Study and Reduction of Noise from a Pneumatic Nail Gun

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ABSTRACT

This paper describes the reduction of noise from a pneumatic 18 gauge nail gun. The objectives were to identify the major sources of noise, implement possible noise reduction measures, and evaluate the effectiveness of the modifications. Sound measurements were taken according to a procedure that was developed based on the ANSI S12.15-1992 standard for power tools. Results show that the nail gun was found to have several sources of noise for reduction consideration. Efforts were taken to reduce the two major sources of noise that contributed the highest sound pressure levels. The first major source of noise occurred right after pulling the trigger when the piston ram was forced into front bumper and the second major source was the compressed air exhausting out of the rear of the nail gun. The noise reduction treatments included new bumper materials inside of the nail gun and different types of mufflers on the exhaust. The sound pressure level measurements of the nail gun with mock-up treatments were compared to the baseline measurements to test the effectiveness of the treatments.

1. INTRODUCTION

Hazardous levels of noise are a part of more than one-half million construction workers' daily lives on the job. In fact, studies have shown that the category of work with the greatest amount of hearing loss for all degrees of severity and at all ages is construction, with part of the highest percentages of overexposed workers being involved in carpentry work [1]. Hearing protection devices such as earmuffs and earplugs that are mandatory in some cases are scarcely used because most workers feel they interfere with communication and they can be impractical if not chosen properly. There has been little incentive in the U.S. over the past few years to enforce tougher noise requirements for construction equipment. This is due partly to the closing of the EPA's Office of Noise Abatement in 1982. The European directives, however, provide some incentives for manufacturers to produce quiet products for sale both in the U.S. and Europe. This has put increasing pressure on American companies to build better and quieter products to compete in a global marketplace.

Professionals in hearing conservation, equipment manufacturers, and workers should make every effort to control excessive noise through the design and purchase of quieter equipment, the retrofit of existing equipment with engineered noise treatments, and proper maintenance precautions. Applying these methods would reduce the amount of hearing loss on the job and aid in the prevention of noise related accidents. Controlling construction noise at the source is the most reliable and efficient means of combating hearing loss on the work site. This paper presents a case study on the radiation, transmission and reduction of noise from a pneumatic nail gun typically used in the construction industry. This project was initiated by the National Institute of Occupational Safety and Health (NIOSH) through a multi University student project program.

2. MECHANICS OF THE NAIL GUN

A schematic diagram of a nail gun is shown in Figure 1. The mechanics of the nail gun can be broken up into two steps. Step one begins when the trigger is pulled. A valve is activated, which allows air to move through a tube from the compressor to an area behind the piston ram. This compressed air pushes on the ram and the ram forces a nail out of the gun. The air that was in front of the piston is compressed and held in an area in the front part of the nail gun for later use. The second action takes place when the trigger is released. Here the valve closes and the air that was behind the piston is exhausted through the rear of the nail gun. The piston returns back to its original position with the help of the air exhaust, creating a small amount of suction on the piston, and the compressed air that was held in front of the piston pushes the piston back into its place. A good animation of this procedure is illustrated on the "How Stuff Works" website: http://www.howstuffworks.com/nail-gun3.htm [2]. By simply listening to the nail gun under operation, it is clear that there are two major sources of noise. The first takes place in step one of the nail gun cycle and the second clearly takes place during the exhausting of air in step two.

3. TEST STANDARDS AND SETUP

Acoustics standard ANSI S12.15-1992 was used as a guideline for the test setup, though this particular standard only applies to portable electric power tools, stationary and fixed electric power tools, and gardening appliances [3]. The standard, however, provided a good template for the sound measurements as it is more recent and simpler than the compressed air and gas institute standard [4].

The standard specifies several conditions that needed to be adhered to in the test setup. First, a free-field environment was needed for sound measurements. To fulfill this requirement, measurements were taken in an anechoic chamber. Second, the ambient background noise in the testing environment needed to be at least 20 dB lower than the sound being measured. Third, the nail gun needed to be operated in a vertical position above and perpendicular to a reflective plane. For the reflective plane, a piece of half inch thick plywood was used. The nail gun was operated at the maximum allowable air pressure, which was 100 psi. The exhaust of the nail gun allowed for a direction control of the exhaust air. For the testing, the exhaust was rotated to point in the opposite direction of the microphone. This was done to make sure that the microphone was reading sound pressure and not the air blast coming from the exhaust. Lastly, the nail gun was fired into a scrap 4x4 wood placed on top of the reflective piece of plywood. A total of five sound measurements were taken for the test as described in ANSI S12.15-1992. A diagram of point locations can be seen in Figure 2. Both the recording and the data analysis were performed using a real time analysis hardware and software made by 01dB systems, Inc.

4. TEST PROCEDURE AND RESULTS

Sound pressure level measurements were taken at each point described in Figure 2 at a distance of 1 meter from the nail gun and the measurements were averaged for analysis. Five seconds of recording time was allowed for each point to ensure that the entire sound pressure history was captured. Figure 3 is a sample image of the sound pressure time history data during one cycle of the nail gun. The first noise peak corresponds to the instance when the trigger is pulled. The second peak is the instance where the trigger is released and compressed air is exhausted. At a pressure of 100 psi, it was found that the initial peak has a sound level of about 100 dBA and the second peak has a sound level of about 98 dBA. Figure 4 is a plot of equivalent sound pressure level, L_{eq} vs. time for one cycle.

The L_{eq} vs. time data shows four distinct peaks in sound pressure. The first peak occurs at about .05 seconds (point A) and is due to the air abruptly moving in behind the piston when the trigger is pulled. The peak at .02 seconds (point B) is from the piston impacting the rubber stopper at the front of the nail gun. The third peak (point C) is from the air being exhausted out of the gun and the last peak (point D) is due to the return impact of the piston when it returns to the rear of the nail gun. The noise of the initial impact of the piston hitting the stopper (point A) and the air exiting the exhaust (point C) were identified as the two major sources of noise for further study.

5. PROPOSED SOLUTIONS

The solution proposed to reduce the initial impact (point A) was to manufacture an additional bumper for the assembly to damp the impact that would reduce the resulting noise. The existing bumper for the piston ram assembly consists of a hard rubber that absorbs little energy during impact. A more energy absorbent material was needed to reduce the noise at impact. Two materials were chosen for their damping properties and their availability. They were Isoloss HD-12 and LS-1519 made by E·A·R Specialty Composites. The samples were cut to correct size to fit around the end of the piston rod assembly. The original and modified piston rod assemblies are shown in Figures 5 and 6.

To reduce the noise created from the exhausting of the compressed air (point C), several different mufflers were made. These would slow and diffuse the exhaust air, reducing the noise levels. An example of one of the proposed mufflers attached to the nail gun can be seen in Figure 7.

The same procedure and test setup developed previously using the ANSI S12.15-1992 was used to test the proposed solutions. Each muffler was fitted to the nail gun exhaust (with the manufacturer-supplied exhaust port end cap removed) and sealed with a tape. Introducing the Isoloss HD-12 bumper reduced the initial noise peak by approximately 6.2 dBA, while the LS-1519 had little effect. The muffler proved the most effective and reduced the sound level by 8.5 dBA. Figure 8 shows a comparison of results from an unmodified current nail gun with a modified nail gun. Figure 9 shows a comparison of the loudness (in sones) between the unmodified and modified nail gun. Next, the sound pressure level data in the frequency domain were examined through one-third octave band analysis to get a better understanding of how the proposed solutions affected the noise levels. This is shown in Figure 10. Additionally, the percentile levels namely, L_{10}, L_{50}, and L_{90} were also examined. A percentile level L_N indicates the sound pressure level that exceeded N % of the time[5]. Usually, L_{90} corresponds to the ambient level, whereas the L_{10} is an indicator of the presence of transients or peaks in the time history. These data clearly shows that the proposed noise treatments significantly reduced the overall sound pressure levels for all frequencies, the effects are more pronounced for frequencies above 125 Hz.

6. CONCLUSIONS

The two major sources of noise, the impact of the piston assembly with the front bumper and the compressed air exhaust, were successfully treated to decrease the overall sound pressure levels produced. A damping material, Isoloss HD-12 made by E·A·R Specialty Composites, was placed on the piston assembly to absorb the energy of the piston hitting the front bumper and produced an 6.2 dBA drop in sound pressure levels. An exhaust muffler made using a combination of rubber and acoustical foam reduced the sound pressure level from exhaust by 8.5 dBA. The treatments were easy to apply, used relatively inexpensive materials, and they did not seem to affect the performance of the nail gun. These proposed solutions have shown that the nail gun sound pressure levels can be dramatically reduced while adding very little weight to the nail gun and still maintaining complete functionality. Future work should examine implementing additional damping materials for the piston bumpers at both the front of the nail gun and at the rear. Also, different acoustical foams should be considered for the exhaust muffler assembly.

ACKNOWLEDGEMENTS

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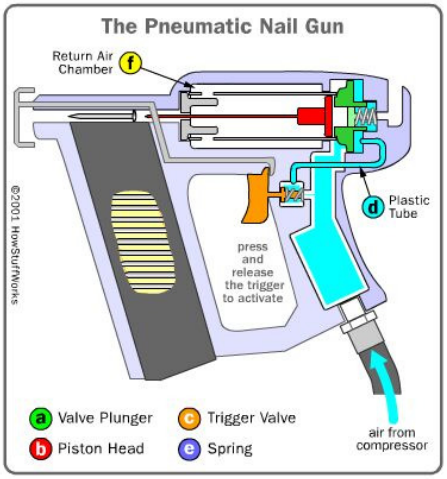

Figure 1: A schematic showing the mechanics of the nail gun. (Copyright: HowStuffworks.com web site)

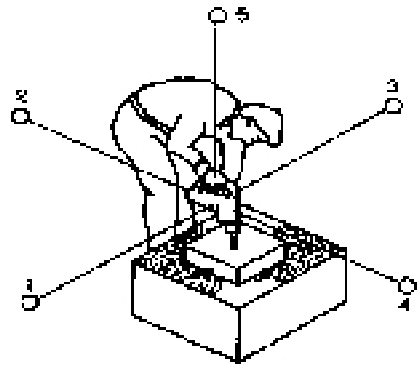

Figure 2: The ANSI S12.15-1992 point locations for sound measurements

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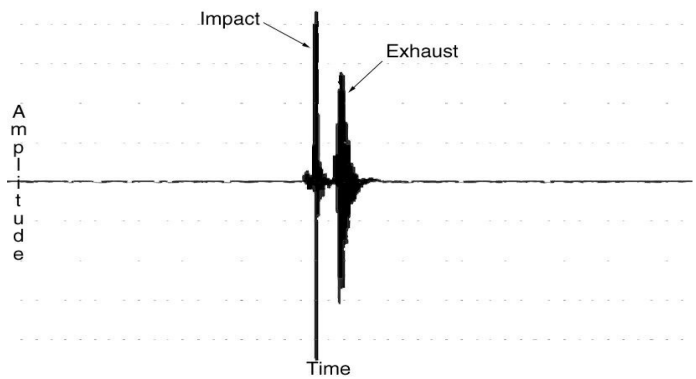

Figure 3: Pressure time-history, one cycle.

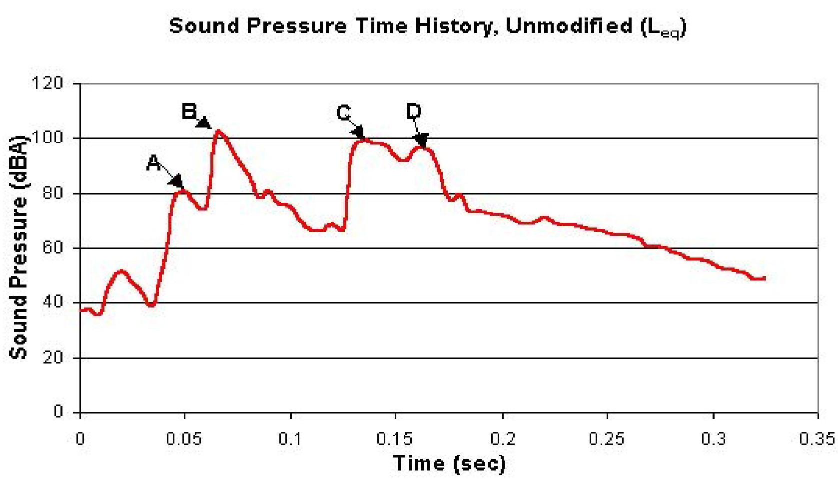

Figure 4: Leq vs Time, one cycle.

Figure 5: Original piston assembly.

Figure 6: Modified piston assembly.

Figure 7: Nail gun with muffler.

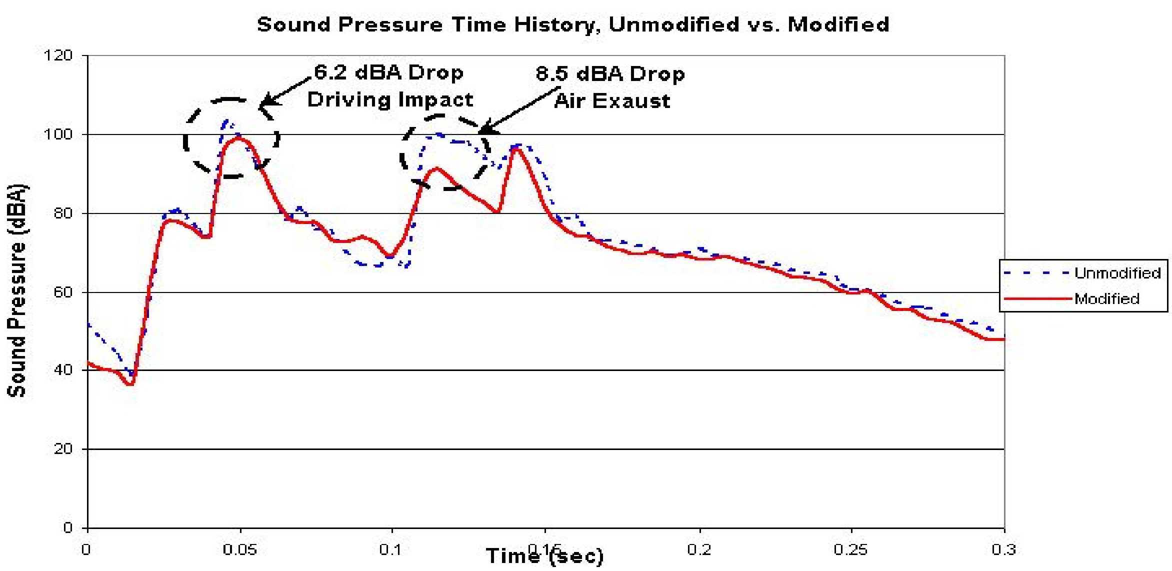

Figure 8: Sound pressure levels, unmodified vs. modified.

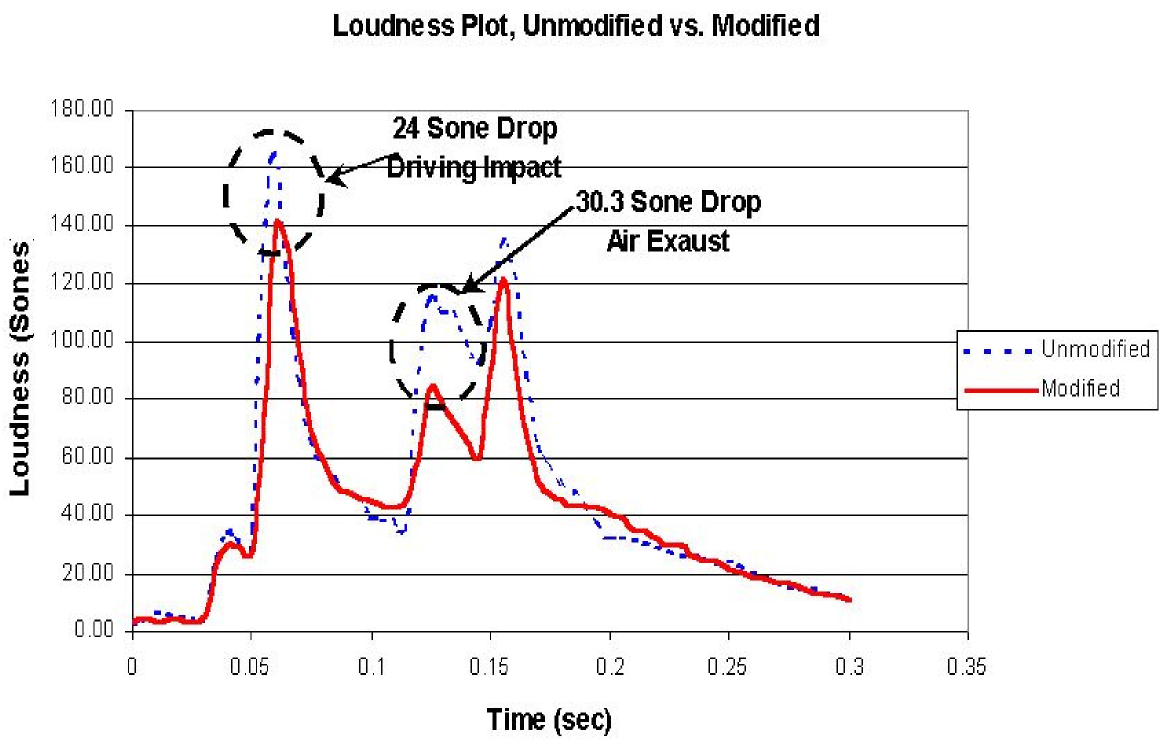

Figure 9: Loudness, unmodified vs. modified.

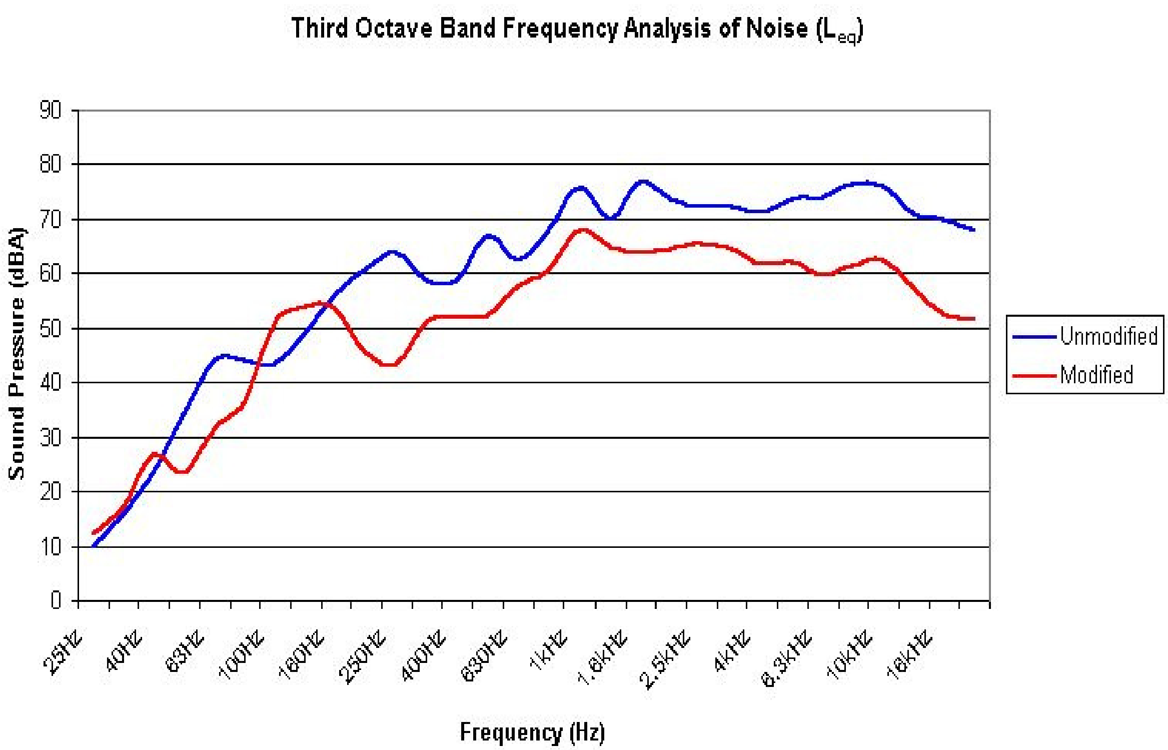

Figure 10: One-third octave band analysis, unmodified vs. modified.