



# Crush Protection Devices for Agricultural All-Terrain Vehicles



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## Introduction

- All-Terrain Vehicle (ATV) is a widely used motorized vehicle in farms (Figure 1)
- In 2015, there were 97,200 ATV-related injuries and 661 ATV-related fatalities in the U.S. About 22% of these reported fatalities had riders younger than 16 years of age



Figure 1. ATV in farms

## ATV Rollover Accidents

- In general, 60% of ATV-related fatalities were associated with ATV overturns (Figure 2)



Figure 2. ATV rollover accident

## ATV in Agriculture

- Three out of five occupational ATV fatalities happened in the agriculture sector (OSHA)

Table 1: Recreational vs. agricultural ATV incidents

	Agricultural	Recreational
<b>Types of accident</b>	ATV rollovers (85%) Rider pinned under ATV (68%) Death by asphyxia (42%)	Riding fast, lost control, was ejected, and collided with a stationary or moving object Rider pinned under ATV (30%) Death by asphyxia (11%)
<b>Injuries</b>	Head injuries (13%) Chest injuries (59%)	Head injuries (49%)
<b>Added load /or passenger</b>	Attachments (~50-75%)	Attachments (~25 to 33%) More possible to carry a passenger

- Therefore, there is a need to distinguish and treat the safety requirements for farm ATV differently compared to the recreational ATV

## Crush Protection Devices

- Roll-Over Protective Structure (ROPS)
- Crush Protection Device (CPD) (Figure 3): CPDs were found to have the potential to prevent deaths and serious injuries and increase ATV stability by 10% to 30%
- Air-Quad (Figure 4)

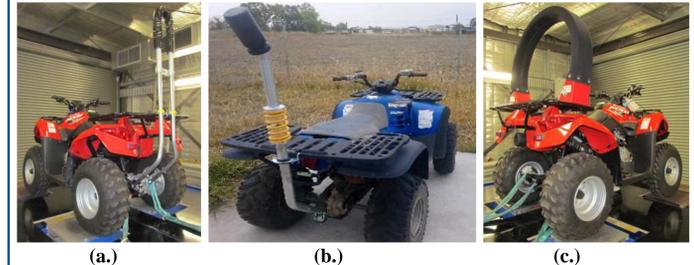


Figure 3. (a.) Quadbar, (b.) Quadbar Flexi, (c.) Lifeguard



Figure 4. (a.) Air-Quad inoperative position, (b.) Air-Quad active position

## CPZ Evaluation

- CPD provides a Crush Protection Zone (CPZ) and absorbs impact energy, which protects the user from crushing and asphyxiation and prevents continuous rollovers
- CPZ of two ATV rollover scenarios (rear and side roll) were compared (Figure 5)

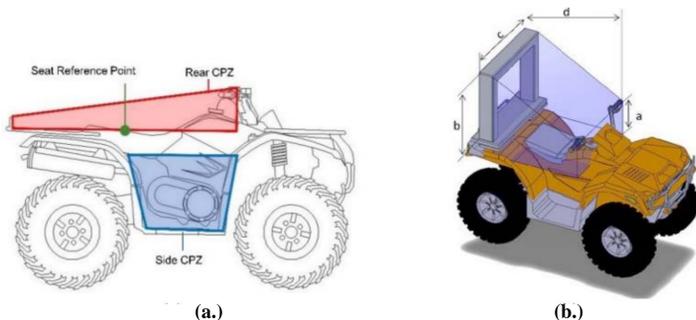


Figure 5. (a.) Trapezoidal Cross Section of CPZ, (b.) General Trapezoid Shape of CPZ

- CPZ volume was calculated by finding the volume of a simple trapezoidal prism formed by the body of the ATV and the imaginary ground surface.
- The vertical distance between the Seat Reference Point (SRP) and the top edge of the CPZ was measured to detail the clearance between ground and ATV in a rear rollover accident.

## CPZ Evaluation- Results

The results compile the CPZ of an ATV with no CPD and an ATV equipped with three different CPDs (Quadbar, Lifeguard, and Air-Quad) (Figure 6, 7)

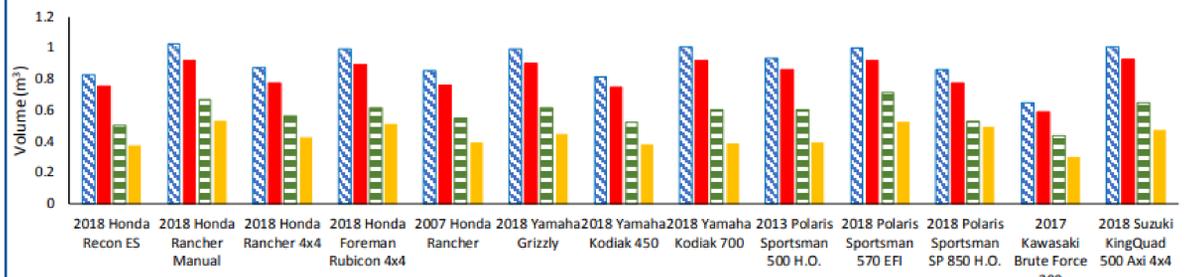


Figure 6. Comparison of rear CPZ for three designs of CPD

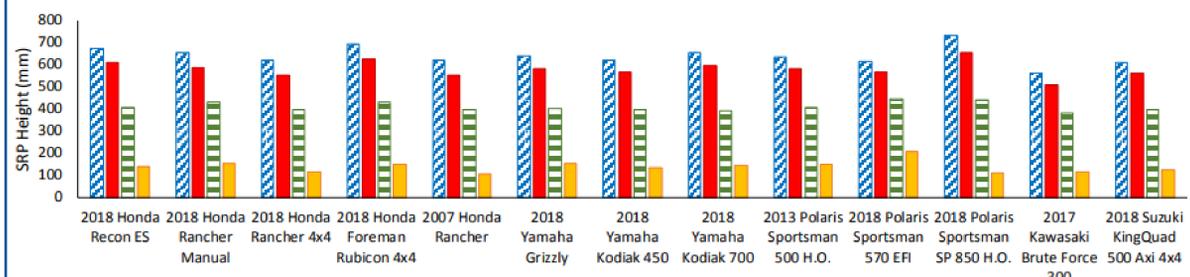


Figure 7. Comparison of vertical height of CPZ above SRP for three designs of CPD

## CPD Evaluation in Rollover Incidents

- The effectiveness of CPD needs to be evaluated by **conducting repeatable experimental field upset tests**. The objectives are:
  - Developing a remotely controlled ATV equipped with an autonomous direction control, to conduct rollover tests
  - Evaluating the performance the remotely controlled ATV

## Remotely Controlled ATV Development

- Remotely controlled ATV is an unmanned vehicle that reduces human error in direction control and allows researchers to conduct repeatable experiments for evaluation of CPD performance in rollover incidents.
- The remote-control systems include three components:
  - Closed-loop steering control system with a line-following feature for accurate ATV guidance
  - Remote cruise control module to control the vehicle speed
  - Remote braking control system and emergency engine shut-off module for safety purpose

- Vision-based sensor records the position of vehicle relative to a colored line painted on the terrain; microcomputer operates vision algorithm to determine optimal steering angle and controlled EPS motor (Figure 8)

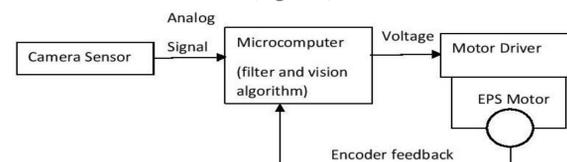


Figure 8. Block diagram of steering control

- Safety precautions are needed to prevent off-controlled situation
- An external system was designed and fabricated to control the foot brake pedal of the ATV (Figure 10)

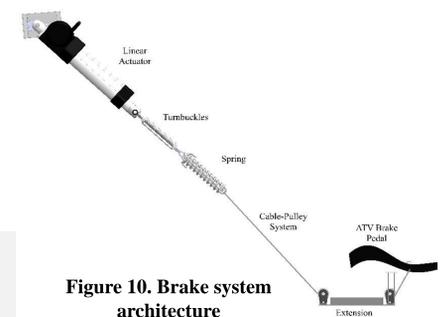


Figure 10. Brake system architecture



Figure 9. Honda FourTrax Rancher 4x4 Auto DCT IRS EPS



Figure 11. Screenshot of MCCruise Bluetooth Control Panel

- QuadCruise control unit developed by MCCruise (Figure 11)
- Precise cruise control system that allows operator to setup a desired speed through a Bluetooth device

Figure 12. Remote Engine Shut-off kits



- Emergency "engine kill-switch" (RES12VX module from 3Built LLC) can shut down ATV engine remotely (Figure 12)