

Evaluation of Self-Modifications to Hand Tools in the Construction Industry

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Hand tools in the construction industry are specifically designed to aid in the execution of a task through manual operation. The large variety of these instruments and their uses are evident throughout the construction process. Preferences on tool types for a specific task and perceived usage of a tool may vary based on the discipline of the user. One result of a single tool being utilized across multiple disciplines is self-modification. Self-modification is often done by the user to revise the tools performance beyond its designed intent or to remove safety measures, allowing for additional freedom of motion or usage. Self-modification and deviations from a tool's intended usage can result in serious injury or potentially death. Manufacturers attempt to mitigate the need for modifications by providing a wide arrange of sizes, shapes, and performance factors to hand tools; however, based on existing data, modifications in the construction industry still occur. This research attempted to quantify through a mixed methods survey the prevalence of hand tool modifications, what trades and tools are being modified, and for what purpose. Of the 56 completed surveys, 39% of respondents had previously modified a hand tool. Based on qualitative coding, three major areas of modification occur, extension of a tool for longer reach, grinding or reshaping for cornering or radii, and adding structural length for torque. Identification of this data could inform the tool manufacturing industry of gaps and minimize the need for modification by producing tools that fit a user's needs.

Key Words: hand tools, self-modification, tool safety, ergonomics

Introduction and Background

Hand tools for the construction industry come in various shapes and sizes and are often designed to perform a range of tasks. Their use has a variety of implications, including productivity, safety, and ergonomics. While larger, less ubiquitous tools may often be provided by and/or selected by employers for particular tasks, hand tools are frequently treated as more personal in nature, with their preference for use being largely a function of the tradesman's taste or inclination. These workers may also be inclined to modify off the shelf devices to better address a specific task or need, if such a tool is not available or does not exist in the marketplace.

The U.S. construction industry employs over 6.6 million workers (Bureau of Labor Statistics 2016). This demographic is comprised of a variety of trade disciplines, including but not limited to carpenters, electricians, plumbers, ironworkers, and sheet metal mechanics. With the respective scopes of work and tasks differing across these trades, hand tool utilization may vary widely. Other tools are more common in nature, and are regularly used across multiple disciplines (e.g. screwdriver). Whether a hand tool is broadly or specifically employed, misuse can occur when individuals employ it to

complete a task for which it was not designed, such as using a screwdriver as a chisel, or a wrench handle as a hammer. Other misuses can occur when individuals use the wrong variation or size of a tool to complete a task. In some instances, misuses can evolve into modifications of the tools themselves, such as modifying a short wrench handle by welding a pipe extension to the handle in order to provide more torque when a longer handled wrench would be more appropriate. A modification is intended to improve the tool's performance for a specific task; however, this is often at the diminution of safety.

Today, the hand tool market is robust, with manufacturers producing multiple variations of a tool to execute specific tasks. However, preliminary data collection has shown that tool modifications are still done in the construction industry. There is little published research that examines how construction tradesmen are using particular hand tools, and how/why they may also be self-modifying them. This is likely due to the reticent nature of the tool industry. Information as to what tools are being modified and how they are modified is of special interest to manufacturers as this information drives their business and innovation. By releasing data on tool modifications, manufacturers are identifying and disseminating gaps that could evolve into lucrative products. Of the information that is published regarding tool usage and modifications, a vast majority is related to tool ergonomics. This research aims to address this gap by evaluating various hand tool uses across a range of skilled tradesmen in the construction industry in an effort to gather data regarding hand tool self-modification.

Literature Review

Much of the literature surrounding hand tools falls into two categories, safety and ergonomics. Aghazdeh and Mital (1987) attempted to quantify the impact of non-powered hand tool injuries in the United States in 1987. Results showed that of all compensable workplace injuries, 9% were due directly to the usage of non-powered hand tools. Although this study is almost 30 years old and it is likely that this percentage has shifted, many of the data points within the study show injuries that still occur today, including the two largest injury contributors, "striking by" and "over-exertion." Knives, hammers, wrenches, and shovels represented the tools with the most injuries; tools that are still very prevalent on construction sites today.

As part of the general safety concern in the industry, misuses and self-modifications of hand tools can result in hand tool failure and physical injury (US Department of Labor 2002). Recognizing the physical dangers and effects of tool use, the Occupational Health and Safety Administration (OSHA) has issued multiple standards pertaining to the conditions and guidelines for safe tool use. Such guidelines are found in OSHA 1910.242, which places the responsibility on the employer for maintaining tools used by their employees in proper working condition. This standard is further enforced in OSHA 1926.301, which also outlines the employers' responsibility for maintaining safe hand tools (US Department of Labor 2016). In addition to proper tool condition, OSHA has outlined standards for proper hand tool usage. The focus of these OSHA requirements is to limit and ultimately prevent injuries resulting from using hand tools in an unsafe manner. The National Institute of Health and Safety (NIOSH), in collaboration with the Center of Disease Control (CDC) and California's division of the Occupational Health and Safety Administration (Cal/OSHA), released a manual and checklist addressing the process of how one should choose the right tool for a task (National Institute

for Occupational Safety and Health 2004). The correct tool for a particular task, as defined through this manual released by NIOSH, is the tool that: fits the job, fits the hand, fits the work space, minimizes necessary applied force, and can be used in a comfortable work position.

For many years, researchers and manufacturers have attempted to mitigate the contribution that hand tools make to acute traumatic and musculoskeletal injuries (Myers and Trent 1988). Out of this has come the field of ergonomics, the study of the physiological effects that hand and power tools have on an individual (Kim 2012). When producing new or variations of tools, manufacturers and designers often take an ergonomic approach. This requires an understanding of the tool functionality and the physical needs of the end users, gearing the tool for safe, efficient, comfortable use to reduce physiological strain and injury (Dorsa 2002). However, research has shown that not all ergonomically designed tools are preferred over traditional models. A study comparing traditional sanders and ergonomically designed sanders revealed that the majority of the participants did not prefer the sanders designed to relieve physical strain (Kim 2012). The result of the Kim (2012) study may indicate that performance factors of a tool outweigh the user's need for comfort. In addition, according to the The Lawrence Berkley National Laboratory (2012), "injuries due to time pressure are most often the result of a worker's decision to circumvent a known preventative measure to a known safety hazard in the interest of getting the task done on time or rushing to keep ahead of a process following close behind." By correlating these two studies, insight into why self-modifications are done by users, even at the expense of tool comfort and safety, can be extrapolated.

Research Methods

The goal of this research was to evaluate how hand tools are being used and/or modified across various skilled trades in the construction industry, as well as the consideration of misuses or self-modifications and the rationale behind them. The investigators partnered with an established manufacturer, who provided expertise and resources to assist in the process. Participants for the survey were based on the manufacturer's consumer market and included construction carpenters, plumbers, pipe fitters, sheet metal workers, and iron workers. The following research questions were constructed to guide the mixed methods approach for data collection and analysis.

Research Questions

1. Are hand tools being modified to perform tasks other than those for which they are designed?
2. What tools are being modified?
3. How are hand tools being modified and for what purpose?

Research Approach

In the study, executed April 2016 - August 2016, researchers traveled to multiple construction sites in the southeastern U.S. to recruit skilled workers across different construction related trades to participate in a survey. Access to the sites was coordinated through the employers, and the study was approved by the institution's IRB. Once on the construction site, workers voluntarily participated in the survey in accordance with the human subjects protocol.

The survey included multiple choice and open-ended questions, along with diagrams to assist in articulating the inquiry. As such, responses provided both quantitative and qualitative data regarding demographics, hand tool preferences, use, modification, and motivation for modification. Data gathered through the survey instrument was input into Microsoft Excel to provide organization and categorization of the data in order to perform initial descriptive statistics. This allowed survey responses to be organized into their respective trades in order to evaluate hand tool usage and modifications across the various trades represented in the sample. Participants who indicated that they have modified a hand tool and provided a qualitative response as to "how" and "why" were also placed in the Excel Spreadsheet. The data was coded by identifying commonalities and patterns among the responses, known as thematic analysis. Based on the qualitative coding, areas of modification are identified and disseminated.

Results

Survey data collected resulted in 56 participants across various skilled trades as shown in Figure 1. Of the 56 participants, 21 indicated that their primary trade was "Other." Eight of the "Other" respondents indicated their primary trade was "Electrician," while the remaining tradesmen considered their primary profession as "Painter," "Glazier," and "Supervisor," among others. However, respondents indicating a primary profession of "Other" all still utilize the hand tools addressed in this research. "Multiple" respondents indicated that their primary profession is a combination of two or more of the professions presented in the survey.

Carpentry was the most common trade found among the 56 participants, with 20 indicating a primary profession of rough, framing, and/or finished carpentry, accounted for 35.7% of the sample size. Electricians accounted for the second largest trade discipline among participants at 14.2%.

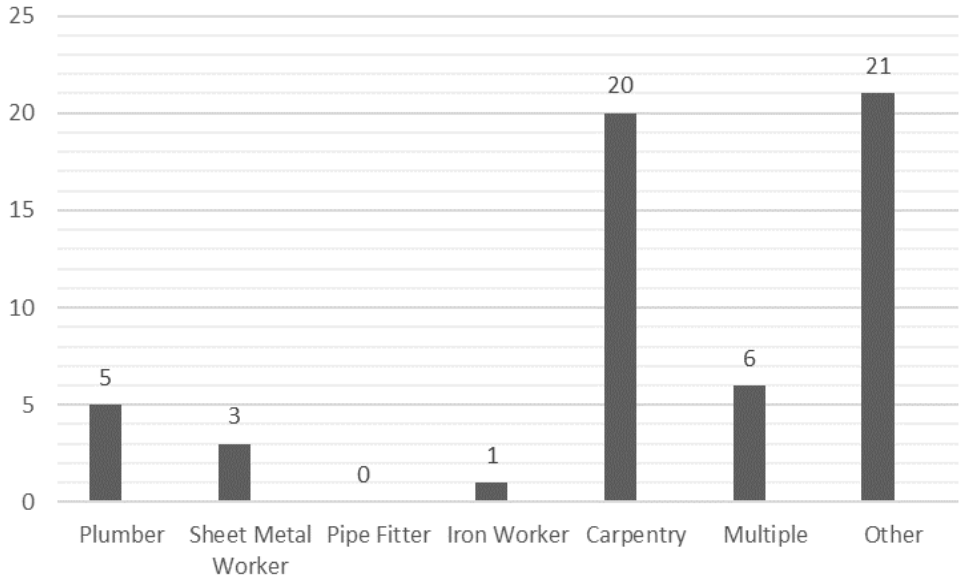

Figure 1: Respondents by Profession

As shown in Figure 2, the average time spent by participants in their respective trades was 18.8 years. However, when asked to indicate the length of time participants have spent in the construction industry as a whole, the average increases to 22.0 years. This indicates that a high percentage of the participants have been exposed to hand tools outside of their primary profession.

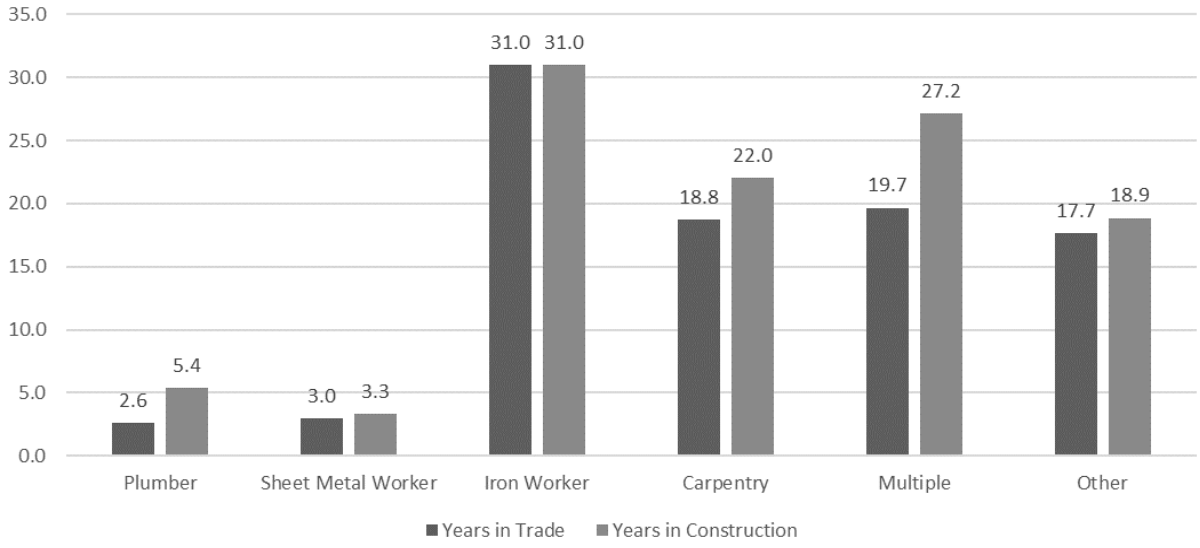

Figure 2: Years in Current Trade vs. Years in Construction Industry

Of the 56 participants, 22 or 39.3% of the sample size indicated that they have modified a hand tool, with three participants indicating that they had modified two or more tools. As shown in Figure 3, a diverse range of tools had been modified. Wrenches were by far the most modified tool, with

modifications being made to a number of different wrench types including, box, barrel, open-ended, and adjustable.

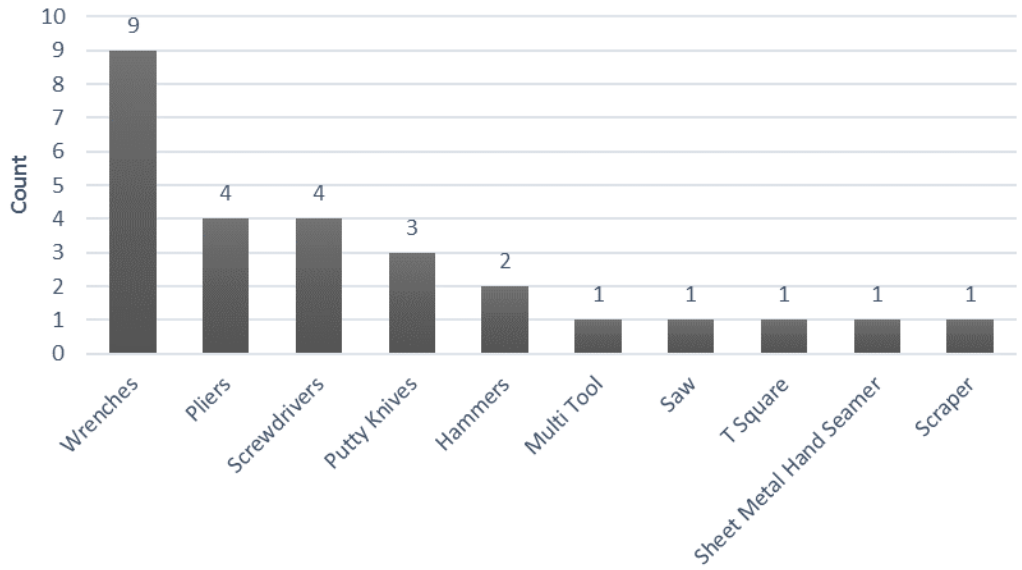

Figure 3: Modified Tools

In order to identify how tools were being modified, qualitative, open-ended questions were utilized on the survey. These two questions where looking to identify the purpose of the tool modification and how the tool modification was executed. The responses from the survey are "coded" by identifying commonalities and patterns among the answers the participants provided. Based on the coded responses of the 22 respondents who had modified a tool, three major areas of modification could be identified. The following identifies the three areas of modification, the definition for each area, and some of the qualitative responses that illuminate the pattern amongst the coded area.

- Extensions – Modifying existing tools for greater reach, through welding or attaching.
  - [Pipe Wrench] "Tack pipe to end of pipe wrench."
  - [Scraper] "Tape extension pole to (scraper)."
  - [Box Wrench] "For reach."

- Finishing – Modifying existing tools such as putty knives and concrete tools in order to fit into tight corners and radii spaces/walls. Usually done through grinding.
  - [Putty knife] "Modify tools to be used in tight spaces. To allow the tool to work its way under materials."
  - [Drywall finishing tool] "To get into tight corners."
  - [Caulking Knives] "For different shaped joints."
  - [Concrete tools] "Small areas and radius."

- Torque – Modifying existing tools by adding length (through welding or attaching) to create greater torque.

- [Wrench] "Using a second wrench to put on the wrench I am using (for torque)."
- [Adjustable Wrench] "I slid a steel pipe over the handle to give me more torque on the bolt."

Discussion and Conclusion

Overall, results from the study indicate that hand tool modification among the construction trades is prevalent, in particular to certain tool groups such as wrenches and pliers. The most common modifications are related to handle extensions, suggesting that there is a need for a larger range of reach and/or torque for many tasks. There were also a variety of modifications illuminated that are related to trowels, knives, and other finishing tools, based on the range of needs and/or requirements associated with respective tasks.

As a demographic, construction tradesmen are open to and willing to make modifications if they believe it to be useful. These modifications suggest that there could be an opportunity to expand the range of available tools, and develop accessories and accouterments for existing tools to improve capacity, performance, or safety. In addition to seeking answers to the research questions, the investigators desired these results to proactively inform a subsequent collaborative research and design effort in which new concepts for tools and devices. This future effort will feature collaboration among construction and industrial design students, as well as end users and a hand tool manufacturing partner.

Future research on the subject could continue to expand the knowledge of what actions, tasks, and motions are statistically associated with on-site injury, as well as with long-term disability based on repetitive use of modified tools. This study would incorporate much of the traditional safety and ergonomics research with modifications research, in an effort to identify a comprehensive impact of self-modification to a user. Additionally, expanding the research to a global marketplace could provide additional data points on modifications and tool usage. Results from such research could help further define opportunities for new hand tools and for improvements to existing devices.

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