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Measurement of Head Angular Acceleration with a 15 Accelerometer Array.

by F.Bendjellal, X.Trosseille, D.Gillet,
F.Chamouard,
LPB-APR-France

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Abstract

This study deals with LPB-APR activities concerning the measurement of the head angular acceleration using linear accelerometers. A 15- accelerometer array was developed on the basis of internal or external studies. This paper presents a short summary of the work performed in 1988 as well as the testing program to be conducted in the future.

1 - Objectives of the study

The purpose of this research can be formulated as follows :

1 - Development of an accurate method for the measurement of the head angular acceleration in crash tests, with and without direct head impact.

2 - Application of 1 as measurement method to the Hybrid III dummy (development of a head mounting).

3 - Comparaison of different technics used for the computation of head angular acceleration.

2 - The existing technic for the computation of head angular acceleration.

Actually there is no method which allows a direct measurement of the head angular acceleration in crash tests. The existing technics are based on the same schema, although the calculation process and the accelerometer array differ. This schema involves the calculation of the head angular acceleration from measurements obtained from linear accelerometers. These technics are :

- the 3.3.3 method (N.M Alem-UMTRI)
- the N.1 method (D.Lestrelin-APR)
- the 3.2.2.2 method (Padgaonkcar-WSU)
- the On line Accelerometry (D.Viano -GM).

All these methods are detailly discussed in the literature and will not be discussed here. One of the objectives of this study is to compare these different methods using similar testing conditions.

3 - Work performed in 1988

A 15-accelerometer array was developed in 1988 by Gillet as a first prototype. Figure 1 shows this configuration with 4 triaxial accelerometers.
A photograph of this is presented in Figure 2.

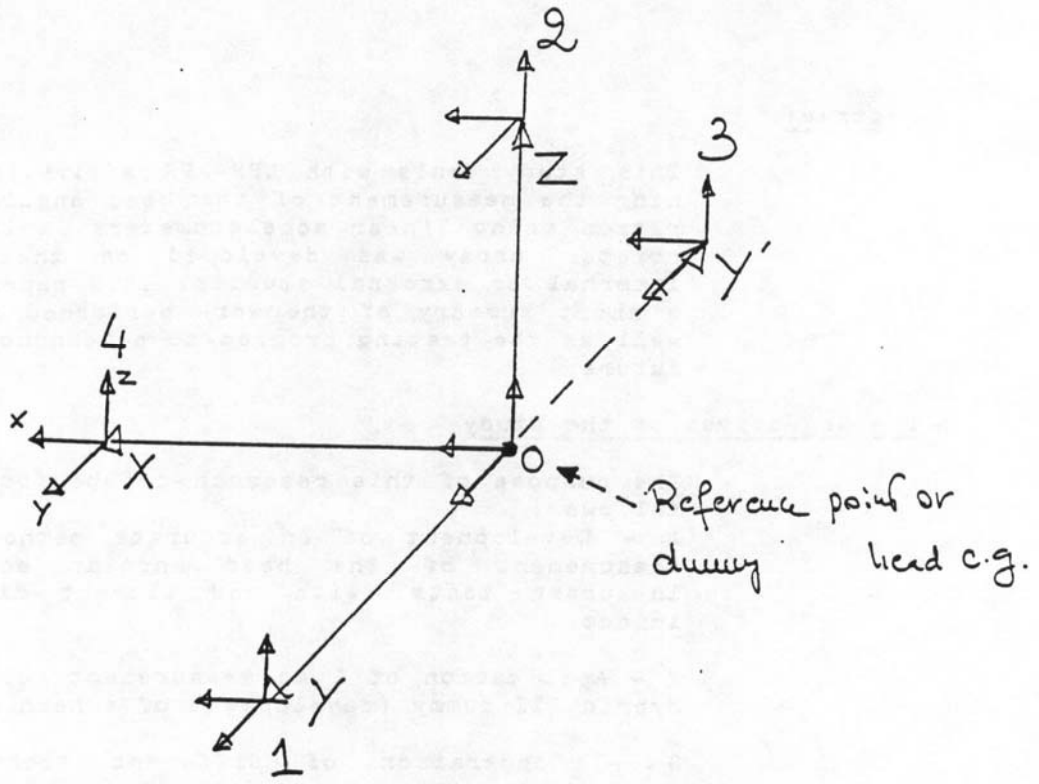

Figure 1 : A 15-accelerometer array

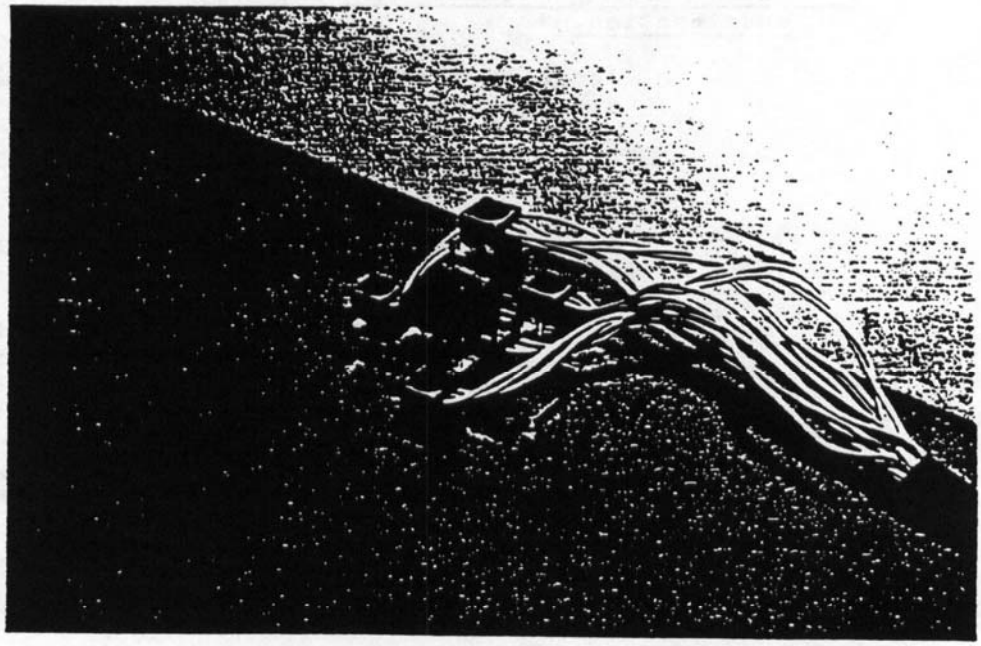

Figure 2 : The first prototype of the accelerometer mounting as developed in 1988.

This first prototype was evaluated under 3 different test conditions. These are :

A - A 14m/s sled test in frontal direction with a head impact using a Hybrid III dummy.

B - Two 7m/s frontal drop tests with and without head impact using a Hybrid III dummy.

C - Lateral sled tests with EUROSID and SID dummies in 7m/s neck biofidelity tests according to ISO DP 9790-2 specifications.

Results corresponding to the configuration B in no-impact head situation are presented respectively in Figures 3,4,5 and 6. The first figures, i.e. 3,4 and 5 present respectively the head linear acceleration, the head angular acceleration and the head angular velocity. The data were obtained using the 3.2.2.2 technics. The last figure N°6 shows a comparaison of the components of the moment vector acting on the Hybrid III head-neck interface obtained from the neck trans- ducer with those from the calculation process. As can be seen here, the results are satisfactory.
Further investigations have shown that the first prototype of the accelerometer mounting was subject to vibrations. The design was then improved and the new mounting is shown in Figure 7. This mounting was developed using the C.A.O technics.

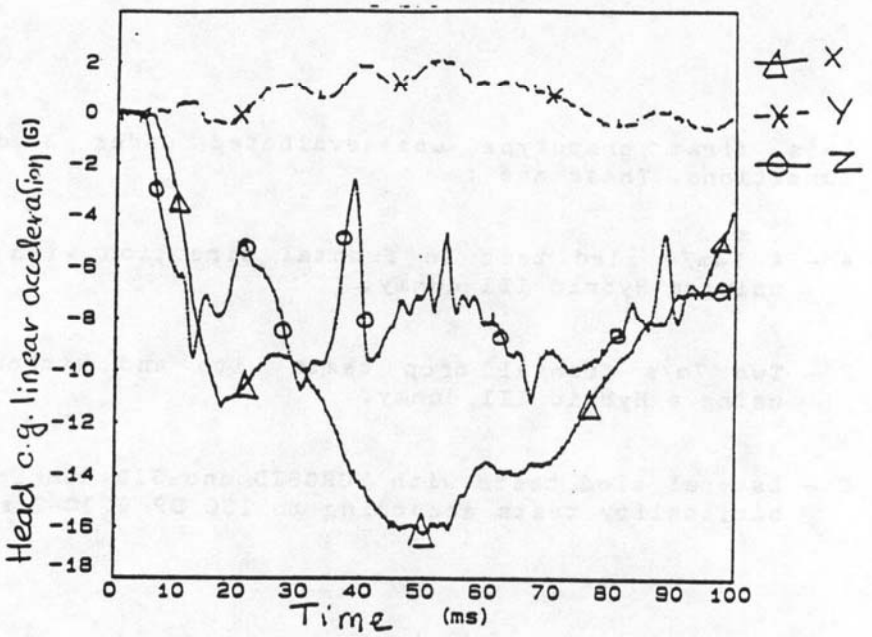

Figure 3 : Head linear acceleration time-histories obtained from a 7m/s drop test using a Hybrid III dummy (no head impact).

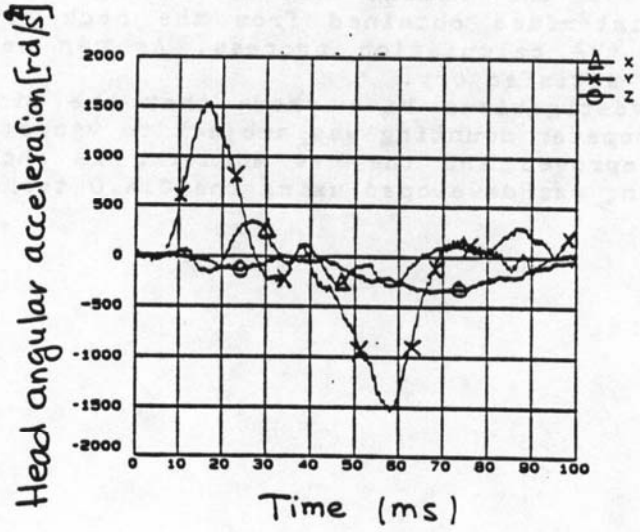

Figure 4 : Head angular acceleration time-histories. The components are expressed with respect to the head anatomical coordinate system.

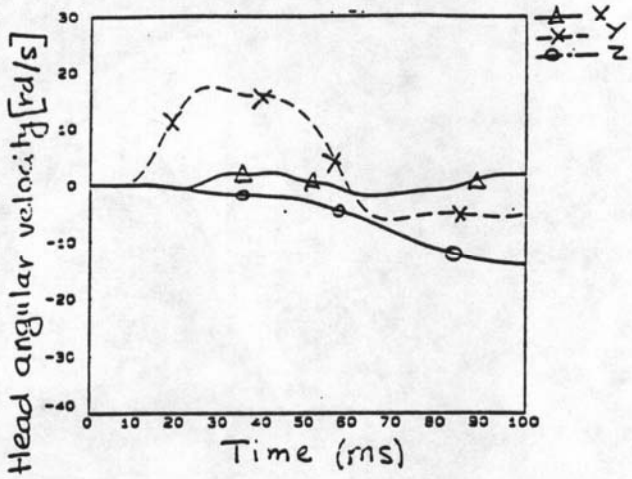

Figure 5 : Head angular velocity time-histories. The components are expressed with respect to the head anatomical coordinate system.

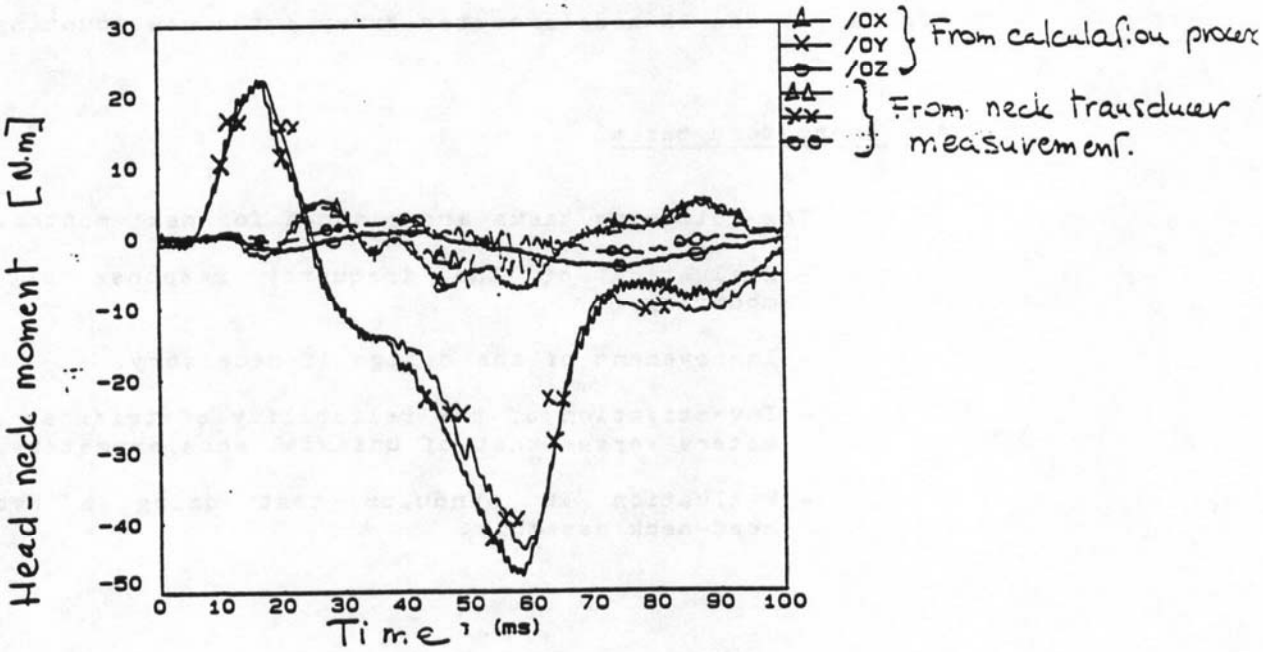

Figure 6 : Comparison of head-neck moments obtained from the calculation process with those provided by the Hybrid III neck instrumentation.

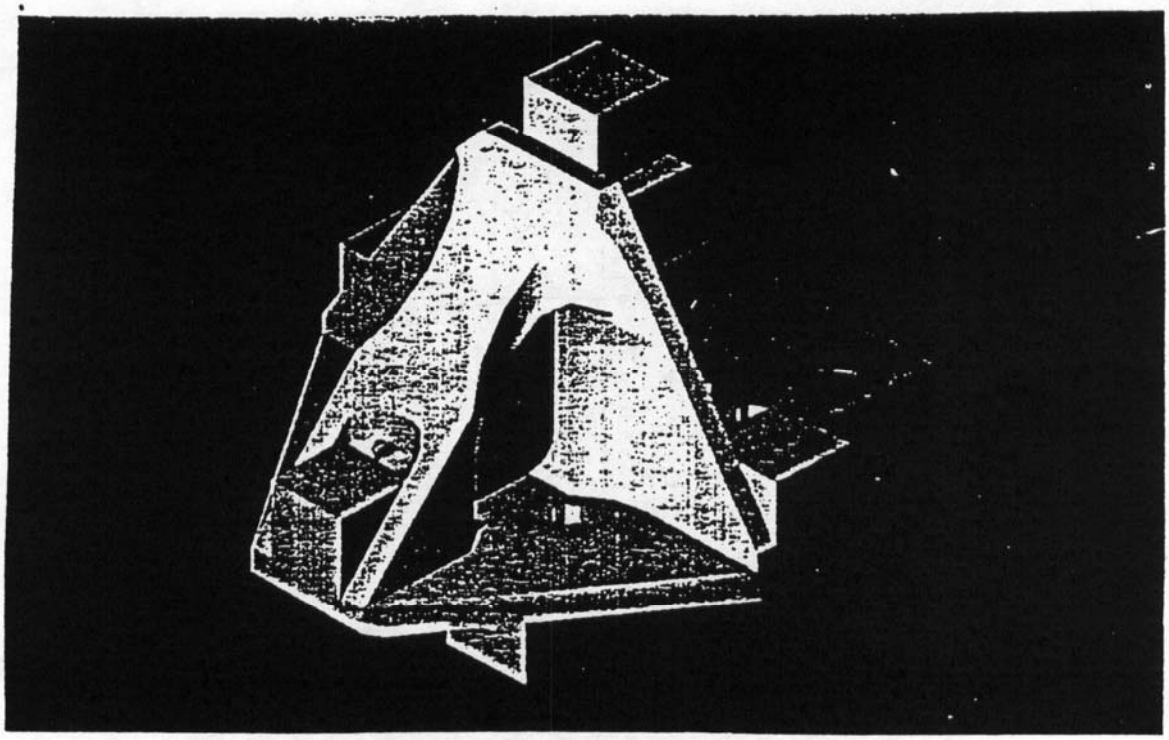

Figure 7 : The 15-accelerometer array : the new mounting system.

4 - Short term tasks

The following tasks are planned for next months.

- Evaluation of the frequency response of the new mounting.
- Improvement of the design if necessary.
- Investigation of the reliability of triaxial accelerometers versus that of uniaxial accelerometers.
- Evaluation in pendulum test using a Hybrid III head-neck assembly.

DISCUSSION

PAPER: Measurement of Head Angular Acceleration with a 15 Accelerometer Array

SPEAKER: Forit Bendjellal, Association of Peugot Renault

Q: Terry Smith, Biokenetics

I'm asking your opinion about whether you think this may be a more accurate technique of determining angular velocity or angular acceleration as opposed to your 15 accelerometer array?

A: Bendjellal, APR

Before last year, our experience was concentrated on the measurement of head angular acceleration using specific instrumentation developed for cadavers. Following that we felt the need to apply this knowledge to the Hybrid III dummy. It is difficult to say what is the best method because the 333 method is accurate, but inverse; a different step of integration, including the head angular acceleration and head angular velocity. The 3222 method is very simple since you get the head angular acceleration directly from the judicious location of the accelerometer. Now, David Viano's method is an elegant method but I have no experience with that. Theoretically this is very elegant, but we need to apply it and see. For the moment, let's say 333 and 3222 are well known. I prefer 3222.

Q: But these devices are designed to specifically measure angular velocity. So then would you simply differentiate to get your angular acceleration component?

A: Yes.

Q: Don't you think that step, simply isolating to three angular velocemeters, would perhaps be easier to manage than, say, a 15 accelerometer system?

A: I'm not sure if I understand your question.

Q: Here in North America, instrumentation is being developed to measure angular velocity directly. I would ask your opinion as to whether you think this could be a more accurate or better direction to go in as opposed to using the 15 accelerometers.

A: We are searching. The reason why we have the complicated 15 accelerometer array is that no precise instrumentation is available and I'm afraid that your instrumentation, even though available, may have to be tested.

Q: John Melvin, General Motors Research Lab

I'd like to make a few comments: With respect to the differentiation of angular velocity data, you have to be worried, of course, if any oscillations in the tranducer will show up as a large angular acceleration when it may not be. Also, mass is a problem. I think that with many of these devices, there's not a lot of room inside the head to do this and at least the accelerometers are small.

I'd like to comment on a the design that you propose, and what we've found with our inline system and the block that we showed at the STAPP Conference two years ago. Because it is mounted on top of the six-axis neck load cell, you can get into resonance problems and you're really never going to get rid of them as long as you use that neck load cell. It may be a mistake to hang a lot of weight on the top of that neck load cell. We've seen ringing at about 1100 Hertz, which is not a particularly good frequency to have in your head impacter. Beware, your structure looks very stiff, but it may be mounted on something that may give you trouble.

A: One of the first steps after the design is to evaluate the frequency response of this mount with and without accelerometers.

Q: Make sure you bolt it to the neck load cell because that's what it mounts to in the dummy. You have to consider its structural features also.

A: Yes.