Safety Science 51 (2013) 427–431

Contents lists available at SciVerse ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Reducing occupational fatalities by using NIOSH 3rd generation automatically deployable rollover protective structure

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ARTICLE INFO

Article history:
Received 10 April 2012
Accepted 15 August 2012
Available online 9 October 2012

Keywords:
NIOSH
Rollover
ROPS
AutoROPS
Compartment (clearance) zone

ABSTRACT

Each year tractor rollovers cause injuries or deaths for farmers despite the fact that an effective safeguard was available in the form of a rollover protective structure (ROPS); however, many ROPS were removed by the tractor's owners, because the ROPS is too tall to allow tractors to enter farm fields because it may damage produce located on low hanging tree branches while working in an orchard, and the loss of crops means loss of money for farmers.

The NIOSH AutoROPS will provide the same level of protection as the conventional ROPS, but instead of having the post as one solid part as with the ROPS, the AutoROPS has a fixed posts located inside the outside deployable posts to meet the farmer's need of low clearance.

This study addressed the need to build and test the NIOSH 3rd generation of the AutoROPS model based on Alkhaledi et al. (2002) model, which was smaller in size with low overhead clearance zone and to insure that the built model would comply with the SAE J2194 standard for static testing.

The results showed that the 3rd generation AutoROPS absorbed all applied loads in sequence, thus satisfying the SAE J2194 standard requirements. No signs of failure were shown for the AutoROPS' base and the latching mechanisms. The successful testing the NIOSH designed AutoROPS lead to the development of the ANSI/ASABE S599 industry standard, which was approved November 2010 as an American national standard for standardized deployment performance of an automatically deployable ROPS for turf & landscape equipment.

1. Introduction

Safety is the ability to perceive and recognize hazard in order to take corrective actions and minimize any loses (Brauer, 2006). The agriculture Industry remains among one of the most hazardous occupational industries to date. Tractor rollovers are the leading cause of occupational agricultural fatalities in the United States, 1412 farmers/workers died between 1992 and 2005 from tractor rollover (Myers, 2009). The protection of the farmer/worker from possible death or injuries is still a major concern for safety researchers.

After 1985 American tractor manufacturers began voluntarily adding ROPS on all farm (agricultural) tractors sold in the United States over 20 horsepower. The rollover protective structure (ROPS) was developed to prevent farm tractor's operators from fatal injuries in case of an overturn incident by providing a protection zone for the operator compartment (see Fig. 1). NIOSH has estimated that fatality rates due to tractor rollover could be reduced by at least 71% if all tractors in the U.S. were equipped with ROPS (Myers, 2009).

There are many tractors without a ROPS still in use today. These tractors were either built before 1986, or have had the protective structures removed. The question is why would someone remove the ROPS, which could save his life? One answer would be because some farmers/operators removed the ROPS because they need low overhead clearance, (e.g. the convenience of driving their tractor below low hanging trees limbs without knocking some crops out of the trees). Another reason for removing the ROPS is the belief, particularly among older farmers, that they know how to control a tractor, without the need for the ROPS (Alkhaledi et al., 2002).

The need for a more convenient ROPS to fit the farmer's use requirements becomes more important than ever, this is where the idea of the AutoROPS originated. The NIOSH AutoROPS will provide the same level of protection as a conventional ROPS, but instead of having the post as one solid part as with the ROPS the AutoROPS will have the post as two telescoping parts; it has one part located inside of the other to meet the farmer's need of low

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http://dx.doi.org/10.1016/j.ssci.2012.08.004

Fig. 1. Factory ROPS mounted on the tractor.

clearance zone. The deployable part of the AutoROPS will only deploy in the event of tractor rollover to provide protection for the operator from severe injury or death.

Some of the fatalities were due to the removal of the ROPS from the tractor, and/or from the driving without wearing a seat belt. AutoROPS are more effective when used in conjunction with seatbelt, because without a seat belt, the operator may not remain in the safety crush zone of the ROPS during an overturn (Kelsey et al., 1996).

2. Review of relevant literature review

Alkhaledi et al. (2002) did a study to increase the level of AutoROPS safety and effectiveness based of SAE J2194 Static Load Standard tests. The first purpose of Alkhaledi work was designing a new generation of the AutoROPS (the NIOSH 3rd generation AutoROPS) that is smaller in size and more cost effective than the 2nd generation AutoROPS which was bulky and heavy. The second purpose was designing the base model for the 3rd generation NIOSH AutoROPS and insures it would be able to absorb the impact energy (impact loads) created during a tractor overturn.

The design for the NIOSH 3rd generation AutoROPS was structurally analyzed using ANSYS® a finite element analysis (FEA) program, the tests and simulations were successfully completed. The results proved that the 3rd generations AutoROPS and the base did absorb all loads applied in sequence and thus satisfied the SAE J2194 standard requirements.

The FEA for the load applied on the AutoROPS was conducted by Gillespie (2000) and focused on the 2nd generations AutoROPS. The study focused on the stresses applied on the posts and the post deflection. Four directions of static loading were applied to the structure to satisfy SAE J2194 standard requirements.

Gillespie determined that the 2nd generation AutoROPS structure satisfied the SAE J2194 standard requirements and no intrusion to the driver's compartment zone was shown. The analysis also indicated that there was no plastic bending at the sliding-fit joint; the study also reported that the structure was heavy and stiff.

Howard (1998) studied the mechanisms performance of the 2nd generation AutoROPS. The study was aimed at the latching mechanisms and energy absorbing (rubber) parts between the deployable posts to insure that they would not fail during impact, and that the upper posts would deploy within the designed time when a rollover signal was sent to pyrotechnic squibs in an internal piston. The results of Howard's study showed the two posts structure consistently deployed in less than 0.3 s and latched securely.

Harris (1995) tested the first generation AutoROPS according to the SAE J2194 ROPS Standard. Those deployable AutoROPS were designed and built for use on the Ford 4600 farm tractor. The tests were aimed to see if the internal mechanisms such as the springs, pistons, and materials could withstand rollover forces, and to confirm that the operator compartment zone would not be compromised in the event of a overturn. The results of those tests showed that the internal and deployment mechanisms worked as designed, and the chosen material withstood the applied loads.

3. Statement of the problem

The purpose of this study was to physically build and test the NIOSH 3rd generation AutoROPS model based on the Alkhaledi et al. (2002) model in the lab to the SAE J2194 static load tests standard. The lab testing was used as a validation of the Finite Elements Analysis model.

The second purpose of this study was to insure the base and the latching mechanisms of the 3rd generation AutoROPS would not fail during testing based on SAE J2194 static load standard tests.

4. Method

4.1. Description of the 3rd generation AutoROPS

The NIOSH 3rd generation AutoROPS was built based on Alkhaledi et al. (2002) design and dimensions with one modification added to it. The design for 3rd generation AutoROPS consists of the outside deployable posts and inside fixed posts and an overlapping area in between them.

The AutoROPS was constructed using square and rectangular steel tubing. The telescoping deployable top section was constructed from (3.5□ × 3.5□ × 0.1875□) square mild A-500 steel tubing. The fixed lower section was constructed from (2□ × 3□ × 0.25□) rectangular steel tubing, making this more similar in material and dimensions to the commercially available fixed ROPS than previous AutoROPS designs. The lower fixed posts welded to the base which has two plate connected method around the axle housing by four grade eight bolts (see Fig. 2).

Alkhaledi's AutoROPS design model was modified by adding two gussets to the top corners to increase the strength with adding minimal extra weight to the design. The AutoROPS was installed on Ford 4600 model tractor – located at the NIOSH test laboratory in Morgantown, West Virginia. The nature of the NIOSH AutoROPS is to be in the retracted position, until a potential safety hazard of overturn is determined to be imminent. It is during the deployment time period that potential safety hazards exist that are not

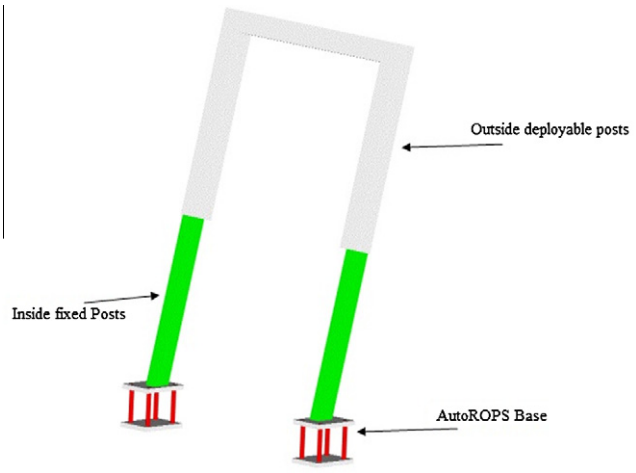

Fig. 2. NIOSH 3rd generation deployable AutoROPS.