

*Study of an impact vehicle-bike at high speed*

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## Introduction

The purpose of this work is to reconstruct the dynamics of a fatal accident that occurred a few years ago, in which 2 boys on bicycles (a male and a female) and 2 boys in a sedan car were involved. The two boys on the bike lost their lives due to the rear-end collision. This is therefore the study of a case that really happened, of which synthetic results are provided which do not give any reference clues. No study of analogous cases was not found in literature; numerous articles can be found in the literature on the vehicle-cyclist impact, but the analyzes are carried out at an impact speed of 13.9 m/s maximum (50 km/h) and with the bike driver only. [1-14, 17].

Pre-crash conditions were set on the basis of the photographic files and video surveillance images, which concern the positioning of the bicycle with respect to the vehicle and the positioning of the cyclists on the bicycle itself.

The accident is reconstructed in this paper through the use of numerical models. Cyclists are represented by anthropomorphic models having the appearance of human beings, to which mass and inertial properties have been attributed; the car and bicycle models were downloaded from google sketup, in a format compatible with the SimWise room. The accelerations of

the heads and the relative parameter of the damage (HIC, AIS), their position respect to the collision point, the points of impact of the head on the vehicle are obtained by the simulations. The tests were carried out at the speeds 20, 22, 25, 27, m/s; they are presumably close to the actual one, as identified by the preliminary investigations. No analysis of the other body parts was performed because the autopsy showed the brain impact as a cause of death for both passengers.

The virtual models are provided with height and mass of the occupants of the bike. The female was sitting on the rear rack of the bicycle. The choices and the relative simplifications carried out are based on the knowledge of biomechanics and in compliance with the provisions of the European regulations concerning the subject of crash tests and according to the possibilities, limits, and peculiar characteristics offered by SimWise. Poser Pro software was used for the three-dimensional geometric shape of the human model, and the proportioning of each body segment. The models were imported to Rhinoceros for compatibility with SimWise. The relative masses of each body segment were determined using the geometric approach method. Having to respect mass and height as binding elements, experimental data obtained by Braune-Fischer, Dempster and Clauser relating to a man of 75 kg mass are used in order to obtain by proportion the relative masses and dimensions of each individual body part, as already determined in previous works [15-18], for the mass of the male (driver) and of the woman respectively.

## **HIC (Head Injury Criterion)**

The current version of the HIC was developed by the NHTSA (National Highway Traffic Safety Administration). The FMVSS directive requires that the HIC does not exceed the 1000 value over a maximum amplitude interval of 36 ms [19-24]. For the sake of brevity, the formula easily found in the bibliography is missed. On the acceleration curve, built with the experimental values by the accelerometers, a moving time window of 36 ms is applied, the corresponding HIC value is calculated for each interval; the value of HIC is the maximum of these. Varying the stiffness of the vehicle area where the impact occurs, the force - deformation bonds and the contact time vary and, therefore, also the HIC value. Typically, more rigid areas correspond to higher HIC values, because there are less vehicle deformations and therefore greater deformation forces transmitted to the pedestrian's head. The highest values of HIC occur at the windscreen pillars, the sides of the hood and the hood-windscreen junction area. It should be noted that it has been proposed to shorten this interval to 15 ms rather than 36 ms to calculate HIC, in the case of head impacts with fairly rigid bodies (eg windshield). [25-27]

## Reproduction of environmental conditions and simulations.

Photographic archive made available shows that the point of impact of the car with the bicycle has an offset of about 50 cm on the right side with respect to the center of the vehicle, as Figure 1 shows.



Figure 1: Characteristics of the point of impact.

From the investigations carried out, some images were selected that allow us to estimate the post impact dynamics. Figure 2 shows the discovery of the woman's tufts of hair on the windshield of the car which gives a clue to the point of contact.

The man was found in the middle of the roadway at about 28.5 meters at least and was not hit for a second time. The woman stopped after about 54 meters at the edge of the road.



Figure 2 – Primary impact position

In the simulations, one of the most usual positions was attributed to cyclists; failure to use the hands is due to the fact that they do not affect either the dynamics of the impact or the extent of the damage. Figure 3 shows the initial conditions seen from the side and from above.

The virtual models are imported into the SimWise environment, maintaining the geometric and mass characteristics. Then the following kinematic settings are assumed:

- The speed of the bicycle at the moment of impact is negligible compared to that of the vehicle.
- It can be considered with a good approximation that the bicycle with the driver and the passenger on board is almost stationary at the moment of impact.
- Accelerometers have been inserted in the center of gravity of the head as required for the calculation of the HIC.

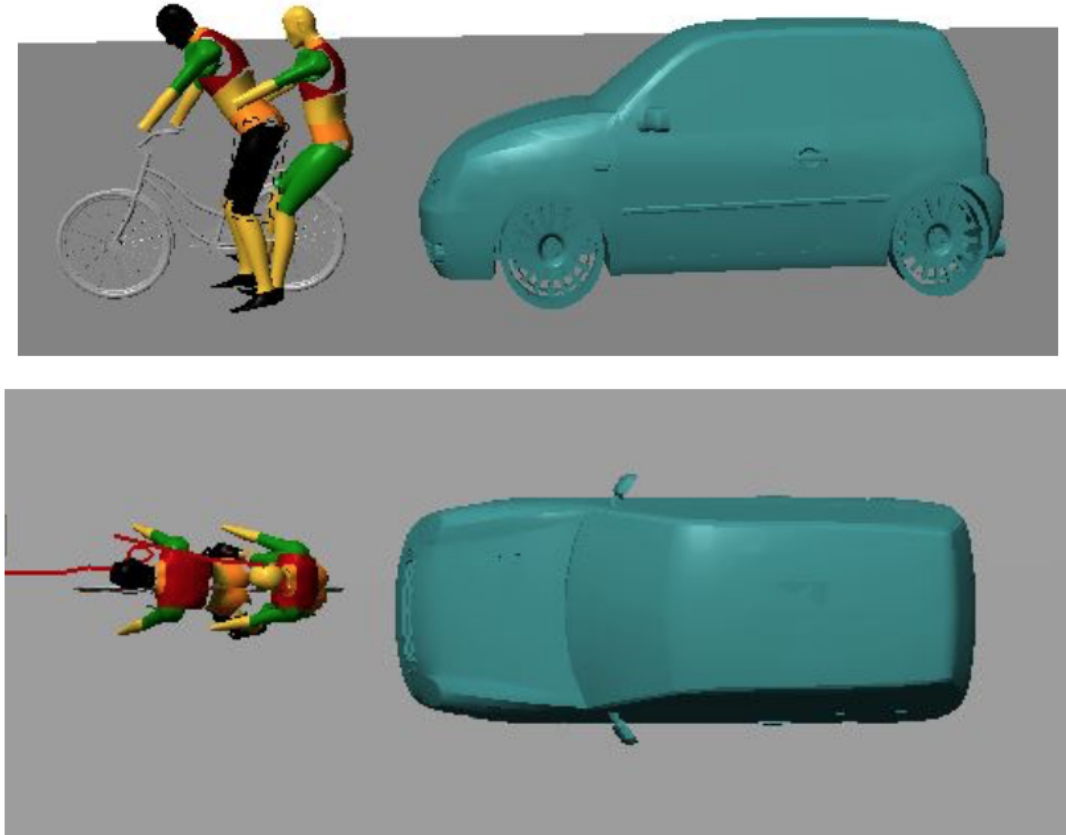


Figure 3: initial condition of the impact seen from the side and from above.

- Position sensors have been inserted so as to be able to monitor the position of the bodies and the distance from the point of impact instant by instant.

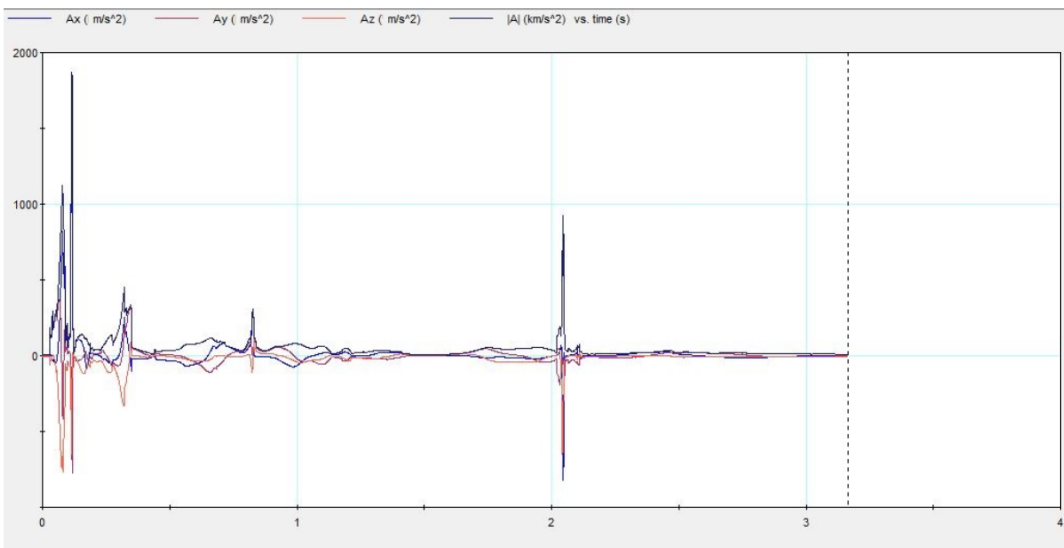
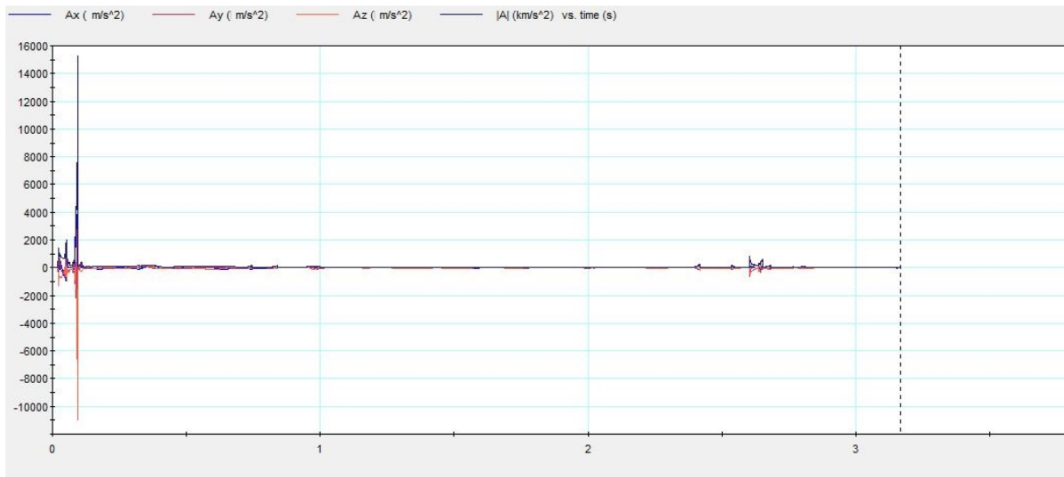
Figure 4 shows the acceleration trend of the woman's head for the entire duration of the impact up to the position of rest.

Figure 4: Woman head acceleration trend at 25 m / s.

Figure 5 shows the acceleration trend of the man's head for the entire duration of the impact up to the position of rest.

Figure 5: Man head acceleration trend at 25 m/s.

Table. 1 – Simulations results



## Discussion

Table 1 summarizes the maximum values of the accelerations expressed in [g], and the corresponding HIC values of the woman and man both in the primary and secondary impact. The probability values  $P(AIS3+)$  and  $P(AIS4+)$  calculated according to the formulas reported in [28, 29] are also determined. The table shows that both passengers on the bike died instantly, in correspondence with the primary impact, which occurred at a presumable speed of 25-27 m / s. With regard to the secondary impact, the acceleration and HIC values strongly depend

Table. 1 – Simulations results

		Primary impact				Secondary impact			
speed [m/s]		20	22	25	27	20	22	25	27
woman	Acc. [g]	1008	1465	1556	1963	1340	301	83	350
	HIC	10991	20258	50693	54978	80	5648	1341	848
	P(AIS3+)	1	1	1	1	0	1	0,81	0,38
	P(AIS4+)	1	1	1	1	0	1	0,42	0,10
man	Acc. [g]	118	143	179	186.8	89	102	94	536
	HIC	701	724	1341	1569	413	302	89	260
	P(AIS3+)	0,26	0,27	0,81	0,91	0,09	0,05	0	0,04
	P(AIS4+)	0,06	0,07	0,42	0,62	0,02	0,01	0	0

on the falling position of the bodies, which, on the other hand, does not happen in the case of a primary impact which presents an increasing trend.

Proceeding step by step, in correspondence with the maximum acceleration value, both the primary impact point of the head on the vehicle and the secondary impact point on the ground can be evaluated. In the following images, the woman's head is represented in yellow and the man's head in black. Figure 6 shows the impact points of the head on the vehicle at the impact speed of 27 m / s; it can be seen how the head of the man instead of impacting on the vehicle, impacts with the head of the woman; this also happens in all simulations at different speeds.

Figure 7 shows the impact points of the head on the road, at the impact speed of 27 m / s.

## Conclusions

From the comparison with the available photos, it can be deduced that the estimated speeds for carrying out the tests are found to cover a good range of possible post-impact dynamics, as the woman's head impacts the vehicle's windshield. From the HIC values and the comparison with the AIS code, it appears that the cyclists have probably caused fatal damage as a result of the primary impact as in the secondary impact the HIC values are rather low.

The post-impact positions of the cyclists allows to deduce that the dynamics before the



Figure 6: Primary impact point of women (left) and men (right)

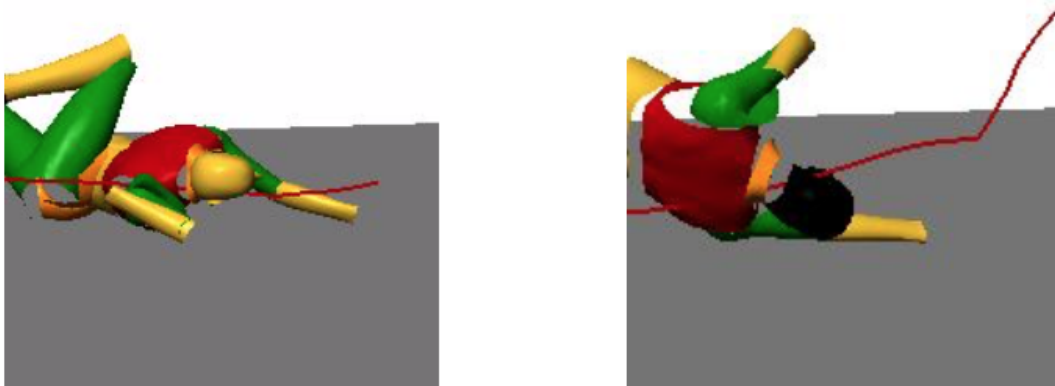


Figure 7: Secondary impact on the ground of the head of the woman (left) and of the man (right)

impact and the respective positions with respect to the vehicle are corrected with due approximations. The body of the man in all the simulations ends up on the road, as regards the woman, in this case too she is projected on the roadside. In all the simulations the man assumes a trajectory with a vault on the roof and a rear fall typical of high speeds. (This confirms that no traces of a second investment have been found on his body). The woman, on the other hand, assumes a pushing motion as she sits on the luggage rack and has a lower center of gravity.



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