Safeguarding machines with an ergonomic spin

By Gary
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The importance of human factors in indstrial safety standards

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Human factors contain elements of psychology, engineering, statistics, and observation. Safety codes and standards often are written based on some aspect of human factors, and it may be critical to have a full understanding of the human factors behind the code or standard before applying the same concept to other equipment.

"**Ergonomics** *is a body of knowledge about human abilities, human limitations, and other human characteristics that are relevant to design.*" [1]

"**Human factors** *focuses on human beings and their interactions with products, equipment, facilities, procedures, and environments used in work and everyday living.*" [2]

Figure 1
While the NSC publications provide generous guidance, two aspects they do not address fully are the application and implication of ergonomics and human factors in the design of machine safeguards.

The National Safety Council (NSC) published the fifth edition of the Power Press Safety Manual and the seventh edition of Safeguarding Concepts Illustrated in 2003. Both of these publications provide discussions, examples, drawings, schematics, check lists, photographs, and references to help equipment designers, rebuilders, modifiers, and users safeguard machinery properly and effectively.

While these publications provide generous guidance, two aspects they do not address fully are the application and implication of ergonomics and human factors (see **Figure 1**) in the design of machine safeguards. (For the purposes of this article, the term human factors will be used in place of ergonomics to describe the design of safe equipment by applying knowledge of the psychological and physiological nature of humans.)

While the two publications do not include much about the use of human factors in equipment safeguarding, they do use the concepts and philosophies of human factors to develop their recommendations, which can be seen in the examples and configurations; however, those untrained or inexperienced in human factors might not recognize the human factors basis for these recommendations.

The Occupational Safety and Health Administration (OSHA) has several publications on human factors in general workplace equipment design and for evaluating worker stress related to ergonomics. Much of that information was included in the 1999 Ergonomics Standard, but it was rescinded in 2000. Currently OSHA does not have a regulation or proposed regulation that addresses human factors in the design of industrial machine safeguards.

While the NSC's Ergonomics, a Practical Guide is dedicated to ergonomics, it also is general in nature and does not really address the particular human factors involved in large industrial equipment and controls.

The American National Standards Institute (ANSI) B11 TR 1-1993, "Ergonomic Guidelines for the Design, Installation and Use of Machine Tools," contains tables of human factor dimensional values such as height as it pertains to reach, but it's more than a decade old and it doesn't address human factors as they relate to new accident prevention mechanisms like light curtains or new equipment designs.

The best way to understand human factors in the design of machine safeguards is to integrate the concepts and findings from textbooks on human factors and equipment design. Four of the philosophical and conceptual issues of human factors in the design of safeguards for metal fabrication and other equipment are explained here.

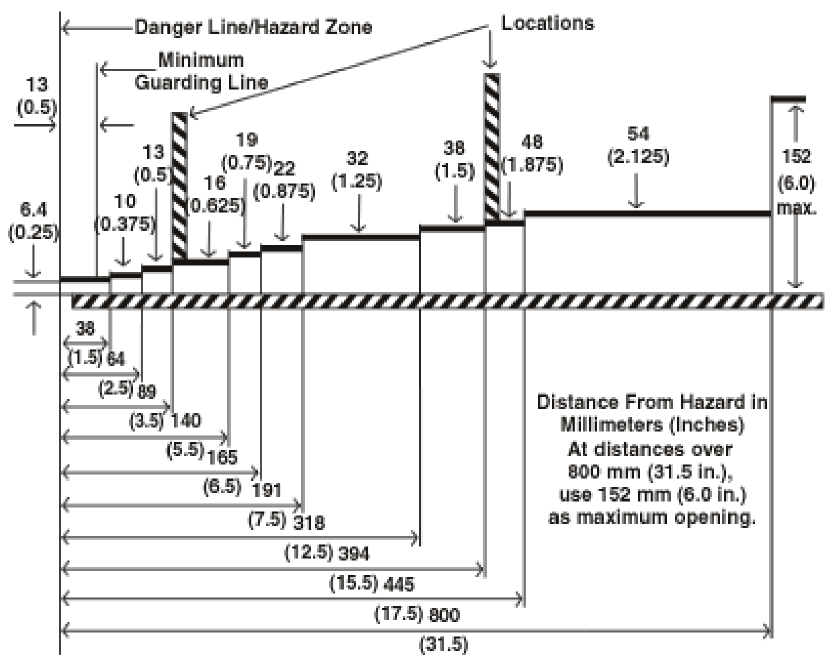

Figure 2
Anthropometry is the science of measuring the human body in terms of size and capabilities. Both of the NSC publications contain a chart and table of allowable guard opening sizes based on the distance from the guard to the hazard.

Anthropometry and Physical Barrier Guards

Anthropometry is the science of measuring the human body in terms of size and capabilities. Both of the NSC publications contain a chart and table of allowable guard opening sizes based on the distance from the guard to the hazard (see **Figure 2**).

The concept is that a person's hand becomes thicker from the fingertips toward the wrist. Hence, an opening of 0.25 inch, big enough for a small finger, can be used only if the hazard is 1.5 in. beyond the guard, but the hazard must be more than 5.5 in. behind the guard if the guard opening is 0.75 in. While this chart originated before the formation of OSHA, it still is considered by that organization to be a compliance threshold.

For a designer of physical barrier guards on equipment, these criteria may be inadequate because of the changing demographics of the workplace. More women and other populations with thinner hands and wrists have entered the workplace in the past 20 years, making the current OSHA criteria not as effective as in the past.

Anthropometry also comes into play in the design of respiratory devices that protect workers from airborne contaminants generated by machine operations. While engineering controls such as chemical reformulation and dedicated exhaust systems are considered the first line of defense to limit occupational exposures, employers often supply respirators to workers as well. (Chapter 12 of Power Press Safety Manual and Chapter 1 of Safeguarding Concepts Illustrated mention the use of respirators.)

Workers must choose from various sizes and shapes to find a respirator that fits properly and provides a good seal around the face. Significant facial hair in the area of contact can cause an improper seal.

Visibility

A review of both NSC publications shows that physical barrier guards often are designed with openings (or are configured to be opened) to allow for physical and visibility access. It is a human factors concept that visibility access may increase an operator's "mental modeling" of the operation. Having a visual understanding, and thus mental model, of how a process works can help workers avoid failures and injuries.

Most machines and safeguards come with written warnings and instructions. The effects of variations in size, color, and configuration of these signs, signal words, and pictures are debated in Safeguarding Concepts Illustrated (see **Figure 3**). While some sign/warning standards may vary on these features for different applications, from a human factors perspective, people have a complex ability to decipher written information. ANSI standards Z 535.1 through Z 535.5. provide codified information about signage, including safety signs.

Controls

Chapter 7 of the Power Press Safety Manual is dedicated to control features and options. It recommends interlocks on disconnect switches and safety blocks, two-hand trip controls, and the use of "safe distance" in positioning controls, all of which are based on certain aspects of human factors.

Interlocks. Interlock configurations help keep operators from making a mistake and also keep the equipment in a safe condition if the operator does make a mistake. An example of a common interlock is found on modern automobiles—an operator cannot start the car when it is in gear and could unexpectedly move forward.

Interlock features would seem universally desirable, but they are not required on all machine controls. One human factors concept that comes into play with interlocks is the potential for "user dependency" on the interlock. In other words, interlocks that keep a machine in a safe condition when an operator makes a mistake need to be 100 percent reliable, because users will tend to depend on them and may begin performing marginally unsafe acts because they are used to the interlock working and protecting them.

Two-hand Trip Controls. Two-hand trips force an operator to have his or her hands away from the hazard. This generally is desirable, but they could cause a secondary hazard when applied to some types of equipment.

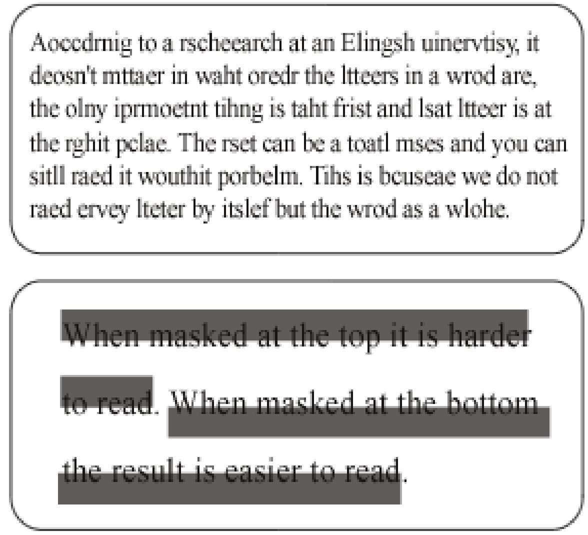

Figure 3
These examples of word perception show that operators may be able to understand the content of difficult-to-see warning signs if they are motivated to read them, and if the warning signs have the necessary information. ANSI standards Z 535.1 through Z 535.5. provide codified information about signage, including safety signs.

Press brakes, for example, have no requirements for two-hand trips because they can cause a counterproductive safety tradeoff. Often the part being worked on needs the support and positioning of the operator's hands. The application of two-hand trips would violate the human factors concept of competing incompatibilities: Do I properly position and support the sheet metal and have my hands near to the point of operation, or do I use two-hand controls and have a problem positioning and supporting the workpiece? Forcing a press brake operator to have his or her hands on the two-hand trips could cause the part to fall or shift, causing other safety hazards.

Safe Distance. Both the ANSI standards and OSHA codes for power presses acknowledge the use of a safe distance to safeguard the point of operation. The concept is that if the controls are located some safe distance from the point of operation, the operator will not be able to move fast enough to reach into the hazard zone at the point of operation. Of course, the speed of the operator's hand and arm movement becomes a critical human factors measurement. The standards are based on a hand speed constant of 63 inches per second. While that is pretty fast, there always is someone out there who moves with unusually high speed.

Obviously, machines that form a point-of-operation hazard at different speeds under different conditions are not compatible with the safe-distance approach to safeguarding. While mechanical power presses have large flywheels and gear-drive mechanisms that keep the operating speed of the ram high and consistent, mixers and belt-driven devices may form the point-of-operation hazard in different time increments, depending on the resistance of the mix and slippage of the belts.

Consistency

Many of the safeguards shown in Safeguarding Concepts Illustrated and other publications are physical barriers that are similar in shape and construction. Human factors studies have determined that people have certain expectations about the performance of many things that they encounter repeatedly, including safeguards.

We blindly stretch our arm around a corner in the dark at chest height to access a wall light switch; we stumble on stairs if the rise is too shallow or too great; and we instinctively reach for a door knob at the same place on the door because they are all at about the same height. These are some of our consistency expectations.

Workers have consistency expectations about safeguards as well. For example, an operator expects a safeguard to be strong enough to keep the hazard from engaging if the operator falls against the barrier guard, and the guard should prevent broken pieces from flying out.

The operator might even expect a physical barrier safeguard to be strong enough to stand on if he or she needs to access something beyond the guard. While the literature on safety does not suggest that guards be used as steps, a guard located in an area where it can perform as a step most likely will be used as a step, so it must be made strong enough for that purpose or be made in a way that prohibits its use as a step.

Human factors comprise elements of psychology, engineering, statistics, and observation. Safety codes and standards often are written based on some aspect of human factors, and it may be critical to have a full understanding of the human factors behind the code or standard before applying the same concept to other equipment.

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Notes

1. Board of Certification in Professional Ergonomics, Ergonomics – A Practical Guide, 2nd ed., (Itasca, Ill.: National Safety Council, 1993), p. 2.

2. Mark S. Sanders and Ernest J. McCormick, Human Factors in Engineering and Design, 7th ed. (McGraw-Hill Science/Engineering/Math, 1993), p. 4.

> *OSHA, www.osha.gov*
> *National Safety Council, www.nsc.org*
> *ANSI, www.ansi.org*

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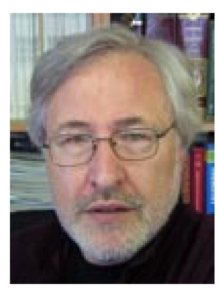

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