**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

### ATV Rollover Accidents
- In general, 60% of ATV-related fatalities were associated with ATV overturns (Figure 2)
- CPZ of two ATV rollover scenarios (rear and side roll) were compared (Figure 5)

**Figure 1. ATV in farms**

**Figure 2. ATV rollover accident**

### 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.

### CPD Evaluation in Rollover Incidents
- 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)
- 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)
- Emergency “engine kill-switch” (RES12VX module from 3Built LLC) can shut down ATV engine remotely (Figure 12)

#### Table 1: Recreational vs. agricultural ATV incidents

<table>
<thead>
<tr>
<th>Types of accident</th>
<th>Agricultural</th>
<th>Recreational</th>
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<tbody>
<tr>
<td>ATV rollovers (85%)</td>
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<td>Rider pinned under ATV (68%)</td>
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<td>Death by asphyxia (42%)</td>
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<td>Head injuries (13%)</td>
<td>Head injuries (49%)</td>
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<td>Chest injuries (59%)</td>
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<td>Attachments (~50-75%)</td>
<td>Attachments (~25 to 33%)</td>
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<td>More possible to carry a passenger</td>
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**Figure 3. (a.) Quadbar, (b.) Quadbar Flexi, (c.) Lifeguard**

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

**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**

**Figure 8. Block diagram of steering control**

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

**Figure 11. Screenshot of MCCruise Bluetooth Control Panel**

**Figure 12. Remote Engine Shut-off kits**