

## EFFECT OF VEHICLE DESIGN IN BICYCLE FRONTAL CRASHES

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### ABSTRACT

The variation of throwing distance and Head Injury Criterion with velocity, point of impact and angle of approach has been studied for bicycle impact with three different categories of vehicles- small cars, sports utility vehicles and buses. Crashes between a bicycle and the vehicles were simulated using multi body models developed in MADYMO<sup>TM</sup> with parametric variations in speed, angle of approach and point of impact. The variation in the angle of approach or point of contact causes significant changes. From the simulations, the large spread in the data reported by reconstruction is predicted to originate from variation in the impact configuration. The changes in the trends can be associated with visible kinematics in the simulations (head impacting car, no impact of rider with car etc.). The kinematics of impact is significantly different for the bus and this leads to changes in the nature of correlations. The HIC values were found to be higher in the case of bus as compared to the SUV and the small car. The paper reinforces the hypothesis that for bicycle accident reconstruction should take into account variations in the impact configuration in addition to the throw distance recorded. The paper also gives data which could form a basis of such reconstructions.

**Keywords:** Bicycle, MADYMO, Crash simulation, throwing distance, impact speed

### INTRODUCTION

THE TRENDS IN THROW DISTANCES IN BICYCLE CRASHES as reported by Otte (2002) can be predicted by MADYMO<sup>TM</sup> based modeling as reported by Mukherjee (2006). This paper studies the effect of change in geometry of the front of the other vehicle (OV) on the bicycle crash kinematics and the estimated HIC values through simulation. The variation of the simulated throwing distances with change in OV and comparison with Otte's regression curve is shown in figure 1.

The variation of the throwing distance and Head Injury Criterion (HIC) values with car velocity, point of impact and angle of approach has been studied for bicycle impact with three different categories of vehicles- small cars, sports utility vehicles (SUV) and buses. Crashes were simulated using multi body models developed in MADYMO<sup>TM</sup>. Load-deformation characteristics of the bumper, bonnet and windscreen was kept the same for the different class of vehicles. The Hybrid III 50th percentile male dummy model, available from MADYMO library has been used.

### MODEL BUILDING

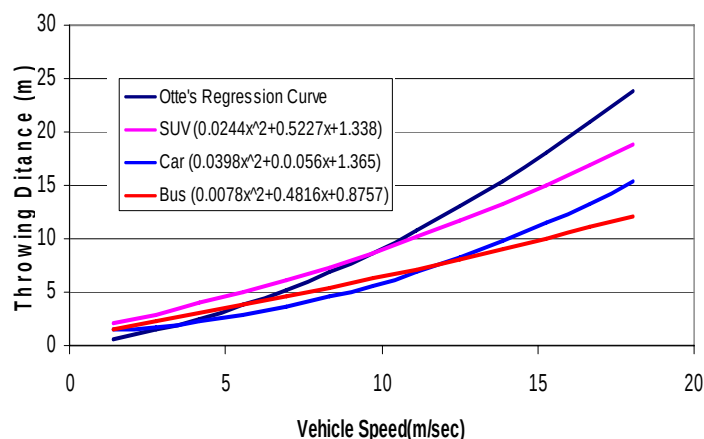


Figure 1 Variation of throwing distance with vehicle types

## SUV IMPACT

SUV MODEL Scale and tape measurements were used to build the geometric models. Average of the headform impact test data reported in Japan ENCAP data for the Wagon R FX which is similar to the Maruti 800 car prevalent in India was used to generate load deformation characteristics. The car model has been reported in Mukherjee (2006)

The vehicle was modelled as one single body, consisting of a combination of cylinders and ellipsoids. It consisted of five rigid bodies- the vehicle body and the four tyres. All the surfaces in the body of the vehicle were rigidly locked against each other. The only movable joint was between the road and the centre of gravity of the vehicle. Thus, there is only one movable part and that is the vehicle body. There is no relative movement possible between the parts. In total the model consists of 59 surfaces and 5 rigid bodies. Out of these 59 surfaces, 54 are ellipsoids while 5 are cylinders. Since from the perspective of a bicyclist, the vehicle is a very large mass, the dynamic loading effects on the SUV velocity were neglected. This allowed the usage of the same tyre properties as for the small car. The windscreen was defined using two ellipsoids while the front hood using a single ellipsoid of degree 8. The bumper was defined using 4 different ellipsoids. Due, to their size, the front headlights were modelled using two separate ellipsoids. Second degree ellipsoids were used to model the A, B C and D pillars. The suspension was also not modelled as it is sufficient to model the tyres and the centre of gravity of the vehicle.

**SIMULATION RESULT** The basic characteristics of the bicycle and car/SUV crash phenomenon are that the rider impacts the hood, and then rolls up the windscreen towards the roof of the car. A lateral movement with respect to the OV leads to the rider rolling off the side in cases. For higher velocities, the rider may clear the roof, landing at the back of the OV. For lower velocities, the rider may be carried on the front end of the car for longer time durations before rolling off. The behavior is qualitatively different for varying car speeds, initial impact locations and bicycle speeds.

## BUS IMPACT

**BUS MODEL** The model of the bus (shown in figure 5a) was developed in a manner similar to that of the SUV. The vehicle was modeled as one single body, consisting of a combination of cylinders and ellipsoids. In total the model contains 31 surfaces and 5 rigid bodies. To further analyze impacts between buses and bicycles, an alternative bus design slanting hood type of front instead of a flat-fronted design was considered.

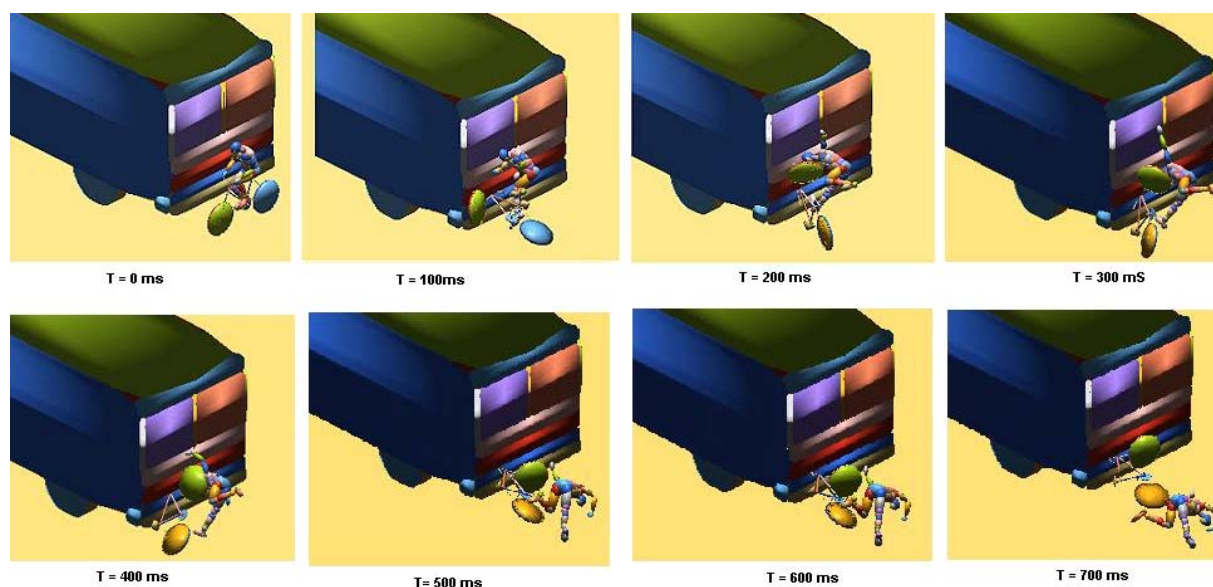


Figure 2: Bus Bicycle Impact

**SIMULATION RESULT** The kinematics of impact of the bicyclist with the bus is quite different from that in case of the SUV and the Car. The first impact usually takes place with the leg or the saddle followed by the rest of the body impacting the bus front. Due to the flat shape of the bus, bicyclist is not launched as high in the air as with the SUV and the car. This leads to lower throw distances due to the flatter trajectory as shown in Figure 2. The spread with change in impact location in the case of the buses is less and this can be attributed to the fact the bus front is similar along its length and the impacting surface does not vary much with offset. The expected trend of monotonically increasing throw distances is observed. The magnitude of the throw distances at high speeds is lower than the SUV and the car due to the difference in the crash phenomena as explained above.

## COMPARISON

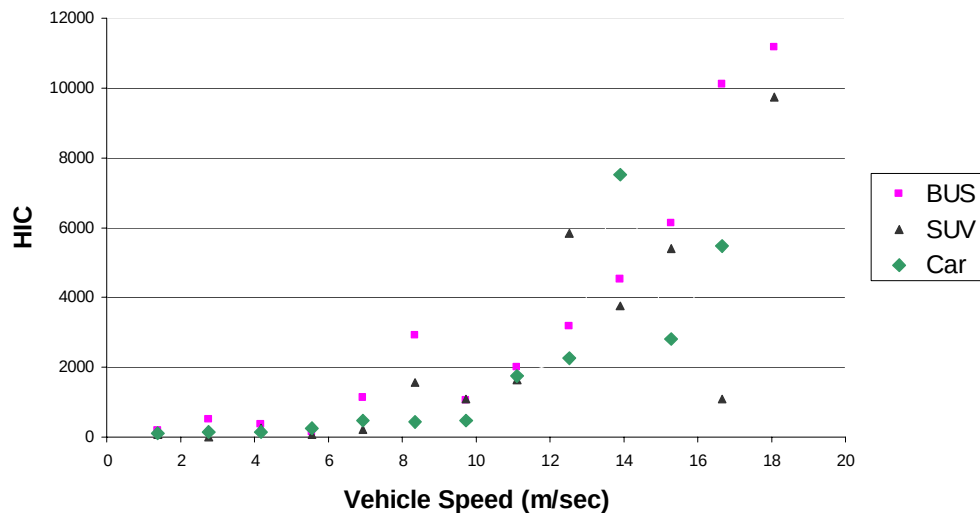


Figure 3: Variation in HIC values with speed of the vehicle

The HIC values calculated in MADYMO™ were compared for the three cases of impacts of the bicyclists with the Car, the SUV and the Bus. The comparison was made for a central impact position in the vehicles and the variation with vehicle speed is shown in Figure 3. Unlike throw distances, the highest HIC values are generally obtained for the bus followed by the SUV. The impact of the head of the vehicle takes place immediately after the first contact in the case of the bus, leading to higher values.

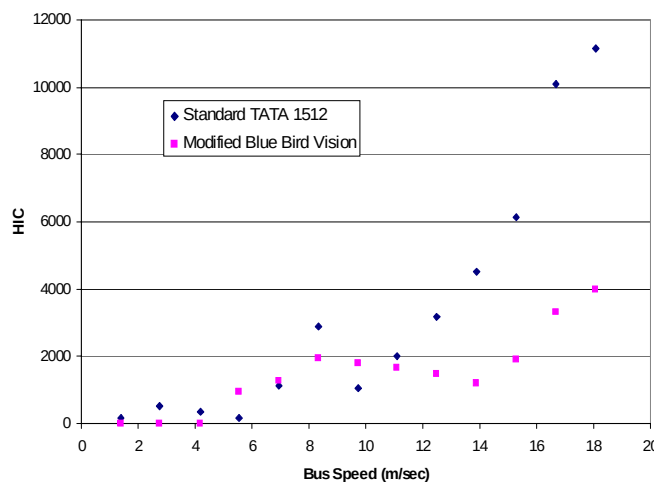


Figure 4: HIC on bus-dummy contact

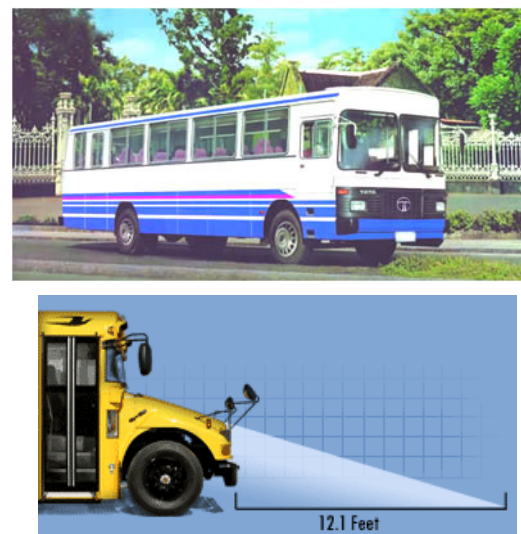


Figure 5 a) TATA 1512 Bus, b) Blue Bird

The design of the bus was modified to reflect that of the Blue Bird Vision (2003) and simulations were done with the new design in which the front of the bus has a slanting hood. The HIC values corresponding to the head impact with bus are plotted with the bus speed in Figure 4. The slanted design has a lower HIC value. This is attributed to the fact that in the slanted front design the head collides with hood after it has been decelerated considerably due to the impact of the bus with the lower extremity. Figure 6 below reports the overall HIC value, including the contact with the ground. The rise in HIC values is not monotonic with the speed and has a local maximum at bus velocities of about 12 m/s. At certain vehicle speeds, the bicyclist rotates in the air and impacts the ground in an orientation which leads to higher energy absorbed by the head.

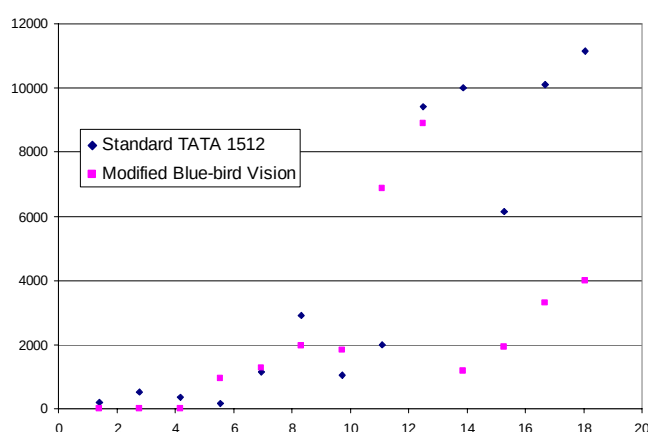


Figure 6 Variation in overall HIC with type of bus front

## CONCLUSIONS

ESTIMATION OF THROWING DISTANCE for OV-bicycle crashes for four types of vehicles with parametric variation in OV speed and the point of impact have been carried out. The change in the nature of impact with change in vehicle front has been highlighted, qualitatively as well as quantitatively. There is qualitative change in the nature of impact with change in vehicle front. The contact point on the vehicle is not significant parameter for impacts with buses with uniform fronts. A flat front design leads to smaller throwing distances of the bicycle rider as the rider is not thrown up. The HIC due to the rider-bus impact is smaller in the slanted front bus. If the rider-ground contact is included, the trend of overall HIC is not so easily predicted. For the slant front bus, as the rider is thrown up, the ground contact could at times be with the head, leading to large HIC values.

Experimental force-deformation relationships were not available for the contact interaction. The confidence in the results would be greater if experimental crash data were available.

## REFERENCES

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