Human Factors Engineering in Construction Hand Power Tool Design and Worker Safety

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Human Factors Engineering (HFE) deficiencies in the design of construction hand power tools contribute to their misuse. These deficiencies are caused by unsatisfactory HFE models. However, current consumer revisions are forcing changes to these models. This paper will outline the deficiencies and list the ongoing and proposed corrections.

Construction has always been based on skilled workers using hand tools. From the beginning of recorded history the construction worker and his/her tools were part of an almost secretive group whose skills earned respect and responsibility beyond that of other occupations. In fact, the designer, as the architect or the engineer part of the construction team was considered the “Master Builder” whose skill elevated him/her above the crafts guild by knowing how to successfully design the structures to be built so that they wouldn’t collapse. Moreover, beginning in medieval times, construction guilds, such as the Freemasons (thus called because they were “free” and not serfs or slaves to king or state) were able to benefit workers with the establishment of apprenticeship and training programs which provided craft based training which still supply the construction trades today. Indeed, the knowledge and skill of construction and the care of the sometimes dangerous tools required to do the job is still a carefully taught and protected training which is free from management and government intervention.

However, as construction has become more commonplace, and the Master Builders of Architect and Engineer have become to be trained separately from the crafts trade, the construction trades find themselves drawing workers from the general population without being able to guarantee adequate training or instruction. Additionally, since the construction industry is project based requiring short-term staffing requirements accordingly, finding skilled workers available who are trained in the safe a proper use of power hand tools has become difficult. In fact, on most construction sites today, workers are employed without the benefit of a trade union, and the skills and training required for operating construction tools are dependent more on the worker’s own ability and government regulations, such as OSHA, rather than formal, careful and long term apprenticed training. Workers are also required to supply their own tools, generally providing them without a union or management’s oversight of the tool’s condition or safety concerns.

The rise of the “do-it-yourselfer” homeowner has also contributed to the ability to misuse construction power tools. At one time a home repair or renovation project was placed in the hands of a skilled professional, be it painter, plumber, or carpenter. However the expense and frustration of securing a contractor and the rise of large home project warehouse stores like Home Depot and Lowe’s has encouraged homeowners to try to do the job him/herself. In this example a homeowner, in order to complete a home improvement task such as installing a garage door, building a deck or installing a new bathroom, will purchase a hand power tool, a power saw, drill, or nailer in the same manner as he/she would purchase an appliance from a department store. This power

hand tool user is as different from the skilled and apprenticed construction professional the tool was originally designed from, as he/she is from the untrained project worker.

Therefore there are now three types (models) of power tool users, 1) the Skilled Professional (the carefully trained and experienced original HFE model), 2) the Itinerant Project Worker (whose training and skill, although adequate, is largely self-taught and without experienced oversight), and 3) the Weekend Project Homeowner user (who purchases a power tool as an appliance, with absolutely no training or skill except for what he/she is able to glean from the manual). These user models affect the power tool HFE requirements accordingly. However, the power hand tool manufacturer who will be the most successful will be the one who is able to deliver a model which best satisfies all three models.

Thus, regarding construction hand power tools, the current HFE issues that will be reviewed include the following:

1. The Ergonomic Design and HFE issues regarding the use of hand power tools in relation to their model groups.
2. Government regulations concerning the safe use of hand power tools.
3. Improvements, planned and currently available for the model users.

History of power hand tools:

In 1813, Sister Tabitha Babbitt, a Shaker, envisioned ringing teeth around the rim of a spinning wheel and changed the mechanics of sawing. Prior to Sister Babbitt, saws and sawmills were comprised of two man long rip saws. Incorporating her spinning design, sawmills everywhere were soon changed. Additionally, the circular blade also lent itself well to mechanical rather than human power, and soon mills were run by water and electricity.

In 1867, Wilhelm Fein created the first hand power drill by attaching a small electric motor to hand drill shaft. Cast-iron and heavy, it required the use of both hands and a breastplate and shoulder strap

In 1891, Justus Traut, working for the Stanley Rule and Level Co. (now Stanley Company) earned one of the first ergonomics patents for his “Hand-y” grooves, which were cuts in the tool’s handle designed to make tools like levels and block planes easier to hold.

In 1923, Joseph W. Sullivan and Edmund Michel developed a power hand circular saw to cut sugar cane which they modified to cut lumber. They called it the “Skilsaw” and priced them at about $1,000 each. (http://www.ebuild.com)

As illustrated above, hand power tools were first developed as smaller versions of their successful commercial cousins. Portability and convenience were initially more important than the HFE design issues, which only typically considered after the required operating functions of the tool are identified and met. HFE issues such as, “How should the user hold the tool?” are examined only after the tool operates and functions adequately. In fact in order to develop a revised working model from which to design hand tools, the manufacturer must recognize the existing deficiencies as HFE function failures rather than as model user defects. However, as it exists now, user safety issues

are at cross-purposes to the operation and function of the tool. Currently, the manufacturers are designing the tool for the professional model user, who, as the model requires, has demonstrated a successful combination working function, where by acquired skill and experience must keep safe around an obviously and clearly dangerous tool.

In this case, for the professional user, who has acquired the skill of using power hand tools safely, the manufacturer's required act of adding retracting guards, limiting shields and safety catches in order to force a safe use, inhibits the usefulness of the tool, and thus spoils the model. This user is often cited by construction safety inspectors for dismantling, blocking, or overriding the tool's safety functions in order to redesign the tool to work the way it should. The HFE objective in this particular model, then, is to try to design safety considerations into the tool which actively improve rather than diminish its functionality.

In other words, the guards, locks, safeties and automatic stops should help rather than hinder the worker in completing his/her work. Therefore the first steps towards a successful HFE user functionality and model has been the addition of better motors, in order to keep the tool's working parts from getting caught while working, adding insulating handles that protect the user from the heat and accidental shock, and then designing lighter and more balanced units. Powerful cordless tools began the next phase of tool improvements by adding additional portability. Powerful and lighter batteries have eliminated the necessity of corded power sources. Some tools, like Paslode's hose-less pneumatic nailer uses self-contained internal combustion fuel cells, which allow power nailing anywhere without compressors or hoses (http://paslode.com/products/tool_catalog/IMCT.html).

For the second type of model user, the itinerant project worker, construction power hand tool safety is still treated as an occupational inherent risk, where a worker who injures him/herself with the hand tool is considered the defective part of the model for not knowing the safety limitations of the tool. In this industry, the worker is responsible for his/her safety, and the industry, in trying to design an actively HFE safe tool is seen as manufacturer reducing its effectiveness.

However, in trying to overcome the deficiencies of this model, there is government intervention in the form of the Occupational Safety and Health Administration (OSHA- http://www.osha.gov) which lists the following minimal requirements for construction power hand tools.

Saws, Portable Circular

Portable, power-driven circular saws shall be equipped with guards above and below the base plate or shoe. The lower guard shall cover the saw to the depth of the teeth, except for the minimum arc required to allow proper retraction and contact with the work, and shall automatically return to the covering position when the blade is removed from the work. (1926.304(d))

Saws, Swing or Sliding Cut-Off

All swing or sliding cut-off saws shall be provided with a hood that will completely enclose the upper half of the saw. (*1926.304(f))

Limit stops shall be provided to prevent swing or sliding type cut-off saws from extending beyond the front or back edges of the table. (1926.304(f))
Each swing or sliding cut-off saw shall be provided with an effective device to return the saw automatically to the back of the table when released at any point of its travel. (1926.304(f))

Inverted sawing of sliding cut-off saws shall be provided with a hood that will cover the part of the saw that protrudes above the top of the table or material being cut. (1926.304(f))

Electric power operated tools shall either be approved double-insulated, or be properly grounded in accordance with subpart K of the standard. (1926.302(a)(1))

For non power hand tools (wrenches and hammers) their guidelines are even more limited and require active intervention by management.

Hand Tools

Employers shall not issue or permit the use of unsafe hand tools. 1926.301(a) Wrenches shall not be used when jaws are sprung to the point that slippage occurs. Impact tools shall be kept free of mushroomed heads. The wooden handles of tools shall be kept free of splinters or cracks and shall be kept tight in the tool. (926.301(b),(c)&(d))

However it is the third model user, the homeowner who purchases the power hand tool as a weekend appliance that offers the most opportunity for improving the model. This user requires an easy to use, comfortable, as well as professionally functional tool. Past attempts by manufacturers in producing a less featured tool for this user have been met with failure. This user wants the opportunity to acquire professional level tools for his/her construction work. Therefore, the manufacturer's opportunity is to revise the model and produce a power tool that is inherently safe and easy to use. Producing a tool for this user also brings new liability. The former inherently dangerous and hard-to-use model protected manufacturer from product liability lawsuits. However, those defenses have been steadily crumbling over the years evidenced by the plethora of warning labels on ladders, buckets, hammers and other ancillary construction tools. Will promoting an inherently safe power saw for use by model group number three cause problems which will not be easily solved by additional warnings?

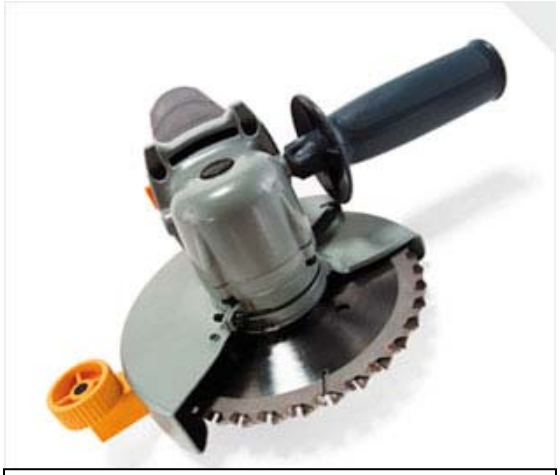

Figure 1 -Craftsman's Twin Cutter

Current available improvements: In addition to the safety items listed above, current proposed functional improvements include better balance, comfortable handles, self-holding triggers, as well as functional modifications such as double rotating blades

(to reduce kickback), for power saws. However, the best proposed improvement maybe something that does away with all the guards and safeties altogether. Known as the “Saw Stop” (www.sawstop.com) system, it is a secondary add-on system which works by recognizing the difference in the electrical conductive properties of wood and the electrical conductive properties of skin. The system as, designed, induces a high-frequency electrical signal on the saw blade and then monitors this signal for changes (the device is built around the blade in the example below). Because of the inherent electrical capacitance and conductivity of wood, the signal remains unchanged when the blade is cutting through wood. However, if the blade makes contact with skin, the blade immediately stops when it senses the difference in capacitance.

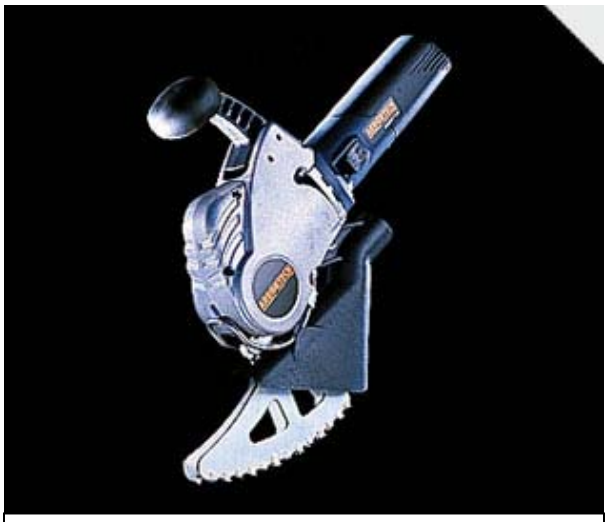

Figure 2 -Arbortech Allsaw 150

Figure 3 –Saw Stop System

In fact, once manufacturers begin producing power tools with this type or similar produced active safety, then a new safety model is successfully realized for the third type of user which will define a successful new model for designing tools for the other two model users. Once realized it will enable changes for all power hand tools.

Therefore, in summary, currently the power hand tool manufacturers informally design for three separate user models: 1) The professional 2) The self-trained itinerate, and 3) The appliance purchasing untrained homeowner. The informal nature of these three models, based more on a dilution of the model for the professional user, is leading to a new model based on active and inherent safety which will incorporate safety as one of the functions of the tool and not just an add-on which reduces the tool’s effectiveness.

This new model will provide manufacturers with the following five model goals as described by Kroemer, et al in Ergonomics (p 328, 2001): 1) Validity –by offering a model that matches all real world users. 2) Utility –by including inherent safety without diminished ability, the model will accomplish the safety objectives. 3) Reliability – repeatability. Now, safety is accomplished by add-ons. A new model would allow new dependable reliability. 4) Comprehensiveness –the model could be administered to all hand power tools. 5) Ease of Use –this model, by incorporating a design that allows the working part of the tool to be exposed to the user, will allow manufacturers, by incorporating the model, to design new types of power hand tools.

In closing, the future of power hand tools will owe itself to a new model that incorporates a design of inherent safety instead of inherent danger for all users.

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