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Reducing Commercial Fishing Deck Hazards with Engineering Solutions for Winch Design

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Abstract

Introduction: The majority (67%) of hospitalized injuries among Alaska commercial fishermen are associated with deck machinery. This paper describes the "Prevention Through Design" process to mitigate one serious machinery entanglement hazard posed by a capstan deck winch. *Methods:* After observing that the capstan winch provides no entanglement protection and the hydraulic controls are usually out of reach of the entangled person, NIOSH personnel met with fishermen and winch manufacturers to discuss various design solutions to mitigate these hazards. *Results:* An emergency-stop ("e-stop") system was developed that incorporated a momentary contact button that when pushed, switches a safety-relay that de-energizes the solenoid of an electro-hydraulic valve stopping the rotating winch. The vessel owners that had the e-stop installed enthusiastically recommend it to other fishermen. NIOSH entered into a Proprietary Technology Licensing Agreement with a company to develop the system for commercial use. *Conclusions:* This is an example of a practical engineering control that effectively protects workers from a hazardous piece of equipment by preventing injuries due to entanglement. This solution could reduce these types of debilitating injuries and fatalities in this industry.

Keywords: Prevention through design; PtD; Commercial fishing; Entanglement hazards; Engineering solution; Injury prevention

1. Introduction

Commercial fishing is the most dangerous occupation in the United States. In 2006, 51 commercial fishermen were killed on the job resulting in an occupational fatality rate of 142 per 100,000 workers, the highest rate for any occupation in the United States and 36 times higher than the average fatality rate for all U.S. workers (Bureau of Labor Statistics [BLS], 2007).

During 1994–2004, 641 commercial fishermen died in the United States. Of these, 332 (52%) died after their vessel sank, and another 184 (29%) fatalities were due to falls overboard. The remainder of the fatalities were due to a variety of causes, including deck injuries (51, 8%; Dickey & Ellis, 2006). These fatal deck injuries are from machinery and fishing gear. In Alaska, fatal deck injuries are even more prevalent, accounting for 12% of all fatalities during 2000–2006 (Commercial Fishing Incident Database [CFID], 2007). Prevention efforts should emphasize preventing the loss of life due to the loss of a vessel, falls overboard, and injuries on deck. This paper focuses on the efforts to prevent injuries on deck, including the redesign of machinery or the retrofitting of safety features on fishing machinery and equipment.

An important issue to address is jurisdiction of regulatory agencies on uninspected commercial fishing vessels. Both the Occupational Safety and Health Administration (OSHA) and the U.S. Coast Guard (USCG) have authority over the safety of employees onboard commercial fishing vessels. The USCG is the lead agency; OSHA only has jurisdiction out to 3 miles from shore. In addition OSHA is precluded from enforcement with respect to working conditions regulated by other federal agencies. Therefore, the promulgation of safety regulations by the USCG preempts OSHA with respect to those working conditions specifically addressed by Coast Guard regulations. The USCG does have regulations in regard to machine guarding, but the extent to which these are enforced is limited.

In Alaska, most fatalities in the commercial fishing industry are also due to the loss of a fishing vessel. However, injury

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epidemiologists at the National Institute for Occupational Safety and Health (NIOSH) Alaska Field Station have shown that most (67%) severe nonfatal injuries occur on deck during the deployment and retrieval of fishing gear (Thomas, Lincoln, Husberg, & Conway, 2001). Severe nonfatal injuries are defined as those requiring hospitalization and include lacerations, broken bones, severe head injuries, and smashed limbs. The deck of a fishing boat is a slippery, constantly moving work platform that is often congested with machinery and fishing equipment. Many of the deck machines used on commercial fishing vessels lack adequate guarding and safety features and entanglement is a particular hazard. NIOSH found that during 1991–2002, 798 fishermen were hospitalized for severe nonfatal injuries, which is equivalent to an annual rate of 410 per 100,000 full-time equivalent fishermen. Of these injuries, 23% were due to being entangled or struck by lines or gear, or being trapped in a winch, pulley, or other deck equipment (Lincoln, Husberg, & Mode, 2006). Experts have recommended that vessel machinery be redesigned or retrofitted with safety features to prevent these types of injuries (Husberg, Lincoln, & Conway, 2001; Burgess, 2001).

The purpose of this paper is to describe the "Prevention Through Design" activities we completed in order to mitigate one machinery entanglement hazard posed by a deck winch commonly found on commercial fishing vessels.

2. Methods

NIOSH is the federal agency responsible for conducting research and making recommendations to improve the safety and health of workers in the United States. The NIOSH Alaska Field Station has worked in the area of commercial fishing safety since 1991. After working with our industry partners on several safety issues, NIOSH developed the Deck Safety Intervention Project, which began in October 2000. Goals of this project were to determine when and where deck injuries occur and to develop intervention strategies. These intervention strategies included engineering designs with industry input to eliminate or lessen the risks deck machines pose.

In 2002, NIOSH injury epidemiologists met with fishermen across Alaska to discuss the problem that 67% of severe hospitalized injuries were a result of deck machinery, with the hope that practical solutions could be developed to prevent these injuries from occurring. One significant entanglement problem fishermen identified was that posed by the capstan-type winches (Fig. 1) typically found on purse-seine vessels.

Vessels fishing with purse-seine gear are generally about 50-feet long and are accompanied by a skiff, which is integral to the fishing operation. The seine is a large net with thick mesh and small openings. It is not designed to catch fish in the mesh; rather, the net acts as a large cage trapping the fish. The seine is set by using the skiff to pull one end of the net off the stern of the vessel. The skiff is brought around so that the seine makes a half circle with the skiff on one end and the vessel on the other end. Both ends are towed equally to gather a school of fish. Then, the skiff pulls its end over to the vessel completing the circle. At this point, a line, which is threaded through rings at the bottom of the net, is wrapped around the drum of the capstan deck winch and pulled in. This line, the "purse-line," draws the bottom of the net together making a large "bag" or purse. The fish trapped in the purse are brought onboard and dumped in the fish hold.

Fig. 1. Photo of capstan-type winch, F/V Lake Bay.

The deck winch on purse-seine vessels is a powerful (up to 1000 foot-pounds of torque) capstan winch, usually mounted in the center of the deck near the wheelhouse. Its drum rotates while the crew is working on deck. Fishermen who lose their balance or are inattentive can become entangled in the purse-line as the line is winding around the drum. Crushing injuries to the hand or arm, and in some cases fatalities if the head or torso is caught, are the results. The winch hydraulic motor controls are usually located on the bulkhead just forward of the winch. Unfortunately, they are usually out of reach of the entangled fisherman to stop the drum rotation.

In June 2002, tragedy struck the captain of a commercial purse-seine vessel fishing for salmon in Prince William Sound, Alaska. The crew had just set the seine around a school of fish. After drifting with the net open for about 15 minutes, the captain called for the skiff-man to close the net, which was done without incident. Then, as the captain wrapped the purse line around the drum of the deck winch to close the bottom of the seine, he reached across the winch, brushing his raincoat sleeve against the moving line. The sleeve caught between the line and the rotating drum. He called for help as he was being wrapped into the spinning drum. Two crewmen charged across the deck from the stern where they tried to work the hydraulic winch controls, located on the backside of the pilot-house. However, the captain had gone around the winch three times before it was stopped. Despite the best efforts of the crew and others nearby, the captain died the next day at an Anchorage hospital from multiple traumatic injuries.

One year later in October 2003, another purse-seine captain was killed in the same type of capstan deck winch near Homer, Alaska. Working alone during an opening for rockfish, he was using the deck winch to lower a bag of fish that he had just weighed into the fish hold. Evidence suggested that the captain's right hand got too close to the rotating drum and his coat sleeve got caught in the line. Entangled in the deck winch, the controls were out of reach and the rotating winch could not be stopped. The captain's body was found mangled and wrapped repeatedly

around the capstan several days later when his wife reported him overdue to the U.S. Coast Guard.

NIOSH investigations identified two major safety hazards: no entanglement protection is provided by the winch and the hydraulic controls are usually out of reach of the person who is entangled. Injury epidemiologists from the NIOSH Alaska Field Station partnered with engineers at the NIOSH Spokane Research Laboratory to design a practical engineering solution to mitigate these safety hazards.

This NIOSH team of epidemiologists and engineers met with vessel owners, purse-seine fishermen, and winch manufacturers to discuss the various safety design options. It was quickly realized that standard machine guarding and "dead-man switch" solutions were either not feasible or applicable to the typical machine use. Pressure mats for the dead-man switch would be subject to false signals from lines being coiled on deck, or from fish as the net is dumped. Physical guards are impractical because lines are fed onto the winch from virtually any angle (Fig. 2) using the fixed winch 'horns' in combination with the rotating drums (complicated by the fact that both drums are sometimes used at the same time with lines from two directions). Rain or ocean spray would interfere with light curtains. Design considerations also favored systems that would be simple, affordable, unobtrusive, applicable to various winch models, use off-the-shelf components, not disable other vessel functions (such as the rudder or anchor winch), not interfere with normal fishing operations if the emergency-stop system failed, and — most importantly — have the capability to be activated by the person being entangled in time to prevent serious injury (McKibbin & Woodward, 2006).

3. Results

The engineering design solution that was developed was an emergency-stop ("e-stop") system that incorporated a robust, low-profile, momentary contact button mounted on the top port-side winch horn (Fig. 3). This location was the preferred mounting spot for a fisherman pursing the net from the starboard side of the vessel (the most common scenario). When pushed, the button energizes a safety-relay that in turn de-energizes the solenoid of an electro-hydraulic valve. This valve, plumbed between the manual valve that controls winch rotation and the winch drive motor, closes the flow of hydraulic oil to and from the winch motor and locks the capstan drums in place. If the emergency switch is pressed in a timely manner and the hydraulic motor does not have significant wear in the vane seals, the winch drums will lock almost instantaneously. When the electro-hydraulic valve is de-energized, the valve-spool shifts to the default position to block the oil flow to and from the winch motor. This functions as a hydraulic brake on the winch enabling a Category 0 stop. If the electric power to the electro-hydraulic valve is turned off for any reason, the hydraulic fluid flow stops and the winch will not operate until the power is returned and the e-stop circuit is reset. If the winch drum has significant external rotational force acting upon it, and the motor seals are in need of repair, back-spooling of the winch drums could occur after the hydraulic valve closes both pump and tank motor ports. The back-spooling drums could effectively unwind the victim from the entanglement.

Fig. 2. Photo of capstan-type winch with lines around, F/V Lake Bay.

The time it takes the victim to strike the emergency switch is thus the controlling factor in arresting the drum rotation, not the valve response time. With the drums turning at a typical working speed (40–60 rpm), and considering a typical human response time (less than 0.5 sec), the winch drums could be stopped in less than 180° of rotation – sufficient to limit serious entanglement injury.

A control box containing the safety-relay, pilot lights to indicate system status, and a system reset button, is mounted adjacent to the winch directional control valve. In the event someone becomes entangled, it is important that the winch directional control valve be returned to neutral before the e-stop system is reset; otherwise, further entanglement or injury could result by the rotating drum. On purse seine vessels, the manual winch directional-control valve is almost always mounted on the rear bulkhead of the vessel, usually about 5- to 6-feet forward of the capstan winch. The normal function of the manual valve precludes having a self-centering spool. The fisherman typically shifts the spool for either a forward or reverse winch operation, then leaves the winch running to execute his/her fishing duties. If there is a winch entanglement and the e-stop is used to stop the drum rotation, the safety relay requires a manual reset. If the prototype system was reset without verifying that the manual valves were in the neutral position, the winch drums may start to rotate again unexpectedly. The position of the reset function was moved from the position of the e-stop switch to the proximity of the manual valves. In the described scenario, this operating location removes the reset-switch operator from the possible hazardous area near the rotating winch drums. Yet, he/she is close enough to make a visual inspection of the clearance around the winch and to be able to observe the position of the manual valves, before resetting the system (Fig. 4).

This design lends itself to the development of more advanced systems. Additional buttons, easily wired in parallel to the winch e-stop button, can be placed in other locations on the vessel such as in the wheelhouse or along the gunwales, leaving

Fig. 3. Photo of Captain Bud Marrese with emergency-stop (e-stop) mounted on capstan-type winch.

the reset switch at the manual winch controls. The e-stop system may be applied to other types of deck machinery, and may eventually incorporate wireless or voice activation features.

A fishing vessel owner/operator home-ported in Seattle, Washington worked with NIOSH on the design and installation of this e-stop system, which was successfully tested during the 2005–2007 Southeast Alaska salmon seasons. This vessel's crew praised the device as a significant safety and, surprisingly, productivity improvement. As of this writing, they continue to use the winch e-stop system. The crewmembers have reported that although they have not had to use it in an emergency, it has come in handy when the purse-line gets knotted up while operating.

This capstan winch e-stop system has been installed by NIOSH on two other seiners that operate in Alaska. Feedback from a qualitative evaluation of the e-stop system was completed. We asked the skippers who are currently using the system questions in regard to its acceptability, use in an emergency, its reliability, durability, possible design improvements, and examples of how it is making their fishing more efficient.

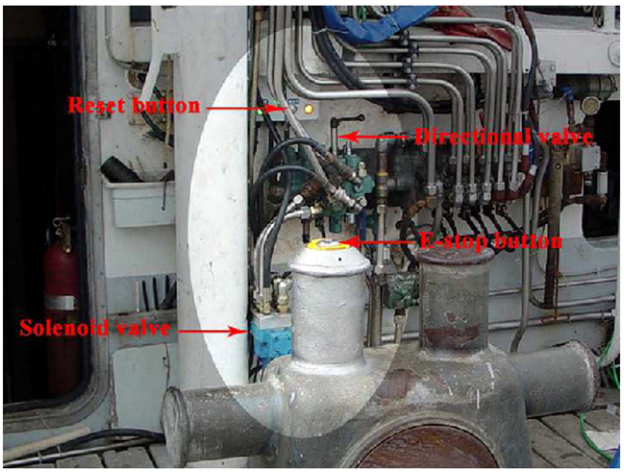

Fig. 4.

The other fishing crews also like having the e-stop on their vessels. They believe the e-stop is very helpful, very important, and would enthusiastically recommend it to other fishermen. None of them have had to use it in an emergency. They did indicate that they found it increases efficiency because they are able to stop the winch faster when something is wrong with the lines. On rare occasions, the button is sometimes pushed unintentionally by someone's hand or elbow, but the system can be quickly reset so as not to be a problem. Note that the NIOSH-designed e-stop does not reset 'automatically,' and it cannot be reset by pushing the e-stop button a second time (i.e. 'toggling'). It requires that someone manually push the reset button mounted in the control box on the rear bulkhead. Fishermen who have used the system are so pleased with it that they have cited other pieces of machinery on their vessels that could be made safer with similar e-stop buttons.

The e-stop has received strong support at industry trade shows. It has been demonstrated at Pacific Marine Expo in Seattle in 2005, 2006 and 2007, the largest commercial fishing trade show in the United States, and at Comfish Alaska in Kodiak in 2007. The e-stop has received an overwhelming positive response from fishermen, with many fishing vessel owners and operators requesting information on how to obtain the device for their vessels. NIOSH staff have also produced and distributed copies of a deck safety awareness DVD that illustrates the entanglement hazard and e-stop solution to the hazard (NIOSH, 2007). Over 100 DVDs have been distributed to fishermen, marine safety organizations, and government agencies in the nine months since production. In the next year, a control technology publication will be written to increase the distribution and impact of this e-stop solution.

The NIOSH intervention design has been licensed to a manufacturer. In November 2007, NIOSH entered into a Proprietary Technology Licensing Agreement with Emerald

Marine Products, LLC (Seattle, WA) to develop the e-stop system for commercial use. Emerald Marine Products, in cooperation with Kolstrand Marine Supply (Seattle, WA), will be manufacturing a similar system based on the NIOSH research. They will be selling the e-stop exclusively through their distributor Go2Marine.

4. Conclusions

The e-stop is an example of a practical engineering control or physical modification that can be implemented to protect workers from a hazardous piece of equipment such as the capstan winch. Taking from the injury prevention literature (Haddon, 1972), the most effective control of the hazard would be to *"Prevent the creation of the hazard in the first place"* by eliminating the use of the deck winch. This type of winch is not used in the European Union and some operators in the United States have eliminated it from their operation as well. However, if this cannot be done, engineering controls are the most desirable type of hazard intervention because they separate the worker from the hazard and decrease the possibility of an incident occurring.

By using injury epidemiology to identify problems, along with practical industry input, effective safety interventions to control such hazards can be designed and implemented. This "prevention through design" approach should prove effective in providing tools for this dangerous industry to prevent injuries on deck, and hopefully inspire others to apply similar ideas to these types of hazards.

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Robert W. McKibbin attended Seattle's Lakeside School and the University of Washington, where he graduated in Mining Engineering in 1971. He joined the former U.S. Bureau of Mines, Spokane Research Center, in 1975. His research has covered a wide range of topics, including mine ventilation and radon gas control, retreat mining methods and machinery, high pressure water-jet drills, slurry transport of mine wastes and backfilling methods, seabed mining, rock mechanics instrumentation and in situ stress determination, technology transfer, automated coal mining machinery, and drilling safety. In 1996, the health and safety research activities of the Bureau of Mines were transferred into the CDC's National Institute for Occupational Safety & Health. His most recent research for this agency has been in the field of commercial fishing health and safety, in particular the safety of deck machinery. He has authored a variety of publications in rock and soil mechanics, mine waste disposal, and radon gas. He has been a member of the Society for Mining, Metallurgy, and Exploration since 1968, and is a Registered Professional Engineer in Washington.

Chelsea Woodward studied at Wenatchee Valley College and at Gonzaga University. Starting in 1980, Mr. Woodward worked in the heavy construction and housing industry as a builder and licensed general contractor. In 1994, he switched his vocation to work as an electrical engineering contractor for the U.S. Bureau of Mines at the Spokane Research Center. Since 1998, he has been employed with the National Institute for Occupational Safety and Health, both at the Spokane Research Laboratory and detailed to the Alaska Field Station as an engineering technician. His professional emphasis at NIOSH has been in developing mechatronic safety systems, motion control and semi-autonomous system designs and applications, hydrogen-fueled vehicle safety systems and gas monitors, data acquisition controls and sensor networking for the mining and commercial fishing industries.

John Bevan attended Washington State University where he graduated in Mechanical Engineering in 1971. From 1971 to 1973 he was employed by Chrysler Corp at their World Headquarters at Highland Park, MI. as a coordination engineer at the Engine Lab Test Facility. In 1975 he joined the former U. S. Bureau of Mine, Spokane Research Center. He has worked on research projects that include a Longer than Seam Height Roof Bolt inserter, Longer than Seam Height Drills, Automated Bolting Modules, Remote Manual Bolting Modules, and Water Jet Drills. In 1996, the health and safety research activities of the Bureau of Mines were transferred into the CDC National Institute for Occupational Safety & Health. Current work is centered on the improving safety of deck machinery in the commercial fishing industry.