Analysis of All Terrain Vehicle Crash Mechanisms

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Abstract: *A new field of engineering research is developing because of the increasing number of ATV (all terrain vehicle) crashes among children. To determine why so many crashes occur and how they can be prevented, a series of ATV tests were conducted. Testing was conducted on a raisable platform in order to simulate an ATV rollover because the machine turning over causes the majority of crashes. The tests included simulating an ATV rolling over with the weight of a child, with added weight of a passenger, and due to a thrust effect. Through testing, the amount of weight needed to flip an ATV was determined. It was concluded that individuals add to the instability of the machine and the additional weight of a passenger creates a higher probability of a rollover. Utility type vehicles (UTVs) were also tested as a machine comparison. The risks were lower with a heavier machine. These preliminary tests allow for new questions and tests to be conducted.*

1. INTRODUCTION

All terrain vehicle (ATV) crashes are becoming more prevalent and leading to an increased number of preventable childhood injuries. ATVs are widely used for recreation, farming, and utility purposes, with 6.2 million 4-wheeled ATVs in use in 2003 [6]. ATVs range in size from youth ATVs with a 90cc engine to adult ATVs with up to 800cc engines. These machines can reach speeds up to 75 mph. The wide variety and manufacturing standards for ATVs create problems for lawmakers and owners.

Children account for almost a third of all ATV related deaths. With injuries mounting, as evidenced by children under 16 years old accounting for 40,400 of a total 136,700 ATV-related injuries in 2005, it is clear that the devastation and risk of injury associated with ATVs is increasing [3]. Youth under 16 years are nearly four times more likely than ATV operators over 16 years to experience an injury requiring emergency department treatment [4]. However, in West Virginia higher annual ATV death rates occurred among males, persons aged 10--17 years [2]. In Arkansas, adolescent females have the highest ATV injury death rate of any state and the fifth highest for adolescent males.

In 2001, 97% of children under 16 years with ATV-related injuries were operating ATVs larger than the manufacturer's recommendations [1]. Statistics have shown that 45% of crashes are the result of the machine flipping or turning over, with 43% of those turning over lateral (side to side) and 57% longitudinal (front to rear) [5]. Since 45% of crashes are the result of a turnover, numerous machines were tested in hopes of understanding the engineering issues behind turnover crashes.

2. MATERIALS AND METHODS

To begin testing, an ATV test bed was designed (Figure 1). To secure the machine, a loose rope was attached to the front of the machine and then to the testing platform. An additional rope was then attached at a 90^o angle to the front of the machine to act as the lifting force. The test bed platform could be raised to a maximum of 60^o, which simulated hills or steep terrain. Each test was started at 0^o and then increased by increments of 10^o (angles were determined by a digital level attached to platform). Once the machine was at the appropriate angle, a lift force was applied to observe turnover weight. Once the machine's tires lifted off of the platform the scale was read to determine the amount of weight. Each machine was tested front to rear and side to side.

The testing process began by driving each machine onto a scale and weighing each individual machine's front axle, rear axle, left and right side, and then the total machine (see Table 1). After the machine was weighed it was secured to the testing bed in the appropriate direction. Once all the ropes were correctly attached, the platform was raised to the proper degree where a lift force would then be applied. After the scale weight was recorded, the rope

Figure 1. *ATV Test Bed.*

tension was loosened and the platform was raised again to calculate the weight at each additional degree. When the machine began to flip with no additional force applied the testing was stopped, the specific angle was recorded and the platform was lowered. The machine was then driven onto the platform in an alternate direction to test different driving simulations, such as uphill, downhill, or lateral driving.

Because most children are injured on adult size ATVs and many have passengers, additional testing was performed with weight added to the rear of the machine to simulate a passenger. The rates at which the machine flipped with and without a passenger were compared. To simulate a child passenger riding on the rear of the machine, 100 pounds of weight was added and secured to the rear. The same tests were repeated with the additional weights and then the results were graphed.

Basic thrust effect testing was also conducted. The machines were parked in front of a 4x4 grid. With a visual measuring tool attached to the front of each machine, the machines were compared at a resting position to a full throttle position. The difference between the resting and full throttle position measurements represented the lift due to thrust.

After the completion of testing, each machine's results were graphed according to front-to-rear and side-to-side data. For the ATVs, turnover rates that accounted for the addition of a passenger were also graphed. The platform's rotational degree was plotted on the x-axis and the weight or lift force required to overturn the machine was plotted on the y-axis.

Table 1- ATV/UTV Machine Weight (in lbs)

	ATV 1	ATV 2	UTV 3	UTV 4	UTV 5
Front Axle	313	458	628	716	728
Rear Axle	261	484	784	1104	840
Left Side	280	454	690	898	775
Ride Side	278	464	696	908	778
Total	590	960	1402	1880	1600

Table 2- Estimated Heights from Thrust/Torque Tests (in inches)

	ATV (unweighted)	UTV (unweighted)	UTV (with weights)
Test 1	10	2	2
Test 2	5	3	2
Test 3	3	3	1
Test 4	6		2
Test 5	6		1
Average	6	2.7	1.6

Table 1. *Testing process on scale, weighing each individual machine's front axle, rear axle, left and right side, and then the total machine.* **Table 2.** *Displays ATV and UTV Thrust/Torque tests.*

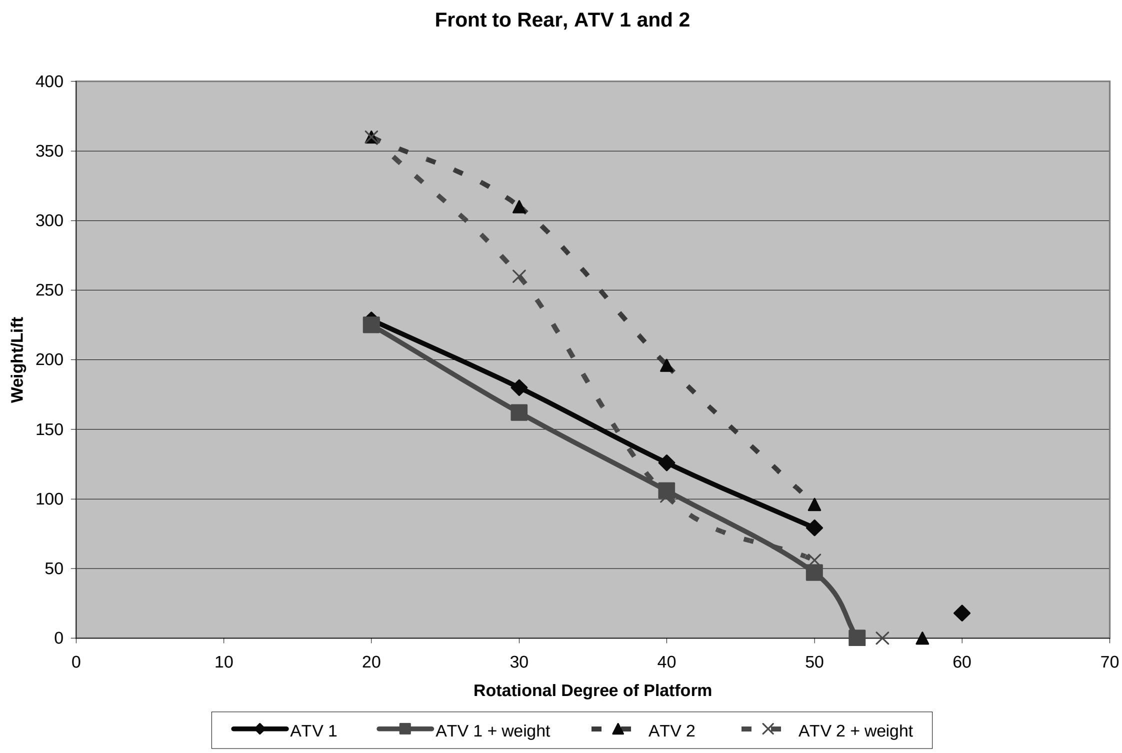

Figure 2. *ATV1 and ATV2 Comparison with Added Weights.*

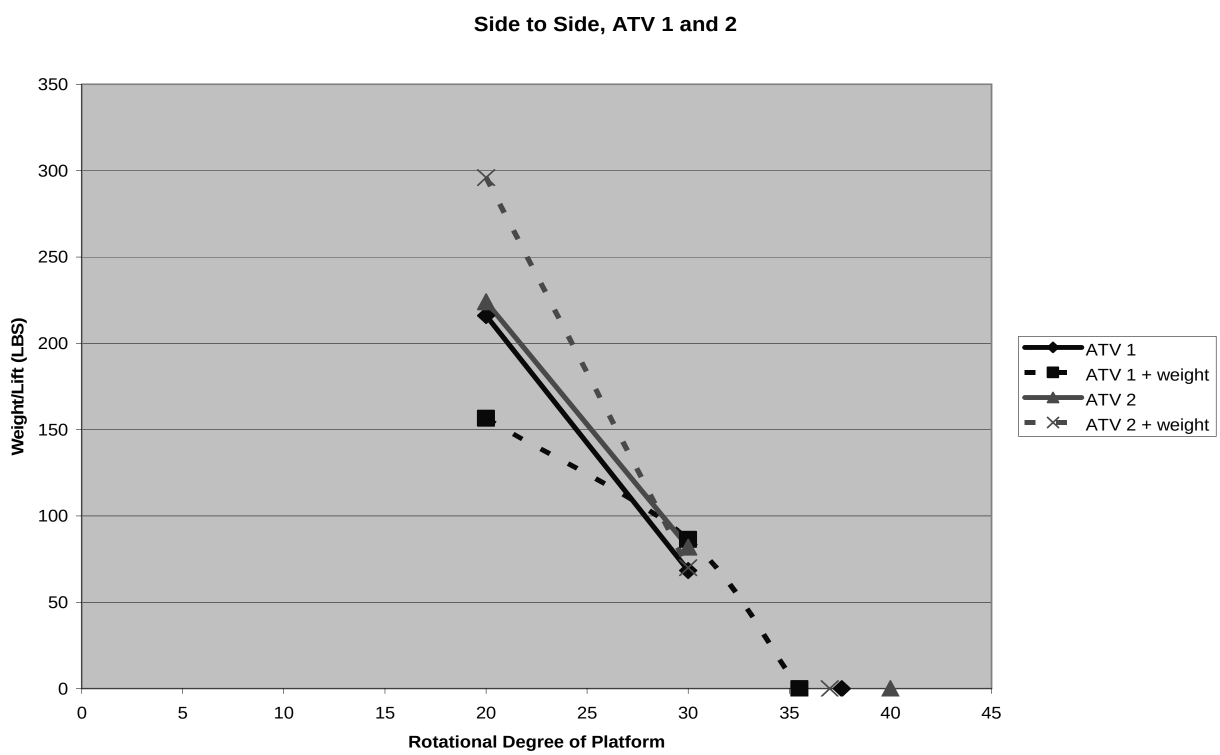

Figure 3. *ATV1 and ATV2 Comparison with Added Weights.*

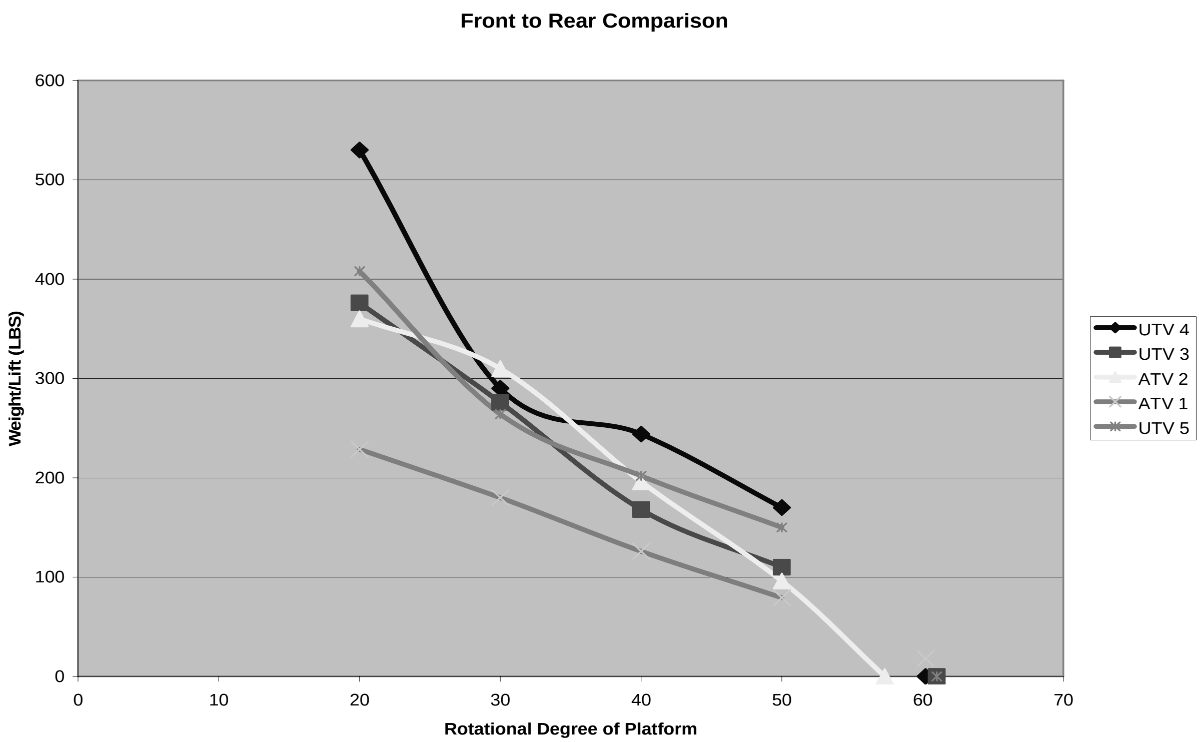

Figure 4. *Front-to-Rear Comparison of All Machines Tested.*

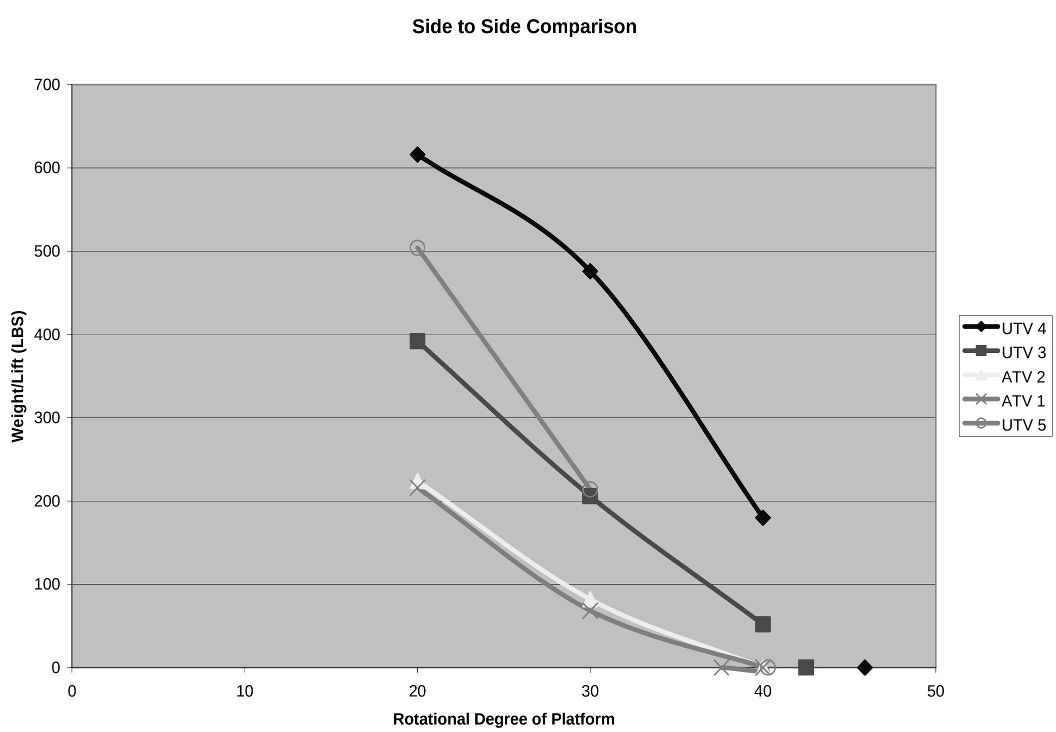

Figure 5. *Side-to-Side Comparison of All Machines Tested.*

3. RESULTS AND DISCUSSION

The data showed that individuals magnify the instability of the machines. Figure 4 shows the results from the front-to-rear testing of all five machines. Front-to-rear signifies that the machine was driven on to the platform with the front wheels facing forward and the back wheels touching the bar closest to the ground. In each of the graphs, the lines closest to the x-axis indicate a turnover requiring less weight or occurring sooner than lines higher on the graph. In Figure 4 the difference between turnover risks is 301.4 lb, which signifies that it took over 300 pounds more to flip UTV 4 than ATV 1. The risk of turning over increases the steeper the degree angle, and the lines converge as the rotational degrees increase. Thus, driving a machine at 20^{o} poses the greatest risk deviation per machine. This is significant because most ATV drivers will not typically be driving the machine past inclines of 30^{o}, but will drive the machine at 20^{o}. So the type and size of the machine greatly affect the risk at normal driving angles. In side-to-side testing (Figure 5), UTVs tested in a different class than the ATVs. The difference between UTV 4 and ATV 1 on side-to-side testing was 400 lb.

Figure 2 represents the data of two ATVs with and without the weight of a passenger. Again, the lower the line on the graph, the sooner the machine flips whereas the higher the line, the safer the machine is because it takes more weight to flip. As seen by Figure 4, additional weights added to the rear of the ATV cause the machine to turnover sooner than without any additional weights. At 60^{o}, ATV1 flipped 7.1^{o} sooner with additional weights and ATV2 only $2.7^{\backslash o}$ sooner. Figure 3 demonstrates this same relationship with regards to side-to-side testing. ATV 1 was more likely to flip with additional weights, but ATV 2 flipped more readily without additional weights. This is likely due to the fact that ATV 2 had a radiator, which caused the rear to weigh much more than the rear axle of ATV 1. Therefore, in order for the rear wheel to raise off the platform it took a significant amount of weight, especially when additional weights were added. Thus, ATV 2 was more unbalanced than ATV 1.

As for thrust effect, Table 2 displays that the ATV lifted off the ground much further than the UTV—with an almost 9 inch difference. It can also be seen that with the UTV, extra weight did not significantly impact the results. The machine did not tend to lift off of the ground, regardless of additional weight. In conclusion, the ATV had a higher risk of overturn due to the upward thrust of the machine. The ATV rose from the ground at a much higher distance than the UTV. This could be due to the heavier weight of the UTV or the longer wheel base. The operator of the machine said he was not aware at anytime that his tires had left the ground, which further reveals that drivers may not be aware of the hazards of the machine. This test also shows that thrust has an affect on rollovers. If the tendency of an ATV to rollover was calculated with the thrust effect, the risk would increase dramatically. Furthermore, if human error could be calculated into the risks of the machines then the results might be staggering.

For ATV 1 and ATV 2 the center of gravity was calculated through conventional physics equations. For ATV 1 the center of gravity was 16 inches above the axles when no weights were added and 23.4 inches with weights. Thus, the weights raise the center of gravity almost 5 inches. For ATV 2 the front-to-rear center of gravity was 20.8 inches and the side-to-side center of gravity was 13.7 inches. ATVs and UTVs already have a high center of gravity, but when a driver gets on the machine the center of gravity is even higher. This higher center of gravity results in quicker turnovers and a greater risk of fatality. In addition to the driver, an additional passenger (or weight) on the rear of the machine raises the risk even higher.

4. CONCLUSIONS

Through testing it was discovered that ATVs have a much higher turnover rate with children as drivers and with the additional weight of a passenger. It was concluded that UTVs are more stable and safer than ATVs because of their rollbar and seatbelt features. The lower center of gravity on UTVs reduces the risk of turnover while the combination of a rollbar and seatbelt help to protect passengers from the machines weight if it were to rollover. Not only did the roll cage make the UTV safer, but also the fact that the UTV is more balanced and a heavier machine means that fewer injuries are likely to occur. However, if an ATV were heavier it would create new hazards. Since an ATV has no roll cage a passenger can become trapped beneath the machine during a rollover. The weight of the machine can either crush a small child or cause severe consequences such as suffocation or drowning in the machines gasoline (an actual event).

The tests conducted on the ATVs and UTVs are a brand new field and little engineering work has been conducted on these machines outside of factory testing. Due to the preliminary nature of these tests, comparison to other testing is difficult to assume. However, it is suggested that future testing look at how thrust from acceleration and rapid deceleration (such as encountering an obstacle), various terrains, and human error affect crash risk.

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