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NIOSH AutoROPS 3rd Generation Static Testing and Human Interaction Element

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Abstract

To address the need for rollover protective structures (ROPS) on farm tractors that are easily adapted to low overhead clearance situations, the Division of Safety Research (DSR), National Institute for Occupational Safety and Health (NIOSH), developed an automatically deploying, telescoping ROPS (AutoROPS). The NIOSH AutoROPS at the present is in the third generation design and static testing phase, and the first phase of human subject (human operator) testing and manufacturing. The static testing is based on the SAE J2194 standard for testing ROPS for agricultural tractor use. The nature of the NIOSH AutoROPS is to be in a retracted position until an overturn is determined to be imminent. It is during the deployment time period that potential safety hazards exist that are not present in a traditional fixed ROPS and not addressed in the standards. Human interaction is a key ingredient in refining the design to be both functional and desirable while considering possible hazards. Feedback from farmers who have operated a tractor with the NIOSH AutoROPS installed and in the ready state will enhance the design and acceptability. NIOSH's goal is to reduce the number of fatal agricultural overturns by increasing the percentage of tractors with ROPS and seatbelts which operate in low clearance environments. This design has met laboratory static testing criteria of the SAE J2194 standard for ROPS on agricultural tractors. Field evaluation of the AutoROPS use by poultry farmers (N=32) in eastern West Virginia showed favorable results and a preference for wanting to purchase and use the NIOSH AutoROPS compared with a currently available manually foldable ROPS.

This paper discusses the overall performance of the NIOSH AutoROPS as subjected to the SAE J2194 standard and human interaction/feedback of operating an agricultural tractor with this added safety device.

Introduction

Since the inception of the NIOSH AutoROPS research program, the need for a passive protective device has not diminished. In 1993 the average fatal agricultural overturns in the United States was 132 (Myers and Snyder, 1993). Myers (2003) showed that tractor rollover fatalities remain high (between 150 and 200 deaths per year), while efforts to equip the 2.5 million tractors without ROPS are moving forward at an unacceptably slow pace. The protection of the farmer/worker from possible injury or death in tractor rollovers in low clearance work environments is still a significant concern. Low profile tractors working in low clearance environments are exempt from OSHA's ROPS regulations. Such work sites are typically inside farm buildings, poultry barns, greenhouses, in orchards or vineyards where overhead obstructions exist and where vertical clearance is not sufficient for safe operation with a fixed ROPS. All tractors sold after 1985 come with a ROPS installed in either a fixed or a foldable configuration. Low clearance tractors typically come with a foldable ROPS and are operated with ROPS in the down position while in the low clearance work environment. A pre-1985 model tractor may not have a ROPS at all. Low clearance tractors may still be operated in a manner that needs the constant protection of a ROPS. The Washington State FACE program investigated 3

tractor rollover related fatalities at work between 1998 and 2001. Two of the three incidents involved low profile orchard tractors that are not required to have ROPS because of low clearance work.

The current design of the NIOSH AutoROPS represents the third generation and is a dramatic change from its predecessors.

Third Generation NIOSH AutoROPS

The current design (Figure 1) is dramatically different in looks, material, and fabrication from its proof-of-concept predecessor shown in Figure 2.

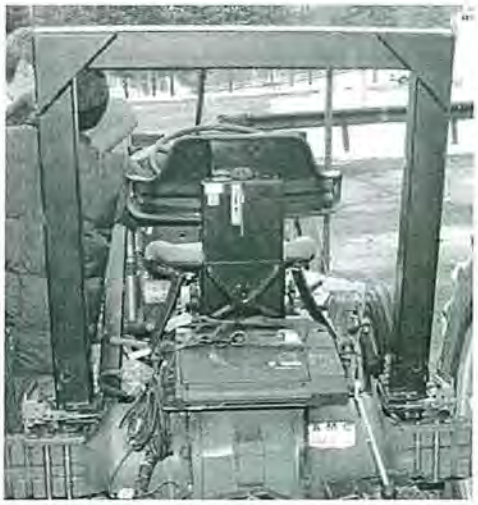

Figure 1 NIOSH AutoROPS 3rd Generation Design

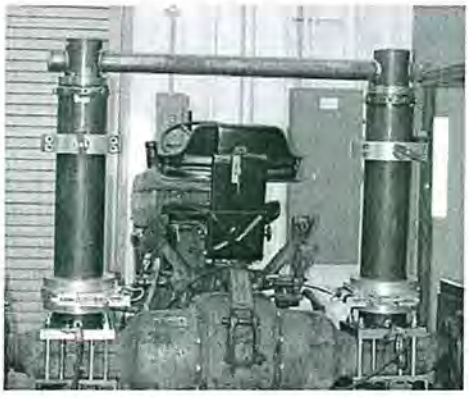

Figure 2 NIOSH AutoROPS 2nd Generation Design

The AutoROPS is constructed out of square and rectangular steel tubing and closely resembles commercially available fixed ROPS. The telescoping deployable section is constructed from (3.5 x 3.5 x 0.1875 inch) square mild steel tubing. The fixed section is constructed from (2 x 3 x 0.25 inch) rectangular steel tubing, making this similar in material and dimensions to the commercially available fixed ROPS. This design is an inverted design of the 2nd generation. As shown in Figure 1, the deployable section covers (receives) the fixed section when retracted. Figure 2 displays how the fixed section of the 2nd generation design covers (receives) the deployable section when retracted. The latching pins are now located inside the fixed section and push out: the 2nd generation had the latch pins on the outside pushing in. The latch and release mechanism (LRM) utilizes the same ball and groove design adapted to square tubing instead of the round tubing used in the second generation design. The retraction method used to set the 3rd generation AutoROPS is an inexpensive external web hoist (max load 1500 pounds) as compared to two internally mounted hydraulic cylinders. The overall benefits to this design are ease of manufacturing, lower manufacturing cost, reduced environmental effects (rust, mud, etc.) on the AutoROPS, ease of operation, and overall visual appeal. The changes can easily be seen in Figure 3 which shows a side-by-side comparison of a single post of the 2nd and 3rd generation AutoROPS as well as the LRMs. A detail of the inner workings of the 2nd generation NIOSH AutoROPS can be found in McKenzie and Etherton (2002).

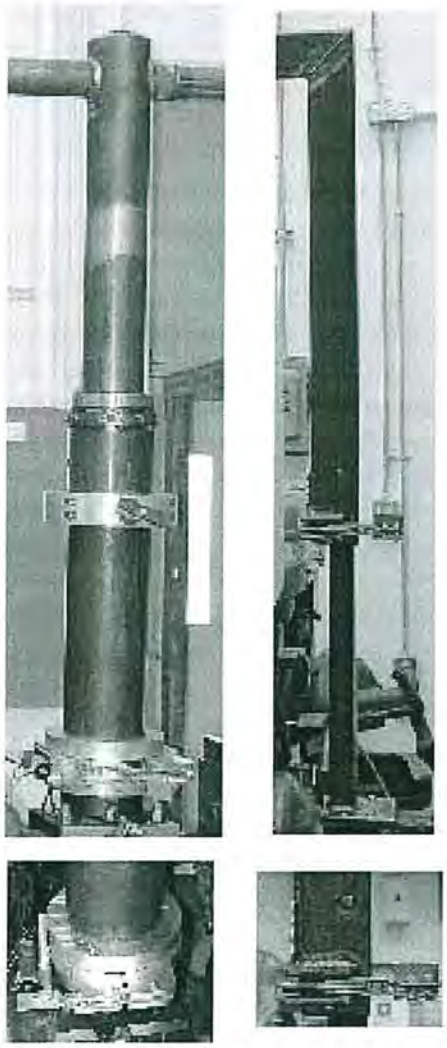

Figure 3 Side-by-Side Comparison of 2nd and 3rd Generation AutoROPS and LRMs Respectively

SAE J2194 Testing

The main purpose of the SAE J2194 static laboratory testing is to simulate field upset in a controlled and repeatable environment (SAE J2194 1997). During the SAE J2194 static laboratory testing the loads are applied slowly over time with the ROPS displacement and applied force collected. From these measurements the energy absorbed by the ROPS can be calculated. The four static loading sequences (a 90° rear overturn, 90° side overturn and a 180°) simulate field all-wheels-up overturn. The rear and side overturn are governed by energy absorption and the 180° all wheels up is governed by applied force. The static loading sequence consists of four tests: (1) longitudinal loading; (2) 1st vertical loading; (3) transverse loading; and (4) 2nd vertical loading. It is important to note that the ROPS cannot be altered (bolts tightened , material repairs, etc.) during any of the four phases of static testing. A complete description of the test procedures can be found in the SAE J2194 standard and in Etherton et.al. (2002). The highest energy criterion (and the most challenging for design) occurs in the transverse test which is shown in Figure 4.

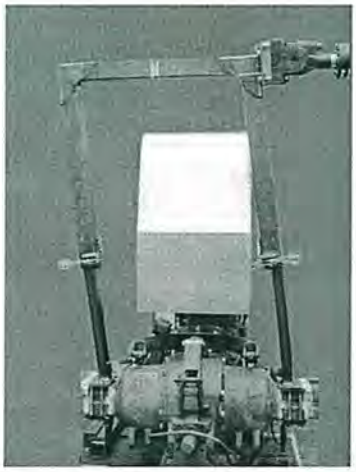

Figure 4 Transverse Loading of NIOSH AutoROPS

Results from Static Testing

The NIOSH AutoROPS has passed the static loading requirements and is ready for field upset testing at the NIOSH Pittsburgh Research Laboratory (PRL). The energy absorbed by the structure during the transverse test is shown in Figure 5 and is illustrative of typical testing results.

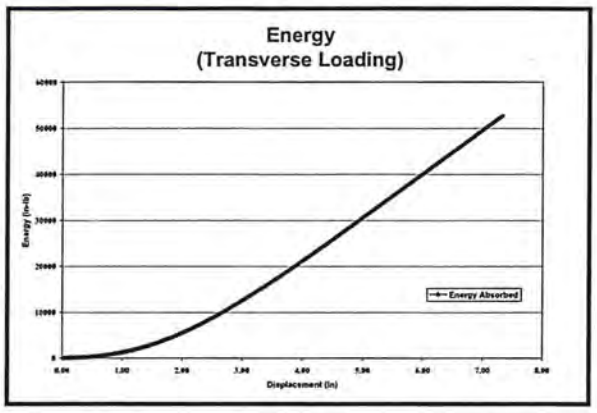

Figure 5 Energy Absorbed During Static Testing (Transverse Loading)

NIOSH AutoROPS End-User Field Evaluation Overview and Objectives

A controlled field evaluation compared a manually adjustable ROPS with the AutoROPS, including operation of an AutoROPS-equipped tractor on level ground, and obtaining responses to preference questions about the manually adjustable ROPS and the AutoROPS. The objective of this study was to determine the acceptability of the AutoROPS among a sample of potential users of the new technology. The study collected potential user responses to questions about how the AutoROPS functions, how an AutoROPS-equipped tractor operates in simple tasks, and preferences in how the AutoROPS was designed.

The study was conducted at large indoor arenas in Grant County and Berkely County, West Virginia. The test subjects were tractor operators who normally work in low clearance environments. Their low clearance work included orchard spraying and harvesting as well as cleaning poultry houses, dairy cattle stalls, and beef cattle feedways. Each of the 32 participants was shown a manual ROPS and asked to operate it (Figure 6). They were then shown an AutoROPS deployment while standing beside the tractor and asked to operate it (Figure 7). Finally they were asked to drive the tractor over a short course and back the tractor up as they would to hitch an implement (Figure 8).

Figure 6 Lowering Manually Adjustable ROPS

Figure 7 Lowering the NIOSH AutoROPS

Figure 8 Driving the NIOSH AutoROPS Equipped Tractor

Ratings were made by the test subjects at the completion of each task. The ratings helped answer the following questions:

- After having observed AutoROPS deployments, does the device appear to provide a more effective way than manually adjusted ROPS to prevent fatalities in tractor

rollover events?

- After having performed the reset (relatching) of the AutoROPS, is this task perceived as one that is more acceptable than manually adjusted ROPS in normal use of the device?
- After having initiated a deployment manually, is this task perceived as one that is more acceptable than manually adjusted ROPS in normal use of the device?
- Is required use of a seatbelt perceived as more acceptable in normal use of the AutoROPS than manually adjusted ROPS?
- After having operated the AutoROPS-equipped tractor on level ground, is normal use of the device perceived as more acceptable than manually adjusted ROPS?
- Is there a perception that operating an AutoROPS-equipped tractor would be safer than operating the manually adjustable ROPS-equipped tractor?
- If a new tractor were being purchased, would an AutoROPS-equipped tractor be of more positive interest than a manually adjusted ROPS-equipped tractor?

Results from the Field Evaluation

The farmer group was of the opinion that the AutoROPS deployment is more effective than the manual ROPS alternative ($p<.0001$) and that the protection effectiveness provided by AutoROPS will be superior to the protection provided by manual ROPS ($p<.01$). Of great prevention importance was the clear increase in interest in purchasing a tractor with an AutoROPS compared to purchasing a tractor with manual ROPS ($p<.0001$). This result is a strong indicator that this new technology can successfully achieve wide use on the farm especially among those with low clearance needs (Figure 9 and 10). Farmer opinions also indicate the need for further design work to improve seating restraint and method for lowering the structure.

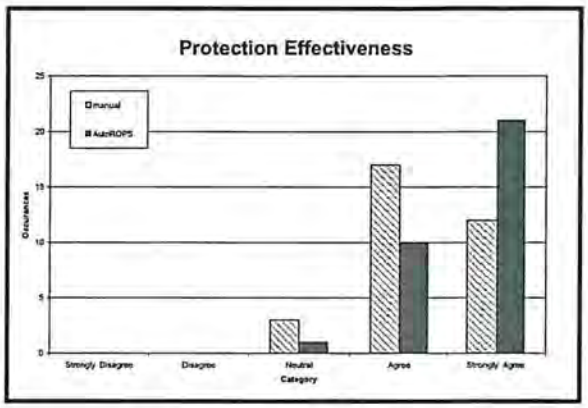

Figure 9 Protection Effectiveness

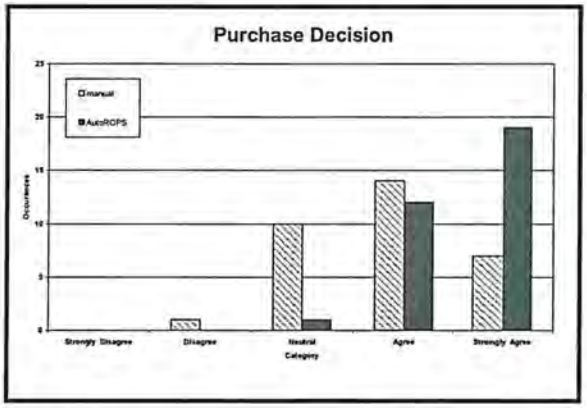

Figure 10 Purchase Decision

Conclusions

The third generation NIOSH AutoROPS has shown both structural integrity by passing the laboratory testing portion of the SAE J2194 standard and end user acceptance based on the field evaluation results.

Future Work

The refinement of this design to ease manufacturing and operational challenges is continuing at the time of this writing. The main focus is to have the NIOSH AutoROPS as an Original Equipment

Manufacturer (OEM) option for the end user in the near future.

References

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