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Time domain identification and ranking of noise sources in a pneumatic nail gun

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ABSTRACT

This paper investigates the noise sources in a pneumatic nail gun. The study combines two complementary experimental approaches. The first uses simultaneous data observation, with sound, acceleration and air pressure signals simultaneously recorded in conjunction with a nail gun motion high speed video. This strategy allows the identification of the physical processes involved in the operation of the machine at different time instants, as well as the associated noise generation mechanisms. However, since multiple noise sources radiate at the same time, this observation technique is not sufficient for noise source identification and ranking. Thus, a second approach introduces a selective wrapping procedure, and the strategy assures a reliable classification of the noise sources. The investigation considers the following noise origins: the air exhaust, the machine body and the workpiece/worktable.

In the standardized setup, the workpiece is placed in a sandbox to minimize its noise contribution. Since the final efficiency of this setup has never been established, the study evaluates the sandbox efficiency and compares it with a more realistic test arrangement, where the workpiece is placed on a worktable. The analysis shows that the sandbox setup does not sufficiently attenuate the workpiece noise. With the worktable setup, the workpiece/worktable noise source appears as the main contributor to the total emitted noise, while the air exhaust and the machine body noise are ranked as the second and third sources, respectively. With the sandbox setup, the workpiece noise is reduced, but remains the dominant source with the air exhaust, in equal measure.

1. Introduction

Pneumatic nail guns, which are commonly used in the construction industry, emit noise at levels high enough to put workers at risk of hearing loss. A first step towards noise reduction at the source is an accurate identification of noise generation processes.

The objective of the present research is to identify and rank the noise sources in a pneumatic nail gun process. In the standardized setup used for the measurement of noise emissions by nail guns [1], the workpiece is a wooden block placed in a sandbox to minimize its noise contribution and obtain the nail gun noise itself. This raises two questions: (1) Is the sandbox setup efficient in reducing the workpiece radiation? (2) What is a typical workpiece contribution at an actual worksite? To answer these questions, the noise source identification is conducted in two cases, the standardized sandbox setup, and a more realistic arrangement, where the workpiece is placed on a worktable.

Although numerous publications are available covering noise sources in various machines and systems [2–14], only three studies [15–17] have examined the noise problem in pneumatic nail guns. Ref. [15] used a simple experimental setup, in which one microphone captures the sound at the operator position to identify the noise sources. The authors distinguished four noise peaks in the sound pressure time history of the process. They attributed these peaks to the following four sources: (1) air exchange after trigger pulling, (2) piston impact with low piston bumper, (3) air exhaust, and (4) piston return impact. The authors of Ref. [16] evaluated the noise reduction obtained during the air exhaust phase when using a silencer device. Recently, Jayakumar and his colleagues [17] used sound pressure time history and noise maps to determine the possible noise sources and the corresponding transmission paths. In the investigation, the workpiece was supported by a sand bed. The authors identified the impact noise transmitted through the structure and the exhaust-related noise as the first and second contributors, respectively, to the total noise. The study also identified four distinct peaks in the noise time history. The authors associated these peaks with the following sources: (1) compressed air flow through inlet port, (2) piston rod-nail impact, (3) nail-wood

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impact, and (4) air exhaust. The present study develops a time domain noise source identification strategy similar to the procedure introduced in Refs. [15,17] and completes it by a selective wrapping procedure.

To identify the noise sources at different time instants, the study carries out a comprehensive experimental time domain analysis of the nail gun operation. The time domain identification uses simultaneous data observation: sound, acceleration and air pressure signals are simultaneously recorded, in conjunction with high speed video of the nail gun operation for post-process analysis. This strategy allows the identification of the physical processes involved in the machine operation at different time instants, as well as the associated noise generation mechanisms at play. However, since multiple noise sources possibly radiate at the same time, this observation technique is limited in the number of sources it can identify and rank. Thus, it is completed by a second approach, namely, a selective wrapping procedure. This strategy assures a reliable classification of the noise sources during the entire nailing operation. These two complementary experimental approaches are detailed in Section 3, following a description of the nail gun operation in Section 2. Section 4 presents the analysis of the test results.

2. Nail gun operation

Fig. 1 shows a schematic representation of a pneumatic nail gun. When the trigger valve (20) is in the released position, the compressed air covers the area above the head valve (10). The resultant force of the air pressure on both sides of the head valve and the compression spring (4) downward force keeps the head valve pressed against the cylinder top (5). Depressing the trigger closes the trigger valve, and stops the air flow to the upper area of the head valve. The remaining compressed air in this area flows out to the atmosphere through the air channel (1). As a result, the head valve opens, while simultaneously closing the air exhaust (7). Therefore, the compressed air flows to chamber no. 1 (2) above the piston head, pushes the piston downward, and drives out the nail. As the piston moves downward, the air inside the cylinder flows through a series of holes to a return chamber (15). Releasing the trigger valve allows a backward motion of the head valve, which stops the compressed air discharge to the piston head, and opens the air exhaust. The pressurized air inside the return chamber then drives the piston upward, while pushing the air above the piston to the atmosphere (Air exhaust phase) simultaneously.

3. Experimental procedure

In previous study [18], the authors investigated and formulated the tribo-dynamic interactions developing between wood-based products and metal nails during penetration at quasi-static velocities (20–500 mm/min range). The investigation published in Ref. [19] demonstrates that the nail size, nail type, and wood type have only a negligible influence on the force, the noise and the vibrations generated during the nail penetration. Therefore, the present study only includes smooth shank nails of 12d penny size that have a length of 82.55 mm (3.25 in.) and a diameter of 3.81 mm, all driven by a Bostitch N80 CB-Coil framing nailer which represents a typical model used in the construction industry.

3.1. Test wood specimens

The analysis concentrated on solid wood, and involved only dry pinewood specimens, with a straight grain, and being free of knots. The specimen size was chosen to reduce the boundary influence on the penetration process. According to preliminary tests (not included here), the optimal dimensions were a width of 152.4 mm (6 in.) and a length of 406.4 mm (16 in.), while, to avoid perforation, the thickness (t) was set to 95.25 mm (3¾ in.).

The hardness modulus, density, and moisture content of the wood specimens were measured according to the ASTM-D1037-12 [20] and ASTM-D4442-07 [21] standards. Table 1 shows the values obtained. The moisture contents shown in Table 1 are similar to the conditions encountered in the construction industry.

3.2. Experimental setups

As mentioned in Section 1, the tests were conducted using two different test setups: a standard sandbox setup and a worktable setup. For the sandbox option, the tests were carried out according to Ref. [1]. This standard aims to eliminate or, at least, minimize the noise emanating from the workpiece: the workpiece is settled in dry sand, with its upper surface at the sand level, and the wood

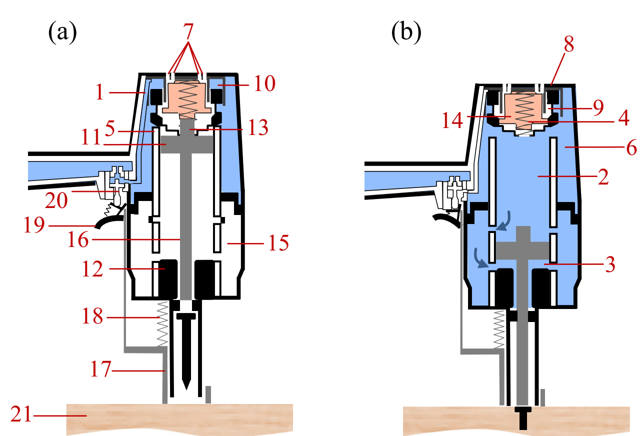

Fig. 1. Schematic representation of a pneumatic nail gun: (a) at rest and (b) during the driving stroke.