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Effects of two ergonomic improvements in brazing coils of air-handler units

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ABSTRACT

The research aims to address the physically loading task and quality and productivity problems in the brazing of coils of air-handler units. Eight operators participated in two intervention studies conducted in a factory in Malaysia to compare the status quo brazing with (1) the use of a new twin-brazing torch that replaced the single-brazing gun and (2) brazing in a sitting position. The outcome measures are related to quality, productivity, monetary costs, body postures and symptoms. After baseline, Interventions I and II were applied for 3 months respectively. The results show a 58.9% quality improvement, 140% productivity increase and 113 times ROI. There was also a reduction in poor work postures e.g. in the raising of the arms and shoulders; bending, twisting and extending of the neck; and bending of left and right wrists, and the back. This research can be replicated in other factories that share similar processes.

1. Introduction

The involvement of ergonomics in business environments has gained importance (Dul and Neumann, 2009; Dul et al., 2012). Companies aspiring to achieve a competitive advantage in terms of quality, productivity, cost savings and workers' well-being seek to adopt various approaches, one of which is the effort to ‘fit work to people’ (i.e. ergonomics) to raise human performance (Dul and Neumann, 2009). As Dul et al. (2012) highlighted, ergonomics should produce two outcomes, i.e. better business performance and improved well-being, for it to be considered important/strategic to a company. In process innovation, numerous ergonomics studies with these outcomes have been conducted (e.g. Edwards and Jensen, 2014; Hemphälä and Eklund, 2013; Tompa et al., 2013, 2009; Erdinc and Yeow, 2011; Caroly et al., 2010; Maudgalya et al., 2008; Yeow and Sen, 2006, 2003; Sen and Yeow, 2003; Abrahamsson, 2000). In this study, the authors chose to focus on the physically loading brazing task in the air-conditioning industry as it requires a lot of bending of the operators' arms, wrists and neck, and raising of arms and shoulders, leading to musculoskeletal symptoms (MSs) and quality and productivity problems. This study aims to improve ergonomics in the brazing process in an air-handler coil factory to achieve better well-being and performance outcomes. The authors published limited preliminary results in Loo and Yeow (2007, 2008) and Yeow and Loo (2009). This paper presents the final results with the inclusion of an additional intervention (Intervention II), an analysis of well-being outcomes in occupational health and safety (OHS) (through the use of a questionnaire and a risk-analysis tool – the Rapid Upper Limb Assessment [McAtamney and Corlett, 1993]), and business performance outcomes in terms of quality, productivity and cost savings.

1.1. Coil assembly in air handler

In the air-conditioning and refrigeration industries, the assembly of coils of air-handler units (ACAHU) is important for heating or cooling air. ACAHU consists of aluminium fins and copper tubes (Fig. 1) installed within an air-handling unit (called air handler) whose function is to heat up or cool down a mixture of outdoor air and return air from a building space. An air-duct system delivers the heated or cooled air mixture into the air-conditioned space to provide heating or cooling comfort to occupants in the building.

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Fig. 1. Air handler coil assembly (AHCA) showing location of fins and U-bends.

1.2. ACAHU manufacturing process

Aluminium sheets from an uncoiler are rolled to the fin stock area in the fin-press room. While lying flat (horizontally) with the fin press (machine), they are stamped and cut into required shapes and sizes. During the process, numerous holes are punched through each of them complete with the formation of circumferential fin collars. Next, with the fin bundle held vertically, copper tubes are inserted horizontally through the holes. The tubes are then expanded by a tube-expander to secure the fin-and-tube assembly. This is achieved by pushing a steel ball by means of hydraulic pressure through each tube of the coil. The ball expands the tubes slightly, creating a tight fit between every individual fin collar and each tube to ensure good heat conduction and effective heat transfer (for central air conditioning) from the tube to the fin. The open ends of the tubes are connected by copper U-bend fittings to form a water circuit. Two header parts are also connected to provide water (or steam) supply and return connections to the assembly. The brazing of each U-bend fitting is done around the joints (at the two ends of the U-bend) to form a leak-proof connection.

1.3. Brazing process

The brazing process is as follows:

Step 1 The ACAHU is placed vertically on the floor (or table) to minimize bending as the operators braze in a standing position. (Placing it horizontally would be too low and require too much bending).

Step 2 The single-brazing gun (SBG) (Fig. 2) is lighted, and its knobs are adjusted to control the acetylene and oxygen flow rates.

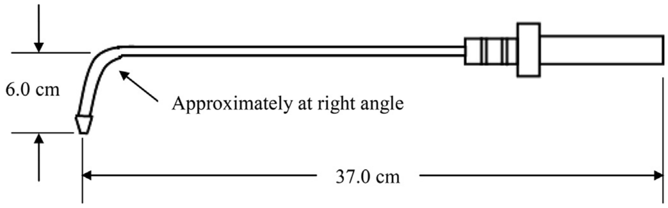

Fig. 2. Single brazing gun (SBG).

The pressure regulator knobs of the acetylene and oxygen gas tanks are both turned on to the preset 40 psi (28,123 kg/m^2) and 15 psi (10,546 kg/m^2) respectively.

Step 3 The open ends of the copper tubes are flared for easy insertion of copper U-bends into the collars (holes).

Step 4 Brazing is performed to connect all straight copper tubes and U-bends (at the joint area) using a silver alloy rod.

a. The brazing operator needs to heat up all sides of a joint area with one hand holding the SBG.
b. When the brazing temperature is reached, the hand holding the brazing rod applies the required filler metal manually by touching the tip of the rod on the heated joint. A short length of the rod will be consumed when filler metal at the tip melts and diffuses into the joint area by capillary action.

Step 5 After brazing, the completed ACAHU undergoes a leak test at a pressure of 350 psi.

a. Compressed air is pumped into the ACAHU via the header part.
b. The ACAHU is tested under water for leakages (indicated by air bubbles rising to the water surface), which normally occur at the U-bend joint areas due to poor brazing workmanship. The leakages are located and marked.
c. The ACAHU is then sent back to the adjacent brazing workstation for reworking (i.e. repairing leaked portions) before being tested again using similar procedures.

The operator works on an 8-h shift with 15 rest breaks (5–10 min each), excluding lunch and two tea breaks. During the rest breaks, the operator conducts a stand-up, body-stretching exercise to increase blood circulation and avoid continuous repetitive movements over a long period. These rest breaks are possible because the operators have to wait for the completed coil to be removed and a new coil to be delivered. The ACAHUs (weighing between 100 kg and 500 kg) are delivered and removed by an overhead travelling crane without any manual handling. The operators solely undertake the brazing task the whole day without job rotation.

2. Method

2.1. Participants

The study group consisted of 8 brazing operators aged between 21 and 41 (mean 28.00 ± 6.52), all of whom had more than one-year experience in brazing. They were all male, with heights between 153 cm and 178 cm (165.8 ± 10.1 cm) and weighing between 56 kg and 81 kg (67.8 ± 9.4 kg). All were right-handed who used their right hand for brazing and their left to hold the filler rod. They were selected from a total of 12 brazing operators in the factory based on their consent to participate in the study.

2.2. Interventions

The study comprised three stages, i.e. pre-intervention and two ergonomic interventions.

2.2.1. Pre-intervention: use of single-brazing gun (SBG) in standing position

All eight operators were instructed to perform brazing following the status quo process as documented in Section 1.3 i.e. using an SBG in a standing position. The outcome measures (see Section 2.4) were taken.