Machine Safety

Developing an operator presence system

By John R. Powers Jr., Douglas E. Ammons and Ivan Brand

STUMP CUTTER SAFETY involves many elements of machine design and safe operating practices. Manufacturers and dealerships provide extensive documentation on the proper operation and safe use of stump cutter machines. ANSI Z133.1-2006 requires that stump cutters be equipped with enclosures and guards to reduce the risk of injury. It also states that operators shall keep the enclosures and guards in place while the cutter is being operated (International Society of Arboriculture, 2006).

However, in some cases, operators have not followed proper procedures and have been injured. American Rental Association (ARA) Insurance Services (2007) reports that since January 2000, six claims have involved people injured while using rented stump cutters. Incidents involving stump cutters can result in serious injuries with workers missing multiple days of work.

An operator presence system may help prevent injuries that can occur when the operator approaches the cutter wheel with the clutch still engaged. Small machines equipped with handlebars have unique safety and operation characteristics and typically utilize traditional operator presence controls. These controls use a separate handle or switch that is activated and held in place by the operator while the machine is being used. These systems are typically found on walk-behind machines, such as lawn mowers, or in the seats of larger machines, such as tractors and forklifts. When the handle or switch is released, power to the cutter wheel disengages automatically. When utilized on small stump cutters, power to the cutter wheel is disengaged automatically.

Larger stump cutters require hydraulic controls for the cutter wheel travel. These cutters have historically not been equipped with operator presence systems at the controls due, in part, to human factors concerns, such as hand/arm fatigue. Traditional operator presence strategies are not practical on these machines.

To address this issue, NIOSH and Vermeer Corp. collaborated to investigate the application of capacitive-sensing technology to detect the operator at the controls of a hydraulic stump cutter.

Early NIOSH Research

In early 2001, NIOSH became interested in developing a passive operator presence system that did not require the operator to engage a separate handle or switch. The system would automatically detect an operator around a machine and shut down the equipment if the operator entered a danger zone. At this same time, Quantum Research Group Ltd. in Great Britain was developing capacitive-sensing components that were inexpensive and easy to use.

Capacitance is the ability of an object or surface to store an electrical charge. It is often discussed as an electrical characteristic between two objects. The objects are separated by some nonconductive material such as air. The substance between the two objects, the material of which the objects are made and the distance between them all affect capacitance. The capacitance between two objects increases with an increase in the objects' surface areas and decreases with an increase in distance between them.

The human body can readily accumulate a measurable charge, which makes it possible to detect using capacitance. Examples of capacitive sensing that uses the human body include touch lamps and faucets that turn on when a person's hands are placed on or near them.

NIOSH became interested in this technology as a

John R. Powers Jr. *is an electrical engineer and team chief with the Protective Technology Branch, Division of Safety Research, NIOSH, Morgantown, WV. He holds a B.S. in Electrical Engineering from Pennsylvania State University. Powers's research focuses on the development of sensors and the implementation of engineering controls in the agricultural, construction and transportation sectors.*

Douglas E. Ammons *is a computer engineer with the Protective Technology Branch, Division of Safety Research, NIOSH, Morgantown, WV. He holds a B.S. in Computer Engineering from West Virginia University and a B.S. in Electronics Technology from Fairmont State University.*

Ivan Brand *is the senior technical coordinator for product safety at Vermeer Corp. His technical training is in safety engineering. He has been responsible for managing the product safety engineering function at Vermeer Corp. for more than 30 years.*

viable means of sensing the presence of a human body around machines or machine parts. In March 2002, researchers began designing a system using numerous sensors manufactured by Quantum Research. By the end of 2003, NIOSH researchers had completed laboratory testing of their design and the search for a partner began.

Locating an Industry Partner

In January 2004, NIOSH posted an announcement in Federal Business Opportunities seeking manufacturers interested in working with NIOSH. Federal Business Opportunities is a medium in which federal agencies post announcements seeking assistance from commercial vendors. The announcement, which focused on wood chippers, described the project and provided criteria that the prospective partner would need to meet:

1) Provide significant intellectual, engineering, and technical expertise in manufacturing the safety system.

2) Provide assistance in setting realistic product cost objectives as well as provide suggestions on how the safety system can achieve product cost goals.

3) Provide a wood chipper for testing and evaluation.

4) Fabricate prototypes for testing and evaluation.

5) Provide expertise to NIOSH in designing and conducting field evaluations.

Vermeer Corp., a manufacturer of agricultural, construction, environmental and industrial equipment, was the only candidate that contacted NIOSH. The company wanted to learn more about capacitive sensing and how NIOSH was applying the technology on wood chippers.

Meetings Between Vermeer & NIOSH

The initial meeting between Vermeer and NIOSH focused on the concept of using capacitive-sensing technology to protect wood chipper operators. One challenge the groups identified was that the capacitive signal must be isolated from the surrounding metal of the wood chipper feed chute. Because the sensor would have to be mounted inside the feed chute, the groups also determined that it would be difficult to protect the electronics from damage caused by the large diameter wood fed into the chute. After further discussion, the groups decided that it was not feasible to apply capacitive sensing to a wood chipper.

Vermeer then asked about applying the technology to a stump cutter. The firm was interested in having the cutting wheel drive disengage automatically when an operator's hands left the controls. After further discussion, the groups decided this project might be possible because the sensor could be mounted near the machine's controls and would be less susceptible to damage than was the case with the wood chipper.

During a June 2004 meeting at Vermeer's headquarters in Pella, IA, NIOSH personnel operated a stump cutter to become familiar with it and to determine possible locations for mounting the sensor. NIOSH engineers also described the technology and its potential application to the stump cutter controls. The firm agreed to supply NIOSH with various pieces of its machine so that testing could be conducted at the NIOSH laboratory in Morgantown, WV.

Research & Development

Research Mechanism

A formal partnership, in the form of a letter of intent for a cooperative research and development agreement, was established so that each party knew what was expected of it. This mechanism allows the parties to perform cooperative research by following a formal research plan. It can also provide protection for any intellectual property developed through the cooperative research. The mechanism consists of a detailed research plan and a description of financial and staffing contributions of each party.

The plan detailed specific action items that each party would address during the project. Under the agreement, NIOSH provided project coordination; developed prototype designs for detecting the operator's hands at the stump cutter's controls; tested and demonstrated the sensor; helped with installation and field testing; provided all design materials; and jointly published results of the project.

Vermeer provided project coordination and had overall design responsibility; provided engineering and technical expertise in implementing the sensor on the cutter; provided stump cutter parts; provided a stump cutter for sensor evaluation; reviewed test results and made recommendations; provided additional design as needed; conducted field tests and developed test criteria; and jointly published results. All funding was the sole responsibility of each organization.

NIOSH Designs

After receiving the stump cutter components, NIOSH began working on two solutions. The research team learned that one sensor (QT9701B2) was not being sold to new customers.

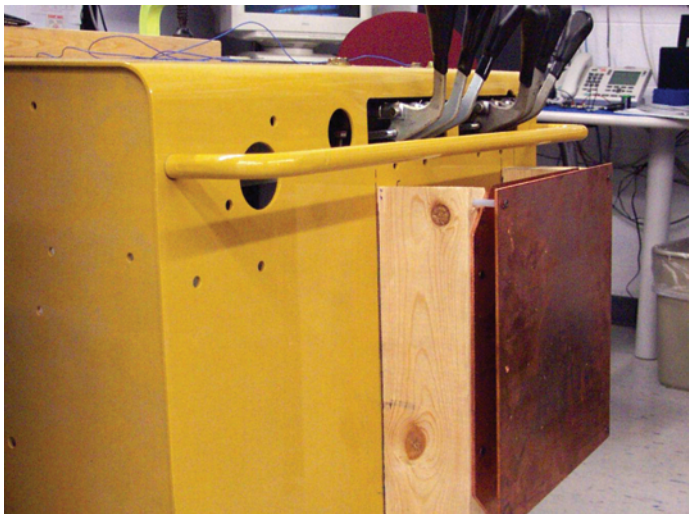
Abstract: *Few hydraulic stump cutters have operator presence systems due, in part, to practicality and operator concerns. Such systems could help prevent injuries that can occur when an operator approaches the cutter wheel with the clutch still engaged. NIOSH and Vermeer Corp. collaborated to investigate the possibility of applying capacitive-sensing technology to detect an operator at the machine's controls. This article details the early developments of this safety system and discusses the mechanisms used to establish this research to practice partnership.*

Research to Practice at NIOSH

Research to Practice (r2p) is a NIOSH initiative focused on the transfer and translation of research findings, technologies and information into highly effective prevention practices and products which are adopted in the workplace.

The goal of r2p is to reduce illness and injury by increasing workplace use of effective NIOSH and NIOSH-funded research findings. To achieve this, NIOSH is continuing to work with its partners to focus research on ways to develop effective products, translate research findings into practice, target dissemination efforts, and evaluate and demonstrate the effectiveness of these efforts in improving worker health and safety.

For more information, visit www.cdc.gov/niosh/r2p.



In one NIOSH design, a copper plate (Photo 1) was connected to the sensor. The lower part of an operator's body could be detected in front of the controls. When the operator moved away from the controls, the sensor would shut off the cutter wheel.

The team identified alternative hardware available from Motorola (MC33794 electric field imaging device) (Eady, 2003). Freescale Semiconductor (2005) was packaging the device as part of a kit that could be used for engineering development and evaluation. The team purchased three kits and incorporated them into the sensing design. The kits proved to be successful and the team began designing prototype solutions.

The objective was to sense the operator's presence at or near the controls of the stump cutter. If the operator left the control area, the clutch driving the cutting wheel would disengage, thus stopping the cutting wheel.

The first solution involved mounting a sensor below the cutter's controls that would detect the presence of an operator's body (Photo 1). In this design, a copper plate was connected to the sensor. The lower part of the operator's body could be detected in front of the controls. When the operator moved away from the controls, the sensor would shut off the cutter wheel.

The second solution involved mounting the sensor inside the stump cutter handles to detect the presence or absence of the operator's hands on the control handles. To do this, a small piece of copper had to be embedded inside the handle and the handle had to be isolated from the machine chassis, since the chassis is grounded and would defeat the sensor. A small wire also had to be embedded into the handle to provide the electrical connection to the sensor.

After an extensive review, Vermeer decided to pursue the design with the sensor inside the control handles since an operator typically has both hands on them while using the machine. This design was more difficult to implement but it was considered to be the better solution. Vermeer took the basic technology suggested by NIOSH and developed it into a prototype handle (Photo 2).

Vermeer Design & Implementation

Vermeer incorporated the prototype handle into a working prototype machine (Photo 3). The firm also developed the system's performance and operational requirements, focusing on criteria that would enhance reliability and user acceptance. Along with the new handles, a new computerized control system was designed to interpret sensor signals to control the cutter wheel. Numerous factors, such as rain and low-lying tree branches, had to be considered so the system would perform properly under rugged outdoor conditions. The prototype machine is shown in Photo 4.

After field testing, it was determined that a new handle design was needed to prevent the computer from interpreting water flow across the handle surface as being the operator's hand. The manufacturer also noted that in some rare instances, heavy vegetation could press against the handles and make the sensor react as though the operator's hand was touching the controls. As a result, vegetation guards were added along both sides of the control levers.

Ultimately, all challenges were resolved and arrangements were made for user field testing and evaluation.

Production/Commercialization

Field Test Units to Production Units

To gather input regarding the design's operational and functional characteristics from actual users, three prototype machines were built. These machines were located in the mid-Atlantic, eastern and southeastern parts of the country. Users were asked to complete a brief questionnaire regarding the new system. Users responded positively and found the system acceptable without significant change.

After some work to enhance reliability and manufacturing efficiency, Vermeer began to install the new safety system on a 2008 model stump cutter (Vermeer Corp., 2008) as stan-

Technology Transfer & Patents

During the early project stages, NIOSH prepared an employee invention report (EIR) to claim intellectual property that was being developed. Vermeer was also included on the EIR. This report is the first step at NIOSH for applying for patent rights. After several months, the CDC Technology Transfer Office decided not to file for a patent as the marketability search report did not look favorable for an operator presence system.

Vermeer decided to take action on its own and submitted two patent applications. One application, which included NIOSH, detailed the operator presence system. The other application, which was specific to Vermeer, detailed the design of the water-ring that was developed to solve the problem with water flow around the control handles.

dard equipment. Plans are underway to incorporate similar technology into another model.

Automating Safety Controls

One key to the successful integration of this system is its transparency to the operator. Experienced operators will operate the machine exactly as they have in the past. This system adds no handles or interlocking switches that the operator must control. The machine simply senses the operator's presence. A similar device could be applied to other machines where there is a need to sense an operator's presence.

Changing Attitudes Toward Government Partnerships

Developing cooperative partnerships between government agencies and private industry can be challenging. Private companies are willing to bid on federal grants to secure funding, yet many are hesitant to enter into a partnership to work side-by-side with government engineers and scientists. Many perceive that the government workers may try to force their ideas and processes onto the private company. This quote from Ivan Brand, Vermeer's senior technical coordinator for product safety, tells a different story.

> I think the cooperative effort between Vermeer and NIOSH was a big success. NIOSH's early awareness of the emerging capacitance-based technology for the automotive industry enabled us, through our partnership, to shape the technology uniquely for this new application. NIOSH relied upon us to be the experts in stump cutter operation and safety, and we relied upon NIOSH to test the concept of applying capacitance technology in an outdoor machine environment. This respectful relationship was one of the keys to the success of this project.

Conclusion

This successful research to practice project demonstrates that private industry and the federal government can partner to develop a product that benefits all parties. The safety system was developed from basic research being conducted at NIOSH. This research was transferred to Vermeer, which integrated the concepts into its stump cutter product line. As a result, a stump cutter now incorporates innovative safety engineering technology that will benefit equipment owners and users. ■

Vermeer took the basic technology suggested by NIOSH and developed it into a prototype handle (Photo 2, left). The company then incorporated the prototype handle into a working prototype machine (Photo 3, below). Along with the new handles, a new computerized control system was designed to interpret sensor signals to control the cutter wheel.

Vermeer created a prototype stump cutter featuring the operator presence system designed through the cooperative arrangement (Photo 4, above).

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