KINEMATIC RECONSTRUCTION OF CAR ACCIDENTS

Princess Diana Spencer’s car crash which took place on 31 August 1997 in Paris (France) gave rise to many speculations about the exact circumstances of the tragedy.

A cinematic reconstruction performed by an independent expert, however, allowed to elucidate much of the prevailing mystery surrounding this accident.

We publish here the summary of this reconstruction and the method used, called 'reverse recovery method.'

This new and original method is to reconstruct the three sequences of an accident scenario (approach, collision, wandering) by proceeding reverse chronological order.

THE DIANA SPENCER CAR CRASH

From the perspective of physics, a collision is defined as a sudden and uncontrolled variation of kinetic energy accumulated by a vehicle.

Accidentology is the science that studies the mechanism of injury, particularly how the kinetic energy dissipates.

Indeed, the variation of kinetic energy resulting from a collision is certainly violent, but rarely complete. Knowledge of the laws of physics can reconstruct an accident scenario.

This work is facilitated by a systematic cutting of different sequences that make up the scenario.

The three sequences common to all accidents are the approach, the percussion, and the wandering. Let us examine them in detail.

The approach is defined as all events occurring between the time the driver is aware of the impending collision and the beginning of the actual collision.

This sequence is important because it affects the initial speed at the time of collision, therefore, the amount of kinetic energy that is dissipated during it and causes damage. Let us say right away, the approach sequence is and will remain the most mysterious, as long as the cars will be devoid of data recording systems.

However, by doing a cross checking, it is often possible to reconstruct this sequence, even if objective data is lacking.

Percussion of the obstacle is the best known sequence. Its mechanism was described in the previous issue.

Recall also that the intensity of the deceleration undergone by a vehicle is a function of the square of the initial velocity, and inverse function of the length of deformation of the car body, according to the relationship:

$$\gamma = ½ v^2 / d$$

(γ: average deceleration, expressed in m/s²; v: initial velocity, expressed in m/s; d: length of deformation of the car body, expressed in m).

The wandering denotes the distance traveled by the vehicle after the collision. Indeed, if the collision has not dispelled all of kinetic energy, the wreck is left to itself and continues its course until complete immobilization.

It is important to know that distance because it is then possible to calculate the residual velocity, ie the speed of the car just after the collision. The dissipated energy during the impact thus appears as the difference between the initial kinetic energy and the residual kinetic energy.

The data it is necessary to collect on the field are: the length of wandering, an estimate of the deceleration of the car on her way, the length of the deformation of the car body, and an estimate deceleration borne by passengers from bodily injury.

Once data are collected, it is best to use them by proceeding in reverse chronological order: first calculate the residual velocity from wandering, then calculate the initial velocity by combining the residual velocity and deceleration experienced by passengers. Once the results obtained, it is finally possible to understand how the accident occurred.

This methodology has enabled to reconstruct the scenario of the accident which took place the 31 August 1997 in Paris, in the tunnel of Alma's bridge, accident in which the Princess Lady Diana Spencer died.

The data that were used are as follows: the wandering is 15 meters. The deceleration of the wreck on its way is estimated at 7 m/s^2. The length of the car body's deformation against the pillar of the tunnel is estimated to be 1 meter.

The deceleration borne by the passengers during this collision is estimated to be 200 m/s^2 (that is serious injury to the right front belted passenger but fatal shock for unbelted passengers).

Finally, the study of the road upstream that precedes the accident site has helped us to develop a hypothesis about the approach sequence.

This is the result of that reconstruction:

1. The car came to rest about fifteen meters after the pillar. Its residual speed (the speed after the collision) was not zero. Grip conditions observed on site for estimating the deceleration of the wreck rubbing on the floor to 7 m/s^2; the residual velocity is calculated as follows:

$$v = (2 . \gamma . d)^{1/2}$$

$$v = (2 \times 7 \times 15)^{1/2}$$

$$v = (210)^{1/2} = 14.5 \text{ m/s} = 32 \text{ mph}$$

2. The intensity of the collision can be assessed by considering indirect damage suffered by the occupants of the car.

Testimonials and some indiscretions suggest that the death of Lady Diana Spencer is due to pulmonary hemorrhage caused by a violent shock chest, itself explained by the belt default.

The driver and another occupant of the car died in the moments following the collision, but we have the least information on the nature of the injuries that caused death.

The only survivor is the right front passenger, belted, who suffers from facial trauma and a broken jaw.

Given this information, it seems likely that the average deceleration experienced by passengers could be around 200 m/s^2.

Indeed, this threshold is generally considered critical for the survival of young and healthy people. A higher deceleration would certainly have triggered a fatal brain hemorrhage, even to a belted person.

In addition, photographs of the wreck make it possible to estimate the total deformation distance resulting from the collision at 1 meter (compression of the left front structure of the car, stretching of the right front passenger's seatbelt). The initial velocity (speed at the time of collision) is calculated as follows:

$$v = [v^2 + (2 \cdot \gamma \cdot d)]^{1/2}$$

$$v = [14.5^2 + (2 \times 200 \times 1)]^{1/2}$$

$$v = (210 + 400)^{1/2}$$

$$v = (610)^{1/2} = 24.7 \text{ m/s} = 55 \text{ mph}$$

3. The characteristics of the 200 meters area upstream of the accident are: a first curve to the left, a straight section of a hundred meters downhill (the slope of about 4% corresponds to the height of the underpass), and then a second curve to the right at the entrance of the tunnel.

The distance between the exit of the first curve and the thirteenth pillar of the tunnel is approximately 140 meters.

4. According to a map of Paris to 1/10,000 scale, the first left curve does not allow a trajectory with a radius greater than 150 meters.

For a transverse acceleration limit value estimated at 9 m/s^2, the critical driving speed in the curve is calculated as follows:

$$v = (r \cdot \gamma)^{1/2}$$

$$v = (150 \times 9)^{1/2}$$

$$v = (1{,}350)^{1/2} = 36.7 \text{ m/s} = 82 \text{ mph}$$

5. Could the speed of the car have varied from 82 mph (in the first curve) to 55 mph (when hitting the pillar)?

This deceleration (< 3 m/s^2) is too low to result from an action on the brakes but can be explained by a series of swerves.

This thesis seems the most likely. While the driver was surprised by the loss of control of the rear after the first curve, he could not react both on the wheel and the brakes.

6. These calculations lead to retain the following hypothesis: the driver approached the first curve slightly above the critical speed.

Surprised, the driver has increased the steering angle of the front wheels, thus causing loading the front of the car, and therefore unloading the rear of the car.

The car was already over steering due to the presence of the rear passengers, so it started a first swerve, accentuated by the slope.

Trying to regain control of the situation by turning the wheel slightly out of sync, the driver swerved off a second time.

This brought the car on the path of the thirteenth pillar which was struck at a speed of about 55 mph.

All in all, the approach sequence lasted less than 5 seconds.

The collision against the pillar varies the speed of the car from 55 to 32 mph and then the rubbing has dispelled the rest of the kinetic energy, until the complete immobilization of the wreck.

Speed variation from 55 to 32 mph seems low.

In reality, it corresponds to a frontal impact against a concrete wall with no way out, with an initial speed of 45 mph and a zero residual velocity, as shown by the following calculation:

$$v = (55^2 - 32^2)^{1/2}$$

$$v = (3{,}025 - 1{,}024)^{1/2}$$

$$v = 2{,}000^{1/2} = 45 \text{ mph}$$

This explains the violence of the collision, and the severity of injuries suffered by the occupants of the car.

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