners with better anti-vibration materials may improve vibration attenuation at the operator's tool-gripping hand.

With regards to work efficiency, the design of the fixture requires parts for assembly to be mounted and removed easily and quickly. Therefore, a loose-fitting L-shape hook was used to expedite lodging of parts during assembly. However, such design still requires an operator to hold the assembly part while tightening the screw top with the impact wrench. This design reduces the HAV of the part-holding hand by 47.4%, in comparison to assembly without the fixture.

This preliminary study demonstrates an economically feasible means of reducing HAV in an industrial context, by using a fixture and anti-vibration polyurethane material. An improved fixture design in the future, particularly one which helps hold the assembly part, seems promising to reduce further the operators' exposures to HAV in their part-holding hands.

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