Mechanical Power Presses

Improving hazard identification using software

By Darrell R. Wallace and Gary P. Maul

MACHINERY DOMINATES the manufacturing production workplace. These machines are a significant source of workplace injuries although the requirements for making them safer are well established. Among these machines, mechanical power presses present hazards that are uniquely interesting for two reasons: First, mechanical power presses are governed by laws and standards that are specific to these machines, not just generalized for all machines. Second, despite such focused legislation and standards, these machines are responsible for a disproportionately high number of injuries, particularly amputations, within the overall annual injury statistics.

Researchers at The Ohio State University have studied this problem and have identified possible explanations for the consistently high number of press injuries. The preliminary objectives of this research are to 1) understand the scope and severity of the problem and 2) suggest possible underlying causes for these types of injuries.

This article presents initial findings on a software tool developed to aid hazard identification. This tool was developed with the hope of allowing those with little press expertise to assess presses with a higher level of competence. However, the findings suggest that it may be more effective than even traditional methods employed by press professionals. These findings are preliminary and limited in terms of both sample size and scope. However, based on strong and unexpected results, further study of the software is merited and may offer great potential for improving press safety.

Machine-Related Injuries

A review of the overall costs of workplace injuries finds that they place a staggering social and economic burden on the American workforce. Leigh, Markowitz, Fahs et al. (1997) estimated that in 1992 the total direct costs of work-related injuries and illnesses were $65 billion and indirect costs were $106 billion—for a combined cost of $175 billion. Of those costs, $145 billion were attributable to injuries rather than illnesses. This study was significant because it was one of the first to acknowledge indirect costs, most of which are borne by the employee and his/her family.

Since then, variations of that cost model have been broadly applied. Unfortunately, because the model changes from year to year, it is impossible to make accurate comparisons over time. This limits the usefulness of cost estimates as a metric for trends from year to year. However, it is still interesting to note that more recent data from 2002 suggest that the cost of workplace injuries was more than $146 billion (NSC, 2003).

The factors considered in the costing model used by Leigh, et al. (1997) are selected based on reasonable assumptions and choices about what is measurable. Leigh, et al. acknowledge that their method, although yielding a much greater cost than any prior cost model, may significantly underestimate the real cost because many indirect costs (such as pain and suffering, or lost productivity by caregivers) are undercounted or impossible to capture. The difficulty in accurately and meaningfully capturing hidden and indirect costs is widely recognized and debated (Koopmanschap & Rutten, 1997; Liljas, 1998). The statistics provided by Leigh, et al. (1997) and the annual NSC cost estimates do not specifically isolate the costs of machine-related injuries. However, based on other statistics, it can be inferred that the relative contribution of machinery to the overall cost is disproportionately high.

Bureau of Labor Statistics (BLS) gathers a wide variety of data related to the American workforce-including information about employment, wages and occupational safety. Because the data are gathered consistently over time, they are particularly useful for considering trends. In addition, because BLS carefully ensures confidentiality in its reporting, the statistics are generally considered more representative than data collected by enforcement agencies, from whom employers may fear repercussions for an incident (BLS, 2005).

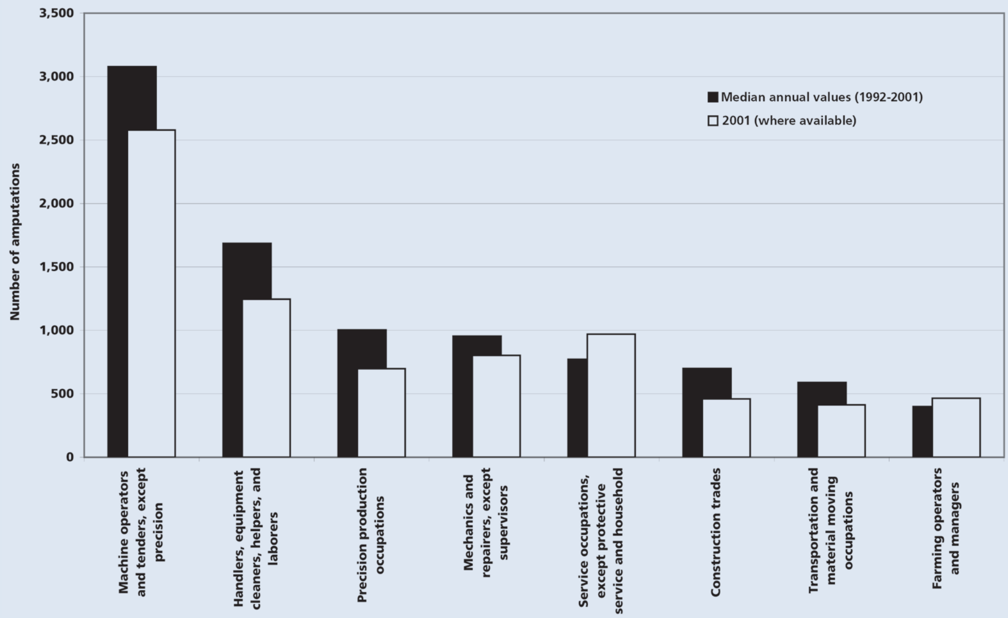
The most recent BLS data used in this research were from 1992 to 2001. This is not the most recent data available, but it is the most recent data that is useful for historical comparisons. For studying trends in machine injuries, one must have a historical record of data that have been collected

Darrell R. Wallace, Ph.D., *is an assistant professor of mechanical and industrial engineering at Youngstown State University. He holds a B.S. and an M.S. in Mechanical Engineering, as well as a Ph.D., all from The Ohio State University.*

Gary P. Maul, Ph.D., P.E., *is an associate professor of industrial, welding and systems engineering at The Ohio State University. He holds an undergraduate degree from Youngstown State University, an M.S. from Purdue University and a Ph.D. from Penn State University. He is a member of ASSE's Central Ohio Chapter.*

Figure 1

Amputation Cases by Occupation



Note: *Data from BLS's Occupational Employment Statistics, and Injuries, Illnesses and Fatalities programs.*

Abstract: *Despite abundant guidelines, legislation and enforcement, machinery in the manufacturing industry continues to contribute disproportionately to some of the most devastating workplace injuries. Mechanical power presses are among the most dangerous of these machines. Injuries that arise from contact with point-of-operation hazards are particularly troublesome because these hazards are well understood and the guidelines for guarding the presses are well established. As part of a study conducted by researchers at The Ohio State University, the underlying causes of press injuries were studied by reviewing narrative data related to press accidents. Among those narratives, failure to comply with applicable OSHA guarding requirements stands out as a consistent factor in most cases. Based on that finding, a software package was developed to help employers assess press guarding and identify hazards in an effort to reduce the number of press-related injuries.*

according to uniform standards. Each time BLS changes its collection and reporting procedures, the historical record is interrupted. Between 1988 and 1991, major changes were made to the collection and reporting procedures (Kydoniefs, 1996). Those changes created a discontinuity in the data and make it impossible to compare data pre- and post-1992.

More recently, in response to the increasingly interwoven economies of the North American countries, BLS is converting its reporting from the Standard Industry Classification system (SIC) to the North American Industry Classification System (NAICS). This process is ongoing and has occurred incrementally throughout various portions of the BLS data collection. The process began in 2002 and is scheduled to be complete by 2007 (BLS, 2004, 2006). The apparent impact of this is twofold: 1) data from before and after the changeover are not comparable; and 2) it will be more than a decade from completion of the transition before another 10-year BLS dataset is available.

Data on employment were gathered from customized tables available through the BLS Occupational Employment Statistics program (www.bls.gov/oes/home.htm). Data on occupational illnesses, injuries and fatalities were gathered from customized tables available through the BLS Injuries, Illnesses and Fatalities programs (www.bls.gov/iif/home.htm). In terms of sheer number of cases, BLS data show that machines are second only to automobiles as a cause of workplace fatalities and are the predominant source of serious injuries within the manufacturing sector.

Employees in manufacturing are twice as likely to suffer a machinery-related injury as the average U.S. employee. Although manufacturing represented less than 15% of the total U.S. employment in 2001, it was responsible for 22.5% of all lost-time private industry traumatic workplace injuries. During the same period, manufacturing was responsible for 37.8% of the 97,634 lost-time injuries where machinery was the source of injury.

Across all industries, machinery is a leading source of amputation injuries. Amputation injuries are of particular concern because they occur with relatively high frequency in injury cases caused by machines and often result in permanent loss of function. Additionally, they require some of the longest recovery times among the conditions tracked by BLS. In 2001, 8,612 nonfatal amputation injuries were reported in private industry. Of those amputations, 49% were incurred by employees in manufacturing.

Based on BLS statistics, it is known that "machine operators" are the most likely category of employee across all sectors to suffer an amputation injury. They are nearly twice as likely to suffer an amputation as the next most likely category, "handlers, equipment cleaners and laborers" (Figure 1). BLS data also show that within the manufacturing sector, industries classified as "fabricated metal products" contribute the greatest number of amputations (Figure 2). From these data, it reasonably may be inferred that machine operators in fabricated metal products have the highest likelihood of suffering amputation injuries.

Although no published BLS data link these injuries to a specific machine type, the fabricated metal industry is dominated by press equipment. Subsectors of the fabricated metals grouping include industries that make significant use of presses in their operations, such as fabricated structural metal products, ordnance and accessories, and metal cans and shipping containers. This industry also includes most industries that use presses as their primary equipment. These industries include all classifications of forgings and stampings.

Power presses tend to cause injuries that result in amputations, which is likely the reason an entire section of the Code of Federal Regulations—29 CFR 1910.217—is devoted to the safeguarding of mechanical power presses. Mechanical press safety is also addressed specifically in ANSI B11.1. Although these documents represent a thorough discussion of the proper methods of guarding mechanical power presses, injuries continue to occur in unacceptable numbers.

In the mid-1990s, recognizing the serious safety risk presented by presses, particularly for amputations, OSHA initiated a national emphasis program, CPL 2-1.24: National Emphasis Program on Mechanical Power Presses, 29 CFR 1910.217. The program focused on 10 manufacturing industries that were responsible for the highest numbers of violations of mechanical power press guarding regulations. Of the 10 targeted industries, the 8 shown in bold are subcomponents of the fabricated metals major group:

- **stamping;**
- **sheet metal;**
- **metal doors;**
- **fabricated steel;**
- **hardware;**
- manufactured furniture;
- motor vehicles;
- **miscellaneous metal;**
- **boiler shops;**
- **wire.**

Despite the focused enforcement effort, manufacturing's contribution to the number of amputation injuries remained relatively unchanged. According to BLS data, between 1997 and 2001, manufacturing's contribution fell from 51.3% to 49.2%. During that same period, BLS data show that employment in manufacturing fell more significantly—dropping from 18.0% to just 15.5% of the total U.S. employment. This suggests that the declining size of the workforce may have been a major contributor to the apparent reduction in amputation injuries.

Regardless of the effectiveness of enforcement efforts, the most recent BLS data confirm that manufacturing still represents nearly half of all work-related amputation injuries occurring in the U.S. Additionally, the nature of injuries arising from contact with machines is generally severe, with more than half of all machine-related injuries resulting in some form of permanent partial disability (Brubaker, 1997).

Because of the prevalence of press equipment in the industries where BLS statistics show these injuries occur most often, it may be inferred that many of the injuries are the direct result of contact with mechanical power presses. That assertion seems to be shared by OSHA (through its national emphasis program) as well as NIOSH (in its publication, *Injuries and Amputations Resulting from Work with Mechanical Power Presses*). The focus of this research was to examine this problem to find new approaches to reducing the number of press injuries.

Examining Specific Injury Cases

Understanding this problem requires more-detailed information about each injury case than is available through BLS. The exact circumstances of each case must be considered. However, such information is not easily accessible. Two possible sources for such detailed accounts are the raw narratives collected by BLS and the accident narratives in OSHA inspection reports.

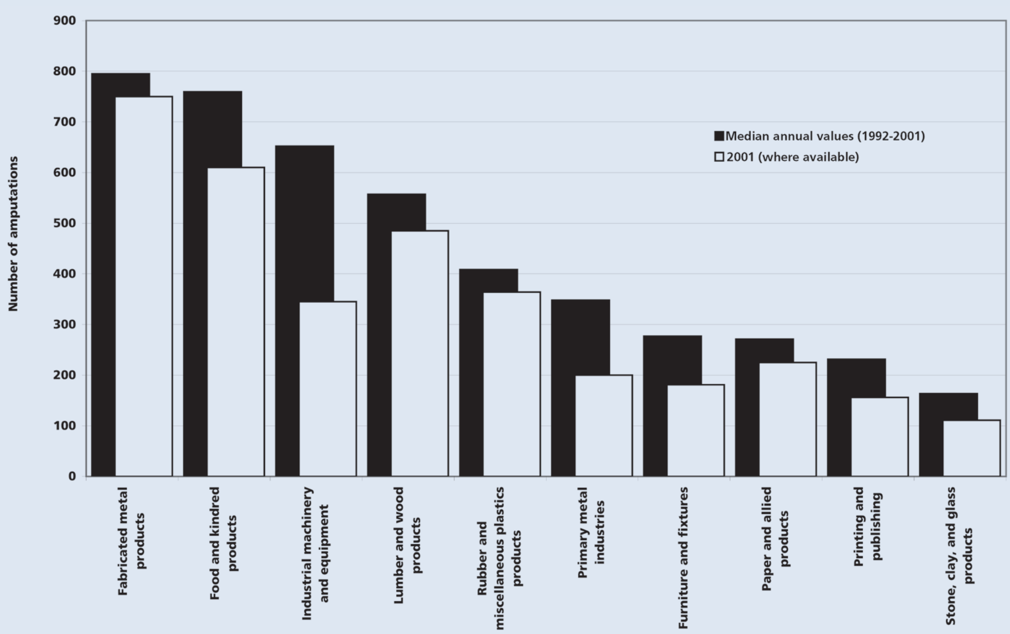
The BLS narratives are preferred because they cover all incidence of injury. They are also presented by the involved parties, not as a third-person account. In the case of OSHA inspections, employers may have an incentive to downplay the significance of events while employees may overstate their significance. The BLS narratives are collected in a manner that is intended to provide the narrator with anonymity and encourage full and accurate disclosure. Unfortunately, to protect the confidentiality of the data, access to raw narratives submitted to BLS is strictly limited.

When OSHA investigates an accident, a narrative is filed with the report. Some of these reports are published. At that point, the narrative can be read and coded in an effort to extract more machine-specific data related to the accident. It should be noted that while the BLS reports are statistically extrapolated to count all press injuries, OSHA only inspects a portion of those incidents. Thus, the OSHA database of accidents is smaller and is limited to reports published and publicly available. Therefore, the number of relevant cases available for review is smaller than might be expected initially.

To better understand the problem of press injuries, narratives were obtained from the published accident investigation narratives available from OSHA's website. Narratives from investigations conducted between 1985 and the time of this writing were searched using the keyword *press.* Results included accident reports related to other types of presses (such as print-

Figure 2

Amputation Cases by Manufacturing Industry



Note: *Data from BLS's Occupational Employment Statistics, and Injuries, Illnesses and Fatalities programs.*

Injuries arising from contact with machines are generally severe, with more than half of all such injuries resulting in some form of permanent partial disability.

ing presses and drill presses) that had to be manually removed from the search results. A total of 290 OSHA narratives related to power press injuries were reviewed by a team of three engineers with experience with power presses. The narratives were coded according to the following rubric:

•Did the injury occur as a result of contact with the point of operation?

•Was the machine missing any required guards?

•Did the machine have a required guard that was functional but had been deliberately circumvented?

•Did the machine have a required guard that was dysfunctional and had been subsequently circumvented?

•Did the machine have a required guard that was ineffective or improper for the application?

•Was there a mechanical malfunction of the machine (excluding safety equipment)?

•Was there a malfunction of the guarding or safety equipment?

This rubric characterizes some fundamental aspects of the injury event that are critical for determining whether the machine was in compliance with applicable laws. Since the law requires that the point of operation be completely guarded, any contact with that hazard in the course of operation is a violation.

From there, it is desirable to determine whether the hazard had always been unguarded or whether some series of actions or omissions had occurred to leave the machine without proper guarding. In some cases, several conditions had occurred simultaneously. Each cause could have independently caused or prevented an accident. Such cases were coded as having multiple contributing causes. The results of this coding process are summarized in Figure 3.

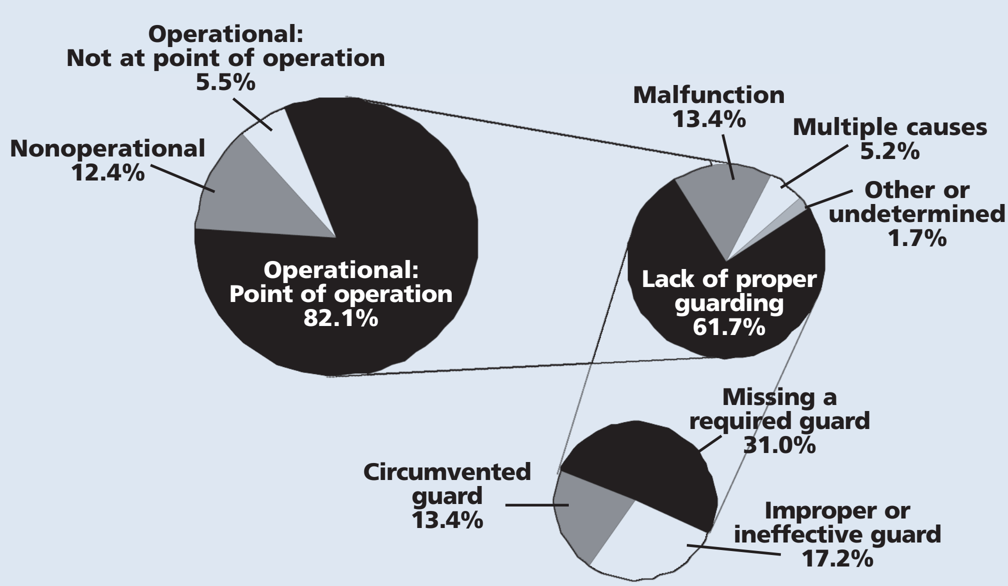
Not surprisingly, most of the injuries (82.1%) occurred at the point of operation, which is recognized in both 29 CFR 1910.212 and 1910.217 as the most significant machine hazard. As such, it is subject to specific guarding requirements. It was unexpected that in a combined 61.7% of cases, a proper point-of-operation guard was not in use. Such a high percentage clearly suggests that employers are not implementing or enforcing proper guarding on these machines.

The data from the OSHA narratives seem to confirm that guard circumvention is a serious problem. In 13.4% of cases, a safeguard had been deliberately circumvented. However, this is a relatively small contribution when compared to the 48.2% of machines that apparently were not equipped with appropriate guards.

OSHA regulations are explicit with respect to point-of-operation hazards. The responsibility of protecting against these hazards falls squarely on the employer, and the hazards must not, under any circumstances, be accessible to the operator when the machine is in use. Under these stipulations, an employer cannot rely on training or work procedures in lieu of guarding. Therefore, except in cases where an employee has deliberately (and illegally) circumvented a guard without the employer's knowledge, it should be physically impossible to suffer a point-of-operation injury. Such occurrences, therefore, must logically indicate a lack of proper guarding or a malfunction of a safety-critical system.

Figure 3

Analysis of 290 OSHA Narratives on Press Injury Incidents



Given these established guarding requirements and the clear placement of responsibility, the review of OSHA narratives seems to strongly suggest that despite the clear regulations set forth in 29 CFR 1910.217, most press accidents occur as a result of missing or improperly designed guards. This leads to only two likely conclusions: 1) the employer is deliberately operating in contradiction of the safety regulations and knowingly creating a hazard; or 2) the employer is unaware of the hazards or does not know how to comply with the standard.

In assessing the problem, the following observations were made:

•One must assume that employers generally do not willfully seek to create hazardous operating conditions in the workplace.

•Review of the OSHA narratives suggests that most press accidents could be prevented by proper compliance with existing regulations.

•Focused enforcement efforts do not appear to have yielded significant reductions in injuries.

Based on these observations, the authors concluded that most press injuries are the result of some disconnect between the regulations and their implementation. In most cases studied, had the OSHA regulations been followed, the injury would have been either extremely unlikely or impossible. The most likely cause is a misunderstanding and misapplication of the standard.

The problem of evaluating a machine thoroughly is not new. Checklists for machine safety are a staple of the SH&E profession. However, such checklists are usually far from comprehensive and, in the case of mechanical power presses, often oversimplify the requirements.

ANSI has adopted a more sophisticated approach. The ANSI B11.TR3 report, "Risk Assessment and Risk Reduction: A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools," provides a structured methodology to aid in the evaluation of hazards associated with the use and maintenance of industrial machinery. This methodology, emerging as the de facto standard for hazard assessment (Etherton, Taubitz, Raafat et al., 2001), provides a structured approach to collecting, organizing and interpreting information related to the hazards associated with any machine.

However, the TR3 methodology lacks specific guidance on how to identify hazards. That judgment is left to the evaluator. For many machines, that level of flexibility is necessary. However, in the case of mechanical power presses, the law is quite explicit and rigid. Application of OSHA's standard to mechanical power presses does not require the level of individual discretion permitted under the TR3 methodology.

The most significant difference between the requirements of ANSI B11.TR3 and the applicable OSHA standards may be seen in application of work rules and training. Both ANSI and OSHA identify the importance of proper training and procedures. However, they differ in whether such training and procedures may be used to protect against hazards. Under the ANSI guidelines, hazards should be eliminated if possible. If they cannot be eliminated, then they should be safeguarded. If safeguarding is deemed impractical or impossible, a combination of training and work rules may be used. Under the OSHA standard, all point-of-operation hazards must be guarded, period. Because TR3 allows for discretion in such matters, its latitude may, in fact, cause evaluators to rely on personal experience and opinion rather than on strict adherence to the OSHA requirements.

Figure 4

Software: Yes/No/Don't Know Question

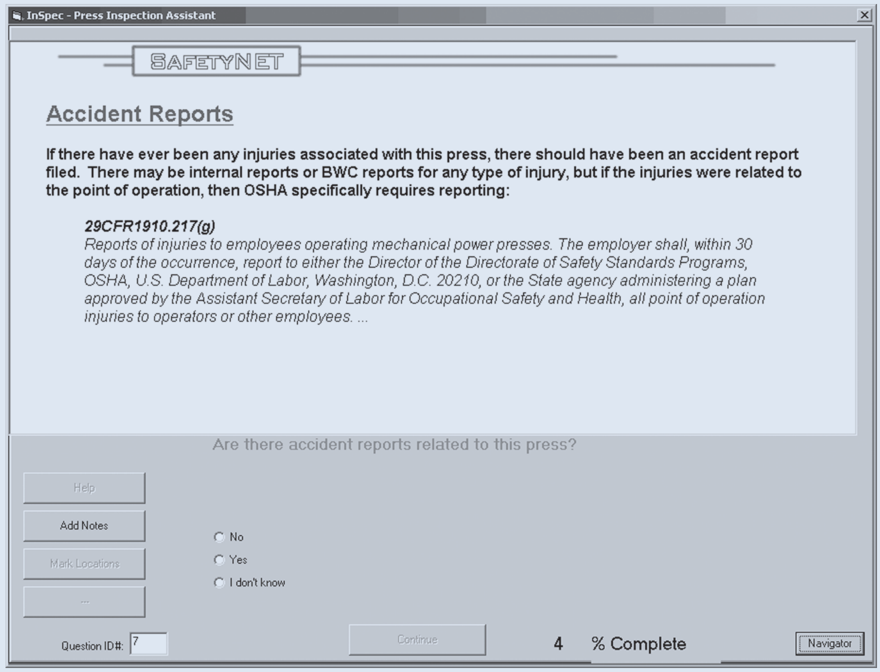
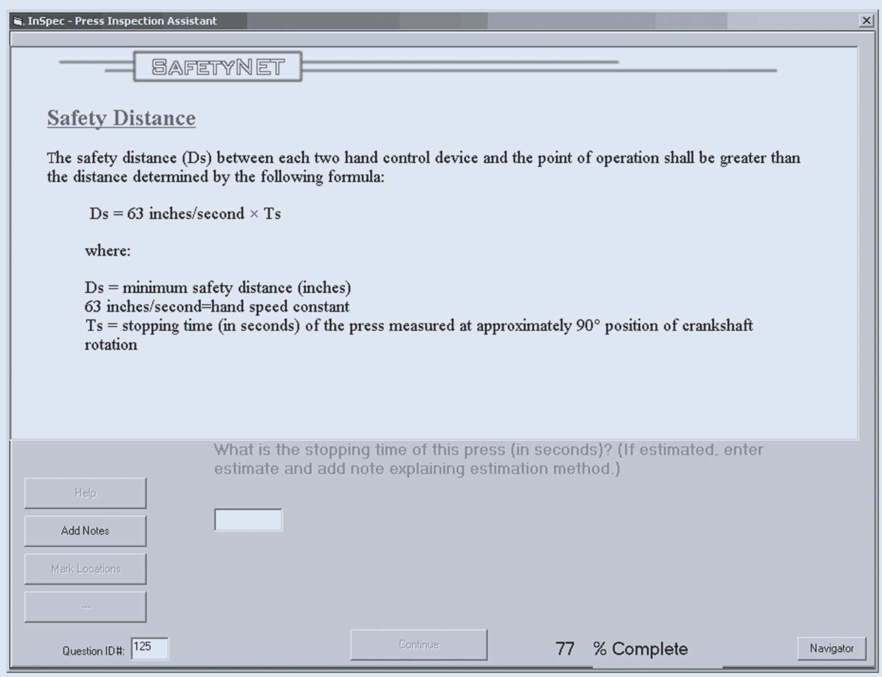


Figure 5

Software: Numerical Answer Question



A New Tool Reveals New Insights

The review of OSHA accident summaries showed that most of the injuries could have been prevented by compliance with applicable regulations. One apparent explanation for noncompliance is that the individuals responsible for the machines may not interpret or apply the laws correctly. Methodologies such as ANSI B11.TR3 provide a good structure for hazard assessment, but do not provide guidance as to what constitutes a hazard.

To facilitate the process of correctly identifying

A disconnect appears to exist between the regulations and their implementation. In most cases studied, had the OSHA regulations been followed, the injury would have been either extremely unlikely or impossible.

press hazards and complying with the applicable laws, a software called SafetyNET has been developed. Owned by The Ohio State University, this software uses a database system to help users assess the hazards inherent in a mechanical power press. It asks a series of simple questions about the user's press, then guides the user in identifying the aspects of the machine setup that are potentially in conflict with general OSHA guarding requirements (29 CFR 1910.212) and the specific requirements for mechanical power presses (29 CFR 1910.217). Figures 4 and 5 show screen captures of the interaction screens.

Questions asked by the software represent the constituent conditions that underlie many of the OSHA requirements. For example, some sections of the OSHA standard apply only to machines that use part-revolution clutches. Other sections apply only to full-revolution clutches. Each section may also contain mandates that are applicable only if the press is operated by palm buttons.

The software is designed to simplify the complex if-then-else conditions and legalese found in the OSHA regulations. The conditions are established one at a time through questions such as, "Is this press activated by a foot pedal?" The assumption is that the user is more likely to respond correctly to concise questions in plain English than to the format found in the standard.

Based on the user's response, the software can determine applicable codes and ask only relevant follow-up questions. Eliminating irrelevant codes based on previous questions speeds the evaluation process. Also, in many sections of the regulation, the conditions under which the requirements apply may have already been established, so the software need not ask the user again, further expediting the process. In effect, the software acts as a sophisticated checklist, enabling the user to address many regulatory requirements by answering a minimal number of questions.

When the user has completed the evaluation, the software produces a list of possible compliance problems. Although the software was not intended as a substitute for expertise, the hope was that it would enable those who lack such expertise to perform inspections with a higher degree of consistency and accuracy.

To test the effectiveness of this tool, three experimental groups were asked to examine several mechanical power presses and identify the aspects of press operation that were not in compliance with OSHA regulations. These groups were:

1) Group 1: Press operators, supervisors and safety personnel who actively work with mechanical power presses. *Method:* Traditional evaluation techniques and the current ANSI B11-TR3 approach.

2) Group 2: Engineering students who have limited experience specific to presses. *Method:* SafetyNET software.

3) Group 3: Engineering students who have limited experience specific to presses. *Method:* Traditional evaluation techniques and the current ANSI B11-TR3 approach.

The press operators, supervisors and safety personnel came from various sites, including two automotive parts manufacturers, two custom fabricators and a research facility. All personnel in this group were actively responsible for press safety either through direct responsibility for setup or as the person responsible for management oversight of safety and operations. Of the press professionals, all indicated that they had received at least informal training on press operations and safety, and 60% reported having received formal training.

Operators from small business operations often lack the level of training that might be found in larger corporations. Active press operators from various small- to medium-size shops were chosen as a representative sample from industry. According to OSHA, nearly 195,000 power presses were in use in the U.S. in 1996. Of the companies using those machines, 88% were small business entities (OSHA, 2004).

The experiments involved the evaluation of three different mechanical presses for compliance with OSHA regulations. The investigation was limited to operational hazards directly affecting or involving the press operator; maintenance, die setting and administrative procedures were not evaluated. Each of the machines was studied by 5 participants from each experimental group. Participants were given access to the machine and an operator for as long as they felt they needed to conduct a thorough assessment.

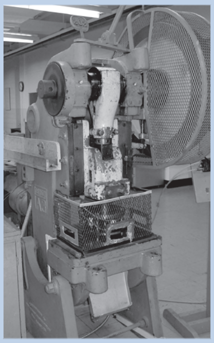
The three machines studied were selected to represent a variety of the types of hazards associated with mechanical power presses (see sidebar on p. 31). The presses were each production-capable machines equipped with production tooling. The three machines studied were:

- **Machine 1: Robinson A3.** This is a full-revolution, open-back inclinable (OBI) press. It is configured with a blanking die that requires a strip to be manually fed into the machine. The press is foot-operated and has a rated load capacity of 25 tons.
- **Machine 2: Minster Model 5.** This machine is a 45-ton, part-revolution, mechanical power press. It is palm-button activated and configured to be operated in either single-stroke or continuous mode. The installed tooling is a progressive stamping die designed for high-volume continuous operation.
- **Machine 3: Havir "Press-Rite."** Machine 3 is a small, 10-ton, mechanical press. The Press-Rite #1 model is a full-revolution press. This press can be configured for either palm-button or foot-switch operation. It can also be configured for either single-stroke operation (such as the current setup) or continuous operation. The installed tooling is a manually fed trimming operation.

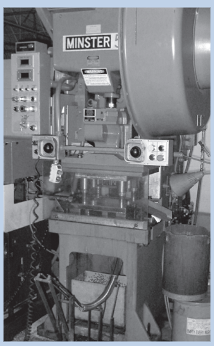
Before the experiments, each participant was provided with copies of 29 CFR 1910.212, 1910.217 and the ANSI B11-TR3 guidelines. The observations made by each test group were transcribed into a database, then correlated to the requirements of 29 CFR 1910.212 and 1910.217.

To compare the relative performance of each experimental group, several scoring methods were

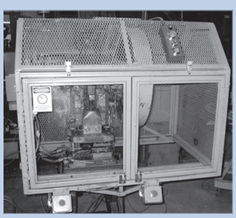
Machines Used in the Experiments



Machine 1
Manufacturer: New Albany Machine Manufacturing
Model: Robinson A3
Clutch style: Full revolution
Tonnage: 25 tons
Activation: Foot pedal
Material feeding: Manual



Machine 2
Manufacturer: Minster
Model: #5
Clutch style: Part revolution
Tonnage: 45 tons
Activation: Palm buttons
Material feeding: Automatic



Machine 3
Manufacturer: Havir
Model: Press-Rite #1
Clutch style: Full revolution
Tonnage: 10 tons
Activation: Selectable palm/foot switch
Material feeding: Manual

employed. The results of two of these scoring methods are presented. Scoring Method 1 is simply a total count of the number of hazards and noncompliances that each participant identified correctly. There is no penalty for wrong answers; wrong answers are simply not counted.

Scoring Method 2 is the number of correctly identified hazard conditions less the number of conditions mistakenly identified as hazardous (in terms of applicable regulatory requirements). Table 1 summarizes the number of observations found by each group, both correct and incorrect, for each machine studied.

Analysis of the data, using a statistical analysis of variance (ANOVA), confirmed that for the sampled populations there is 95% confidence that the novice group using SafetyNET will identify violations of the OSHA standards with greater accuracy than either control group. The differences between the results of the professionals (Group 1) as compared with the press novices (Group 3) were statistically insignificant at the 95% confidence level.

Although the software users had the highest number of correctly identified hazards, they also had the highest numbers of incorrectly identified hazards. The number of incorrectly identified hazards is of little concern from a safety standpoint because the identified errors only indicate false-positive responses. A high number of errors indicates that the individual often identified conditions as hazardous when in fact they were not. Even so, the number of incorrect answers is a measure of the software's accuracy and provides an additional metric for comparing the performance of the three groups.

Table 2 summarizes the results of the three groups aggregated across the three machines studied. From this table, it is again illustrated that Group 2 (software) accurately identified more than twice the number of hazards as either comparison group. As might be expected, Table 2 shows that the unassisted novices had the highest error ratio. It also shows that Group 2 had the highest number of falsely identified hazards. However, because these are false-positive responses, they represent a higher degree of conservatism in identifying hazards. In terms of falsely identified hazards, the industry professionals performed best.

Several conclusions may be reached by considering the error numbers and ratios. Although the professionals were less likely to identify an acceptable operating condition as being hazardous, they also identified only half as many total hazards as the software users. Several reasons may explain this behavior, but the net result is that the press professionals tend to identify fewer hazardous conditions, both correct and incorrect, than did the software users.

Although the software users had the highest number of falsely identified hazards, this does not necessarily reflect badly on the software's performance. First, because they are false-positives, the numbers represent overcaution in identifying hazards. Second, since the erroneously identified hazards represent less than 10% of the total number identified, the overwhelming majority of identified hazards are indeed valid. Third, the statistics presented do not capture the fact that the software group was far more consistent than either comparison group.

Of the hazards that were misidentified by software users, 80% of users incorrectly identified the same hazard. That level of consistency reinforces the strength of the software tool. Since most of the software users arrived at the same incorrect identification, the flaw is more likely within the structure of the identification logic for that specific hazard than a weakness in the overall software approach.

Although the software is limited by the strength or weakness of its question database, the preliminary results demonstrate that it can yield more uniform results across several users than is observed within either comparison group using traditional

Table 1

Number of Hazards Correctly & Incorrectly Identified

	Correctly identified hazards									Incorrectly identified hazards								
	Machine 1			Machine 2			Machine 3			Machine 1			Machine 2			Machine 3		
Experimental group	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
29 CFR 1910.212(a)(2)	3	3	1	1														
29 CFR 1910.212(a)(3)(ii)	4	5	3	5	5	4	3	3	3									
29 CFR 1910.212(b)											1	1						
29 CFR 1910.217(a)(4)		5			3			5										
29 CFR 1910.217(b)(3)(ii)							1	5	1	1	1							
29 CFR 1910.217(b)(4)(i)	4	5	3													1		
29 CFR 1910.217(b)(4)(ii)	1	4	2														1	
29 CFR 1910.217(b)(4)(iii)		4	1														1	
29 CFR 1910.217(b)(6)(i)							2	4	2									
29 CFR 1910.217(b)(6)(ii)									1									
29 CFR 1910.217(b)(7)(i)														2				
29 CFR 1910.217(b)(7)(ii)												2						
29 CFR 1910.217(b)(7)(iv)																1		
29 CFR 1910.217(b)(7)(v)(a)																		1
29 CFR 1910.217(b)(7)(v)(b)														2				
29 CFR 1910.217(b)(7)(v)(d)																1		
29 CFR 1910.217(b)(8)(i)						1												1
29 CFR 1910.217(b)(8)(ii)														3			3	
29 CFR 1910.217(b)(8)(iii)			1															1
29 CFR 1910.217(c)(1)(i)				1			1											
29 CFR 1910.217(c)(2)(i)(a)	5	5	3	5	5	5	3	3	3									
29 CFR 1910.217(c)(2)(i)(b)	3	5	3	5	4	5	3	5	3									
29 CFR 1910.217(c)(2)(i)(c)	3	3	1	1														
29 CFR 1910.217(c)(2)(i)(d)		4		1	5	1		4										
29 CFR 1910.217(c)(2)(i)(f)			1		1			1	1									
29 CFR 1910.217(c)(2)(iv)											1							
29 CFR 1910.217(c)(2)(v)								3										
29 CFR 1910.217(c)(2)(vii)		5			5		1	5										
29 CFR 1910.217(c)(3)(v)														1				
29 CFR 1910.217(d)(1)	1	5			5			4										
29 CFR 1910.217(d)(6)(i)										1		1			1			1
29 CFR 1910.217(e)(1)(i)	1		1	2			2											
29 CFR 1910.217(e)(1)(ii)	2		2	2			2											
2 9CFR 1910.217(e)(2)		5	2		3			5	1									
29 CFR 1910.217(f)(2)	2	5	1	1	5		1	5										
29 CFR 1910.217(f)(3)	1	1	2	1	1	3			3									
Incorrectly identified as a violation of 212/217										1		4			1			1

Table 2

Aggregate Summary of Correctly & Incorrectly Identified Hazards

Hazards	Group 1	Group 2	Group 3
Correctly identified (total)	**74**	**158**	**64**
Machine 1	30	64	27
Machine 2	25	42	19
Machine 3	19	52	18
Incorrectly identified (total)	**5**	**16**	**9**
Machine 1	2	3	4
Machine 2	0	8	1
Machine 3	3	5	4
Error ratio *[Incorrect/(Incorrect+Correct)]*	6.3%	9.2%	12.3%

hazard assessment techniques. In addition to consistency, the SafetyNET evaluations were more thorough and accurately identified more hazards. Based on that finding, it is expected that future research will find that all user groups, professionals and novices alike, may benefit from using the software. Further investigations will be conducted to confirm that expectation, particularly regarding the potential use of this software by press professionals.

Conclusion

The number and severity of mechanical power press injuries continues to take an undue toll on the American manufacturing community. The high overall costs of these accidents demand the continuous pursuit of all reasonable opportunities to reduce such injuries.

The OSHA standards that govern the operation and guarding of mechanical power presses provide sound guidance and, if followed, can reasonably be expected to prevent most press accidents. However, the regulations are ineffective if they are not correctly understood and properly implemented.

Various tools have been developed to help industry professionals evaluate the safety of machinery. Among them, the ANSI TR3 methodology offers a widely accepted structure within which to evaluate any machine. However, in the case of mechanical power presses, where the requirements are explicit, the TR3 methodology does not necessarily ensure that the evaluator will interpret the applicable regulations accurately.

SafetyNET software offers an evaluation tool that specifically aids in evaluating mechanical power presses by reducing portions of the OSHA regulations into plain-English questions. The software lacks the flexibility of the TR3 approach, but it appears to be effective in guiding users—even those with limited specialized knowledge—through the sometimes-confusing language of applicable OSHA regulations.

The effectiveness of the software is rooted in the reduction of regulations to terms and questions that are easily understood by most users. Thus, it is expected to be usable by most people, ranging from untrained workers to seasoned professionals. Because the software has preliminarily allowed novices to identify hazards more effectively than professionals, it should be equally if not more effective when applied by press professionals. ■

References

Brubaker, S. (1997, Dec.). Optimum machine guarding. *Occupational Health & Safety,* 37-40.

Bureau of Labor Statistics (BLS). (2004, May 3). Conversion to North American Industry Classification System (NAICS). Washington, DC: Author. Retrieved Feb. 2, 2006, from http://www.bls.gov/lpc/iprnaics.htm.

BLS. (2005). *BLS handbook of methods.* Washington, DC: Author. Retrieved Dec. 14, 2006, from http://www.bls.gov/opub/hom/homtoc.htm.

BLS. (2006, Feb. 2). North American Industry Classification System (NAICS) at BLS. Washington, DC: Author. Retrieved Dec. 14, 2006, from http://www.bls.gov/lpc/iprnaics.htm.

Etherton, J., Taubitz, M., Raafat, H., et al. (2001). Machinery risk assessment for risk reduction. *Human and Ecological Risk Assessment, 7,* 1787-1800.

Koopmanschap, M.A. & Rutten, F.F.H. (1997). A practical guide for calculating indirect costs of disease. *Pharmacoeconomics, 10,* 460-466.

Kydoniefs, L. (1996). The occupational safety and health survey: Instrument redesign. *Proceedings of Section on Survey Methods Research, American Statistical Association, USA.*

Leigh, J.P., Markowitz, S.B., Fahs, M., et al. (1997). Occupational injury and illness in the United States: Estimates of costs, morbidity and mortality. *Archives of Internal Medicine, 157,* 1557-1568.

Liljas, B. (1998). Current opinion: How to calculate indirect costs in economic evaluations. *Pharmacoeconomics, 13,* 1-7.

National Safety Council (NSC). (2003). *Injury facts.* Itasca, IL : Author.

NIOSH. (1987). *Injuries and amputations resulting from work with mechanical power presses.* Washington, DC: Author.

OSHA. (1997, Feb. 28). CPL 2-1.24: National emphasis program on mechanical power presses, 29 CFR 1910.217. Washington, DC: Author.

OSHA. (2001, Nov. 9). *CPL 2-1.33: National emphasis program on amputations.* Washington, DC: Author.

OSHA. (2004, May). *Regulatory review of OSHA's presence sensing device initiation (PSDI) standard.* Washington, DC: Author, Directorate of Evaluation and Analysis Office of Evaluations and Audit Analysis.

OSHA. (2005). OSHA facts: December 2004. Washington, DC: Author. Retrieved May 15, 2005, from http://www.osha.gov/as/opa/oshafacts.html.

Further Study Is Required

The authors are actively continuing to study the SafetyNET software and the general problem of machine safety.

These results, although promising, are preliminary. Further studies must be performed to confirm the full potential of this approach to hazard identification. Ongoing studies are being developed to test the effectiveness of the software on a larger sample of presses and with a more diverse set of users. Those tests will yield better insights into the tool's strengths and weaknesses, and will help to guide further development.

Readers who would like more information or who are interested in participating in upcoming studies should contact Darrell Wallace at drwallace01@ysu.edu.