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Ergonomic redesign and evaluation of a clamping tool handle

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Abstract

The handle of a commercial bar clamp was redesigned using ergonomic principles and then compared with an original clamp. Ten male and ten female students participated in simulated clamping tasks under various conditions, including different clamping heights, clamping methods, and handle-gripping methods, with respect to the dependent variables of clamping and handle-squeezing forces. The results showed that the redesigned clamp produced larger clamping force with lower handle-squeezing forces than the original clamp. As expected, males exerted more force than females in both clamping and squeezing forces. A pistol grip method was superior to an upside-down handle-gripping method. Two-handed operation was recommended for this type of clamp by simultaneously pulling the trigger and sliding the bar in order to initially tighten around objects. This study shows that the application of ergonomic guidelines increases the efficiency and usability of manual handtools.

Keywords: Manual clamping tool handle; Ergonomic redesign and evaluation

1. Introduction

Although many facilities have been automated, many tasks still require a manual handtool and new tools are still being developed for better assistance to workers. However, just as new technology can be worse than no technology if it is not done correctly, ergonomic research has clearly demonstrated the relationship between injury risk and poorly designed handtools. Guidelines have been suggested on handtool design to alleviate this problem (Aghazadeh and Mital, 1987; Mital and Kilbom, 1992b).

As an example of such handtool design, user-centered ergonomic redesign of the manual handtool handle was initiated on the Quick-Grip® bar clamp (standard version, 6″/150 mm) manufactured by American Tool Companies, Inc. This manual clamping tool consists of front and rear jaws, a trigger, and a handle seen in Fig. 1. There are two ways to use this tool; first, for one-handed operation, the handle is repeatedly squeezed to move the front jaw closer to the rear until the desired positions of jaws are reached so that an object is gripped; second, for two-handed operation, the desired positions of jaws can be adjusted by sliding the bar with one hand while pulling the trigger with the other hand and then gripping an object by squeezing the handle once at the end of the clamping movement.

The objectives of this study were to redesign and fabricate a new handle for this clamp from an ergonomic or user-centered perspective and to compare this redesigned clamp with an original clamp under different simulated working conditions in order to identify the relative benefit of an ergonomically redesigned manual handtool.

2. Ergonomic handle development

In order to develop a new handle for the Quick-Grip® bar clamp, the original handle was evaluated according to ergonomic handtool guidelines and anthropometric

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Fig. 1. Original clamp.

Fig. 2. Redesigned clamp.

data, as well as examining how the handle would be utilized in a work task. As seen in Fig. 1, the flaring handle at the end was too wide to accommodate digits 4 and 5. This also reduced the actual contact handle length with the hand to only 80 mm. This length could accommodate only the 55th percentile female hand (Greiner, 1991). The protruding portions of the original handle severely compressed the fingers and palm.

In order to alleviate these problems, the length of a new handle was increased to 125 mm to accommodate the 95th percentile male handbreadth even when wearing gloves. A cylindrical shape was adopted to maximize contact area and reduce concentrated pressure between handle and hand. Additionally, flanges were added at the tip of a new handle to avoid slippage and allow the user to partially relax the hand between grips to close the clamp (Mital and Kilbom, 1992a,b; Johnson, 1993), especially if employed inverted or upside-down.

After drawing the new handle using Pro/Engineer® (Parametric Technology Corporation), the mockup of a redesigned clamp with the new handle was fabricated using stereolithography at the Center for Nontraditional Manufacturing Research in the University of Nebraska as shown in Fig. 2 (Mettu, 2000).

3. Method

3.1. Participants

Twenty students (10 males and 10 females), all right-handed, who had no previous upper limb illnesses or injuries voluntarily participated in the study. They clamped an object using the dominant hand during the study. The average age, height, and weight of the participants were 22.1 ± 4.1 yr, 1719 ± 96 mm, 71.2 ± 18.8 kg, respectively, where the $\pm$ numbers represent standard deviations.

3.2. Apparatus

The original and redesigned clamps were both fabricated using stereolithography, painted flat black, and had the logo obscured. Therefore, any effects of the manufacture of the clamps, such as surface finish, were consistent over both.

A S-type load cell (Omega® LCCA-500) and a miniature load cell (Sensotec® 13/2444-06-10) were used for each clamp to measure clamping force and grasping force, respectively. An aluminum frame was machined to secure the S-type load cell to the rear jaw of the clamp. The miniature load cell was installed inside the main body of the clamp seen in Fig. 3. Both load cells were wired to a DAS-1701AO board (Keithley Instruments) that was installed in an IBM compatible PC. Data acquisition software, TestPoint™ (Keithley

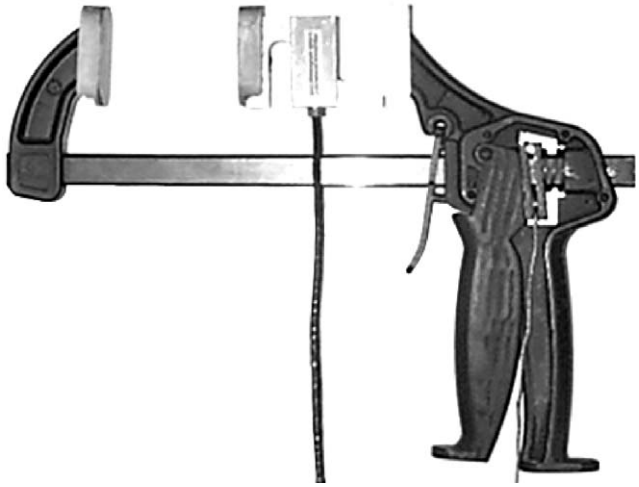

Fig. 3. Installation of load cells.