HEAD KINEMATICS OF A BABOON SUBJECTED TO IN-VEHICLE TESTS

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1. INTRODUCTION

In the study of the influence of various impact parameters on the dynamic response of the head neck-system, it appeared interesting to investigate the effect of a rotational component during the crash, such as those being observed for instance in non-symmetrical frontal crashes. Since this phenomenon must be difficult to simulate on a sled, to see if it was of interest to design a specific sled for this, it was decided to conduct a few tests in real conditions with vehicles.

Also, owing to the experts discussions dealing with the conditions in which global tests for a frontal crash have to be performed (symmetrical, non symmetrical or oblique), it would be valuable to know if these situations result in the same consequenses as regards the body kinematics.

2. METHODOLOGY

Three frontal crashes, one symmetrical (01) and two non-symmetrical (02 and 03) have been performed with the same techniques we used for our previous study and which are described in a detailled form in reference 1 (Preparation and equipment of the baboon, data collection and processing). It has been necessary although to adapt these techniques to the special requirements of real conditions tests.

The vehicle (see figure 1) is launched either against a wall perpendicular to the displacement axis for the symmetrical frontal crash, or against a fixed obstacle figured by a concrete parallelipipede, for the non-symmetrical crash. This obstacle is located in order to be hit by the front right quarter of the vehicle and to determine large yaw and pitch components during the crash. The speed of launching is about 50 km/h (53 for 01 and 02 and 50 for 03).

The baboon is sitting at the center of the cabin, the mid sagittal plane of the body laying on the longitudinal axis of the vehicle. The thorax is restrained by a rigid plate and only the head and the neck can move freely. A head mechanical system enables to control the head position just prior to the crash.

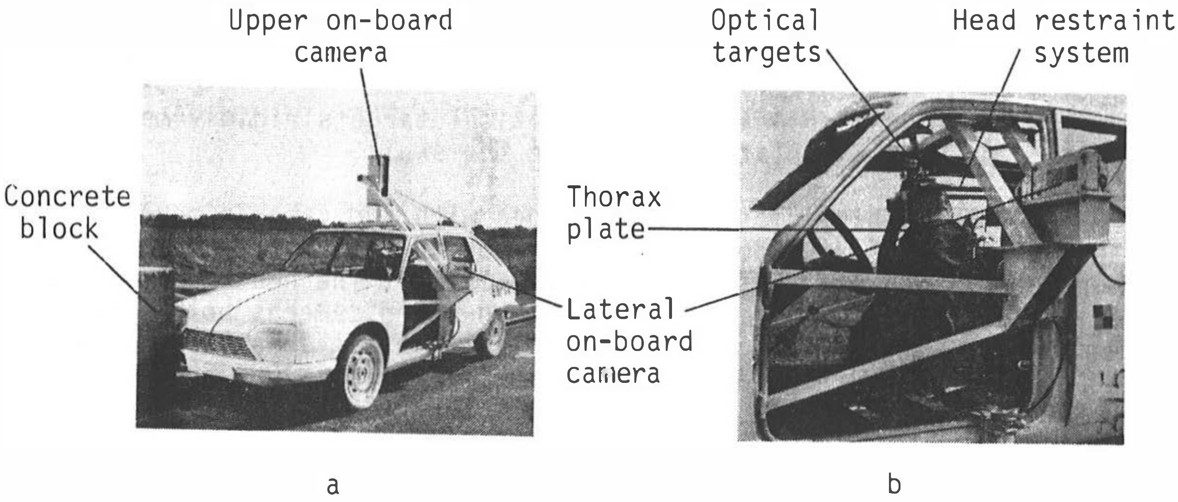


Fig 1 : a) vehicle ready for test at impact point
b) side view of the cabin. The baboon is sitting at the center. The three optical targets on the top of the head and the two arms of the head restraint system can be seen. Note the rigid frame supporting the two on-board cameras.

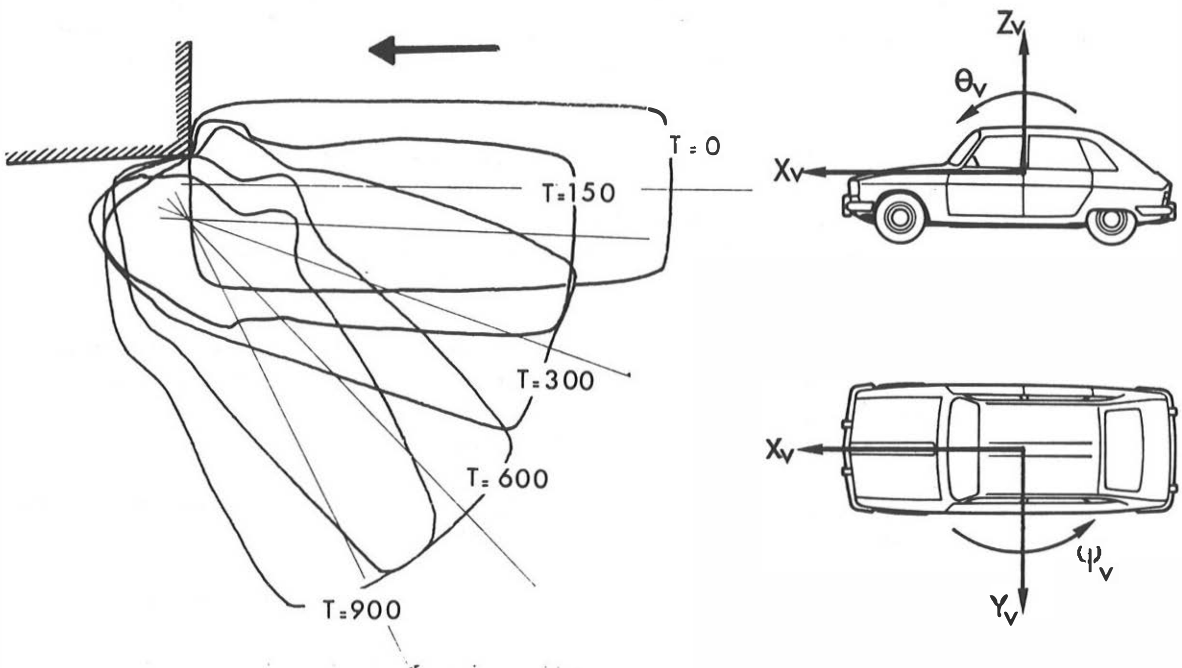


Fig 2 : Left : kinematics of the vehicle in non-symmetrical crash (test 02) as seen from the top fixed camera. Time is expressed in ms.
Right : Reference frame and angles of motion for the vehicle.

The head is wearing three optical targets rigidly mounted on it by means of metallic plates screwed on the skull.

The vehicle motion is recorded with two cameras perpendicular to the displacement axis,located above and on the left side of the impact point (200 and 500 frames / sec. respectively). The head motion with respect to the vehicle is recorded by two on-board cameras both filming at 400 frames / sec. A special care has been taken to fix these cameras in order to secure their mutual position in spite of the deformations sustained by the vehicle.

Because of the use of wide angle lenses, it has been necessary to make a correction of film data for lens distorsion. This has been done by filming a calibration grid.

3. RESULTS

3.1. Kinematics of the vehicle

The vehicle motion can be expressed by three coordinates and three angles. But for the purpose of this paper, it appeared sufficent to consider only two coordinates (X and Y) and two angles (Ψ_v = yaw and θ_v = pitch); Z and ϕ (Roll) being of less interest in this step.

Figure 2 illustrates the whole crash for test 02 (non-symmetrical) as seen from the above located camera. The total duration is 900 ms and the vehicle rotation (Ψ_v) after this period is more than 70°. For test 01 (symmetrical) this rotation is neglectible and the forward motion results from the vehicle crush.

Figure 3 shows the XY displacement curve of the reference point of the seat for a period inside which all the main phenomena occurring at the head-neck level take place. This period is about 250 ms long. From this figure it can be noted that :

- for test 01, there is no lateral (Y) motion and the forward motion (X) is relatively small (75 cm).

- tests 02 and 03 are not identical in spite of same crash conditions (except for speed 53 vs 50 km/h respectively). Lateral and forward motions are greater for test 03 than for 02, which shows the less severity of test 03.

On figure 4 are drawn the curves of Y_v (lateral motion of seat reference point) and of Ψ_v (yaw motion of vehicle) versus time.

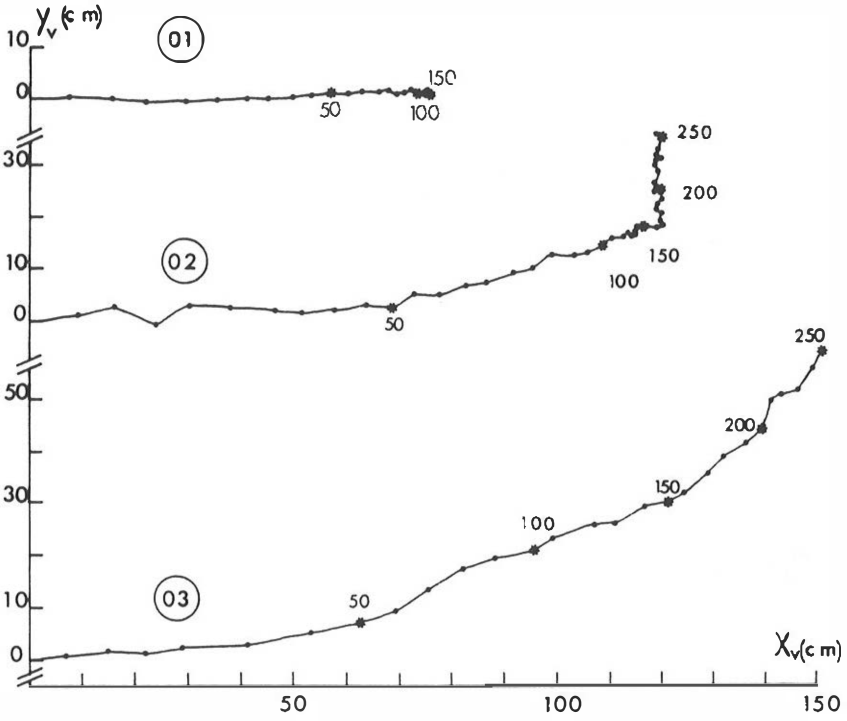


Fig 3 : XY displacement of seat reference point for tests 01, 02 and 03 (from 0 to 250 ms). For each curve the origin corresponds to the position at t = 0. Time between two points : 10 ms ; time between two stars : 50 ms.

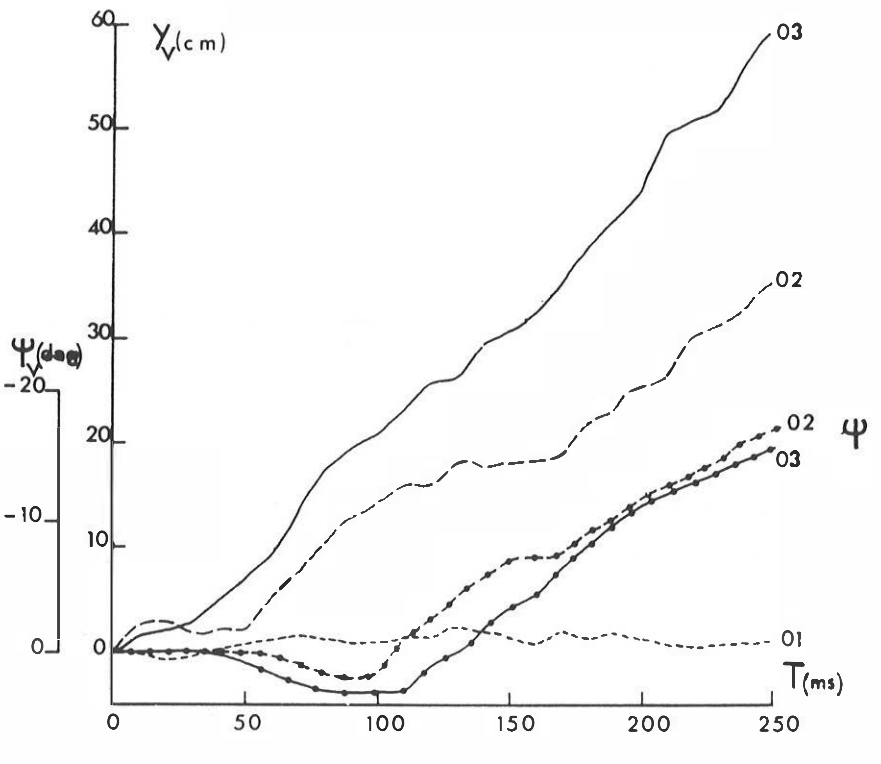


Fig 4 : Curves of lateral displacement of the seat reference point (Y_v) and yaw motion of vehicle versus time.

It can be seen that, during the first 110-130 ms, the vehicle is translating along a front left direction, and the Ψ_v rotation only occurs after this period. On the contrary, θ_v (pitch motion) begins to vary from the beginning of the crash as can be seen on figure 5. The lower value of θ_v for test 03 confirms the less violence of the crash in this case.

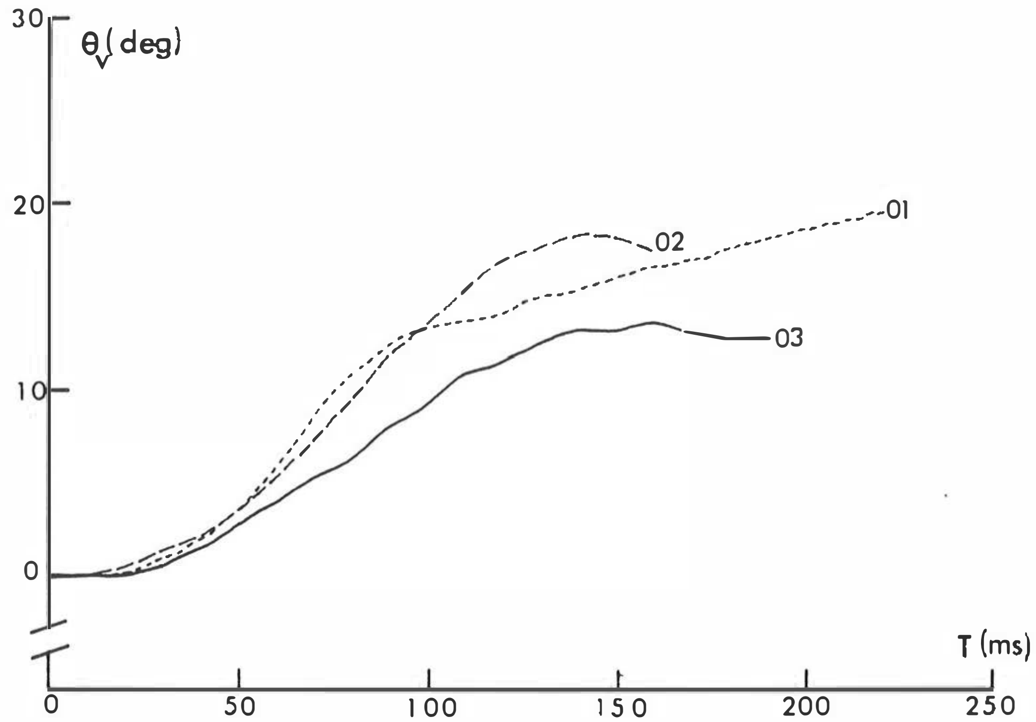


Fig 5 : Curves of pitch motion of the vehicle (θv) versus time for the three tests.

3.2. Baboon head-neck kinematics

Except for the ZY projection, the results are expressed under the same form as in our preceeding paper(Ref 1):

- XZ and XY projection of the trajectories of three points of the head : occipital cc dyle - T -, vertex - A' - and maxilla extremity - B' - (see figure 6, 7 and 8).

- head yaw (Ψ_T), pitch (Θ_T) and Roll (ϕ_T) curves versus time (see figure 9)

Unfornately, although we used a head restraint system to provide a reproducible neutral position, this latter changes a lot from one test to another, as regards to the pitch value especially (head extension for test 01, flexion for 03 and good position for 02). This is responsible for noticeable kinematic modifications as we showed on previous sled tests (Réf 1) ; however, by the comparative study of the trajectories and the angle curves, the following points can be put forward :

. the main phenomenon takes place within the first 250 ms. After this period only little movements occur.

. the more violent the crash is, the greater the speed of head motion is and the earlier the maximum flexion point is reached (01 greater than 02 greater than 03).

. there is a gradual increase of the head lateral stroke (Y) from test 01 to 03.

For 01 it is very little and corresponds to a small rotation (Ψ_T) of the head due to the initial position and which can be seen on angle curve.

For 02 the stroke is more marked and, in fact, is a real translation of the head mid sagittal plane, for Ψ_T and ϕ_T remain constant for the whole crash duration.

For 03 the stroke is still greater because in addition to the translation there is a rotation resulting from the initial orientation of the head.

If the occipital condyle is taken as origin of the head, the rigthward translational motion of this point (towards the negative values of y_T) is greater for 03 than for 02. This motion is to be related to those observed for the vehicle. In fact, the head, because of its inertia, tends to keep its motion direction whereas

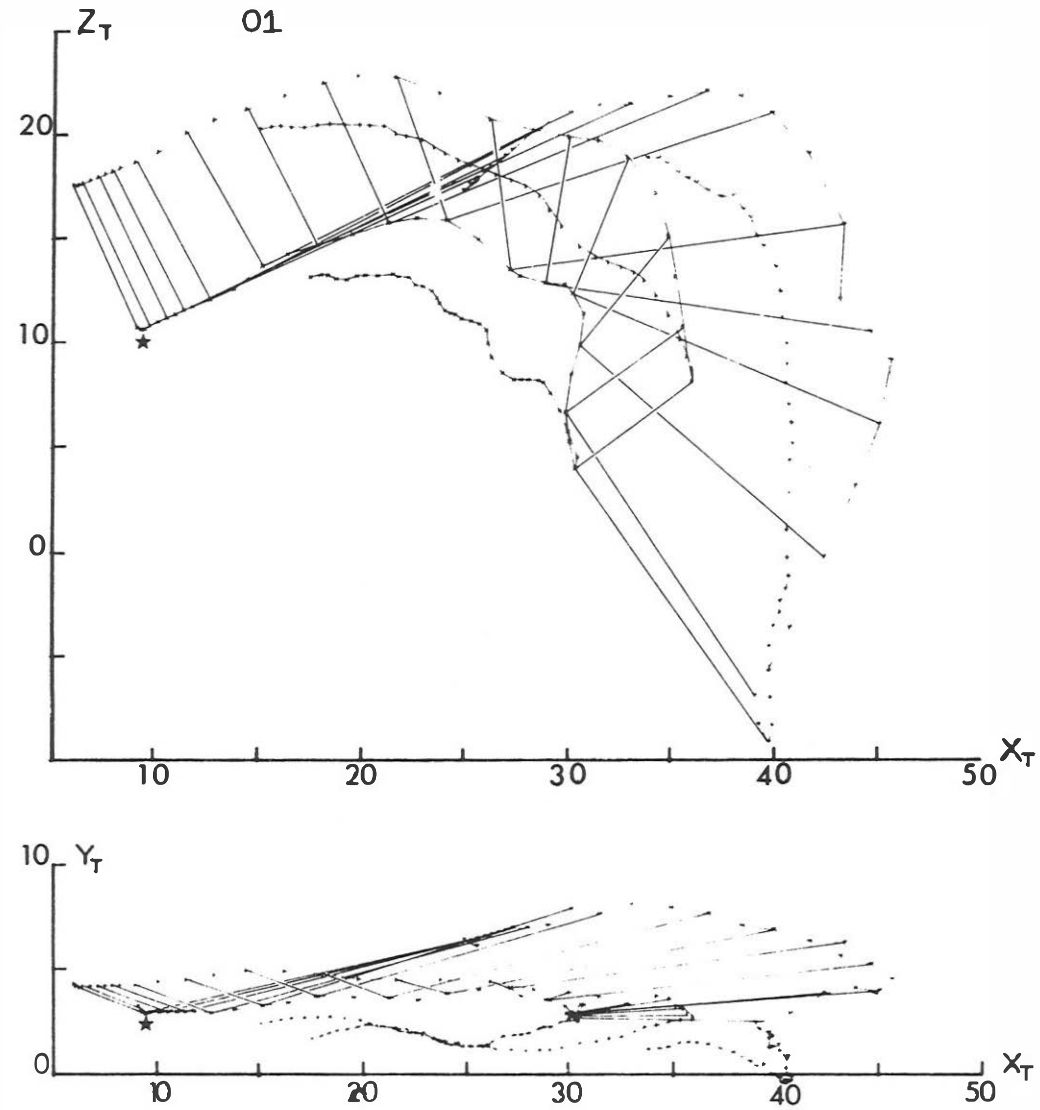
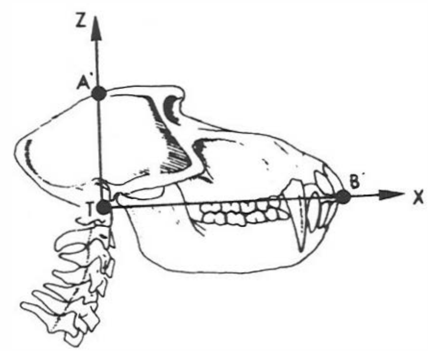
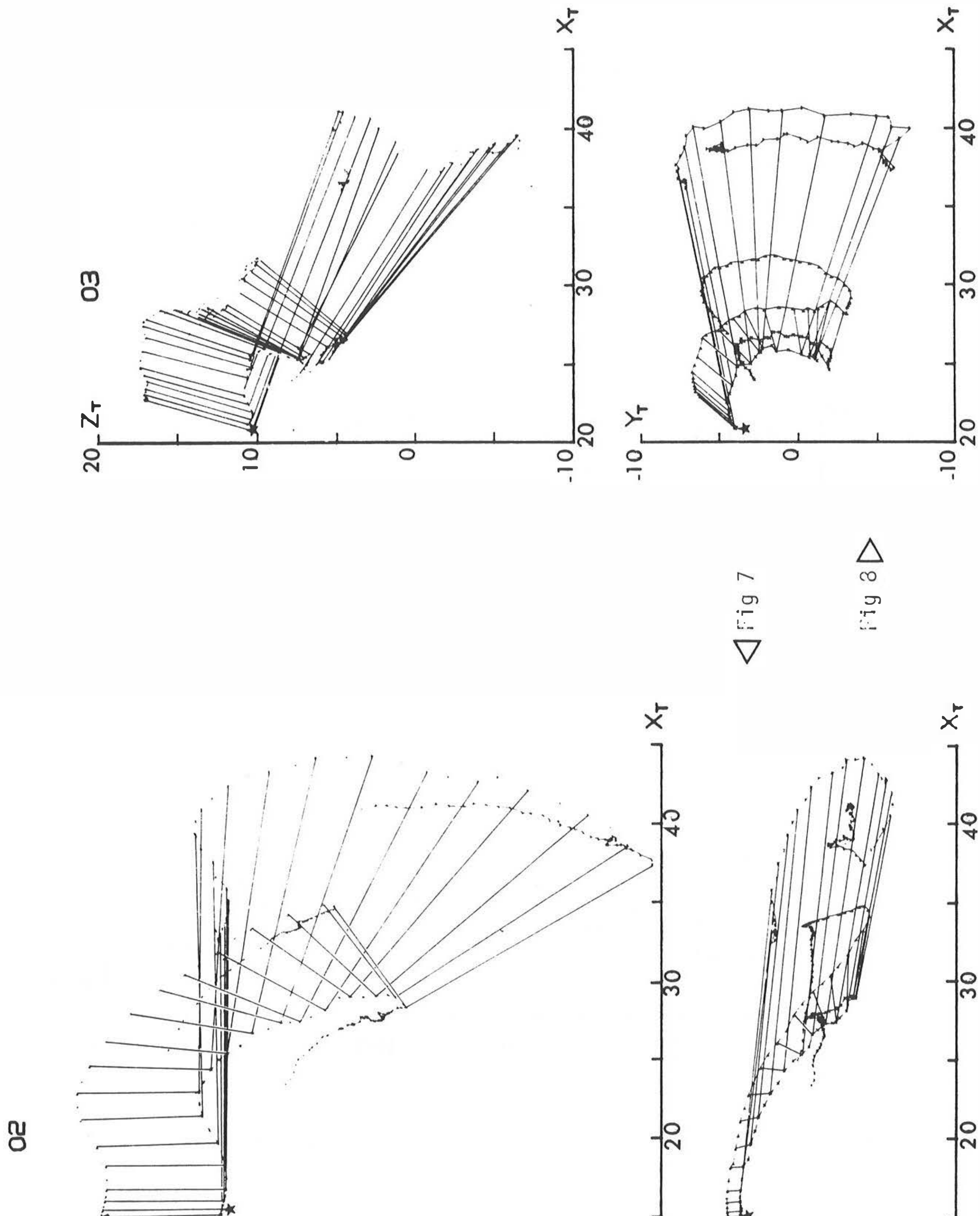


Fig 6

Left : ZX and YX projections of head points trajectories with respect to the seat (Test 01). The star indicates the position of the occipital condyle at t = 0. The time interval between two points of a curve is 3 ms and the segments TA' and TB' have been drawn every 6 ms until the maximum flexion point is reached (scales are in cm).

Down : Location of points T, A' and B' on the skull.





◁ Fig 7

Fig 8 ▷

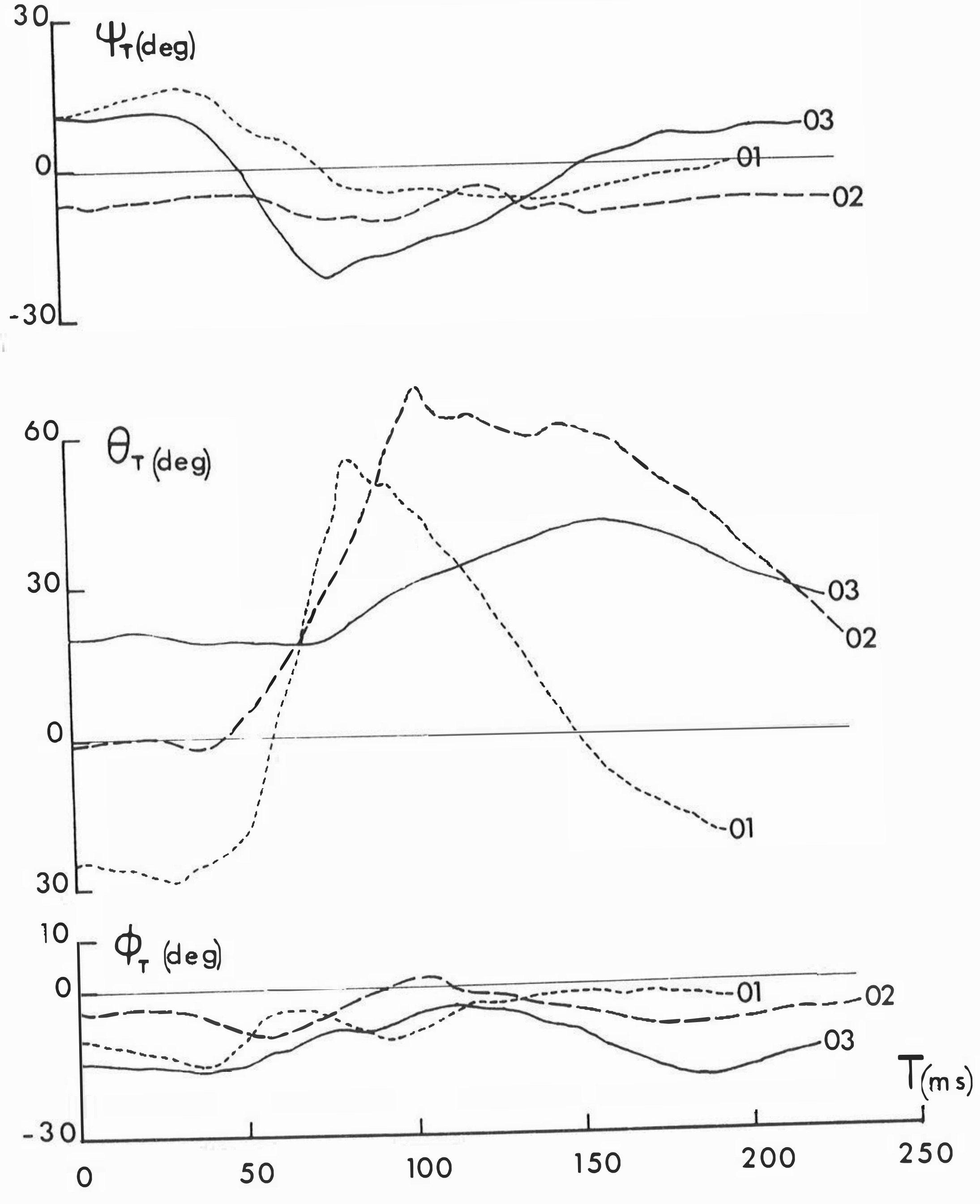


Fig 9 : Angular motion of head (yaw, pitch, roll) for tests 01, 02, 03.

the seat moves left ward. Since head motion is expressed with respect to a reference frame bound to the seat, it appears as a translation in the opposite direction of the vehicle's one.

The upward stroke of the head which can be seen on ZX projection at the beginning of the response (after 30 ms about) esp cially for test 02 could be explained in the same way as above by a downward translation of the vehicle due to a collapse of the floor but this has not been proved formally.

The curve of θ_T versus time for test 03 shows that head maximum flexion is quite small. To explain this, three facts can be put forward : first the very flexed initial position of the head ; second, the subsided position of the body in the seat for this test whereas the thorax restraint plate remains at the same place and ; third, the less crash severity with respect to the other tests.

CONCLUSIONS

1°) The non-symmetrical frontal crash differs from the symmetrical one by a marked yaw rotation component and a side ward shifting of the vehicle. These characteristics make this type of crash very difficult to simulate with a dynamic sled.

2°) The yaw rotation component of the vehicle has no effect on the head kinematics since it occurs too late and is still too small when the main head motion takes place.

3°) On the opposite, the side ward (Y) motion of the vehicle has a significant effect on the head kinematics, and with a less rigid restraint system than ours, such as belt restraint system, this effect must be much greater and must concern the entire body.

4°) The initial position and orientation are very important factors for the determination of kinematics, and this must be more effective for a passenger in a car because of the higher number of degrees of freedom.

5°) The pitch motion of the vehicle appears very soon. The vehicle rotates in the same time as the head does but the effect of this pitch on the head motion is not clear.

REFERENCE

CHAPON A., MARTIN F., VERRIEST JP., BIARD R. (1977)

Tridimensional cinematographic analysis of the head kinematics under lateral impact conditions

Proc. IRCOBI meeting - BERLIN, september 1977.