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NIOSH AutoROPS Research to Practice: Zero Turn Commercial Mowers

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Abstract

Marketing new safety devices is a critical function on the research-to-practice path. This path to adoption of new safety technology is not always straightforward. The National Institute for Occupational Safety and Health (NIOSH) Automatically deployable Rollover Protective Structure (AutoROPS) is a passive safety device developed to protect tractor operators in an overturn event. Tractor overturns kill more than 100 farmers each year in the United States (Myers, 2003). This technology was first designed to target the agricultural low-clearance environments involving "low-profile" tractors where traditional ROPS may not be feasible. These tractors are exempted from ROPS use as stated in OSHA 1928.51(b) (5) (i & ii). The upper portion of the AutoROPS remains retracted under low clearance areas but deploys to full height when an overturn is detected. The AutoROPS has been tested under both field and laboratory conditions prescribed in the ROPS performance standard, SAE J2194. To translate successful research into occupational practice, NIOSH formed a partnership with FEMCO, a ROPS manufacturer, in 2003. FEMCO's efforts found Scag Power Equipment, a zero-turn commercial mower manufacturer. NIOSH has partnered with them as well. The Scag AutoROPS has been successfully laboratory

tested to industry standards. Preliminary field evaluations of the deployment system have been conducted in preparation for field upset tests. Product development, test procedures, test results, and current marketing efforts are presented on this innovative safety device.

Introduction

Newly designed safety technology is not always met with immediate acceptance in the market place by either the manufacturers or consumers. The NIOSH-developed AutoROPS technology falls into this category of new safety technology. In 2003 a NIOSH initiative, Research to Practice (r2p), 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 (internal) and NIOSH (external) funded research findings. In order to achieve this, NIOSH is continuing to work with our 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.

The NIOSH AutoROPS started in 1994 and today is poised to make its first appearance on the market.

Several designs and revisions have been explored on the latch and release mechanism (McKenzie and Etherton, 2002), and the structural design and testing, both structural and human interaction (McKenzie, et al., 2003), (Etherton et al., 2004). In order for NIOSH to effectively fulfill the r2p initiative by networking with manufacturers and industry key players required forming partnerships with some of the key players or stakeholders. Search efforts by NIOSH identified two stakeholders (FEMCO and Scag Power Equipment) and developed letters of agreement (partnerships) with them. To accomplish the necessary marketing efforts, the NIOSH AutoROPS team was awarded a two-part grant from California State University, San Bernardino (CSUSB), Office of Technology Transfer and Commercialization (OTTC). The first part was a market study performed with Emerging Growth Enterprise LLC (EGE), and the second part was a product development testing and engineering, (PDTE) grant. The combination of the above-mentioned partnerships has thrust the NIOSH AutoROPS to the edge of the market place.

The current research efforts are focused on a Scag *Turf Tiger* commercial zero-turn riding mower. Industry wide, the increase in shipments of commercial riding mowers grew 39% in model year 2004; “The most exuberant commercial turf category is zero turn radius technology...” (OPEI, 2004). Between 2000 – 2005 rollover incidents (injury or fatality) nearly doubled from the previous five-year period (1995 – 1999). “A potential explanation of this trend in mowers could be the increased access and purchase by small- and medium- sized businesses of supplies and equipment, including ride-on mowers, through home improvement and warehouse-pricing consumer channels. This includes the zero-turn ride-on mower.” (EGE market study, 2005). With the increase in shipments of zero-turn radius mowers it might be suggested that the rollover incidents will increase as well.

AutoROPS general description

NIOSH/Division of Safety Research (DSR) has developed a prototype telescoping ROPS system that automatically deploys (AutoROPS). 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 rollover detection sensor that monitors and compares the operating angle and the rate-of-roll of the tractor. The sensor continuously monitors (100Hz) the two directional axes (longitudinal and transverse) of the tractor. During normal operation, the sensor compares the rate-of-roll (100 degrees/second) to a preset angle of incidence (45-longitudinal and 35-transverse degrees). If both criteria are met, it is considered a potential overturn condition and the AutoROPS deployment sequence is initiated. The sensor also has a preset maximum angle of incidence which is independent of the rate-of-roll of the tractor. These criteria will also deploy the AutoROPS when 50-longitudinal and 45-transverse degrees are exceeded. An added feature derived from the end user study (Etherton et al., 2004), an operator deployment button (ODB) was integrated in the system. Pressing the ODB will deploy the AutoROPS at the discretion of the operator. A successful deployment locks the AutoROPS in the full upright position before the overturning tractor contacts the ground. Figure 1 shows the AutoROPS on the remote-controlled modified Scag *Turf Tiger* (Lutz and McKenzie, 2005). The AutoROPS is in the retracted position.

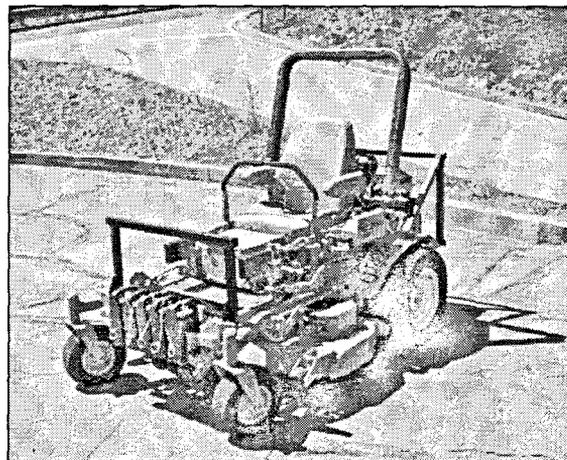


Figure 1. Scag *Turf Tiger* with AutoROPS in Retracted Position

In Figure 2, the Deployable and Fixed sections of the AutoROPS are shown. The deployment sensor is mounted under the AutoROPS behind the seat

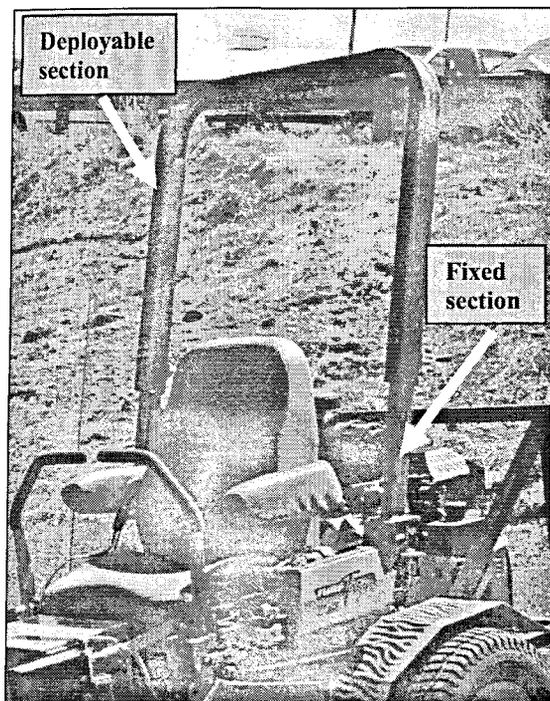


Figure 2. Scag Turf Tiger with AutoROPS in the Deployed Position

Partnerships

Currently the NIOSH AutoROPS team has three active partnerships: two letters of agreements (LOA) and one product development funded project. The LOAs are with FEMCO and Scag power equipment and the PDTE is with OTTC. The specific obligations and progress is discussed below.

FEMCO

LOA Obligations

FEMCO is a well-established ROPS manufacturer located in McPherson, KS. FEMCO and NIOSH entered into an LOA with NIOSH was to address alternative ROPS solutions to low-clearance agricultural tractor use. FEMCO's main contribution to the partnership were: (a) to locate a tractor OEM to provide NIOSH with a tractor for development of an AutoROPS for their product line; (b) to

manufacture the formed (or the deployable) portion of the AutoROPS; (c) to provide significant intellectual, engineering, and technical expertise during the manufacture of the AutoROPS (including cost estimates).

LOA Progress

To date FEMCO has identified Scag Power Equipment of Maysville, WI as the OEM tractor manufacturer. The tractor chosen was the *Turf Tiger* model of the Scag zero-turn riding commercial mower/tractor division. The formed (deployable) portion of the AutoROPS has been manufactured, delivered, and implemented into the design for the *Turf Tiger*. The exchange of intellectual engineering and expertise continues to flow.

Scag Power Equipment

LOA Obligations

Scag Power Equipment is a leading manufacturer of lawn and turf care equipment, including walk-behind zero-turn and riding zero-turn commercial mowers. This company was identified by FEMCO because it is considered an industry leader with a progressive design philosophy. Scag's main contribution to the partnership were providing: (a) the tractor/mower *Turf Tiger* for remote-controlled field upset testing (including spare parts); (b) *Turf Tiger* frames for static testing; (c) engineering and technical expertise; and (d) manufacturing cost estimates and design techniques.

LOA Progress

Scag Power Equipment has delivered to NIOSH a *Turf Tiger*, and accessories that accommodate different configurations of the tractor. They have supplied four frames for static testing; these frames were destroyed during the testing process. Scag has reviewed the first design and has suggested modifications to the latch-and-release mechanism.

Office of Technology Transfer and Commercialization (OTTC)

As stated on their web site (<http://ottc.csusb.edu/>) "The mission of the Office of Technology Transfer and Commercialization (OTTC) at California State University San Bernardino is to provide exemplary, timely and responsive business and research services to government agencies, private enterprise

and academia in order to assist them in moving their technologies through the commercialization process. We strive to be a leader in advancing and transitioning to full commercialization promising new technologies from government and academic laboratories, to businesses and from the private sector and academia to government agencies.”

The NIOSH AutoROPS team competed for and was awarded a prototype development, testing, and evaluation (PDTE) grant and a marketing study grant to commercialize the AutoROPS and bring the technology to the market sector. The PDTE efforts were done by NIOSH and its partners, and the marketing study was contracted to EMERGING GROWTH Enterprises™, LLC, (EGE) a partner with OTTC.

Current Research Efforts

Product development: AutoROPS Design Efforts and Standard Testing

The AutoROPS for the Scag *Turf Tiger* is a modification of the 3rd generation AutoROPS designed for a Ford 4600 agricultural tractor, (McKenzie and Etherton, 2002). The system is made from steel: (a) the fixed section is a welded combination of 2 x 3 x 3/16 inch tube and 1.5 x 2 x 3/16 inch tube and 3/8 inch flat plate; (b) the deployable section is a 2 x 3 x 3/16 inch tube formed into a U-shape by FEMCO. The major modifications from the Ford 4600 model and the Scag *Turf Tiger* model were the size of the material and the method of mounting the fixed section to the frame. The Scag *Turf Tiger* is manufactured with existing mounts for a fixed formed ROPS; these same mounts were utilized for the AutoROPS.

Static Testing

There are a number of performance and design standards for agricultural and commercial mowing tractors (some are ANSI B71.4, ISO 21299, and OSHA 1928.52), the test standard chosen to evaluate the effectiveness of the AutoROPS was SAE J2194. This was chosen due to its stringent energy criteria, and was considered to be the worst case scenario for the tractor operator. The energy requirements were

based on a maximum total weight of the *Turf Tiger* to be 2200 lb (Mower, 1600 lb; Grass Catcher, 400 lb; and the Operator, 200 lb), and are in table 1 below.

Table 1. SAE J2194 Energy Testing Requirements for the Scag *Turf Tiger*

Energy Requirements		
	Energy	
Loading	Criteria	In-lbs
Longitudinal	1.4 * Mt ¹	12350
Transverse	1.75 * Mt ¹	15437
	Applied Force	
Loading	Criteria	Lbs
Vertical Crush	20 * Mt ¹	4482

(Mt¹ = reference mass of the tractor)

The standard calls for a series of four tests that consist of: (1) Longitudinal Push, (2) First Vertical Crush, (3) Transverse Push, and (4) Second Vertical Crush. Test 1 and 3 are based on energy absorption of the ROPS and the ROPS mounts, test 2 and 4 are based on applied force. Test 2 and 4 (vertical crush) were uneventful in terms of displayable data. The AutoROPS passed both tests by resisting the load of 4482 lbs. Test 1 (longitudinal push) is shown in figure 3, there are 3 panes: the left is the start position, the middle is during the test, and the right is the final position. The max travel was 10.24 inches under a load of 1699 lbs. Energy absorption was 12,359 in-lbs. The energy absorption curve is shown in the graph in figure 4.

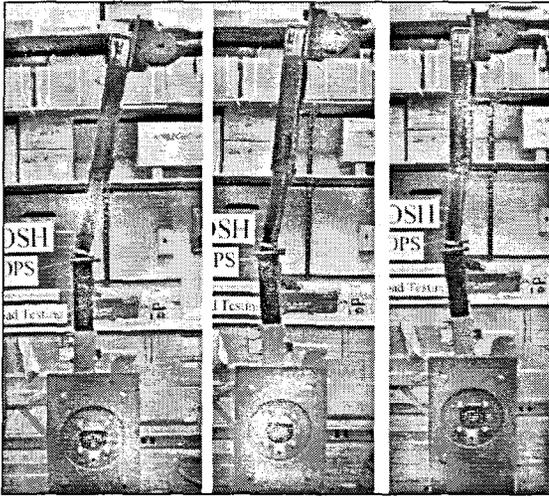


Figure 3. Test 1 Longitudinal Push

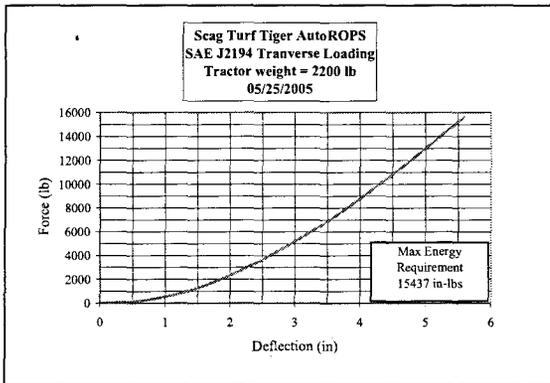


Figure 4. Test 1 Longitudinal Push Energy Absorption

Test 2 (transverse push) is shown in figure 5, there are 3 panes: the left is the start position, the middle is during the test, and the right is the final position. The max travel was 5.54 inches under a load of 4551 lbs. Energy absorption was 15,446 in-lbs. The energy absorption curve is shown in the graph in figure 6.

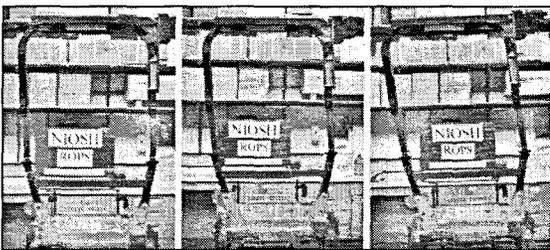


Figure 5. Test 3 Transverse Push

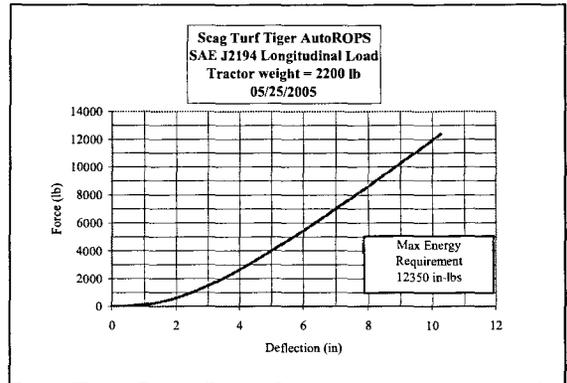


Figure 6. Transverse Push Energy Absorption

Static testing discussion

The Scag AutoROPS successfully passed according to SAE J2194. The AutoROPS has a layback angle of the 11 degrees which can be seen at the start of the test in figure 3, left pane. In figure 3, right pane (at the end of the test) the layback angle from the mount on the frame to the top of the AutoROPS is nearly zero. The fixed ROPS that comes on the Turf Tiger has a layback angle of zero; hence by adding the layback angle into the AutoROPS design the effectiveness of the ROPS is increased for the operator by not encroaching on the occupant clearance zone.

Market Study: Emerging Growth Enterprise LLC

The second part of the OTTC award was a marketing study by EGE from their web site www.emergingenterprise.com; "EGE team members work with growing companies in an interim executive or management team role. We were founded to fill the need for professional, outsourced EIR services in San Diego.

EGE conducted a 12-week market study including NIOSH, OTTC, representatives from: John Deere, Scag, Toro, and Walker, standards committee members (United States and international), and some university professors. From this initial study, it was determined that "OEM equipment manufacturers consider the "standards" compliant design aspect of new equipment integration as critical as liability protection and profitable economics from the project. Manufactures making the ultimate AutoROPS integration will either themselves confirm that the AutoROPS device is covered in set Standards and/or look to the ROPS manufacturer to identify and confirm that the

AutoROPS device is compliant with all relevant standards.” With the efforts of the marketing team the AutoROPS has recently being included in the latest version of the ISO 21299 standard. Patent attempts for the AutoROPS failed in 2002, the EGE team is investigating the avenue of licensing the technology to the industry.

Marketing Study discussion

The efforts of EGE have opened a window to the manufacture by raising awareness to the AutoROPS technology, and gaining acceptance from the Standards community. This is just the first step in the r2p efforts of this project and NIOSH as an Institute.

Conclusions

The NIOSH AutoROPS technology has developed from a prototype technology to a manufacturer and regulation compliant product. With the efforts of the three partners, FEMCO, Scag, and OTTC (including EGE) the research to practice initiative of NIOSH is inching closer to a reality.

Disclaimers

The findings and conclusions in this report are those of the author(s) and do not represent the views of the National Institute for Occupational Safety and Health

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