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A universal rig for supporting large hammer drills: Reduced injury risk and improved productivity

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ABSTRACT

Drilling holes into concrete with heavy hammer and rock drills is one of the most physically demanding tasks performed in commercial construction and poses risks for musculoskeletal disorders, noise induced hearing loss, hand arm vibration syndrome and silicosis. The aim of this study was to (1) use a participatory process to develop a rig to support pneumatic rock drills or large electric hammer drills in order to reduce the health risks and (2) evaluate the usability of the rig. Seven prototype rigs for supporting large hammer drills were developed and modified with feedback from commercial contractors and construction workers. The final design was evaluated by laborers and electricians ($N = 29$) who performed their usual concrete drilling with the usual method and the new rig. Subjective regional fatigue was significantly less in the neck, shoulders, hands and arms, and lower back when using the universal rig compared to the usual manual method. Usability ratings for the rig were significantly better than the usual method on stability, control, drilling, accuracy, and vibration. Drilling time was reduced by approximately 50% with the rig. Commercial construction contractors, laborers and electricians who use large hammer drills for drilling many holes should consider using such a rig to prevent musculoskeletal disorders, fatigue, and silicosis.

1. Introduction

Drilling into concrete is a physically demanding task associated with exposure to hand vibration, noise, silica dust and high forces to the upper body. These exposures are associated with whole body fatigue, upper body musculoskeletal disorders, hand arm vibration disorders, noise induced hearing loss, and silicosis (Flanagan et al., 2006; Herberts et al., 1984; Miranda et al., 2008; Palmer et al., 2000; Edwards and Holt, 2006; Shepherd et al., 2009; Balmes, 2007). In commercial construction, drilling holes into concrete is a common task for placing anchor bolts or for setting rebar for retrofitting and seismic upgrades, e.g., dowel and rod drilling (Fig. 1). For example, approximately 25,000 1″ diameter, 12″ deep holes were drilled recently on a sound wall expansion job in the Bay Area. On a concrete bridge structural upgrade, laborers drilled 5000 1″ diameter holes each 12″ deep. The work is usually done with large (10–36 lb) pneumatic rock drills or electric hammer drills. The work is exhausting; high forces are required to both support the drill and to push the drill into the concrete and these high forces and handle vibration are transmitted through the hands, arms, shoulders and back (Hagberg, 1981). The typical hand vibration levels are 8–16 m/s^2 for hammer drills and 14–20 m/s^2 for pneumatic rock drills (Griffin et al., 2006) – much higher vibration levels than most vibrating hand tools.

Many trades drill into concrete or stone, especially laborers (814,470), brick and block masons (57,090), cement masons (135,200), carpenters (567,820), electricians (519,850), and plumbers (340,370) [BLS employment numbers 2012]. In 2012 the nonfatal injury rate for highway, street and bridge construction (NAICS 2373) was 4.2 per 100 FTE, and for foundation, structure and building exterior (NAICS 2381) was 4.7; both were well above rates for all construction (3.7) and for all of private industry (3.4) (BLS, 2014). Although many of these are traumatic injuries, many are also sprains and strains associated with tool use.

Devices to support smaller hammer drills for just overhead drilling have been developed (Rempel et al., 2010) and commercialized (e.g., DrillRite, Telpro Inc, Grand Forks, ND). In addition, large air powered devices have been developed for supporting and simultaneously driving multiple pneumatic rock hammers into concrete for tarmac, highway, and structural upgrades (e.g., E-Z

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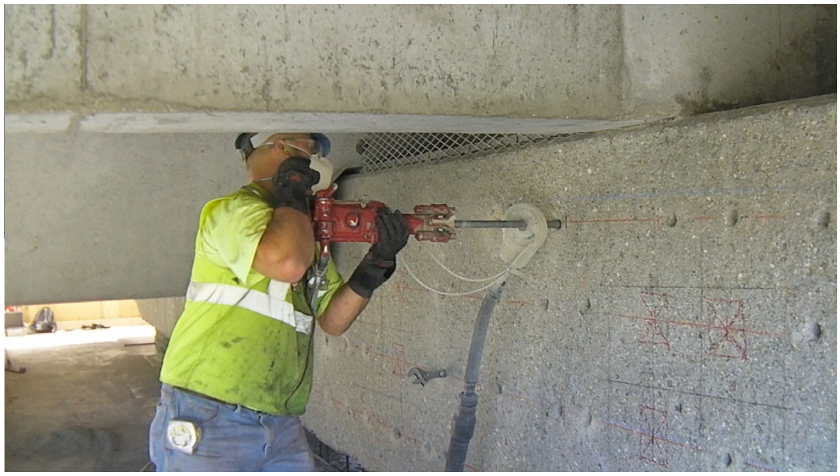

Fig. 1. Usual method for drilling with a 36 lb pneumatic rock drill to drill hundreds of holes for structural upgrade to concrete columns supporting train tracks.

Drill Inc, Stillwater, OK; Minnich Manufacturing Inc, Mansfield, OH). However, no smaller support devices exist for use from the ground, scaffolding or scissor lifts with easy manual advancement of the drill and easy adjustment of drilling height and angle.

The goal of the current study was to use a participatory process with construction workers to develop a new rig to support large hammer drills and evaluate the productivity, fatigue and usability in comparison to the usual method for drilling in commercial construction settings. Other aims were to reduce exposure to hand vibration and respirable silica dust. The intention was to design a universal rig that could use pneumatic rock drills or electric hammer drills of many sizes and shapes. The long-term aim of this line of research is to develop interventions for concrete drilling and grinding that will reduce fatigue, risk factors for upper extremity musculoskeletal disorders, and respirable silica dust exposure while not interfering with productivity.

Previously, we demonstrated that an early version of the universal drilling rig, when used with a pneumatic rock drill, reduced mean respirable silica dust from 0.68 to 0.30 mg/m^3 (the NIOSH REL (recommend exposure limit) is 0.05 mg/m^3; NIOSH, 2002). Drilling with the rig and dust control reduced the level to 0.04 mg/m^3 (Cooper et al., 2012).

2. Methods

2.1. Study sites and subject recruitment

Commercial construction sites where drilling into concrete with large electric or pneumatic hammer drills was to be performed were identified with outreach to general, highway and electrical contractors. Full-time construction workers who would be drilling for one or more days were recruited to the study. The construction workers performed their usual work and received their usual pay during their participation in the study. The study was approved by the university committee on human research.

2.2. Participatory feedback: design of the universal drill rig

The first prototype was designed by the researchers and included a base with wheels, a 5′ double vertical strut column, a carriage that rode up and down the column, a barrel attached to the carriage that could be adjusted to different heights and angles with bolt pins. The barrel had a sliding tube system that extended with a cranked linear gear (12:1). At the end of the barrel was a saddle that held the drill. A cable wrapped around the drill trigger and activated the drill when remotely tensioned. Thus, drilling could be done from horizontal to vertical and at different heights. The drill saddle was secured to the barrel with a spring mount so that drill vibration was dampened between the carriage and the saddle (Fig. 2).

The rig went through seven design modifications based on observations of use in the field, feedback from construction workers, and observed wear patterns on the rig. After each worker used the rig a short questionnaire was administered that used open ended questions to ask about the positive and negative features of the rig and recommended changes to improve the design. Bushings were added to the main drive axle/gearbox interface to improve serviceability of wearing parts. An electric winch was added to raise and lower the carriage, barrel and drill based on feedback that it was heavy to lift by hand and took too long. The carriage attachment to the vertical column was replaced with a brake caliper to allow the barrel to be rapidly rotated and securely locked at any angle over a 360° range. This change was made because the prior process for changing the drilling angle was slow and had discrete locking locations that limited the selection of drilling angles. Rolling bearings were added to the sliding tubes in the barrel because near full extension extending or retracting the drill required high crank forces to overcome sliding friction. The saddle was redesigned to accommodate almost any drill because the drills used by contractors varied widely in manufacturer and size. The design of the drill trigger activation mechanism was changed to improve reliability. A T-bar was added to the end of the barrel to allow simultaneous drilling with 2 drills. This was recommended by the electrical workers in order to drill two aligned holes for brackets and improved productivity. The rig was designed to be modular so that the base could be changed and the rig could be used in a scissor lift. The dimensions and weight of the final rig were: 20″$W \times$ 32″$L \times$ 68″H at 215 lbs (Fig. 3).

2.3. Field testing

The commercial construction workers who participated in the field study were union laborers ($N = 22$) and electricians ($N = 7$). All were male journeymen with 1–38 years of experience in the trade. Eighteen were Hispanic, seven were White, two were Asian and one was Black. The mean age was 40 (±9) years, the mean height was 175 (±9) cm, and the mean body mass was 86 (±14) kg. Participants reported that they typically used a hammer drill 4 days per month (range 1–15 days).

The field data collection was carried out at commercial construction sites that involved structural upgrades (e.g., dowel and rod) or drilling holes for large anchor bolts. The holes for structural