Pelvic Injury Potential and Motorcycle Gas Tanks

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ABSTRACT

The objective of this study was to use motorcycle and rider models in a crash simulation to identify pelvic injury potential. MADYMO was used to construct and analyze realistic frontal motorcycle crash scenarios. Vertical gas tank orientation and pelvic reaction force were measured at increasing Delta-Vs. Statistical analysis was performed to determine if the change in gas tank angle, at different impact severities, was significant. Delta-V and gas tank angle correlated significantly ($p < .05$) with pelvic reaction force. The average pelvic force increased exponentially ($R^2 > .99$) as the gas tank angle increased.

Keywords: Biomechanics, Motorcycle, Gas Tank, Frontal Impacts, Injury Severity

DEATH AND INJURY associated with motorcycle collisions is a serious health hazard in the United States (Peak et al, 1994 and NHTSA, 2000). A NHTSA review of motorcycle crashes in the United States in the year 2004 revealed that motorcyclist fatalities increased from 3,661 in 2003 to 4,100 (up 12%). In 2004, 70,000 motorcyclists were injured, which represents an increase of 3,000 from the previous year (NHTSA 2003). For motorcyclists, the fatality rate per 100 million vehicle miles traveled is over 26 times greater than for passenger car occupants. These statistics are indicative of the risk that motorcycle riders face in a traffic environment and warrant the need for further research focusing on motorcyclist injury prevention. Recommendations from the National Agenda for Motorcycle Safety (NAMS) reads as follows: "immediate action should be taken by government and industry to address the critical questions in motorcycle safety through comprehensive, in depth studies as well as studies focused on specific topics" and "Studies of earlier types of machines have shown that fuel tanks that rise abruptly from the saddle immediately in front of the rider contribute to severe pelvic injuries in frontal impacts (Ouellet, 1981). Most current sportbike tanks have a similar style and are likely to present a similar injury mechanism" (NHTSA, 2000).

Validation of the motorcycle and rider models was previously performed. Figure 1 shows the motorcycle and rider models in the initial (pre-simulation) position. A total of 36 total simulation runs (12 simulation trial groups) were performed for this study (Table 1). Two basic modifications were investigated: 1) Three vertical gas tank angles (20, 55, and 90 degrees above horizontal). 2) Frontal change in Delta-V (10 mph, 20 mph, 30 mph). In the previous study, other geometric modifications included the windshield and handlebars.

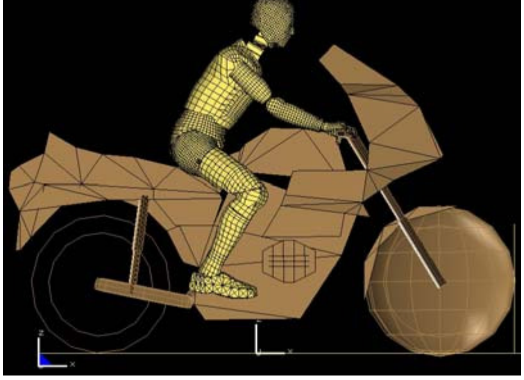

Fig. 1 - MADYMO motorcycle model with rider in initial position

Table 1 - 12 test trial groupings

Trial Group	Variables		
1	10 mph, 20 degree angle	10 mph, 55 degree angle	10 mph, 90 degree angle
2	10 mph, 20 degree angle	10 mph, 55 degree angle	10 mph, 90 degree angle
3	10 mph, 20 degree angle	10 mph, 55 degree angle	10 mph, 90 degree angle
4	10 mph, 20 degree angle	10 mph, 55 degree angle	10 mph, 90 degree angle
5	20 mph, 20 degree angle	20 mph, 55 degree angle	20 mph, 90 degree angle
6	20 mph, 20 degree angle	20 mph, 55 degree angle	20 mph, 90 degree angle
7	20 mph, 20 degree angle	20 mph, 55 degree angle	20 mph, 90 degree angle
8	20 mph, 20 degree angle	20 mph, 55 degree angle	20 mph, 90 degree angle
9	30 mph, 20 degree angle	30 mph, 55 degree angle	30 mph, 90 degree angle
10	30 mph, 20 degree angle	30 mph, 55 degree angle	30 mph, 90 degree angle
11	30 mph, 20 degree angle	30 mph, 55 degree angle	30 mph, 90 degree angle
12	30 mph, 20 degree angle	30 mph, 55 degree angle	30 mph, 90 degree angle

RESULTS

Figure 2 also shows the results of the 36 total simulation runs (12 simulation trial groups).

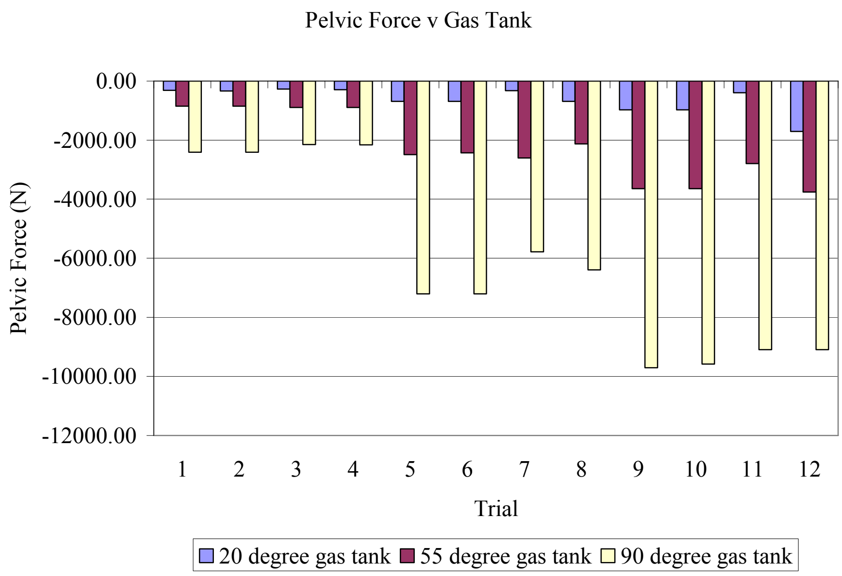

Fig. 2 - Results for average pelvic force

Table 2 shows the results for average pelvic force for a group of 4 runs at same impact velocity and tank angle.

Table 2 - Results for average pelvic force

Impact Velocity	Tank Angle (degrees)	Average Pelvis Force (N)
10 (4 runs)	20.00	301.22
10 (4 runs)	55.00	868.61
10 (4 runs)	90.00	2278.68
20 (4 runs)	20.00	591.32
20 (4 runs)	55.00	2413.20
20 (4 runs)	90.00	6644.90
30 (4 runs)	20.00	1009.28
30 (4 runs)	55.00	3460.33
30 (4 runs)	90.00	9370.55

Correlational Analysis: Delta-V and gas tank angle correlated significantly ($p < .05$) with pelvic reaction force for each of the 36 individual simulation runs (Table 3).

Table 3 - Correlational analysis

N=36		Pelvic Force
Tank Angle	R	-.761
	Sig.	.001
Delta-V	R	-.482
	Sig.	.003

Exponential Regression: Figure 3 shows the exponential regression analysis for average pelvic force at 20, 55, and 90 degrees at Delta-Vs of 10, 20, and 30 mph (values seen in Table 2). R-squared values were significant ($p < .01$), showing that the average force imparted on the pelvis by the gas tank grew exponentially. The exponential regression equations calculated were:

For 30 mph Delta-V: Pelvic Force = $555.38e^{0.0318 \times (\text{Tank Angle})}$ $R^2 = 0.996$ $p < .01$

For 20 mph Delta-V: Pelvic Force = $316.31e^{0.0346 \times (\text{Tank Angle})}$ $R^2 = 0.991$ $p < .01$

For 10 mph Delta-V: Pelvic Force = $171.65e^{0.0289 \times (\text{Tank Angle})}$ $R^2 = 0.999$ $p < .01$

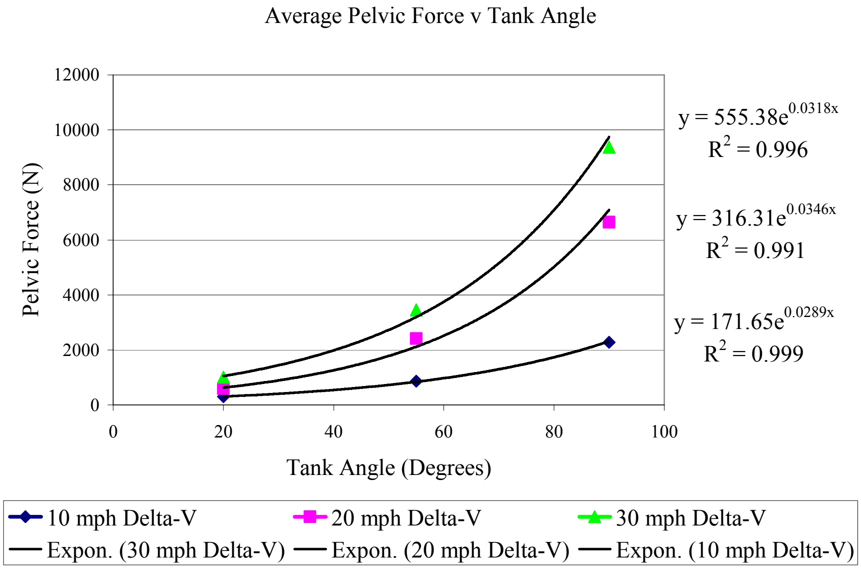

Fig. 3 - Exponential regression for average pelvic force and gas tank angle

EFFECT OF GAS TANK ANGLE: As seen above, significant statistical results came from increasing the vertical gas tank angle. For years, researchers have known that the gas tank plays a role in rider injury potential (Ouellet, 1981). However, there have not been any significant studies or quantitative conclusions on the subject. This study clearly shows that injury potential is increased for the pelvis as the vertical angle of the gas tank is increased as well as increased Delta-Vs. Figure 2, graphically shows that as the gas tank angle increased so did the pelvic force (increased in the negative direction due the coordinate system orientation).

The most interesting finding regarding gas tank angle and pelvic force came from the exponential analysis. The average pelvic force increased exponentially ($R^2 > .99$) as the gas tank angle increased. This is an important finding as a large number of current sportbike designs have dramatically rising gas tanks, located directly in front of the rider's pelvis. Pelvic injuries may not be as "life threatening" as a head injury but, they can be very debilitating and result in dysfunctions affecting an individual's ability to reproduce, ability to walk, ability to urinate, etc., and a dramatic decrease in quality of life.

DISCUSSION

This study was limited and specific in scope. The crash configuration studied was focused on frontal motorcycle collisions. It is important to note that the results of this study are valid mostly in a relative sense. Using the validated rider and motorcycle models gives the best possible results. There is a large variation of motorcycle types as well as individuals in the motorcycle riding population. This study used a "sportbike" motorcycle model and a 50th percentile sized male. Different sized motorcycles and riders will undoubtedly change the forces and rider kinematics involved during collisions.

The values reported in this study were values calculated in a previous study that included slight modifications to the windshield and handlebars. However, those modifications did not significantly affect the results relating to pelvic injury potential.

There is very limited publicly available scientific research regarding motorcycle crash simulation and biomechanical analysis. This study is very unique and adds a great deal to an already limited field of research.

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