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NIOSH AutoROPS
Latch and Release Mechanism: Second Generation

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Abstract

Approximately 132 agricultural tractor overturn fatalities occur per year (Myers and Snyder, 1993). The use of rollover protective structures on farm tractors (ROPS), along with operator seat belt use, is the best known method for preventing these fatalities. One impediment to universal ROPS use, however, is low clearance situations, such as orchards and animal confinement buildings.

To address the need for ROPS that are easily adapted to low clearance situations, the Division of Safety Research (DSR), National Institute for Occupational Safety and Health (NIOSH), developed a prototype automatically deploying, telescoping ROPS (AutoROPS). The NIOSH AutoROPS consists of two subsystems. The first is a retractable ROPS that is normally mounted to the tractor axle and latched in its lowered position for day-to-day use. The second subsystem is a sensor that monitors the operating angle and rate of roll on two axes of the tractor. If an overturn condition is detected by the sensor, the retracted ROPS will deploy and lock in the full upright position before ground contact.

This paper discusses the second generation design of the latch and release mechanism (LRM) for the NIOSH AutoROPS and recommends key areas for future surveillance and design research to best facilitate reduction in farm rollover fatalities.

Introduction

Tractor overturns are the leading cause of fatalities in the agricultural industry. Approximately 132 fatalities occur per year (Myers and Snyder, 1993). The use of a rollover protective structure (ROPS), along with concurrent seat belt use, is a system with the potential of preventing these fatalities. Although ROPS use is increasing (Zwerling, 1997), the number of overturn-related fatalities per year has not been declining significantly (National Safety Council, 1997).

One impediment to ROPS use is low clearance situations, such as orchards and animal confinement buildings. Many smaller tractors are now equipped with manually extending or foldable ROPS for use in such situations. However, between 10 and 20 % of new tractors are reported to be operating without ROPS (Myers and Snyder, 1993). Lower use or non-use of manually extending or foldable ROPS may be due to a need to operate these tractors in low clearance situations. These ROPS will only provide protection if the operator selects to properly deploy them.

Current data on injuries and fatalities due to the lack of manual deployment of adjustable ROPS is absent. To address the need for ROPS that are easily adapted to low clearance situations, NIOSH has adopted the innovative technology used to protect drivers and passengers from overturn hazards when operating convertible automobiles (Mowry, 1999; Mercedes-Benz AG, 1995; U.S. Department of

Transportation, 1989). NIOSH/DSR has developed a prototype telescoping ROPS (AutoROPS) system that automatically deploys. The NIOSH AutoROPS is a passive device consisting of a retractable ROPS that is normally latched in its lowered position for day-to-day use, and a sensor that monitors the operating angle of the tractor. If an overturn condition is detected by the sensor, the retracted ROPS deploys and locks in the full upright position before the overturning tractor contacts the ground.

Static load testing and field upset tests of the NIOSH AutoROPS have been conducted in accordance with SAE J2194. Additionally, timed trials of the AutoROPS deployment mechanism were performed. The NIOSH designed system has successfully completed each of the required tests, meeting or exceeding the industry standards.

First Generation Latch and Release Mechanism.

The first generation LRM, shown in Figure 1, was comprised of two steel pins, two pyrotechnic squibs and two compression springs, mounted in a housing on the outside of the fixed tube of the NIOSH AutoROPS, and opposed 180 degrees to each other. The retracted/deployable tube of the NIOSH AutoROPS was latched in the retracted position by means of 2 single shear steel pins held into place by compression springs. Each steel pin has a disk attached to the end that will be used in the deployment process. The steel pins pass through the tube wall of the fixed tube and inside the wall of the deployable tube. The pyrotechnic squibs are screwed into the mounting blocks at an expansion chamber. In the event of a detected potential rollover, the pyrotechnic squibs are ignited by a 1.2 amp, two millisecond duration current. This explosion creates an initial 550 kPa (80 psi)/10 cc pyrotechnic gas expansion. Both steel pins are simultaneously disengaged by the expanding gas pressure against the disks attached to the steel pins, freeing the NIOSH AutoROPS into a deployed position. The pyrotechnic squibs are a one-time use item with an approximate cost of fifty dollars per squib. It is possible with this system to have a false deployment if the operator can correct the tractor before the roll. Deployment, false or not, would cost in the range of two hundred dollars.

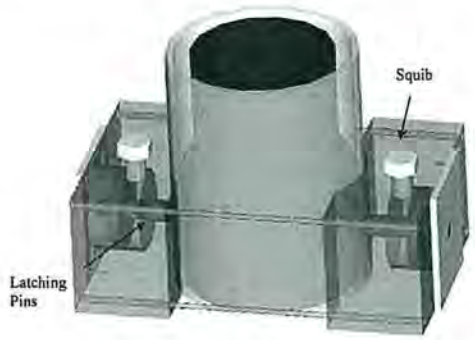

Figure 1. First Generation LRM

This configuration has proven to be highly reliable but cumbersome and labor intensive to latch the system in the retracted position. However, facilitating the operator's ability to operate and maintain the NIOSH AutoROPS was considered a key design objective improvement. Therefore, a better latch and release mechanism was needed.

Second Generation Latch and Release Mechanism

Design Areas of Interest

The second generation LRM was designed to improve on ease of resetting and cost deficiencies of the initial design.

a) The first design area of interest was to reduce the amount of effort (number of people) required to latch the NIOSH AutoROPS in the retracted position;

b) The second design area of interest was to eliminate alignment difficulties when latching the mechanism in the retracted position inherent to the first generation design.

c) The third design area was the safety concerns that could result from an inadvertent detonation of the squibs during installation or maintenance.

d) The forth design area of interest was to have the new design be reusable at no additional cost in the event of a false deployment or a deployment without a roll.

The new latch and release mechanism for the NIOSH AutoROPS is referenced as the CS2000 LRM. The CS2000 LRM uses the combination of a ball, a groove, an over-center latch and a solenoid to create a mechanism that is capable of latching (holding) and releasing, see Figure 2.

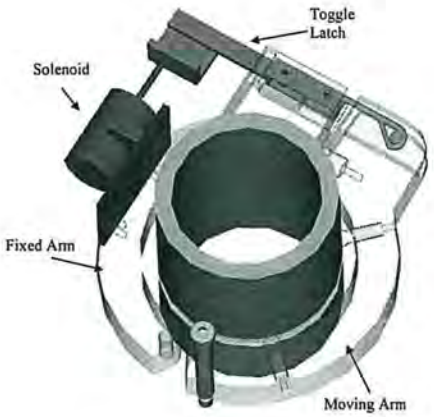

Figure 2. CS2000 LRM

The core of the CS2000 LRM is the machined groove in the outside edge of the piston, Figure 3. The groove in the piston has a radius of 0.6 inches at a depth of 0.3 inches in the radial direction of the piston.

Figure 3. Ball Grove and Ball Pins

The piston is welded/fixed to the inside tube (the deployable/moving portion) of the AutoROPS system. The latch is held fixed to the outside tube (rigidly fixed portion) of the AutoROPS system that is mounted to the axle housing of the tractor. The latch consists of two arms (one fixed, one moveable), a toggle latch, a solenoid, two ball pins and two retaining rings. The two retaining rings mount one above the arms of the CS2000 LRM and one below. They

serve as a rigid mount as well as a guide for the movable arm. The fixed arm holds the solenoid and half of the toggle latch. The moving arm serves as a mounting location for the two ball pins, Figure 4. The two ball pins are steel pins with a diameter of 0.50 inches with 0.60 inch spherical ends. The 0.50 inch diameter end is mounted into the movable arm leaving the spherical end exposed. The two arms are preloaded with a 20-lb/in chrome-vanadium die spring (0.625 inch diameter with a length of 2.50 inches).

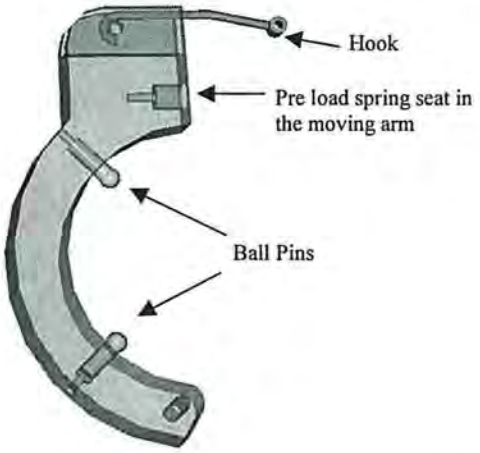

Figure 4. Moving Arm with Ball Pins and Hook

When the CS2000 LRM is latched, the spherical end (ball end) of the ball pin is pressed into the groove and held in place by the toggle latch. The AutoROPS is locked into the retracted position. When the rollover sensor detects a pre-described rollover condition the solenoid is actuated, striking (pushing) the toggle switch and releasing the holding pressure created by the CS2000 LRM. The combination of the radial force applied tangentially to the ball pin by the groove, and the preload force created by the spring, forces the moving arm to rotate about a fixed point on the retaining rings. When the ball pins are removed from the groove, the inside tube is free to deploy and is thrust upward by the energy stored in the compressed spring. A four position representation of the release process is shown sequentially in Figures 5.

Figure 5. Four Position Simulation of CS200 LRM

Results

The CS2000 LRM has performed in the laboratory setting as designed. The minimum number of people required to latch the NIOSH AutoROPS is one. The alignment difficulties inherent to the first generation LRM have been totally eliminated. This generation LRM has proven to be both reliable and reusable without any additional cost per deployment. The average deployment time is 0.190 seconds.

Conclusion

The CS2000 LRM is a notable improvement over the first generation LRM in performance, ease of operation, repeatable use, and cost effectiveness.

Future Work

The CS2000 LRM is to be field tested. The field test will help validate the reliability shown in the laboratory setting. On future NIOSH AutoROPS the CS2000 LRM will be reduced in size, complexity, and cost, in part, by welding the upper and lower retaining rings and the fixed arm to the outside fixed post.

Future Surveillance

To better understand, and formulate strategies for an effective response to current occupational agricultural tractor injury trends it would be important to gather information in several of the following areas; (a) seat belt use, (b) incidents with manual extending ROPS in the un-extended position, (c) fatalities on ROPS equipped tractors with/without seatbelt use.

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