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DEVELOPMENT OF AN EMERGENCY STOP SYSTEM FOR A HYDRAULIC DECK WINCH

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Abstract

From 1980-1989, Alaskan workers died at a rate approximately five times the U.S. national rate, due in large part to accidents in the commercial fishing industry. In response to this problem, in 1991, the National Institute for Occupational Safety and Health (NIOSH) established the Alaska Field Station (AFS) in Anchorage, Alaska. A principal goal of AFS is to gather and analyze fishing fatality and injury data and make recommendations for research to address problem areas. One area that AFS staff identified was hazards related to deck machinery, specifically the capstan winches typically found on purse seine fishing vessels. For example, fishermen can become entangled in the ropes and can't shut-off the winches.

In 2004, Spokane Research Laboratory (SRL) of NIOSH, in collaboration with AFS, began development of an engineering intervention to improve safety for such a winch. SRL staff met with vessel owners, seine fishermen, and winch manufacturers to discuss various design options. The final design, an emergency-stop (e-stop) system, incorporates a momentary contact switch mounted directly on the winch and an adjunct electro-hydraulic control circuitry. The prototype e-stop system was installed on an operating purse seine vessel and tested successfully during the summer 2005 fishing season in Alaska. The system is currently being refined in preparation for additional testing in 2006.

This presentation discusses the basis for research into deck machinery safety, engineering intervention options, details of the SRL e-stop system as installed, initial results of field tests, and recommendations for additional development.

Keywords: Fishing safety, seine winch, deck winch, purse seine

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Background

The National Institute for Occupational Safety and Health (NIOSH), a part of the Centers for Disease Control, is the U.S. Government agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. With a staff of over 1,400 people representing a wide range of disciplines including epidemiology, medicine, industrial hygiene, safety, psychology, engineering, chemistry, and statistics, NIOSH works with virtually every industry to achieve these goals.

NIOSH established its Alaska Field Station (AFS) in Anchorage in 1991, after research showed that Alaska workers were at a higher risk for occupational injuries and death. Alaska experienced 34.8 worker deaths for every 100,000 workers employed in the state during the 1980's, a rate approximately five times the U.S. national rate of 7.0 per 100,000. A principal goal of AFS is to gather and analyze fishing fatality and injury data, and make recommendations for research to address problem areas. AFS staff found that, from 1990 through 2004, 861 people in Alaska died from work-related injuries. Of these fatalities, 251 (29%) occurred in the commercial fishing industry. Data from studies in other developed countries (Roberts, 2004; and, Driscoll et al., 1994) support these statistics.

Equally significant is the number of serious injuries sustained on the working deck from machinery and lines during the deployment and retrieval of fishing gear. In Alaska alone, for the period 1991-2002, there were 798 fishermen hospitalized for severe nonfatal injuries, equivalent to an annual rate of 410/100,000 full-time 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; and, of the 41 amputations requiring hospitalization identified, 54% were attributed to machinery (Lincoln et al., 2006). Deck machinery and gear are also factors in many fatal injuries aboard fishing vessels. The U.S. Coast Guard has documented that from 1994-2000, 8% (37) of all fishing-related fatalities nationally were a result of either getting caught in gear, or getting struck by gear while operating machinery (Dickey, 2003). These data show that further efforts are required to prevent injuries on deck, including the redesign of machinery or the retrofitting of safety features on fishing machinery and equipment (Husberg et al., 2001; and, Burgess, 2001).

In 2004, AFS began a collaborative effort with the NIOSH Spokane Research Laboratory (SRL) entitled "Injury Prevention in the Commercial Fishing Industry", the goals of which are to develop engineering interventions which reduce the incidence of traumatic injuries in the commercial fishing industry, and to transmit these developments to stakeholders in a timely and effective manner. AFS staff used their epidemiologic and injury prevention expertise to analyze a variety of data sources and identify the mechanisms which are the leading causes of both fatal and severe nonfatal injuries. The technological and engineering expertise of SRL staff was then applied to further examine these mechanisms and the interaction between the fishermen, the vessel equipment, and the working environment. One significant problem which had been identified by AFS staff was that of entanglement in deck machinery, specifically the capstan-type winches (Fig. 1) typically found on purse seine vessels. Along with AFS, SRL staff developed an emergency-stop (e-stop) system for such a winch; development of the system is described here.

Design Considerations

The primary task of this project was to design and test a system which has the potential to reduce entanglement injuries in the capstan deck winch typically found on purse seining vessels. This type of winch requires easy access to the rotating winding drums (gypsies) from all angles, and requires workers to stand near it during operation. Fishermen who lose their balance or are



Fig. 1 – Capstan deck winch



Fig. 2 – Multiple lines

inattentive can be quickly entangled in the purse line as it is winding onto the gypsy drum. Crushing injuries to the hand or arm (and in some cases fatalities if the head or torso is caught) are the inevitable result. SRL staff considered a wide range of potential technologies for preventing entanglement or stopping the winch in the event someone became entangled. These included: pressure mats or pedals on the deck near the winch, activated either by the fisherman stepping onto or off the mat/pedal; guard rails or cables around the gypsies, with or without kill switches; and, various types of e-stops such as light curtains, buttons, or tensioned cables. Each of these options could function either by disconnecting power to only the winch or by disengaging the engine clutch driving the hydraulic pump or generator.

SRL staff met with vessel owners, seine fishermen, and winch manufacturers to discuss the various design options. It was quickly realized that standard machine guarding or deadman solutions were not possible. Pressure mats 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 gypsies (complicated by the fact that both gypsies 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 windlass), not interfere with normal fishing operations if the e-stop system fails, and -- most importantly -- have the capability to be activated by the person being entangled in time to prevent serious injury.

The prototype design, which takes into account the above considerations and stakeholder input, is an e-stop system that incorporates a robust, momentary contact button mounted on the top port-side winch horn. This location was the preferred mounting spot for a right-handed fisherman pursuing the net from the starboard side of the vessel (the most common scenario). When pushed, the button energizes a latching relay that in turn 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 gypsies in place. A control box containing the latching 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 would likely result. The proximity of the reset button next to the winch directional control facilitates that action.

Finally, this design lends itself to the development of more advanced systems. Additional buttons, easily wired in parallel to the winch button, can be placed in other locations on the vessel such as the wheelhouse or along the gunwales. The system may be applied to other types of deck machinery, and may eventually incorporate wireless or voice activation features.

Selection of test vessel

Seattle, Washington is home to one of the largest fleets of purse seine vessels on the west coast of the U.S., and is the closest port to the SRL located in Spokane, Washington, a distance of 450 km. For that reason, efforts to find a cooperator willing to assist in development of the proposed e-stop system were focused in Seattle. SRL staff were fortunate to find such a cooperator in Mr. Bud Marrese, owner and skipper of the fishing vessel (F/V) Lake Bay, a 17.7-meter vessel typical of the purse seine fleet (Fig. 3). Mr. Marrese is a very safety-conscious skipper, and was willing to install the NIOSH prototype e-stop system on his vessel and test it under actual fishing conditions.



Fig. 3 – F/V Lake Bay

Mr. Marrese and his crew usually fish in southeast Alaska, first for herring in March, then salmon from June through September. Following the Alaska fisheries, they return to Washington for some additional salmon fishing near Seattle in October and November.

The F/V Lake Bay was built in the early 1970's at Delta Marine in Seattle, Washington, and is equipped with a Kolstrand 5N capstan deck winch, manufactured in Seattle. Hydraulics are driven by a pump connected through a pneumatic-actuated clutch to the vessel's main engine. The winch directional control valve is mounted on the rear bulkhead adjacent to the mast, approximately 1.5 meters forward of the winch. The vessel's electrics are 32-volt dc. SRL staff traveled to Seattle in March, 2005 to obtain the necessary measurements that would allow for detailed engineering design of the prototype e-stop system. These included: layout of equipment on the working deck; placement, size and manufacturer of the various hydraulic components; location of electrical panels and wiring runs; and, the mounting and internal construction of the deck winch (Fig. 4).



Fig. 4 – Measuring deck layout

Detailed design

After collecting the needed design measurements, SRL staff developed a detailed engineering design for the prototype e-stop system. This design included: the plan for installation of the momentary contact button; routing of electrical cables and hydraulic lines; mounting of the control box and solenoid valve; a schematic of the electrical components; parts specifications; and, engineering drawings. The schematic was based on generally accepted e-stop principles, with one notable exception. There was concern on the part of SRL staff that, in the event any component of the prototype e-stop system were to malfunction, the ability to continue fishing (as

normal) should not be compromised. That is, in the event of an electrical power interruption to the e-stop circuit, the deck winch could continue to operate. This necessitated a 'reverse logic' design where electrical power is required to stop hydraulic flow to the motor; whereas in most industrial e-stop applications, a 'normal logic' circuit would require that an electrical disconnect disable the protected device or machine until the e-stop system is reset manually (thus re-energizing the electric circuit).

Individual e-stop system components include:

1. the momentary-contact button, manufactured by Polara Engineering. This button is typically used as an actuator for pedestrian crosswalk signals and, as such, is waterproof and can withstand severe impacts. The button is recessed into a machined steel ring (Fig. 5) that is in turn welded to the top winch horn. The conical-shaped ring permits lines to slip over the button without actuating it as the winch is being used, but still allows for a fisherman to depress the button. The ring also lessens the chance that a tensioned line could shear the button off the horn. The wire connecting the button to the control box is a marine-grade, non-wicking, wire-shielded cable fastened to the terminals of the button and sealed with an electrical potting epoxy;



Fig. 5 – Button, steel ring, and cable

2. a 10-amp circuit breaker, added to the vessel's main breaker panel in the engine room. This protects the e-stop circuit and allows the crew to disable the entire e-stop system in case of any malfunction. The same marine-grade cable was used to bring power from the breaker to the e-stop control box;

3. a 32-volt to 12-volt dc converter, housed in the control box. The converter was needed because the F/V Lake Bay is equipped with a 32-volt dc electrical system, and most readily available solenoid valves are either 12- or 24-volt dc;

4. a latching relay that is energized when the winch e-stop button is pushed. It remains latched until the 'reset' button, mounted on the control box, is depressed. Pilot lights (green to indicate power on, and yellow to indicate 'tripped') complete the control box circuitry. These components are housed in a waterproof enclosure mounted to the rear bulkhead, with strain reliefs for the cables and marine sealant as needed;

5. and, a Vickers electro-hydraulic solenoid valve (Fig. 6). This valve was plumbed between the vessel's existing winch directional control valve and the winch drive motor. When the latching relay is energized, power is sent to the 12-volt solenoid, thus actuating the valve, shutting off the flow of oil to and from the winch motor, and locking the winch gypsies in place. The valve was plumbed using hard tubing.



Fig. 6 – Solenoid-actuated hydraulic valve

Installation

Installation of the prototype e-stop system occurred in June, 2005, just prior to the beginning of the southeast Alaska salmon fishing season. The first step was to weld the tapered steel ring to the top of the winch horn, and drill the holes through the horn and bottom of the winch case for the electrical cable. The weld was ground smooth (Fig. 7), the hole in the winch horn was chamfered to prevent chafing of the cable, and the hole in the bottom of the winch was tapped to receive a threaded strain relief fitting. After securing the button to the steel ring with four mounting screws, the cable was routed to the control box through the winch via the drilled holes (with appropriate strain reliefs and marine-grade waterproofing sealant), and then under the vessel's false deck. Routing in this manner eliminates the chance of lines or equipment snagging and tearing out the cable ends.



Fig. 7 – Grinding the welded ring smooth



Fig. 8 – Control box mounted on bulkhead

The waterproof box housing the electrical control components was mounted to the vessels rear bulkhead (Fig. 8), directly above the bank of valves which control the deck winch, power block and other mast winches. Three cables enter the box: 32-volt dc power from the circuit breaker in the engine room; the cable from the button on the winch; and, the cable connecting the solenoid valve. All entry points have strain reliefs and marine sealant. The box lid has a full gasket, which allows the lid to be easily removed for inspection or service of the internal components.

The solenoid valve was first mounted on a bracket welded to the vessel's mast. Once in place, this allowed the hydraulic contractor to precisely measure for, and install, the stainless steel tubing runs between the solenoid valve, the winch directional control valve, and the winch motor -- a total of four new tubes. Finally, the cable from the control box was connected to the solenoid and sealed.

Once all components were mounted, the system was tested under power at dockside. The hydraulics were powered up and the winch cycled several times at maximum speed in both directions. The functions of the e-stop button, pilot lights, and reset button were tested. Voltages were measured at all points in the circuit to ensure they conformed to the schematic as designed. Finally, the e-stop system was activated and the solenoid valve energized for two hours to check heat rise in both the valve and control box. The e-stop system was found to be in complete working order. The F/V Lake Bay departed for Alaska on June 22, 2005.

Summer test

The crew of the F/V Lake Bay fished for salmon throughout southeast Alaska from late June through mid September and then returned to the Puget Sound (Seattle) area, where they fished until mid November. The NIOSH-developed e-stop system was active the entire time and

operated without any malfunction. Fortunately, there were no actual emergencies or winch entanglements. However, the crew still used the e-stop on a routine basis, and reported that it enhanced their productivity by eliminating the need to walk the few steps between the winch and the directional control valve every time they wanted to shut off gypsy rotation. The crew reported that the e-stop was particularly helpful in case of a 'wrap-up' -- where the purse line becomes crossed over itself on the rotating gypsy and there is a need to stop rotation as quickly as possible to avoid further fouling of the purse line.

The fact that the e-stop system is routinely used in this manner serves two important purposes. First, with each activation, the proper functioning of the system is being tested and verified to the crew. Second, and most important, is that the crew becomes conditioned in the use of the e-stop button. This ensures that, in the case of a real entanglement emergency, reaching for the button would be a 'second nature' habit that could be performed quickly and would hopefully prevent a serious injury or fatality.

Conclusions and recommendations

The initial five-month sea trial of the prototype e-stop system aboard the F/V Lake Bay was considered a success. Given that success, the crew's acceptance of the device, and the reliability demonstrated by the system components, SRL staff feel that a second generation system should be developed using a 'normal' logic circuit. This will bring the e-stop into compliance with generally accepted industrial practice, and standards as codified in American National Standards Institute B11.19. Only minor alterations to the e-stop circuitry are required for the prototype normal logic design. An additional set of manual valves would serve to bypass the solenoid valve in case it malfunctions, allowing fishing to continue until the solenoid valve is repaired.

Once the second generation normal logic system is developed and laboratory tested, a second season of testing under actual fishing conditions would be required to demonstrate its reliability and ensure acceptance by the crew. If a high enough confidence level is established with respect to the solenoid valve, consideration should be given to elimination of the manual bypass valves from the circuit, especially if the system is commercialized.

Another recommendation is that the momentary-contact button's housing be re-designed. As manufactured by Polara Engineering, the button housing has straight sides, necessitating the addition of the custom-machined tapered ring to prevent lines from catching or activating the button. Elimination of the machined ring could be accomplished with a tapered-side button housing, which would save in machining and installation costs. Again, this would be an important improvement if the e-stop system is commercialized.

Additional types of deck machinery, to include other types of winches or, in particular, crab bait choppers, may benefit from application of this e-stop system. SRL staff recommend that available data bases be examined to assess the mechanism and extent of injuries involving these types of deck machines, as was done with the capstan style winches; and, that the e-stop system be considered as a potential engineering intervention to reduce or eliminate such injuries.

Finally, it is recommended that emerging technologies such as wireless remote, radio frequency identification, or voice activation be incorporated into the e-stop circuitry if and when it can be demonstrated that such technologies would enhance the safety or reliability of the e-stop systems.

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