Guidelines for a new European standard proposal for impacts of motorcyclists vs. road infrastructure.

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EXECUTIVE SUMARY

This deliverable is a result of the task 4.2.3 ‘Proposal of a new standard’, in WP 4.2 ‘Motorcyclists vs. road infrastructure’ of Aprosys SP4 ‘Motorcyclists accidents’. It is one of the objectives of this WP to develop a proposal of test procedures to evaluate road infrastructure in terms of motorcyclists’ safety.

For that purpose, a prior work has been carried out in order to know the most representative configurations of accidents involving motorcyclist impacts against infrastructure. Aspects such as impact angles, trajectories, distance of sliding on the carriageway, injuries, etc, have been investigated to define the better impact conditions to be contained in the standard proposal.

Although most of the information used comes from MAIDS project database (‘In-depth investigation of motorcyclist accidents’) and DIANA (in-depth accidents database developed by CIDAUT), also a literature review has been done to obtain some data related to other accident studies and related to motorcyclist tests which are being performed in different countries.

From the database analysis, no conclusive results have been obtained. A theoretical study and computer simulation works have been performed in order to select the set of parameters (incidence angle, impact speed…) to be used or recommended in the standard proposal. This study is fully described in deliverable D4.2.1.A and Annexe I.

In the end, an impact angle has been chosen and a minimum impact speed has been recommended, after having demonstrated that the injury severity provoked in that configuration is close to the injury level provoked in real accident conditions.

This document describes the testing procedure to be followed to assess the performance of road furniture in terms of motorcyclists’ protection. The standard is applicable to the scenario in which a motorcyclist slides on the ground and impacts against the road element.

NOMENCLATURE

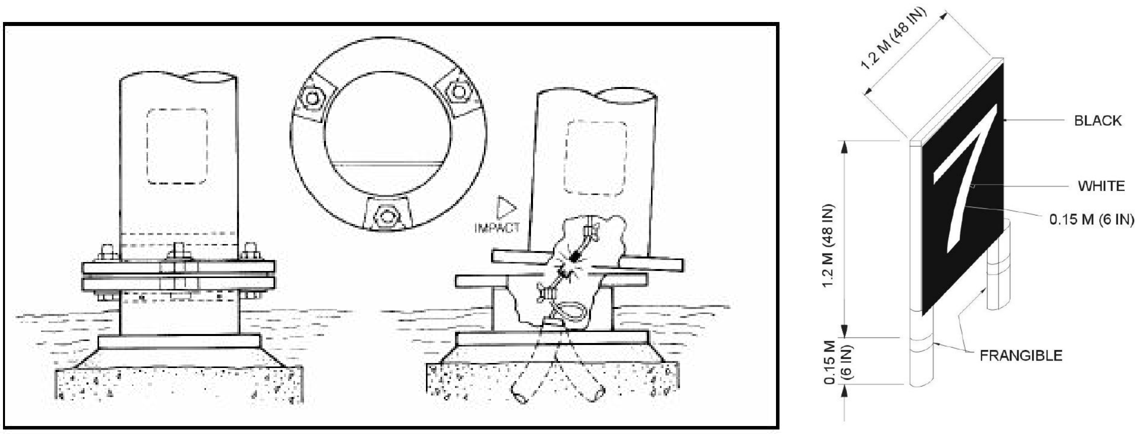
Motorcyclist protection system (MPS) is defined as a system installed on a roadside obstacle (on a barrier, street lamp, etc) or around the area close to this obstacle or included properly in the obstacle in order to reduce the impact severity on the motorcyclist body in case of an impact against the obstacle. The system could work absorbing the kinematic energy, guiding the motorcyclist body to a clean-safety area, breaking away the system or the obstacle without body injury,…, or any composition of them.

In the general state of the art, motorcyclist protection systems who guide the motorcyclist body to a clean-safety area while absorbing partially the kinematic energy allow higher impact speed than full-absorbing systems who do not guide. For example, in the Spanish Standard: ‘Evaluation of the behaviour of the systems for protection of motorcyclists in the barriers of security and parapets’, a guided system is a continuous MPS metallic barrier (Figure 1) and a non-guided system is a punctual MPS on the post of a metallic barrier (Figure 2).

Figure 1 - Continuous MPS metallic barrier.

The frangible systems are usually frangible obstacles when they have the frangible device inside them as a part of their structure (Figure 3). Frangible obstacles are systems that break away themselves when they are impacted by errant drivers. These systems have design limitations because the obstacle in the most of the cases must to pass other standards, like EN-40 about the rigidity of the system in order to resist the air when it blows for example. For that reason, they should be used in minor traffic signals in case of motorcyclist safety, (Figure 4).

Figure 2 - Punctual MPS metallic barrier.



(A) (B)

Figure 3 - Frangible obstacles: A) Frangible street lamp for errant car drivers and B) Frangible road panel.

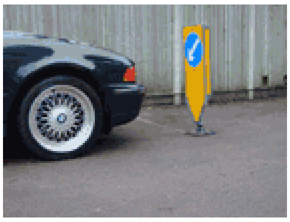


Figure 4 - Frangible obstacle: Minor traffic signal.

Approximation angle is the angle between the trajectory shown by the impact speed vector (approximation trajectory) and the longitudinal line axis of the traffic lane or the longitudinal line of the protection system for continuous systems. The longitudinal axis of the dummy and the approximation trajectory defines the position angle.

Impact angle is the angle formed by the dummy's longitudinal axis and the longitudinal line of the road or the longitudinal line of the protection system for continuous systems.

The working width (w) is the distance between the face of the safety barrier or bridge parapet with MPS nearest to the traffic before impact and the farthest lateral position or any part of the safety barrier or bridge parapet with MPS or the dummy reaches during impact. In case of punctual obstacles, working area is defined as the clean-safety area needed in order to permit the performance of the system in a good way without any other obstacle that could disturb its operation.

Safety area is the clean-obstacle area where dummy stops after the first impact against a punctual obstacle or combination of them with or without MPS. In case of punctual MPS installed on a barrier, the concepts of safety area and working area are not applicable and working width terminology has to be applied.

1. INTRODUCTION

It is widely known that infrastructure constitute a particular hazard to motorcyclists. Ideally, motorcyclists wish to have clear zones close to the road, but this type of areas adjacent to the traffic lane, that should be kept free from features potentially hazardous to errant vehicles, are impossible in the most of the cases.

Where economically viable, the clear zone should be kept free of hazards. Alternatively, hazards within the clear zone should be treated to make them safe or be shielded by a safety barrier. The last ones give a solution for errant car drivers but they can provoke serious injuries to motorcyclists when they are not designed specifically for motorcyclist or they do not include a specific motorcyclist protection system, MPS.

The following paragraph identifies hazards that may be found in the roadside environment and possible treatments to reduce the risk of these hazards to motorcyclists. For the purpose of hazard identification, the types of hazard that may be encountered in roadsides can be divided into five broad categories:

- rigid objects as trees, utility poles, etc.
- cross median crashes
- embankments
- open drains
- bodies of water in case of injuried motorcyclist (unconscious, for example).

Depending on the physical, environmental and economic constraints, the preferred treatments of roadside hazards, in order of preference, are:

1. removal
2. relocation to reduce the chance of them being hit
3. redesign so that they can be safely traversed
4. redesign to make them frangible
5. shielding with a traffic barrier or impact attenuator
6. delineation of the hazard.

In the case that roadside hazards cannot be removed or relocated, the solution involves to work on the object that causes the hazard. The current proposal standard tries to cover this work. From point three to six, the methodology evaluates the motorcyclist safety when these kinds of obstacles are installed in the roadside.

On the other hand, representative impact conditions and biofidelic dummies with associated injury criteria for these particular impacts are needed for the development of a crash test proposal. For that reason, an analysis of different databases and a literature review have been performed to gain knowledge of the parameters involved in accidents of motorcyclists against roadside infrastructure.

In summary, the typical impact scenarios against road infrastructure are based on high velocities (above 50km/h), shallow impact angles and upright riding position as well as sliding after separation from the PTW. As far as the content of the analysed databases allows to look at injuries, head, thorax and lower extremities seem to be the most commonly injured areas by such impacts.

The followed studies are examples of the type of information used to develop the guidelines for the standard proposal.

1.1 Barrier testing procedures

Several testing procedures have been developed in order to give reproducible results for the evaluation of roadside barriers and additional protective devices. Three different situations can be identified: motorcyclist sliding alone, motorcyclist and his motorcycle sliding together and motorcyclist impacting against the barrier while driving the motorcycle.

For example, Quincey et al [1] developed a testing procedure in order to analyze the injury risks or motorcyclists when impacting different barrier types. The dummy was ejected from a moving platform, laying on the back and was sliding alone for 2 meters before impacting the barrier with the head forward at a speed of 55 km/h. The angle between the longitudinal axis of the dummy and the barrier was 30 degrees.

The 'Institut National De Recherche Sur Les Transports Et Leur Sécurité' (INRETS) defined an experimental test of motorcyclist impacts against metal barriers which has been carried out by the 'Laboratoire INRETS d'Équipements de la Route' (LIER) [2]. The test is based on the consideration that 'when a motorcyclist has an accident in a bend, the vehicle skids and the motorcyclist falls'. After that, the motorcyclist slips on the roadway following a straight trajectory, runs off the roadway and impacts against an obstacle. The test consists of launching a Hybrid III dummy against the metal barrier with an impact speed of 60 km/h and an impact angle of 30º. The dummy slips on its back and with the head towards the barrier.

The Spanish standard (UNE 135900) 'Evaluation of the MPS behaviour of the systems for protection of motorcyclists in the barriers of security and parapets' was defined in 2005 [3]. This standard defines the methods that allow the assessment of motorcyclist protection systems' (MPS) performance. The Spanish standard defines an impact speed of 60 km/h and depending on the kind of system to be tested (punctual -SP- or continuous -SC-), a different trajectory is performed:

- Trajectory 1 – Post centred impact: Applicable to punctual and continuous MPS (Figure 5).

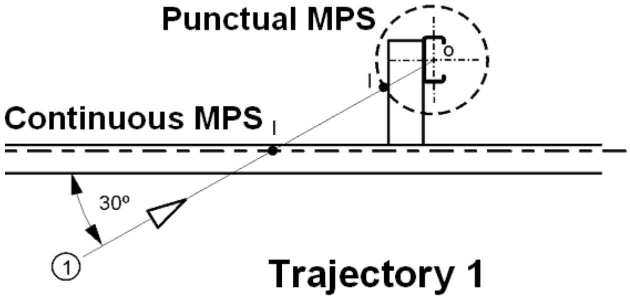


Figure 5 - Trajectory 1: Post centred impact

- Trajectory 2 – Post off-centred impact: Applicable only to punctual MPS (Figure 6).

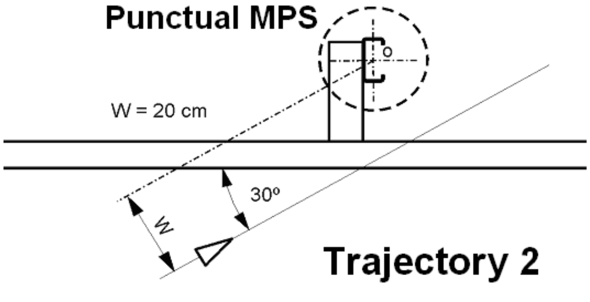


Figure 6 - Trajectory 2: Post off-centred impact

- Trajectory 3 – Mid-span centred impact: Applicable only to continuous MPS (Figure 7).

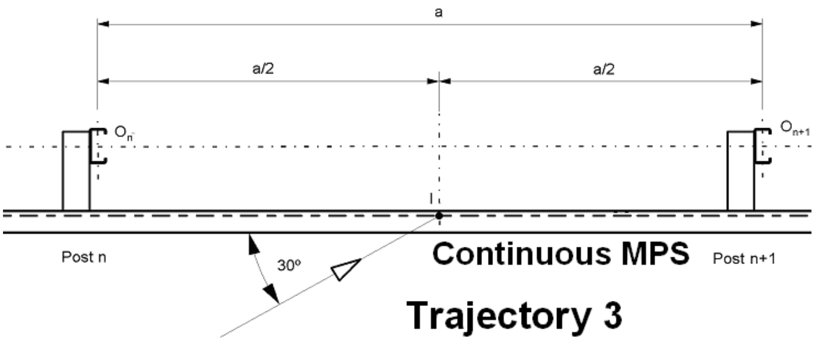


Figure 7 - Trajectory 3: Mid-span centred impact

These three studies are based on the case of a motorcyclist sliding alone. The other two situations were analyzed by BASt based on a statistical study with few cases [4, 5]. One of the BASt tests carried out by DEKRA consists of launching a motorcyclist dummy on its motorcycle, sliding on the ground, with an impact speed at 60 km/h and an impact angle between 12º and 25º. The other one consists of launching a motorcyclist dummy on its motorcycle in an upright driving position. In both cases, motorcycle influence is very important in the results. In the case of upright position, lower extremities are the most usual injury when a motorcyclist impacts against a barrier on the motorcycle. Depending on the clearance zone behind the barrier -barrier installation normative- and the shape of the upper end of the barrier -design suggestions-, it is possible to avoid amputated extremities.

To sum up, this proposal explains the case about a motorcyclist sliding alone when impacts against an obstacle.

1.2 Other studies based on all types of collisions.

A reviewed analysis was carried out within the COST 327 project [6]. Angles were related to the part of the body which was injured. As for impacts with head injuries, the study indicates that nearly 60% of the 253 cases of serious head injuries took place with impact angles equal to or lower than 30º. Regarding neck injuries, the angle was equal to or lower than 30º in 42% of the cases. The impact speed of 60 km/h is the average impact speed of all the accidents where head injuries of motorcyclists occurred. For the accidents in which the motorcyclist' neck was injured, the average impact speed was equal to 56 km/h.

The University of Heidelberg performed impact tests using cadavers with a speed of 33km/h against IPE 100 and sigma posts [7]. The crashtest with a cadaver against an IPE 100 post without a crash-absorber resulted in AIS 3 level, because it provoked the amputation of the upper arm and as a result it provokes the death in few minutes by the loss of blood.

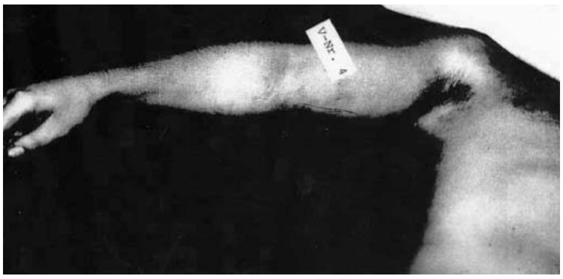


Figure 8 - Test performed on IPE 100 post in Inst. f. Rechtsmedizin der Universität Heidelberg

The Hurt study [8] was a detailed study of 900 motorcyclist accidents in the area of Los Angeles. In this study, the motorcyclist average travelling speed was 48 km/h, while the average impact speed was 35 km/h.

Otte studied 876 motorcyclist accidents during the period 1985-1995 in the region of Hannover (Germany) [9]. It shows collisions with an impact speed lower than 50 km/h because all type of collisions are included.

Finally, other two motorcyclist accidents studies establish the following ‘impact speeds’: 39 km/h for the study carried out in the United Kingdom by Whitaker [10]; and 51 km/h for the study carried out by Mooi and Galliano in 1999 over 23 motorcyclist accidents [11].

2. OBJECTIVE AND APPLICABILITY

2.1 Objective

In Aprosys SP4 ‘Motorcycle accidents’, one of the main objectives is to define the guidelines for a test procedure aimed at evaluating road infrastructure in terms of motorcyclists’ safety.

The proposal standard is based on the consideration that ‘when a motorcyclist has an accident in a bend, the vehicle skids and the motorcyclist falls’. After that, it is assumed that the motorcyclist slips on the roadway following a straight trajectory, runs off the roadway and impacts against an obstacle.

The test consists of launching a Hybrid III dummy against the obstacle with a defined impact speed and an impact angle of 30º respect the traffic lane. The dummy slips on its back and with the head towards the obstacle.

The proposed standard should identify whether a motorcyclist protection system is valid or not with regard to its objective. For this goal, the behaviour of the dummy should be one part of the acceptance criteria and the behaviour of the safety device should be the other one.

3. DUMMY CHOICE AND ITS MODIFICATIONS

3.1 Hybrid III dummy

Once the configuration (see section 2.1) has been proposed, it becomes necessary to look for the requirements for the dummy selection. The requirements of this procedure are that the dummy travels sliding on the ground by itself and hits the protection system to be tested with a trajectory angle of 30º.

Post mortem human surrogate (PMHS) data are not available and neither is a physical dummy specially designed to be used in the proposed configuration. For these reasons, a careful dummy selection is a critical task. The use of Eurosid and other dummies are not considered because a hip making possible a straight dummy position is not available for these dummies. Such a special hip exists only for the Hybrid III and is called kit pedestrian. There are other reasons which make not advisable the use of these dummies, for example, situations in which lateral dummies are weak in several impact cases. A straight or standing position is recommended for repeatability reasons, in order to launch the dummy in a stable way.

The best option is the Hybrid III dummy, although its biofidelity has needed to be further assessed for this particular application. The Hybrid III 50th Percentile Male dummy (Title 49, CFR Part 572, Subpart E) will be used, equipped as follows:

- Kit pedestrian that allows a standing position,
- Neck bracket in -7º position,
- Both original clavicles will be changed by frangible clavicles which are described in the 3.2 section,
- Neck foam, reference 1039006.

3.2 Dummy shoulders with controlled breakage.

The Hybrid III dummy was designed for frontal impact testing. However, as the dummy is not biofidelic in lateral loading, the measurement results may be misleading. As a first step to improve the biofidelity for a sliding impact of a motorcyclist into obstacles, it is proposed to use frangible shoulders for the following reasons:

- The Hybrid III is designed initially for different test conditions.
- A rigid impact causes the measured values to be distorted in comparison with reality.
- One clavicle whose breakage is not controlled can vary the movement of the dummy during the test.
- Other potential fractures cannot be quantified.
- A frangible shoulder reduces the risk of expensive parts replacement.

Such a shoulder fracture has already been reported by Buerkle and Berg [12]. The Spanish impact standard also considers a modified shoulder for the Hybrid III, but only in one side.

Inertial moments and weight are not changed significantly from the original dummy and its failure is aiming at reproducing with more accuracy the behaviour of the human clavicle. It is possible to say that in 80% of the cases the clavicle fracture happens in a third of way along its length. On the other hand, it has to be remarked that the breakage of clavicle is not considered serious in terms of injury severity, and is valued as an AIS2 injury in agreement with Faverjon (1994).

From what has been previously explained, it seems logical to estimate that the impacts are more likely to happen on the shoulder and the first third of the clavicle next to the shoulder. Impacts closer to the neck are understood as a hooked part of the body and have to be avoided.

The clavicle parts of the dummy are shown in Figure 9. The weakest parts of the assembly of the dummy clavicle are the two pieces shown in the upper part of Figure 9 and they break close to the place where usually breaks the human clavicle. The resistance and rigidity of these pieces are modified in order to the dummy clavicle breaks at the same level of load that a human clavicle.

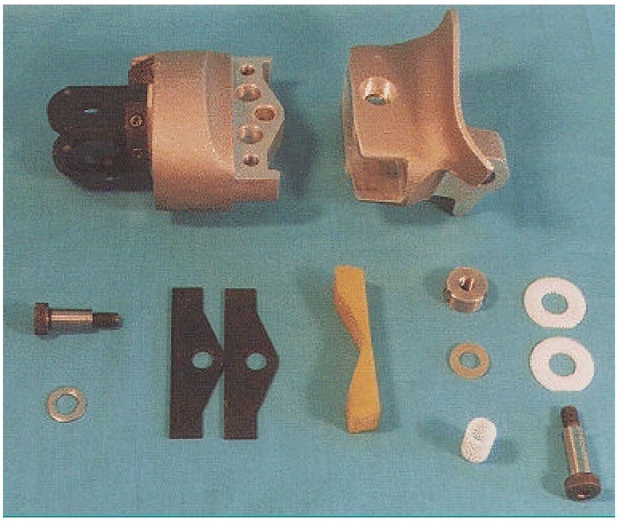
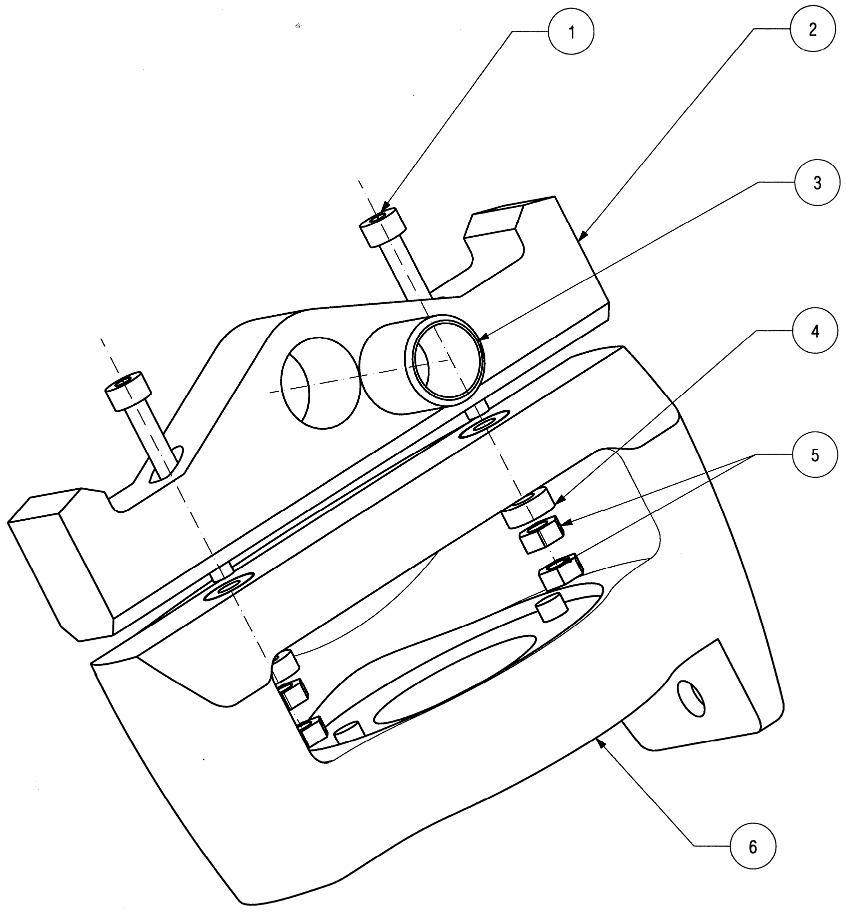


Figure 9 - Original dummy clavicle.

The determining factors to be taken into account to fulfil the breakage of the dummy clavicle are, from one side, the bone's properties and geometry and, on the other hand, the lack of muscles in the broken area. Once the parameter for the clavicle breakage has been obtained, the fusible piece has been designed using computer simulation tools, taking into account that weight and dynamic characteristics of the modified piece have to be the same than in the original piece. After a series of simulations tests, a result is found with a dispersion of 3.3 %, less than 5% requested by the ISO13232 [13] for the frangible femur average breakage force.

Each frangible shoulder bone shall be installed together with two shoulder retaining cables to prevent the loss of portions of the dummy arm when the frangible shoulder bone fractures. The cable diameter is 4 mm for each frontal and back side cable joined to the two pieces shown in the upper image of Figure 9 by screws M8 8.8 with a washer and its nominal failure force 957 Kp ± 10 %. The cables shall be installed with 20 mm to 30 mm of slack along the clavicle axis.

In summary, left clavicle (reference is 78051-141) and right clavicle (reference 78051-142) will be changed by modified clavicles from the original as the drawing shows in the case of left clavicle from Figure 10 to Figure 14. Right clavicle is symmetrical to the left one.



Brand	Denomination	Commercial Ref.	Drawing No.	No. of Parts	Material	Dimensions
6	PART B		1	1	ALUMINIUM	
5	NUT	M4 - DIN 934 - 8		4		
4	WASHER		2	2	F 1140	
3	BUSH		3	1	PVC	
2	PART A		4	1	AA5083	
1	SCREW	M4 X 35 - DIN 912 - 8.8		2		

Revisions
Author
Date
R1 No.

Treatment:
General Tol.
UNE 22768-mK
Scale
1:1
Denomination
ASSEMBLY
UNE 1032
Date
Name
Drawn by
Approved by
UNE 22553 (If the opposite is not indicated in welded unions)
z
z = plate thickness / 2
UNE 1037
= N9

Figure 10 - Drawing of fungible left shoulder set

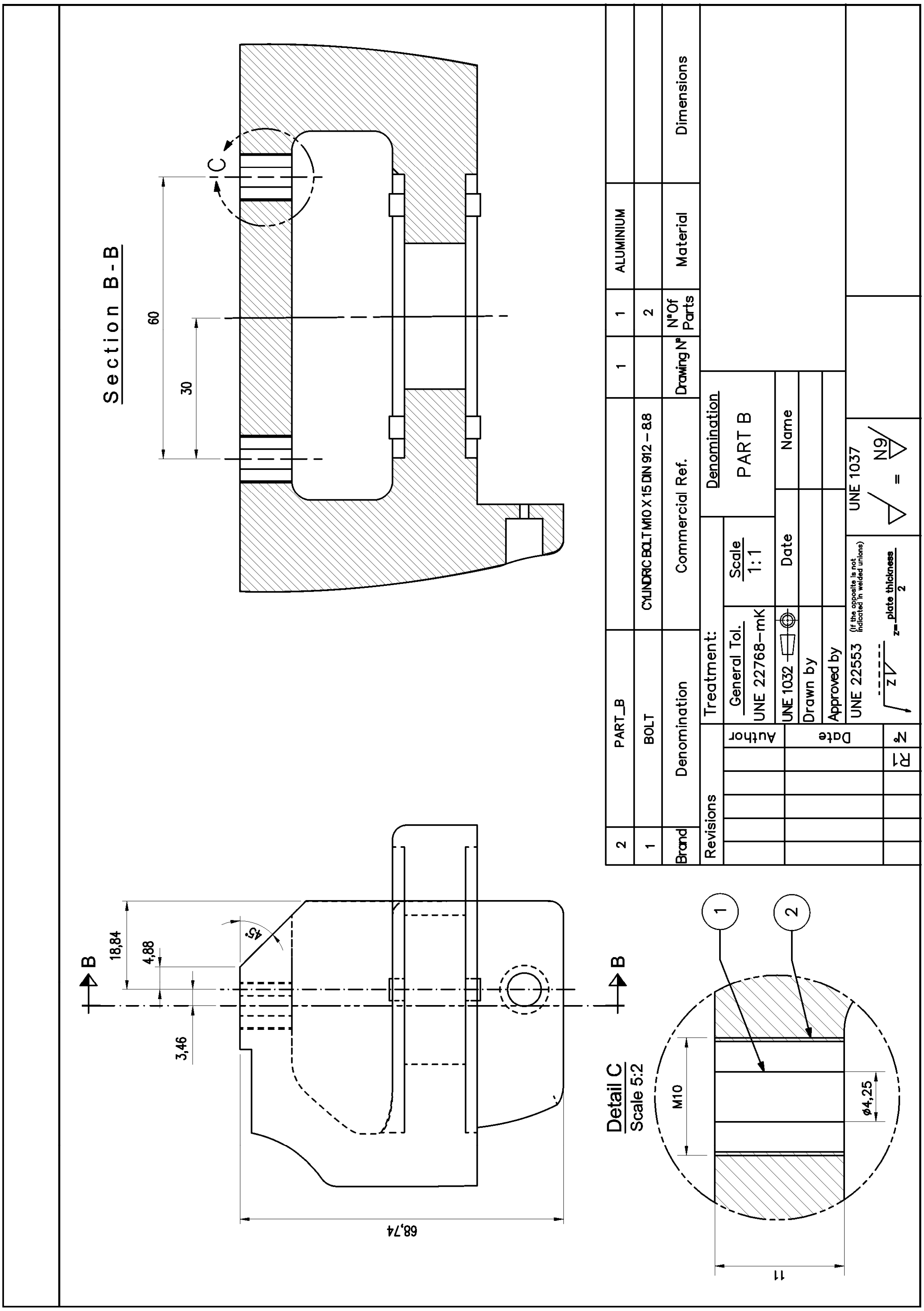
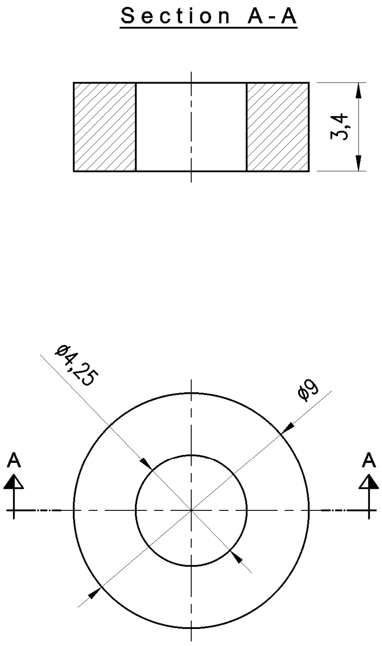


Figure 11 - Drawing of the original left side part and its modifications



	WASHER			2	F 1140	Ø9 x 5
Brand	Denomination	Commercial Ref.	Drawing N°	N°Of Parts	Material	Dimensions

Revisions
Author
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Treatment:
General Tol.
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Scale
5: 1
Denomination
PART B
UNE 1032

	Date	Name
Drawn by		
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UNE 22553 (If the opposite is not indicated in welded unions)
Z
z= plate thickness / 2
UNE 1037
= N9

Figure 12 - Drawing of the washer

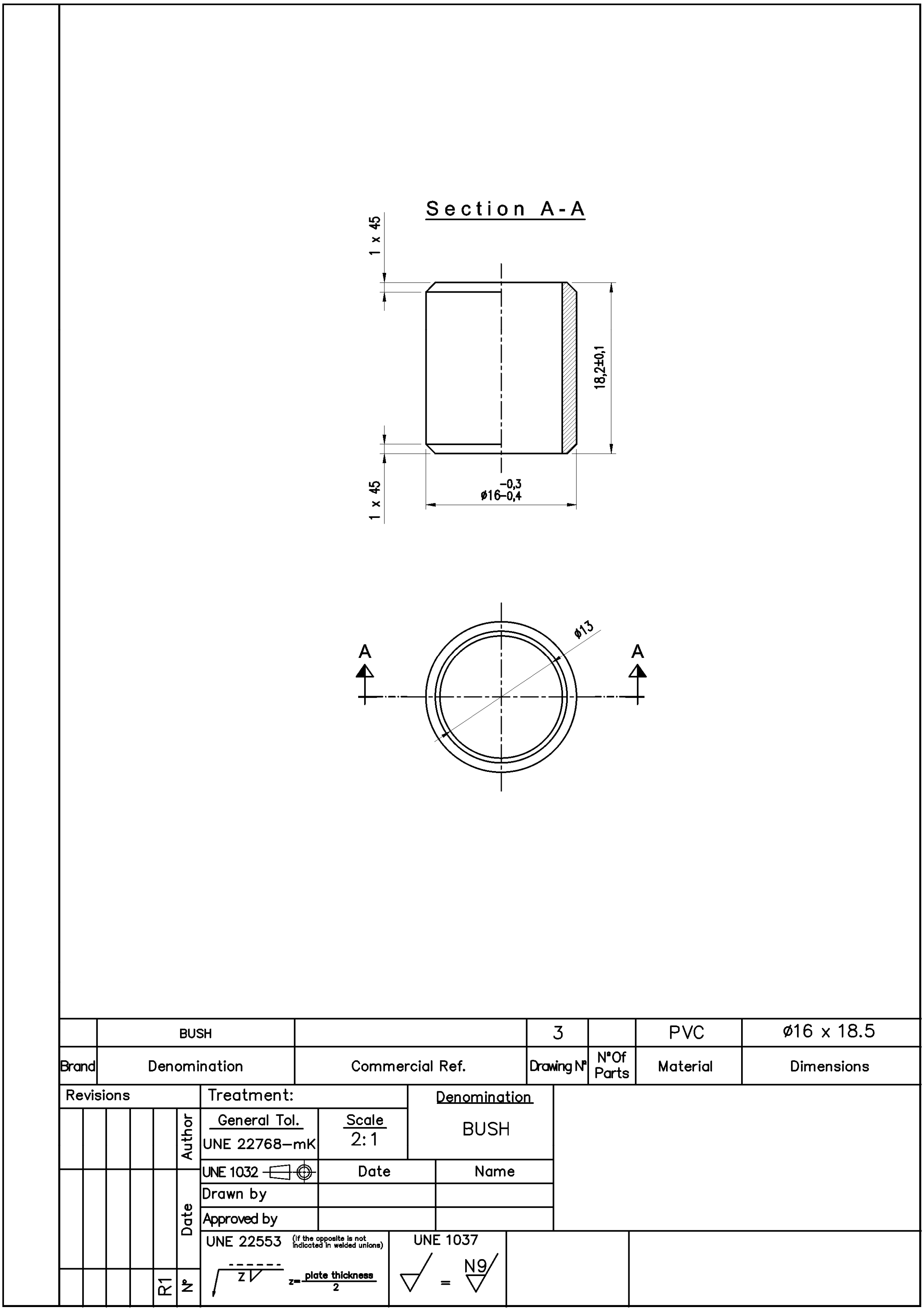


Figure 13 - Drawing of the bush

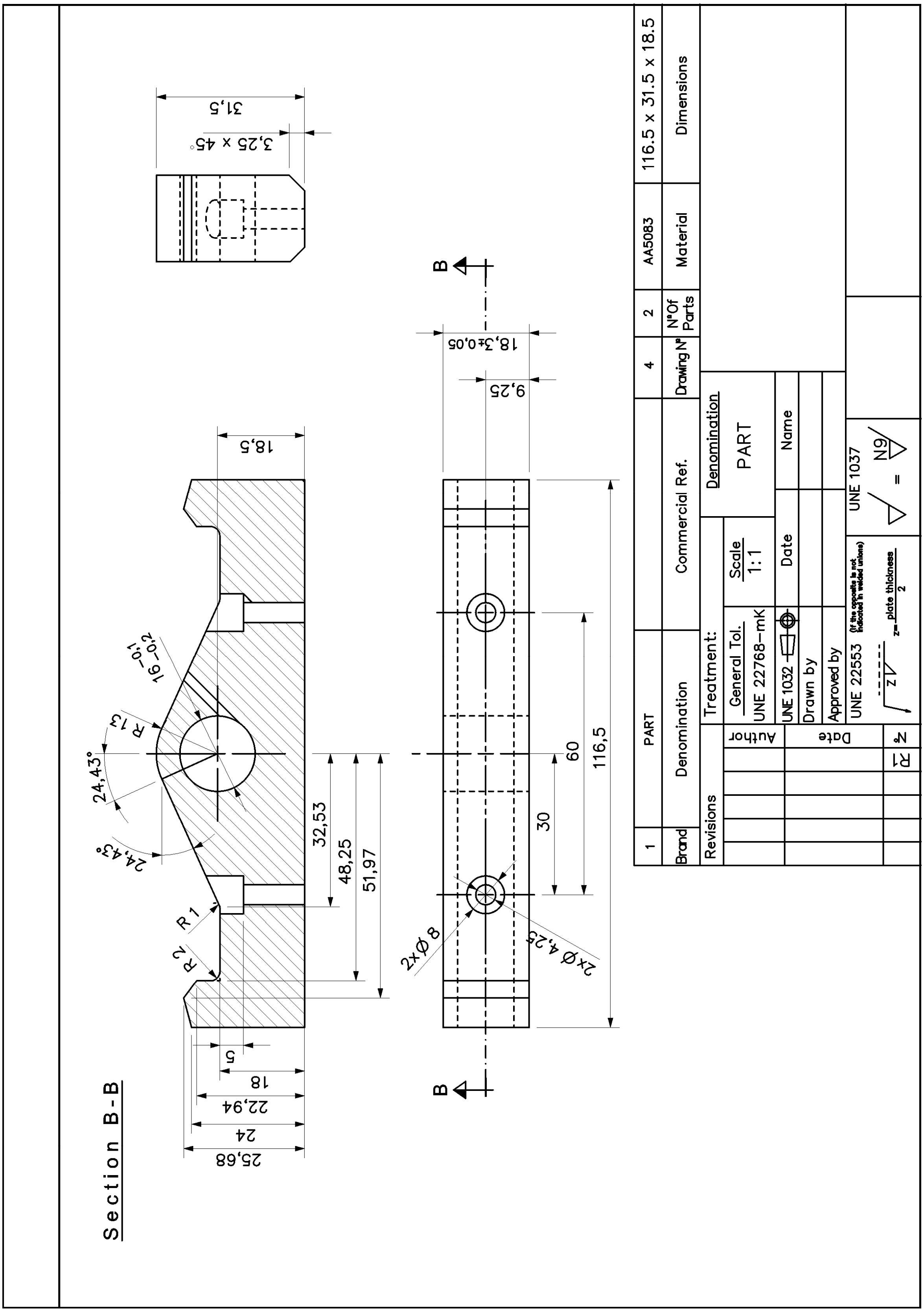


Figure 14 - Drawing of the part A joining piece

Pieces 1 and 5 are commercial screws and nuts. Conformity of production (the highest requirements) has to be demonstrated at a tolerance of 5% in a traction test.

4. ADAPTATION OF BIOMECHANIC INDEXES FOR IMPACT SEVERITY EVALUATION

4.1 Head injury criteria

To talk about head injuries in general terms is complicated. In the case of accidents of motorcyclists against infrastructure there are a couple of effects to be considered: the non penetrating impacts and the inertial effects. Penetrating impacts are saved by the application of measures of injury prevention such as the motorcyclist helmet which is in charge of avoiding intrusive effects in general terms.

The main problem resides in the existence of numerous studies made for frontal impacts (in relation to impacts of vehicles type saloon car) and few for the case of lateral impacts.

Since the 1960s, in the United States a considerable effort has been made to determine the mechanisms of head injury and injury criteria. Although much has been learned about head injuries, the only criterion currently in use is Head Injury Criterion (HIC) that was adopted 25 years ago.

It is possible to say that, at the moment, the representative index of the risk of injuries to the head commonly accepted in spite of its limitations is the HIC, included some standards and/or protocols of lateral impact as for example the EuroNCAP [14]. For this reason, it will be one of the criteria to be used in the evaluation of motorcyclists´ protection systems.

$$HIC_{36} = \max\left[\frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} a \cdot dt\right]^{2.5} \cdot (t_2 - t_1):$$

where

a: acceleration resulting in the centre of gravity of the head expressed as units of gravity (1 g = 9.81 m/s2);

$$a = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

a_X: acceleration X-axis;
a_Y: acceleration Y-axis;
a_z: acceleration Z-axis.

4.2 Neck injury criteria

A great variety of terminologies exists in this field due to the high number of studies of cervical traumas made by an ample variety of institutions and sources. On the other hand, the classification of the injuries is complicated due to the lack of a common methodology in determining the injury.

It is to be remarked a study made in Los Angeles by the University of the South of California on the atlas and the axis cervical vertebrae in mortal collisions of motorcyclists [15]. This study states that the causes of injury to the neck of greater frequency are the axial force in neck, Fz, and the lateral flexion, Mx, see Figure 15.

The proposed test takes this into account and gives as the most important mechanisms of damage the lateral compression-flexion and the lateral traction-flexion. Figure 16 shows an example of these results obtained in the case of an impact against a rigid wall at a speed of 22 km/h.

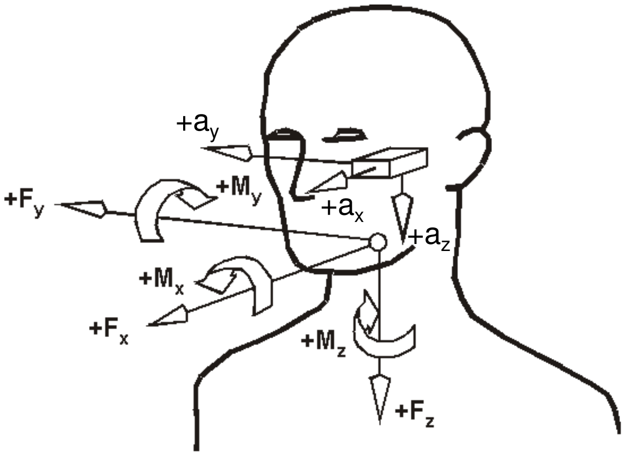


Figure 15 – Direction and sense of accelerations, forces and moments in the dummy.

Nomenclature:

- Anterior-posterior cutting force (Fx)
- Lateral cutting force (Fy)
- Traction/compression force (Fz)
- Moment of lateral flexion calculated about the occipital condyle (Mcox)
- Moment of flexion/extension calculated about the occipital condyle (Mcoy)
- Torsion moment (Mz)

The main load seems to be the component of traction or compression, being the lateral moment the one responsible for aggravating the scenario.

The protocol of test for motorcyclists´ protective systems will be based on the values of Mertz. The main problem is that the value of Mx is not defined by Mertz, being important in lateral impacts.

In the American standard of frontal impact, FMVSS 208, the used criteria are the Nij, which have been developed including out of position tests [16]. These out of position tests are very interesting since there are tests similar to the situation of a motorcyclist neck when it hits a barrier. In Europe, the tests of the out of position situation are regulated by ISO/TR 14933 standard for the case of lateral airbag [17]. However, this standard does not establish injury criteria.

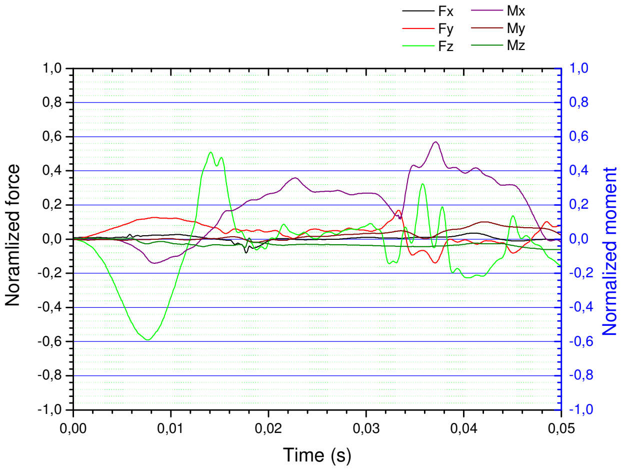


Figure 16 - Normalized values in case of an impact against a rigid wall at a speed of 22 km/h.

Nevertheless, NHTSA, in the last revisions of the Nij, has established value limits. Despite all, there is relatively little experience measuring the moments of neck on dummies, and the injury values recently proposed have their origin in the experience of experts in biomechanic of a technical working group. The moment of torsion (Mz) is established as an equal value to the moment of extension (My), while the value of lateral flexion (Mx) is established as the average value between the extension and the flexion moments, My [18].
The out of position tests are made with children and female Hybrid III dummies, and with SID-IIs dummies. As there are no values for Hybrid III 50% male, a limit value of 134 Nm for Mx is obtained by scaling [19].

4.3 Thorax injury criteria

For the proposal test, first the head and then the shoulder hit the lower plate of the barrier, for example. The thorax loading initiates through the shoulder, fracturing the clavicle and deforming the upper ribs while the motorcyclist is guided along the barrier. Following this, the loading is transformed into an almost purely lateral one. Inner organs and the vascular system are seen to be affected by inertial effects. The main loads on the vertebral column are traction-compression and lateral-flexion [20].

In the definition of a thorax criterion, PMHS data have not been available for this kind of impact. Besides, the biofidelity of Hybrid III dummy needed to be assessed for this particular application. The selection of the injury criteria, especially for the thorax, has taken into consideration the peculiarities of this dummy. The interior of the human thorax is more complex than the Hybrid III thorax. Non-deformable lateral ribs, lack of measurements on organs and bones (ribs) except the vertebral column provokes that the proposed thorax injury criteria must cover all the possible thorax injuries and its measurement must be available on dummy instrumentation.

These interior injuries have been analysed by military researchers, who have studied the accelerations limits on PMHS and have modified Hybrid III. They concluded that the inertial effect between the internal level limits of the column and the organs are correlated [21].

Perhaps, rib fractures would be other interesting criterion but in that case multidirectional frangible ribs would be needed. In addition, once rib fractures occur, no additional information can be obtained beyond that point.

On the other hand, the force magnitude of an impact to the thorax is also transmitted directly to the column by the bones. On many occasions both inertial and force transmissions are added. It is for this reason that the most suitable place to calculate the severity of the impact is the vertebral column, particularly, when the dummy has available measurement points in that place.

There are vertebrae criteria in different standards. For the suitable selection of a criterion, it is necessary to consider diverse factors such as the biofidelity of the dummy, the type and mechanism of impact, the injuries that would be inflicted on a human body, the type of measurement, etc.

Lateral equivalence between the Eurosid physical dummy and Hybrid III with kit pedestrian has been searched with the aim of correlating lateral force measured in Eurosid, Fy. This force Fy on Hybrid III needs a compensation due to two different causes. First, the biofidelity of Hybrid III is not good for lateral impacts. Second, the different location of physical measurement devices in both dummies (T12 for Eurosid and T9 for Hybrid III) has to be taken into account.

A correlation coefficient is obtained by lateral pendulum tests on pelvis and ribs to Hybrid III from Eurosid dummy, based on ISO/TR 9790 [22]. It has been found a very good correlation between T9 Hybrid III vertebra and T12 Eurosid vertebra regarding lateral force and moment Mx. A correlation in force on z-axis is not available between both dummies.

In Table 1 the maximum peak values are shown. From each pair of values, impact point and measured value, a correlation coefficient is obtained. Then, the average value of both correlation coefficients has been calculated.

	Mx measurement (Nm)			Fy measurement (KN)		
	Eurosid	**Hybrid III**	**Mx coefficient**	**Eurosid**	**Hybrid III**	**Fy coefficient**
Pelvis	65,960	113,856	1,726	0,528	0,606	1,147
Ribs	134,454	236,471	1,759	1,529	1,771	1,159
			1,74			**1,15**

Table 1 - Correlation coefficient.

After the above discussion, it is decided that Eurosid lateral criteria can be used on Hybrid III by applying a correlation coefficient. If Eurosid lateral criteria on Fy is 2 kN and on Mx 200 Nm, now it is 2.3 kN and 350 Nm for Hybrid III.

4.4 Conclusions

In summary, the measured values on Hybrid III 50th percentile male dummy are shown in Figure 17. These values are used to define the injury criteria which are used to evaluate the MPS.

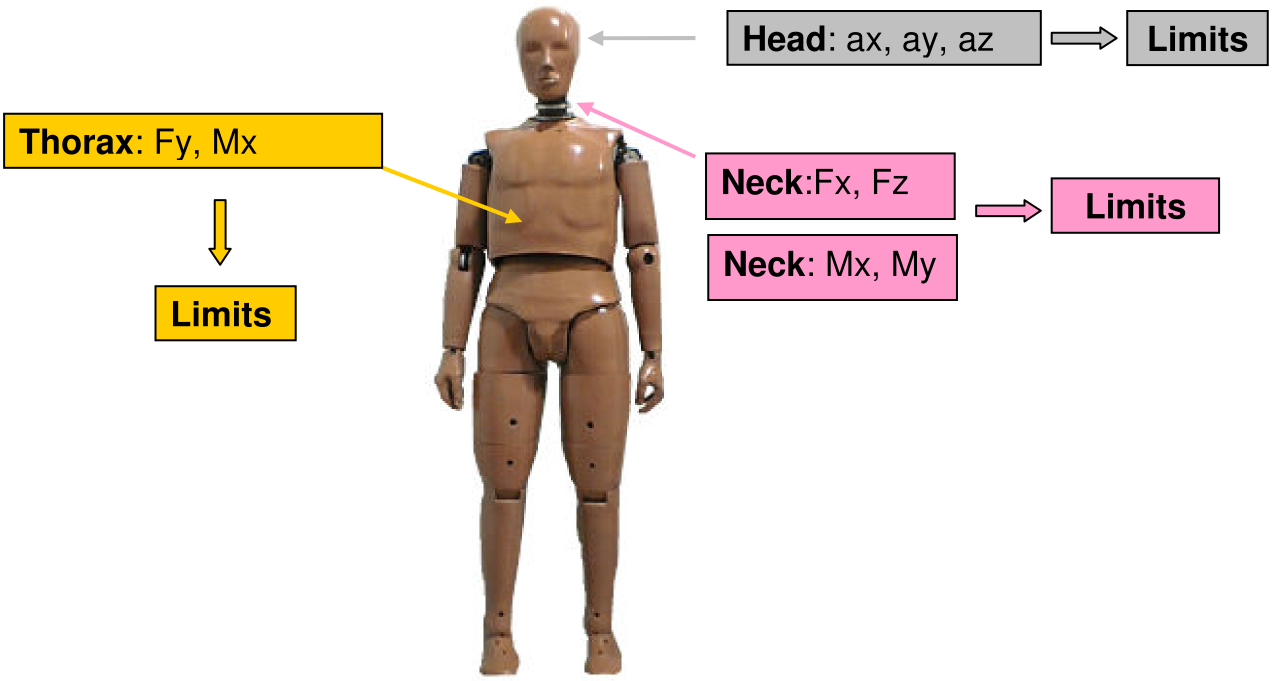


Figure 17 - Measured values on Hybrid III.

All necessary measurements to evaluate the biomechanical indexes will be carried out with measurement systems compliant with the standard ISO 6487.

The resulting acceleration in the centre of gravity of the dummy's head will be calculated from the tri-axial components of the acceleration recorded with Canal Frequency Class 1 000 (CFC 1 000) and a Channel Amplitude Class of 500 g (CAC 500 g).

The forces and moments of the upper part of the dummy's neck will be recorded in the following way:

- Fx and Fy with a CAC of 8 kN and a CFC of 1000 and Fz with a CAC of 13 kN and a CFC of 1000

- Mx, My and Mz with a CAC of 280 Nm and a CFC of 600

Forces and moments in the spinal column, thoracic spine load cell (T-9), will be recorded by:

- Fy with a CAC of 13 KN and a CFC of 600
- Fz with a CAC of 17 KN and a CFC 600
- Mx with a CAC of 650 Nm and a CFC 600.

5. TEST PROCEDURE

5.1 General description

The full-size impact test consists of the launching of a dummy at a certain speed against an obstacle with the motorcyclist protection system, MPS. The dummy slides on the ground with the most of its body, specially its back and its head, in a stable way at the time of the impact.

The launching position is defined as described by the Figure 18, with the dummy spine axis along the approximation trajectory.

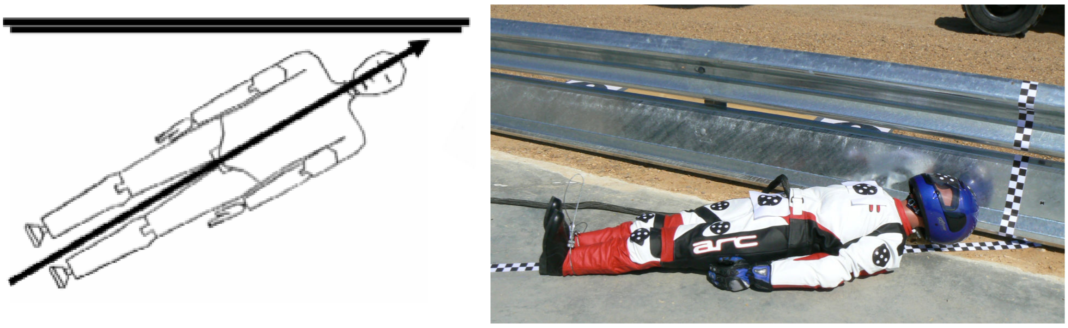


Figure 18 - Launching position

This proposal of standard does not define the impact point and impact speed. Only trajectory angle, 30º, is defined and the impact point can be a laboratory test decision in case of impact points leading to worse conditions. With the exemption of this particular consideration, the worst impact points are defined in the Spanish standard (Figures 5, 6 and 7) and recommended in this proposal. Two different impact points have to be analyzed. The obtained impact point must not deviate a distance above 60 mm from the defined impact point.

The impact velocity is a manufacturer decision and it is measured no longer than 0.5 meters from the theoretic impact point along the approximation trajectory. Impact speed must be increased in values of 10 Km/h starting from 60 Km/h.

The requirements of this procedure are that the Hybrid III dummy should travel sliding on the ground by itself and hit the protection system to be tested. For that reason, three areas are identified: a launcher area, a sliding area and an impact area. The last one has to be prepared with the same ground conditions as in a regular installation on the road or at least, the worst condition should be selected. The impact obstacle is installed in the same way as it is installed in its regular use in the ground.

The ground of the sliding and impact has to be flat, unsharp, without ice, puddles or snow at the time of the test. The sliding area must be sufficiently smooth and strong for the purpose of the test, having no obstacle that might affect the free passage of the dummy across the surface or interfere with the impact speed. The surfaces of the helmet and the impacted obstacle have to be clean and dry, without any substance or element which could disturb the free contact between both surfaces.

For testing, the dummy shall be a Hybrid III 50th percentile male, equipped with a kit pedestrian that allows a standing position. Frangible clavicles have been designed after some biomechanical considerations to improve the dummy biofidelity. The dummy has to be free at the time of the impact and at least two meters before the first impact and it could be stopped 7 meters minimum after the first impact or higher if the safety area or working area is bigger than 15 meters. The limits, 7 and 15 meters, are reached when one part of the dummy body starts to cross the limit.

5.2 Dummy considerations

The dummy will be equipped with a full front commercial helmet with a polycarbonate shell and fulfilling the requirements of Regulation 22. It has to weight 1.300 kg +- 0.050 kg. The helmet surface has to be free of edges, air ducts holes, prominences, wrinkled surface, or any element that might disturb the contact between the helmet and the impacted obstacle.

The helmet will be located using the pattern in figure 19. This pattern will coincide with the nose section of the Hybrid III 50th Percentile Male and will provide the measurement of the angle between the plane of intersection of the head and the horizontal.

The correct head position inside the helmet is achieved when making the pattern coincide with the face section of the dummy, the upper edge of the pattern makes contact with the vision orifice of the helmet on its upper part.

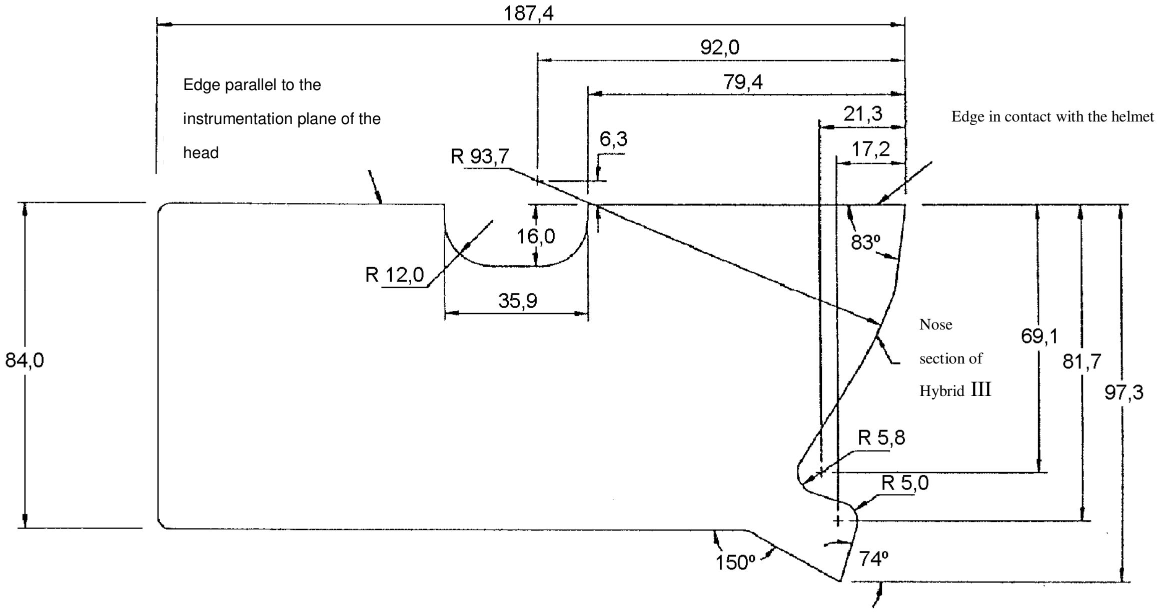


Figure 19 - Helmet position tool.

Material: 3 mm aluminium sheet
The linear dimensions are in mm and have a + 0.03 mm tolerance
The angular dimensions have a + 1º tolerance
All the radii are 3.2 mm unless otherwise specified. Sharp edges will be removed

The dummy will be dressed in a long-sleeved cotton vest, leather gloves, boots and a leather one-piece (or two pieces joined together) motorcycle suit complying with the Standard EN 1621. Protection pieces tested by EN 1621 inside the motorcycle suit have to be removed. Comfort padding should be avoid or be as thin as possible.

Dummy weight full equip should weight 87 ±2.5 Kg.

6. EVALUATION CRITERIA

The level of behaviour of the motorcyclist protection system (MPS) is defined by two criteria:

- Protection level (relative to impact speed).
- Impact severity (relative to injury criteria).

It is supposed that an MPS that fulfils this standard proposal at a defined level of behaviour, it will fulfil it at lower velocities, unless it incorporates some kind of mechanism which does not work properly at lower velocities.

6.1 Protection level

The protection level is defined by the highest speed at which the impact meets the criteria defined in section 6.2 for both impact points.

6.2 Impact severity

The maximum accepted values are those included in Table 2. Measured injury parameters should not be higher than the maximum accepted values for head, neck and thorax.

Head	**Neck**						**Thorax**	
HIC_{36}	Fx (N)	Fz traction (N)	Fz compression (N)	Mco_x (N.m)	Mco_y extension (N.m)	Mco_y flexion (N.m)	Fy (N)	M_x (N.m)
1 000	Diagram D1	Diagram D2	Diagram D3	134	57	190	2300	350

Table 2 - Accepted values for severity parameters

Recommended compression T9 vertebra limit in the spinal column is 5900 N.

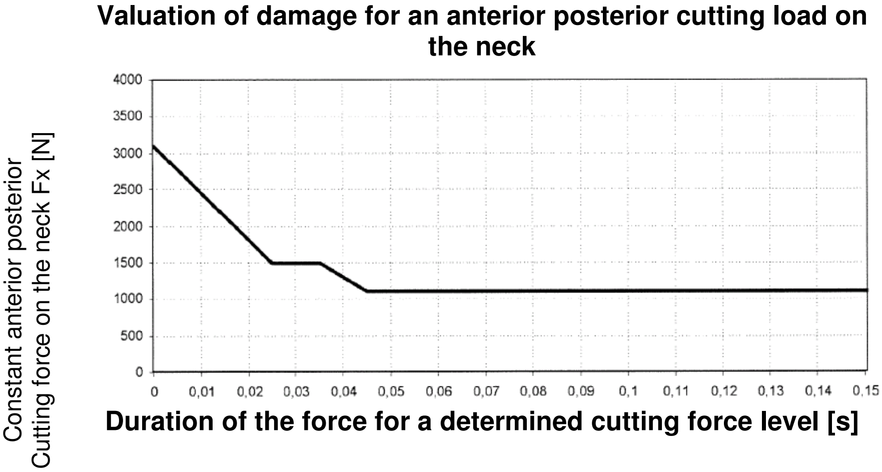
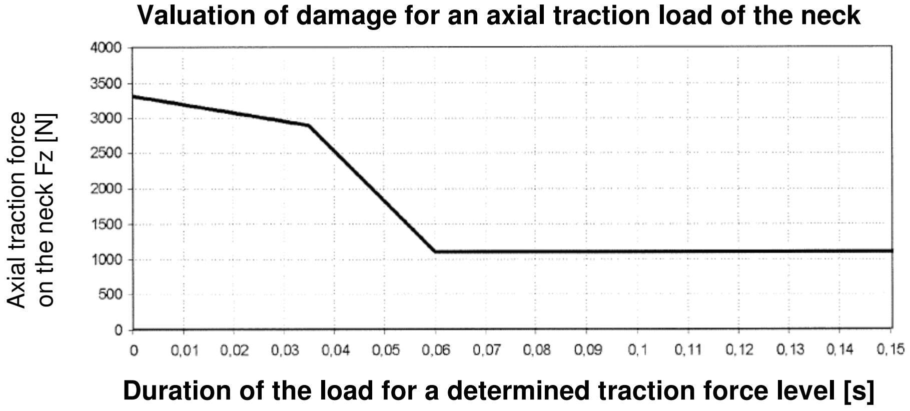
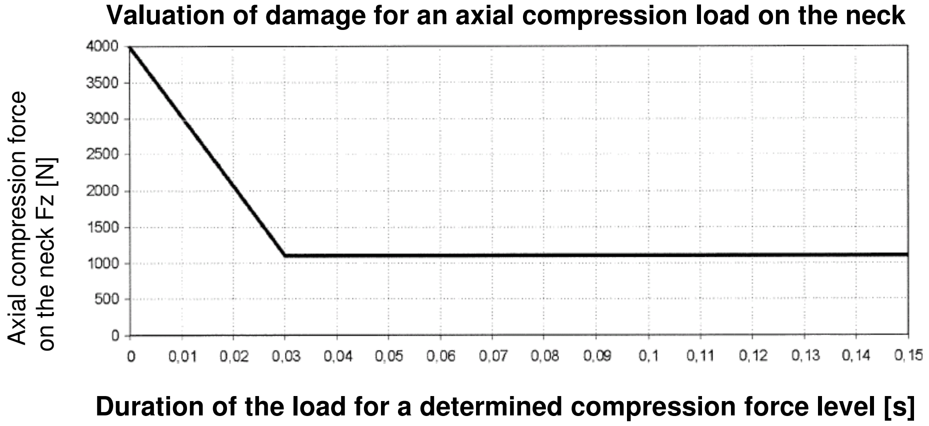


Diagram D1 - Shear neck force



[s]	[N]
0,000	3 300
0,035	2 900
≥ 0,060	1 100

Diagram D2 - Traction level force



[s]	[N]
0,000	4 000
≥ 0,030	1 100

Diagram D3 - Compression neck force

6.3 Acceptance criteria

This proposal standard tries to give some guidelines in order to identify whether a motorcyclist protection system is valid or not with regard to its objective.

Once a test is performed, the conclusions about the behaviour of a specific protection device are obtained taking into account the severity level defined in this standard and the behaviour of the safety device. Besides, section 6.4 has to be considered.

- ***Behaviour of the MPS***

The first part of the acceptance criteria is the behaviour of the safety device. No element from the crash safety device weighing 2 Kg or more should be separated from the device except if it is necessary for its correct performance (for example, frangible systems). Elements weighing 2 Kg or more from crash safety device or the obstacles never have to fall on the traffic lanes or cross through them.

In case of impact barriers, the working width and dynamic deflection of the device after the dummy impact should not be under any circumstances equal to or higher than those defined by the Standard EN 1317-2 for a vehicle impact. In case of continuous barriers, dummy parts never have to be in contact with the punctual post, except they are designed to work in that way (sigma post vs. IPN post).

- ***Behaviour of the dummy***

The behaviour of the dummy is the second part of the acceptance criteria. The dummy used for the test should not have intrusions, dummy breakage except for the clavicles, be beheaded or suffer any dismemberment.

No entangling of the dummy in any part of the road infrastructure or railing with MPS is allowed that would prevent its freeing without tools after the impact.

The maximum accepted values, according to the severity level, are those included in Table 2. Measured injury level should not be higher than the maximum accepted values for head, neck and thorax.

Second impacts and contacts of the dummy against the ground have to be considered within the acceptance criteria until the dummy stopped or is stopped 7 or more meters after the first impact point by test tools in continuous barriers, or until 15 meters after first impact point, if the safety area or working area are higher in case of punctual obstacles.

6.4 Other considerations

In case of the barriers, every crash barrier especially designed to improve motorcyclists´ protection, has to guarantee that it does not affect negatively to the performance when impacted by road vehicles, according to EN 1317-2 and other users.

In case of other road infrastructure, they have to be according to other standards like EN-12899 in the case of vertical road traffic signs, EN-12767 in the case of passive safety of support structures for road equipment, etc, and they do not affect negatively the performance when impacted by other users.

A sliding impact of the motorcyclist is only one variety in PTW accidents. The sliding rider totally separated from the PTW is also only one option and this proposal standard does not assure a full safety in all situations.

Periodic maintenance should be considered part of the installation criteria.

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ANNEXE I: SIMULATION ACTIVITIES

1. Introduction

This annexe presents the work performed by ALTAIR within the scope of task 4.2.3 “Proposal of a new standard”.

The main objective of Task 4.2.3 is to propose a new standard for impacts of motorcyclists versus road infrastructure. In order to verify the feasibility of a new approach using simulations it was decided to launch a series of parametric simulations in order to identify the influence of some uncertain crash parameters. This section reports on the outcome of those simulations.

The scenario used for simulations was taken from Deliverable 4.2.2. ALTAIR, using ADVISER, estimated how small variations of some of the impact configuration (taken from Deliverable 4.2.2) influence the outcome of the tests. Three different variables were studied:

- Motorcyclist impact velocity
- Motorcyclist impact angle
- Location of impact on the barrier regarding motorcyclist to pole position

It was observed that:

- the study range has an influence on the responses analysis;
- impact location point is the main parameter and induces high variations on responses;
- velocity is increasing responses’ sensitivities to the two other parameters;
- head resultant acceleration and HIC are the most stable usable injury criteria.

The aim of this work was to evaluate the influence of parameters variations on test results. ADVISER was used to perform and analyse this set of parametric tests.

2. Test configurations

Preliminary works in workpackage 4.2.2 lead to the definition of some cases to be studied (obstacle definition, impact angle, velocity, …). In this workpackage two cases were studied (“head on” and “side on” configuration) and one was choosen to be used as basis for the new standard creation.

To simulate a motorcycle rider sliding on the road after falling, Hybrid III modified dummy (standard Hybrid III 50th dummy transformed into a standing dummy, equipped with a riding suit) is launched sliding face up into the pole of a steel deformable road barrier. The impact angle of the dummy on the obstacle is equal to 30° and the initial velocity of the motorcyclist is set to 60 km/h. (Figure A1)

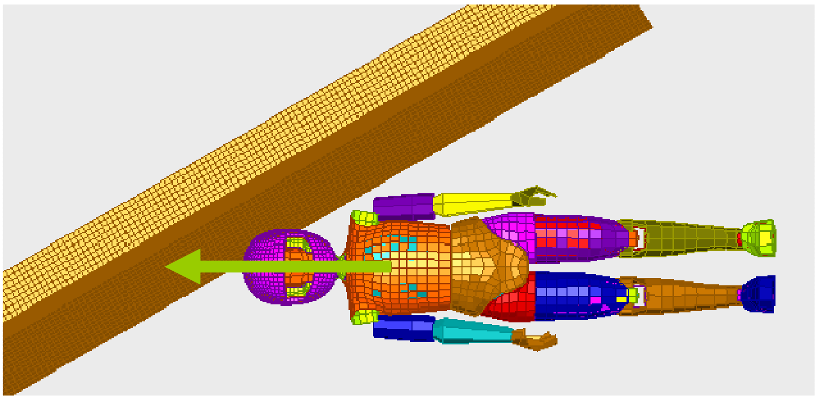


Figure A1 - Chosen test configuration

To evaluate the results’ variations w.r.t. initial conditions, three main “uncertain” parameters were introduce into the model:

- Impact velocity, varying of +/- 10 km/h
- Impact angle, varying of +/- 5°
- Point of impact on the barrier, varying of +/- 500 mm

An additional case was investigated to decide if the face up / face down difference was important enough to be studied.

3. *Face up and down comparison*

- ***Kinematic behaviour***

Hybrid III dummy was launched on the pole of the steel barrier at 60 km/h with an angle of 30°. (Figures A2 and A3) Face down Hybrid III dummy was obtained by a 180° rotation around Z axis of the face up model.

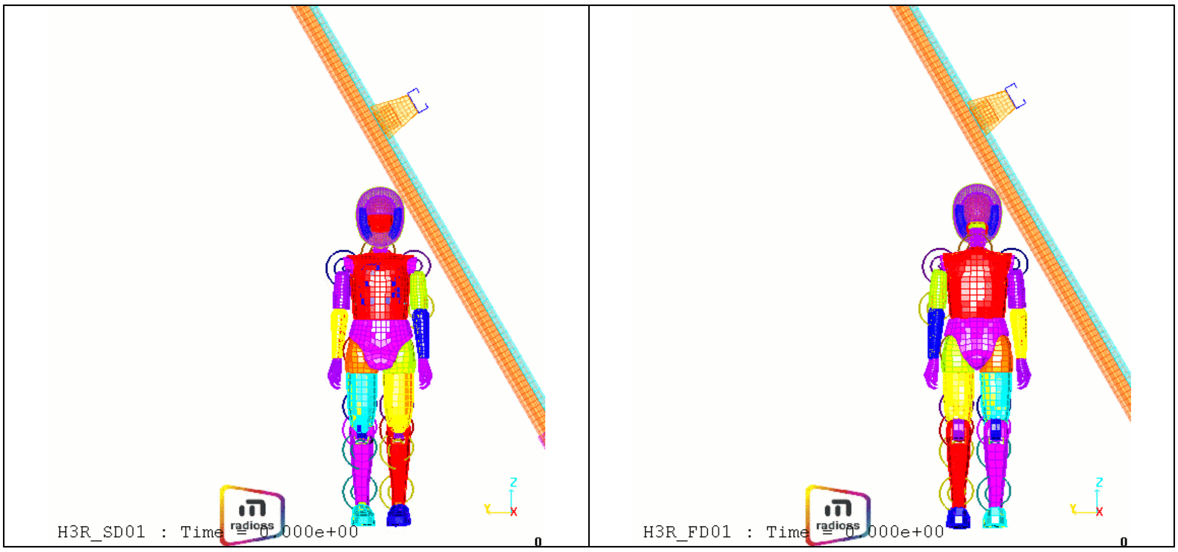


Figure A2 - Top view of the initial dummy position for face up (left column) / face down (right column) simulations

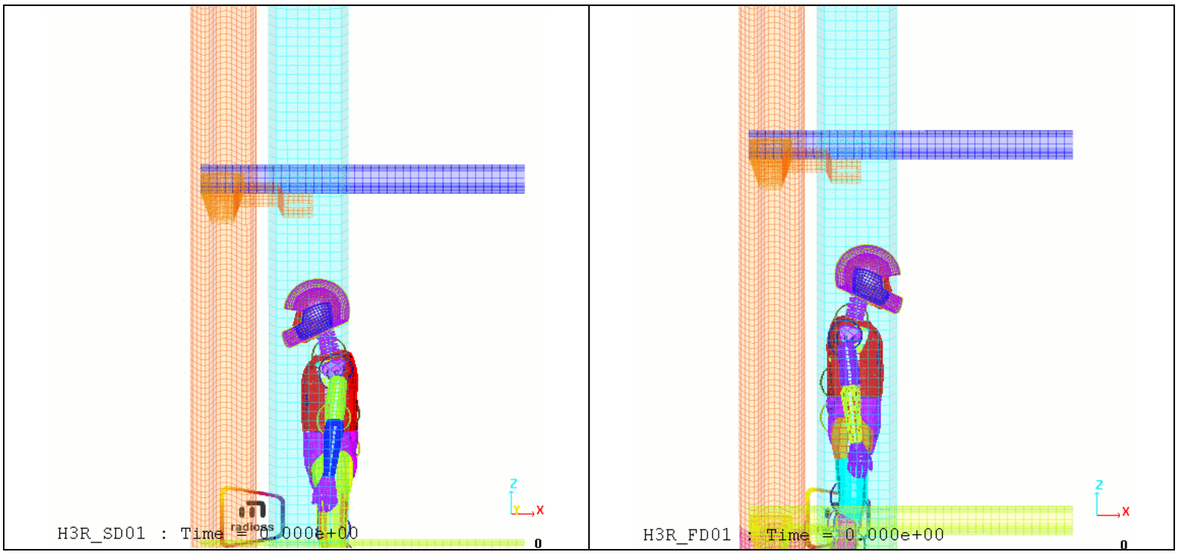


Figure A3 - Lateral view of the initial dummy position for face up (left column) / face down (right column) simulations

In both cases the kinematic behaviour are close. (Figures A4 and A5)

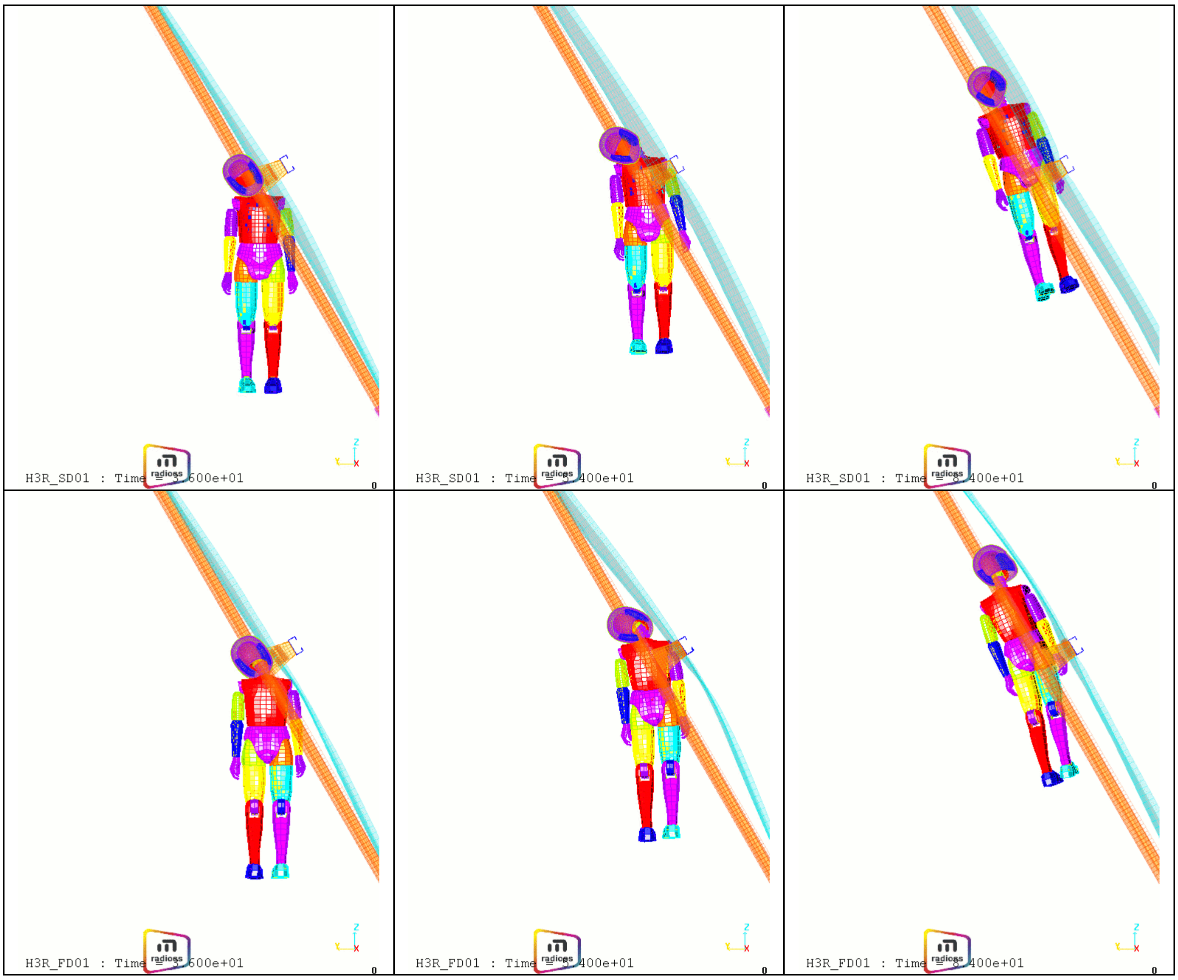
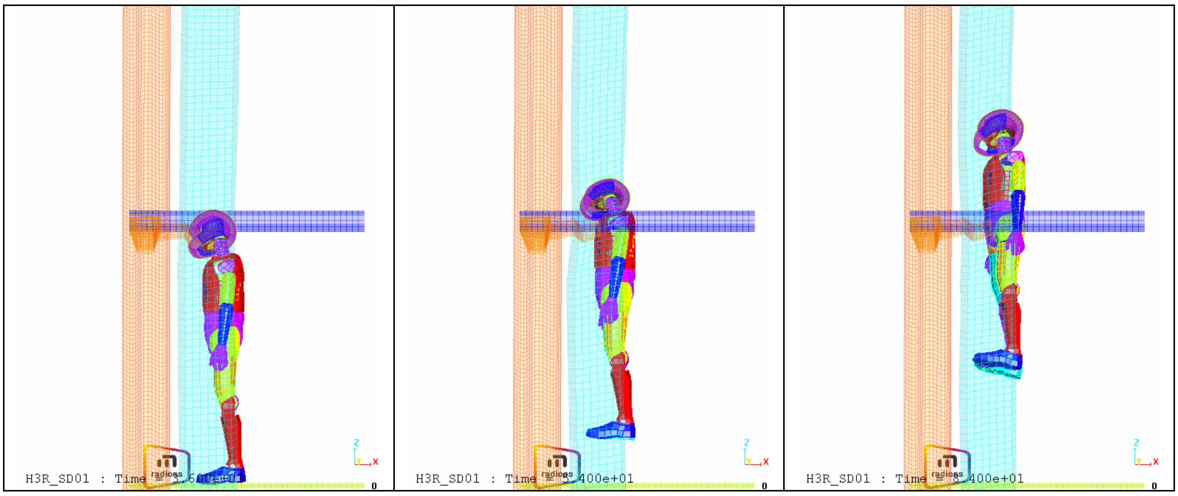


Figure A4 - Top views of the evolution in time of face up (first line) / face down (second line) simulations



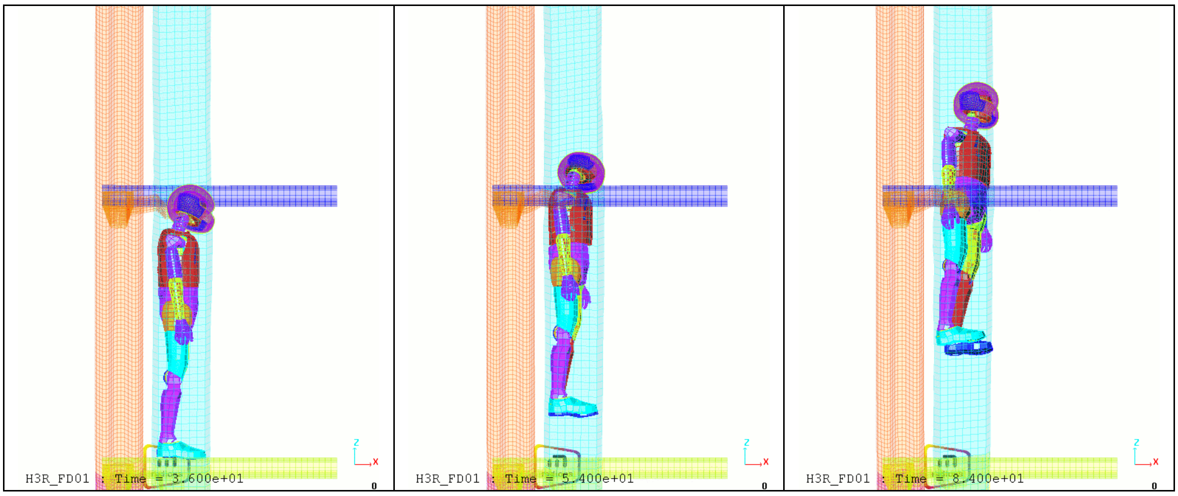


Figure A5 - Lateral views of the evolution in time of face up (first line) / face down (second line) simulations

- ***Numerical results***

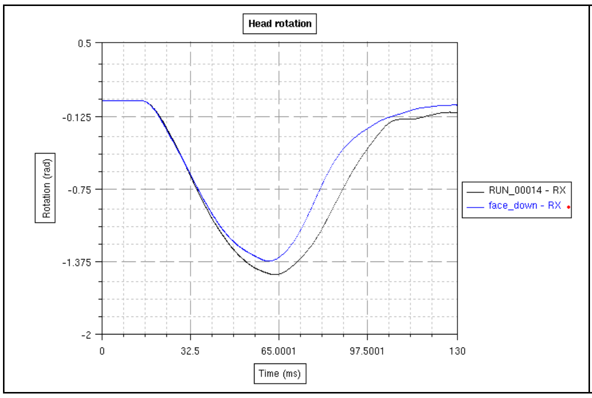
For each case, main numerical criteria were extracted using the ADVISER Evaluation table created in task 422. (Table A1)

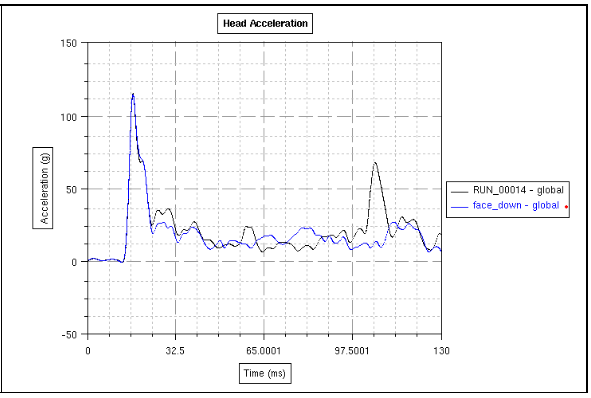
	HIC	Head 3ms
Face Up	387,4	77,19 g
Face Down	399,7	80,55 g

Table A1 - HIC and C3ms for face up and face down configurations

These scalar criteria are very close (difference is around 3% on the HIC value).

Time history plots for the main channels are plotted below. A limited effect of the face up – face down configuration is seen on these curves.





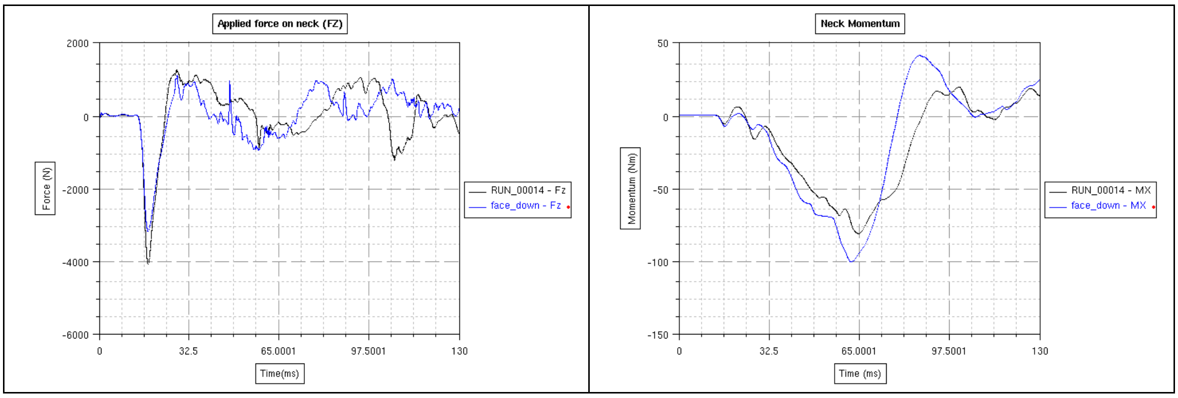


Figure A6 - Head rotation around Y axis (top left), Head acceleration (top right), Applied force on neck (bottom left) and Neck momentum around Y axis (bottom right) for face up (black curves) and face down (blue curves) configurations

• *Conclusion*

Hybrid III dummy behaviour is similar in the two configurations, face up and face down. There is no need to include this parameter into the parametric analysis to be performed in the task 423.

4. Parametric Analysis

• *Variables samples definition*

A full factorial design of experiment is defined for this parametric analysis. Each variable (impact velocity, impact angle and impact point location) takes three values, leading to a set of 27 (=3^3) samples (one of them being the initial configuration).

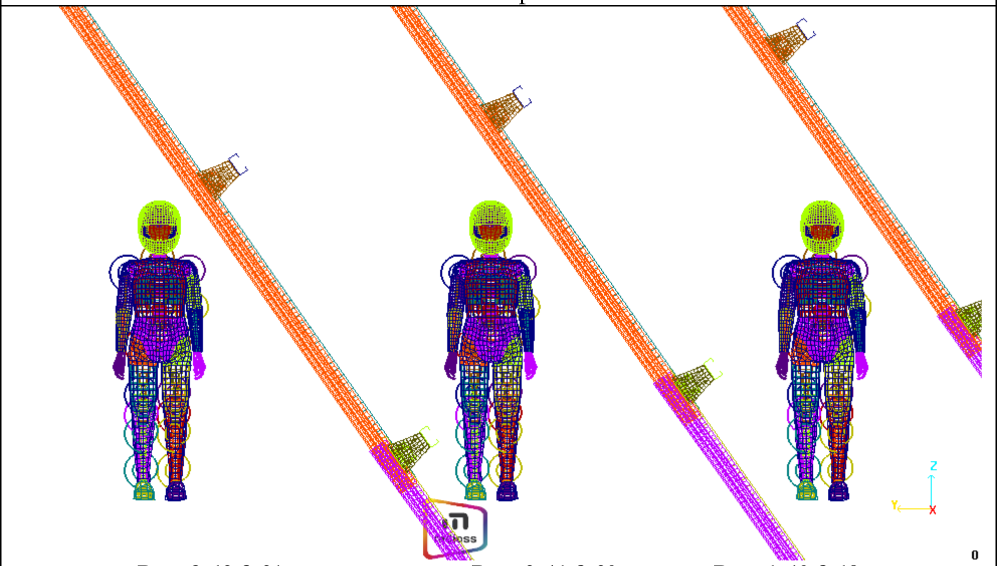
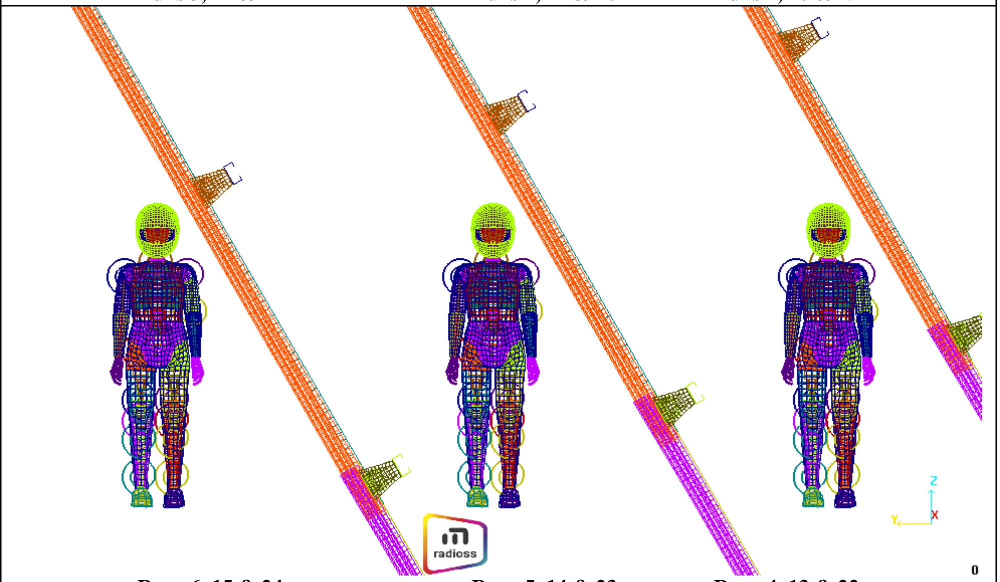
Refer to Table A2 for a complete definition of the simulations and refer to figure 7 for an illustration of the effect of each parameter.

Run	Velocity	Angle	Location
Run 1	50 km/h	35°	- 500 mm
Run 2	50 km/h	35°	0 mm
Run 3	50 km/h	35°	+ 500 mm
Run 4	50 km/h	30°	- 500 mm
Run 5	50 km/h	30°	0 mm
Run 6	50 km/h	30°	+ 500 mm
Run 7	50 km/h	25°	- 500 mm
Run 8	50 km/h	25°	0 mm
Run 9	50 km/h	25°	+ 500 mm
Run 10	60 km/h	35°	- 500 mm
Run 11	60 km/h	35°	0 mm
Run 12	60 km/h	35°	+ 500 mm
Run 13	60 km/h	30°	- 500 mm
Run 14	60 km/h	30°	0 mm
Run 15	60 km/h	30°	+ 500 mm
Run 16	60 km/h	25°	- 500 mm
Run 17	60 km/h	25°	0 mm
Run 18	60 km/h	25°	+ 500 mm
Run 19	70 km/h	35°	- 500 mm
Run 20	70 km/h	35°	0 mm
Run 21	70 km/h	35°	+ 500 mm

Run 22	70 km/h	30°	- 500 mm
Run 23	70 km/h	30°	0 mm
Run 24	70 km/h	30°	+ 500 mm
Run 25	70 km/h	25°	- 500 mm
Run 26	70 km/h	25°	0 mm
Run 27	70 km/h	25°	+ 500 mm

Table A2 - Generated samples

All simulations were performed with RADIOSS, using the model developed in task 422.

	+ 500 mm	on the pole	- 500 mm
Impact angle 35°			
	Runs 3, 12 & 21	**Runs 2, 11 & 20**	**Runs 1, 10 & 19**
Impact angle 30°			
	Runs 6, 15 & 24	**Runs 5, 14 & 23**	**Runs 4, 13 & 22**

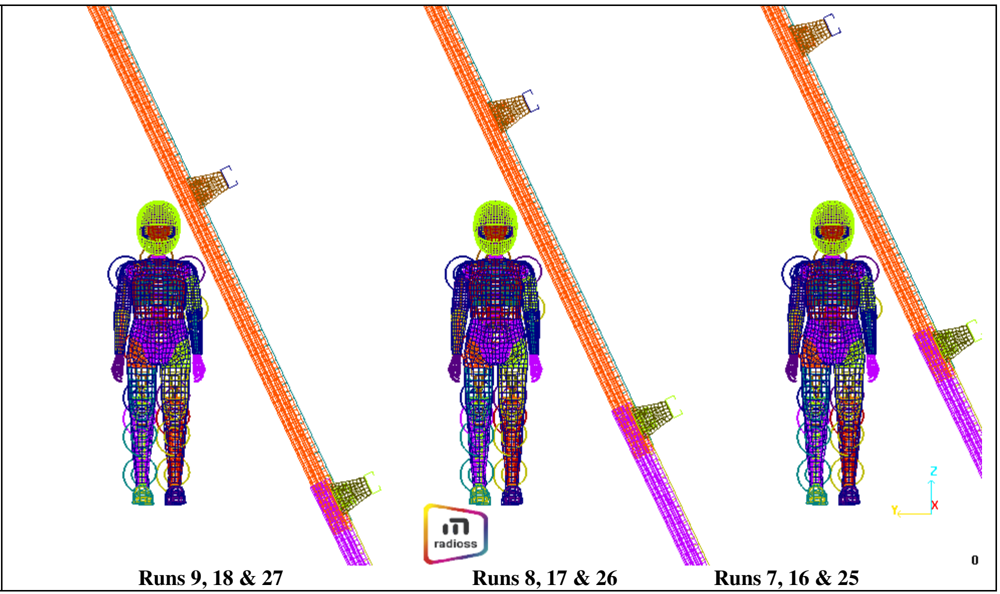
Impact angle 25°	

Figure A7 - Different impact angles and impact point locations

- ***Parametric Analysis of the DOE results***
  - ***Dynamic behaviour***

Within the set of 27 simulations performed, two main different behaviours leading to two "end configurations" were observed:

- Hard impact (dummy stopped by a pole – see Figure A8)
- Escape trajectory (dummy sliding along the barrier – see Figure A9)

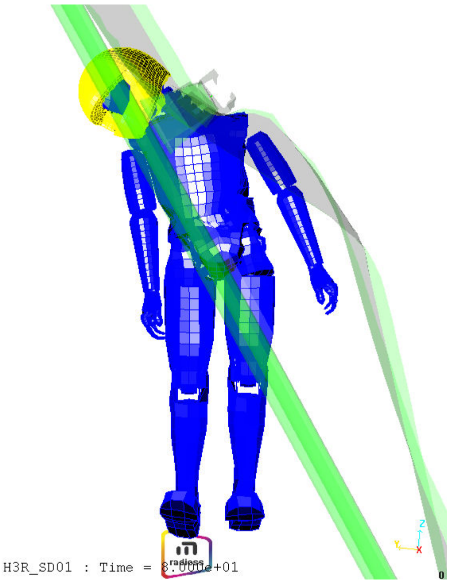


Figure A8 - Shoulder / neck stopped by the pole (end configuration)

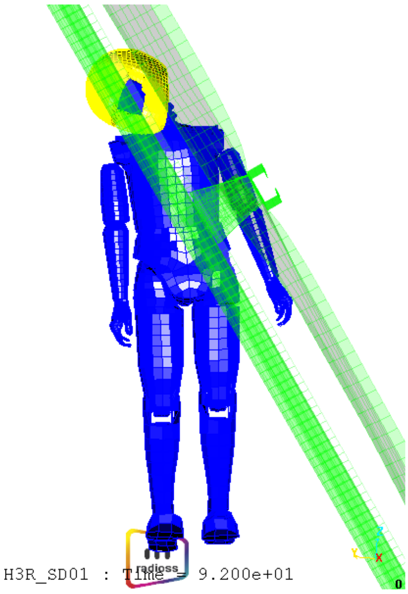


Figure A9 - Dummy sliding along the rail

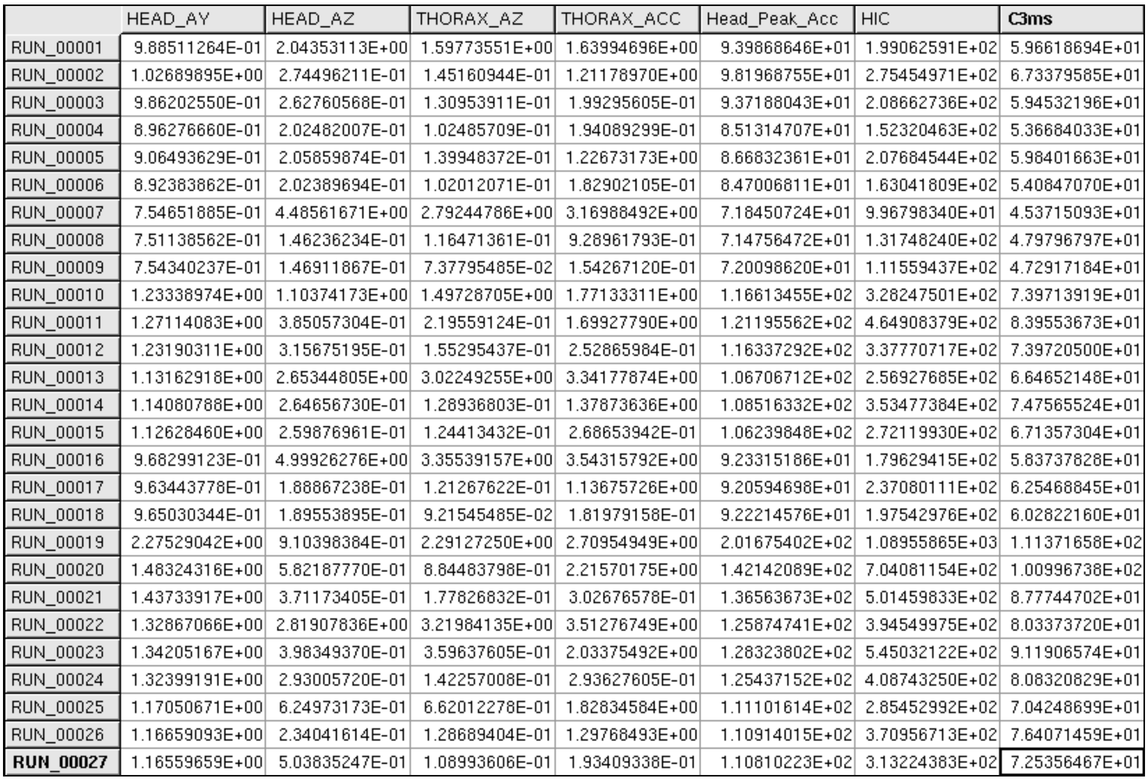
Depending on the end configuration one or two impact peaks can be seen on numerical curves. The first one is corresponding to the first impact of the dummy on the barrier, leading to an angle change in its trajectory, and the second one is corresponding to the possible hard impact of the shoulder on the pole.

These two scenarios lead to differences in the time histories extracted: before 60 to 70 ms, all configurations lead to the same order of magnitude for the responses, but after and up to 120 ms, large differences can occur depending on the scenario.

In the analysis below, signals and scalar values are evaluated twice: first in the range 0 to 60 ms, then in the full range (0 to 120 ms).

- ### *Numerical results*

An ADVISER table was used to extract automatically the results of the 27 runs.



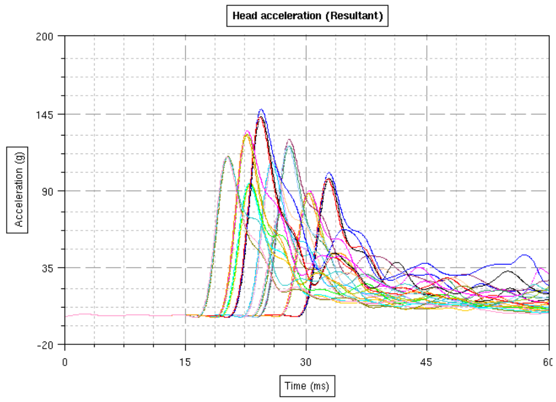
	HEAD_AY	HEAD_AZ	THORAX_AZ	THORAX_ACC	Head_Peak_Acc	HIC	**C3ms**
RUN_00001	9.88511264E-01	2.04353113E+00	1.59773551E+00	1.63994696E+00	9.39868646E+01	1.99062591E+02	5.96618694E+01
RUN_00002	1.02689895E+00	2.74496211E-01	1.45160944E-01	1.21178970E+00	9.81968755E+01	2.75454971E+02	6.73379585E+01
RUN_00003	9.86202550E-01	2.62760568E-01	1.30953911E-01	1.99295605E-01	9.37188043E+01	2.08662736E+02	5.94532196E+01
RUN_00004	8.96276660E-01	2.02482007E-01	1.02485709E-01	1.94089299E-01	8.51314707E+01	1.52320463E+02	5.36684033E+01
RUN_00005	9.06493629E-01	2.05859874E-01	1.39948372E-01	1.22673173E+00	8.66832361E+01	2.07684544E+02	5.98401663E+01
RUN_00006	8.92383862E-01	2.02389694E-01	1.02012071E-01	1.82902105E-01	8.47006811E+01	1.63041809E+02	5.40847070E+01
RUN_00007	7.54651885E-01	4.48561671E+00	2.79244786E+00	3.16988492E+00	7.18450724E+01	9.96798340E+01	4.53715093E+01
RUN_00008	7.51138562E-01	1.46236234E-01	1.16471361E-01	9.28961793E-01	7.14756472E+01	1.31748240E+02	4.79796797E+01
RUN_00009	7.54340237E-01	1.46911867E-01	7.37795485E-02	1.54267120E-01	7.20098620E+01	1.11559437E+02	4.72917184E+01
RUN_00010	1.23338974E+00	1.10374173E+00	1.49728705E+00	1.77133311E+00	1.16613455E+02	3.28247501E+02	7.39713919E+01
RUN_00011	1.27114083E+00	3.85057304E-01	2.19559124E-01	1.69927790E+00	1.21195562E+02	4.64908379E+02	8.39553673E+01
RUN_00012	1.23190311E+00	3.15675195E-01	1.55295437E-01	2.52865984E-01	1.16337292E+02	3.37770717E+02	7.39720500E+01
RUN_00013	1.13162918E+00	2.65344805E+00	3.02249255E+00	3.34177874E+00	1.06706712E+02	2.56927685E+02	6.64652148E+01
RUN_00014	1.14080788E+00	2.64656730E-01	1.28936803E-01	1.37873636E+00	1.08516332E+02	3.53477384E+02	7.47565524E+01
RUN_00015	1.12628460E+00	2.59876961E-01	1.24413432E-01	2.68653942E-01	1.06239848E+02	2.72119930E+02	6.71357304E+01
RUN_00016	9.68299123E-01	4.99926276E+00	3.35539157E+00	3.54315792E+00	9.23315186E+01	1.79629415E+02	5.83737828E+01
RUN_00017	9.63443778E-01	1.88867238E-01	1.21267622E-01	1.13675726E+00	9.20594698E+01	2.37080111E+02	6.25468845E+01
RUN_00018	9.65030344E-01	1.89553895E-01	9.21545485E-02	1.81979158E-01	9.22214576E+01	1.97542976E+02	6.02822160E+01
RUN_00019	2.27529042E+00	9.10398384E-01	2.29127250E+00	2.70954949E+00	2.01675402E+02	1.08955865E+03	1.11371658E+02
RUN_00020	1.48324316E+00	5.82187770E-01	8.84483798E-01	2.21570175E+00	1.42142089E+02	7.04081154E+02	1.00996738E+02
RUN_00021	1.43733917E+00	3.71173405E-01	1.77826832E-01	3.02676578E-01	1.36563673E+02	5.01459833E+02	8.77744702E+01
RUN_00022	1.32867066E+00	2.81907836E+00	3.21984135E+00	3.51276749E+00	1.25874741E+02	3.94549975E+02	8.03373720E+01
RUN_00023	1.34205167E+00	3.98349370E-01	3.59637605E-01	2.03375492E+00	1.28323802E+02	5.45032122E+02	9.11906574E+01
RUN_00024	1.32399191E+00	2.93005720E-01	1.42257008E-01	2.93627605E-01	1.25437152E+02	4.08743250E+02	8.08320829E+01
RUN_00025	1.17050671E+00	6.24973173E-01	6.62012278E-01	1.82834584E+00	1.11101614E+02	2.85452992E+02	7.04248699E+01
RUN_00026	1.16659093E+00	2.34041614E-01	1.28689404E-01	1.29768493E+00	1.10914015E+02	3.70956713E+02	7.64071459E+01
RUN_00027	1.16559659E+00	5.03835247E-01	1.08993606E-01	1.93409338E-01	1.10810223E+02	3.13224383E+02	7.25356467E+01

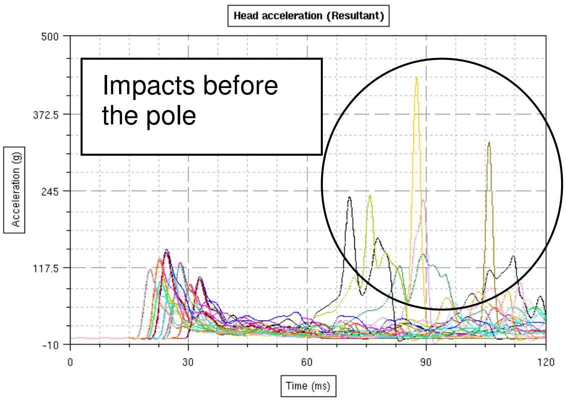
Table A3 - ADVISER table summarizing responses values

Next are shown the curves obtained in the 27 simulations. The instant of impact depending on the speed and initial position, a small time shift can be observed when comparing curves.

Curves on the left only show the 0 to 60 ms time range. Curves on the right cover the 0 to 120 ms time range.

Head Accelerations





Impacts before the pole

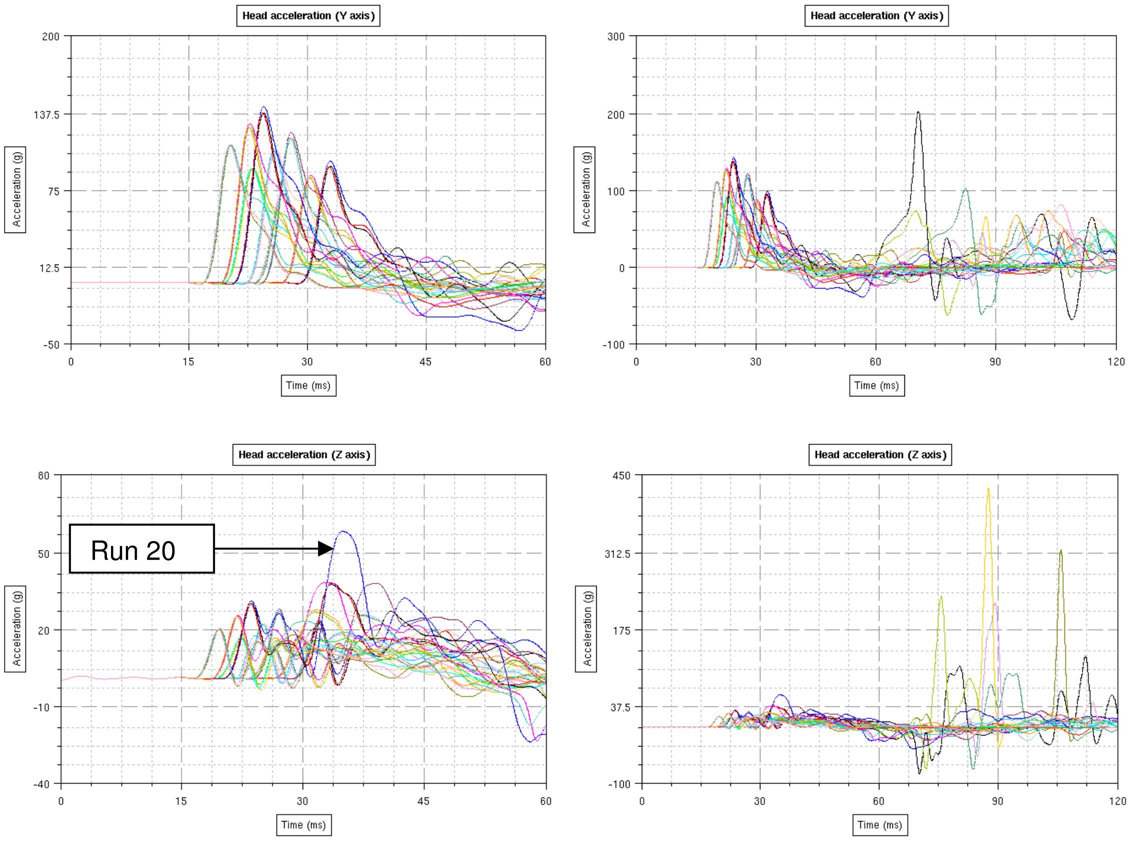


Figure A10 - head acceleration curves

On the first time range (0 to 60 ms) the head accelerations curves are mainly similar. However on head acceleration in Z axis curve, the Run 20 can be separated from the others (blue curve reaching 57 g). It is corresponding to the harder head/barrier impact: higher speed, higher angle, impact of the head directly on the pole.

On the large time range, runs 1, 7, 10, 13, 16, 19 and 22 show high acceleration peak after 60 ms. All of them are corresponding to impact point located before the pole and are conducing to an hard impact end configuration.

<u>Thorax Accelerations</u>

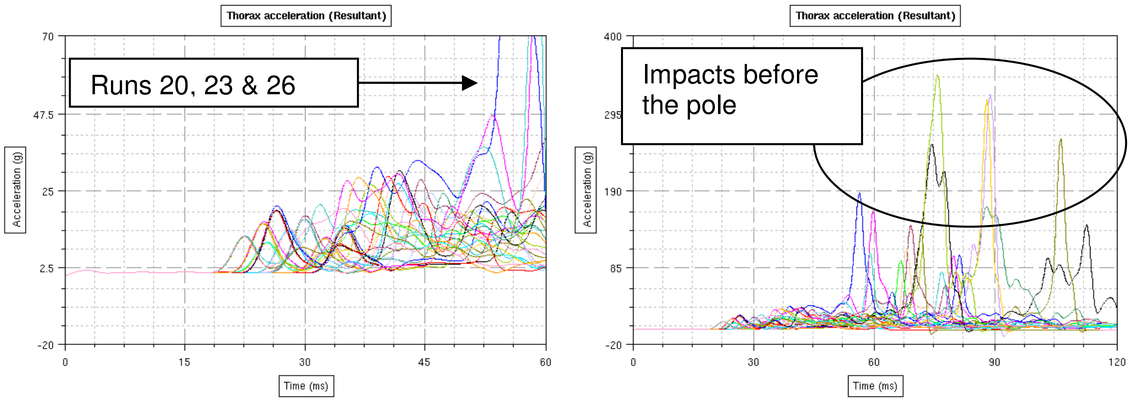


Figure A11 - thorax acceleration curves

On the first 60 ms, runs 20, 23 and 26 shows large variation after 50 ms. All of them are corresponding to a direct impact on the pole at high velocity. This impact is inducing a great acceleration in the thorax as it was seen for the head.

High thorax acceleration peaks can be seen on the 0 to 120 ms range. They are corresponding to runs 10, 13, 16, 19 and 22, which are the medium and high speeds impacts located before the pole. The acceleration peak is consecutive to the contact of the dummy with the pole.

Neck Forces and Moments

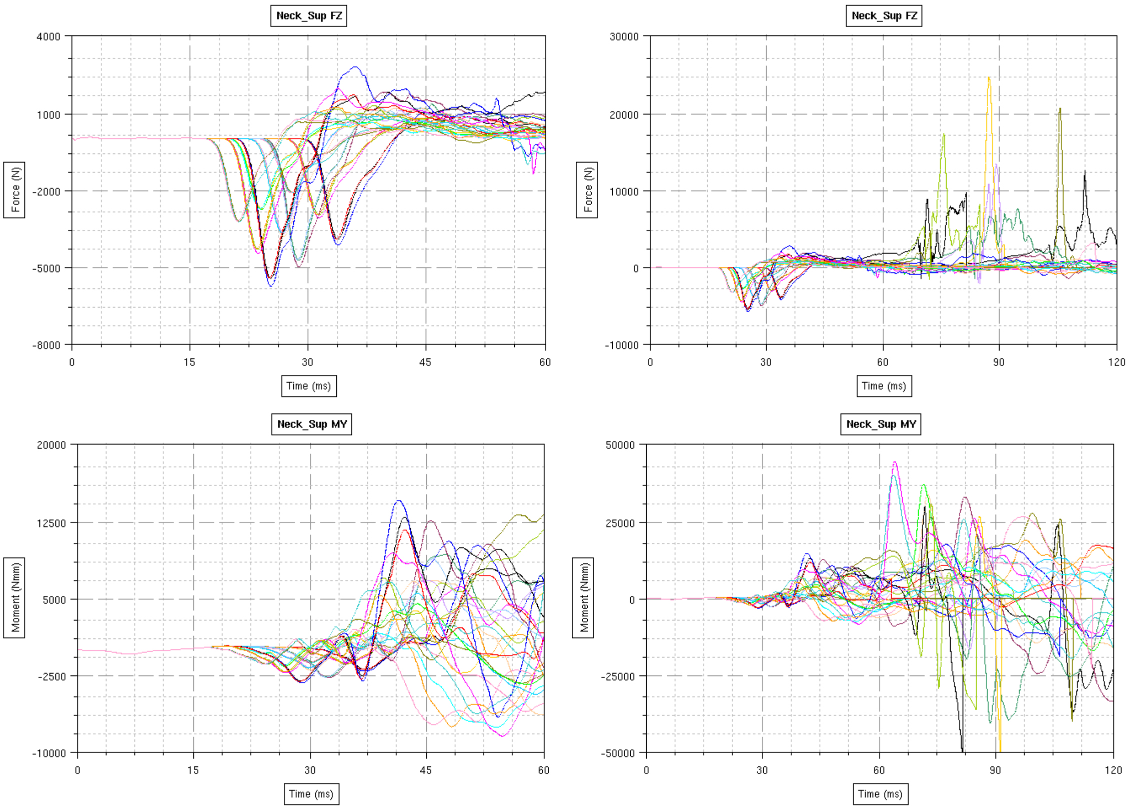
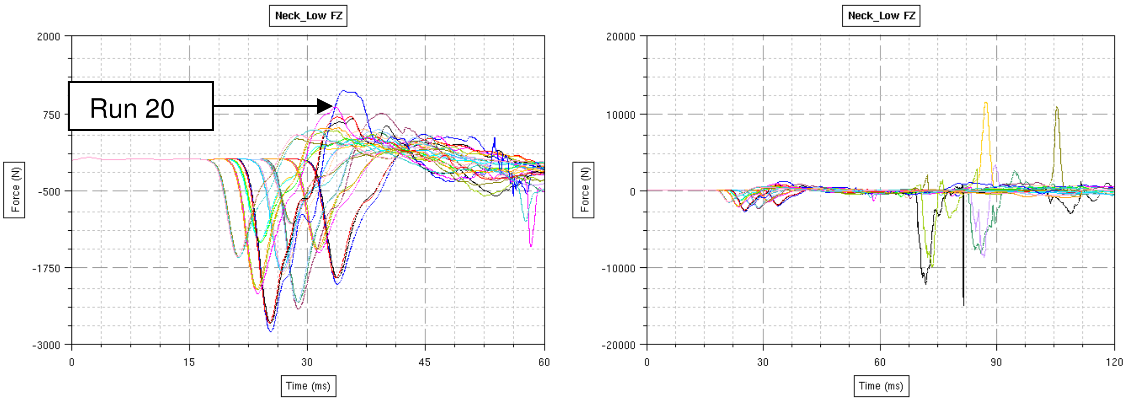


Figure A12 - upper neck moments and forces curves



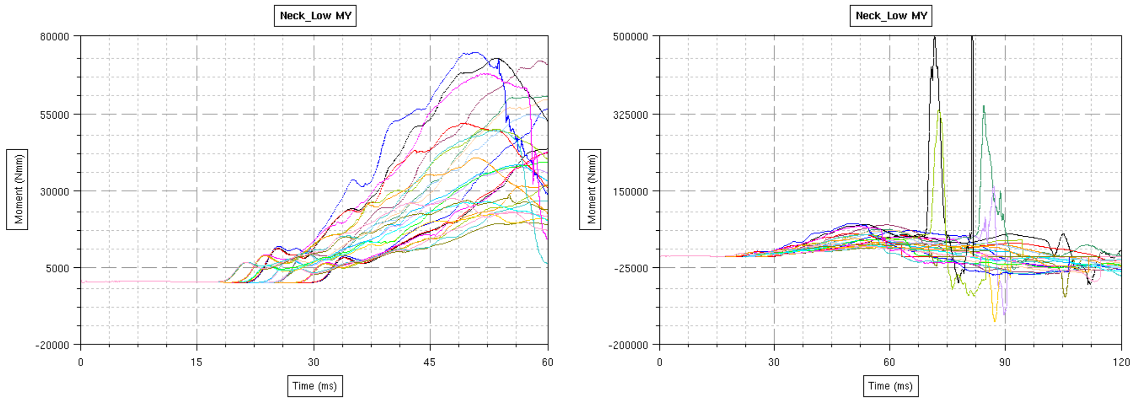
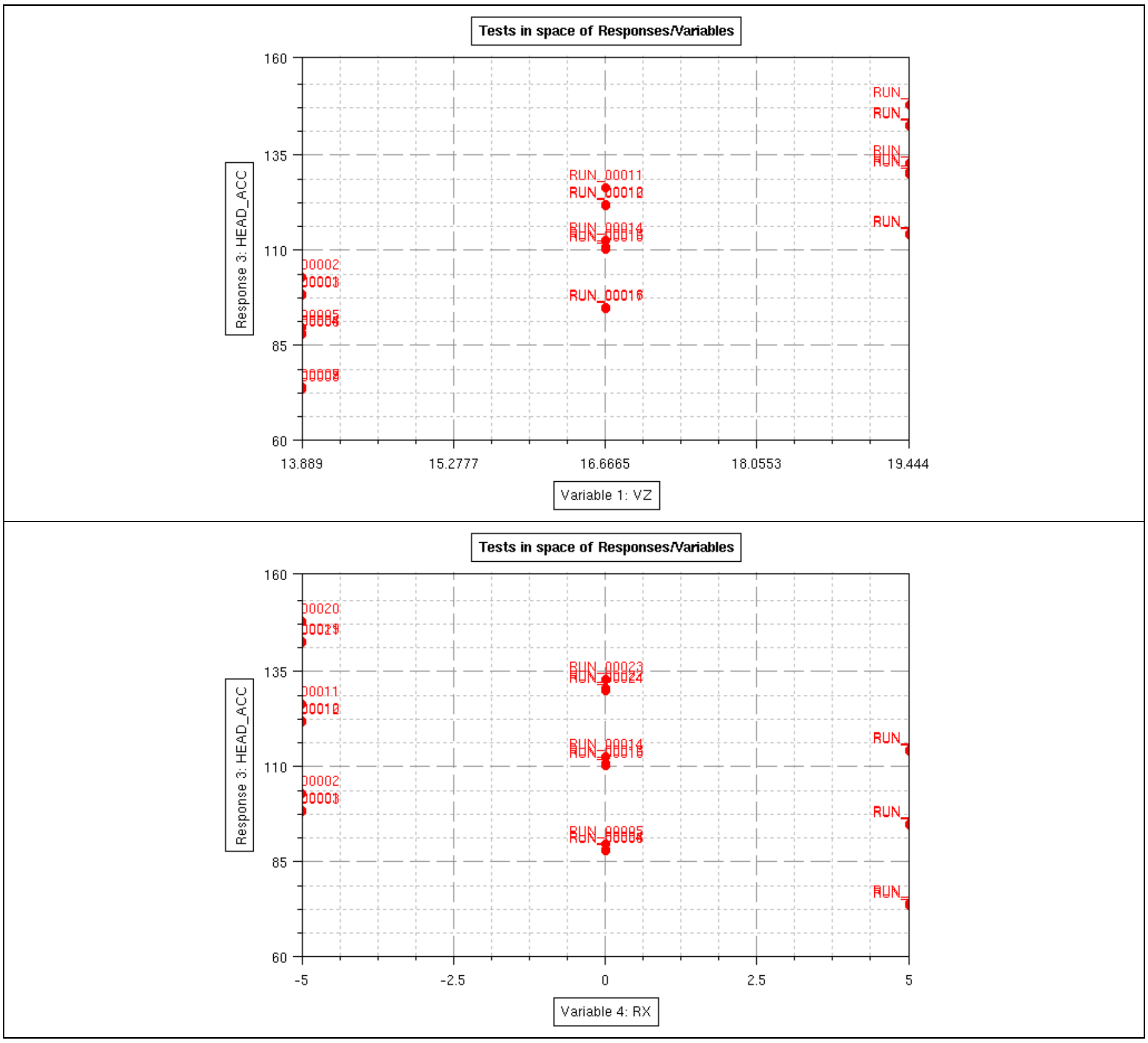


Figure A13 - lower neck moments and forces curves

Neck forces and moment analysis mainly leads to the same conclusion as the head acceleration study.
For the first range, 0 to 60 ms, the results are similar. Run 20 can be seen on force applied along Z axis.
For the higher range, from 0 to 120 ms, second impact is producing large differences for Runs corresponding to an impact point located before the pole.

○ ***Responses analysis***



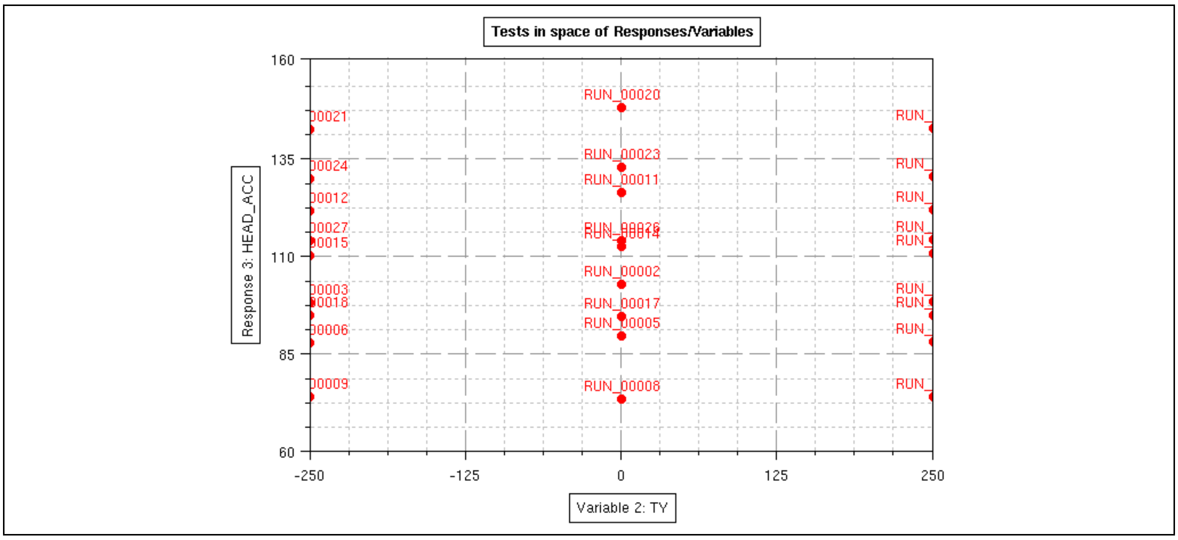
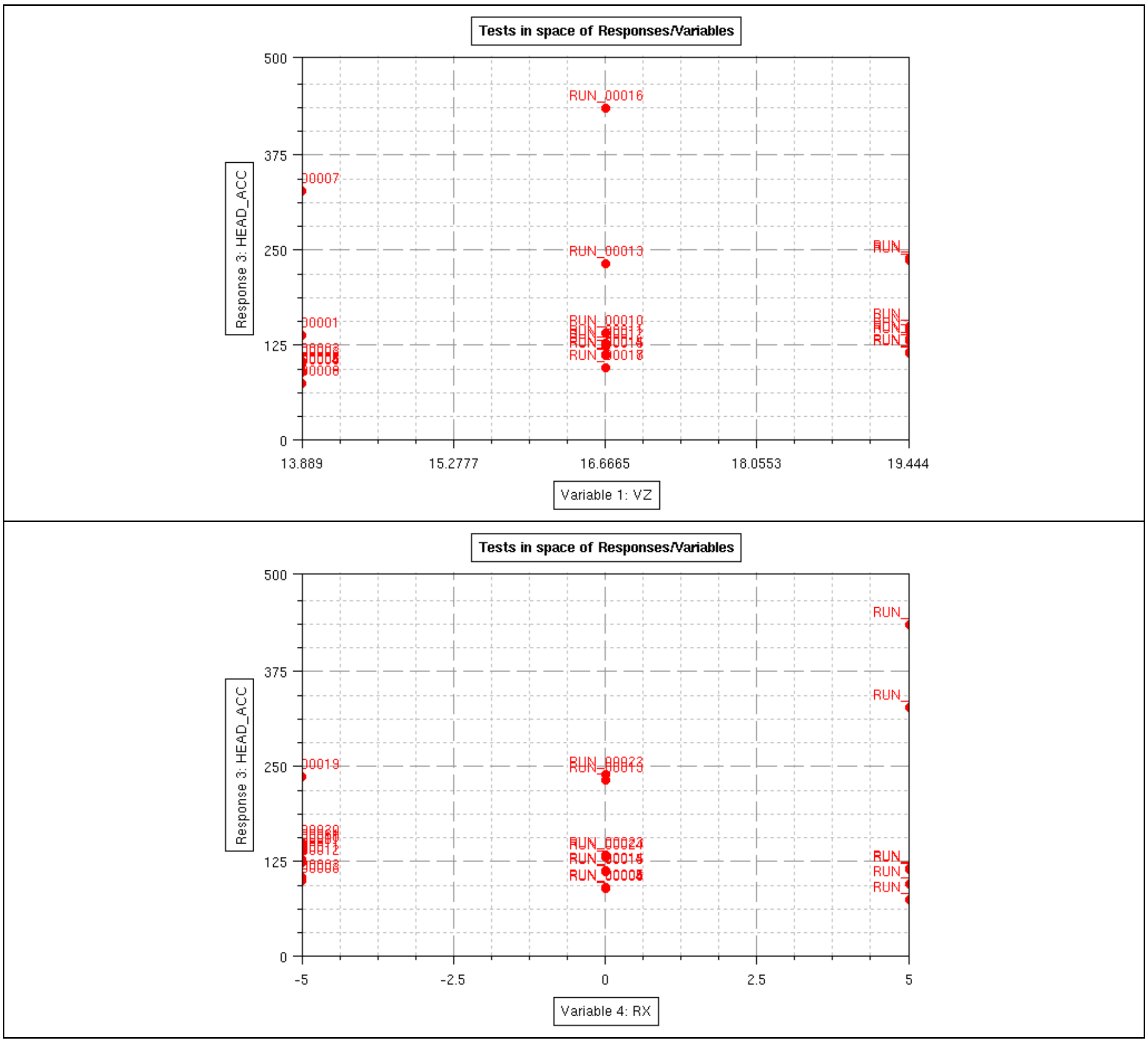


Figure A14 - Head Resultant maximal acceleration (signal analyzed up to 60ms)

The maximal head resultant acceleration level is depending on velocity and angle, but is clearly independent of the impact point location. Velocity and angle changes offset the head resultant maximal acceleration value.



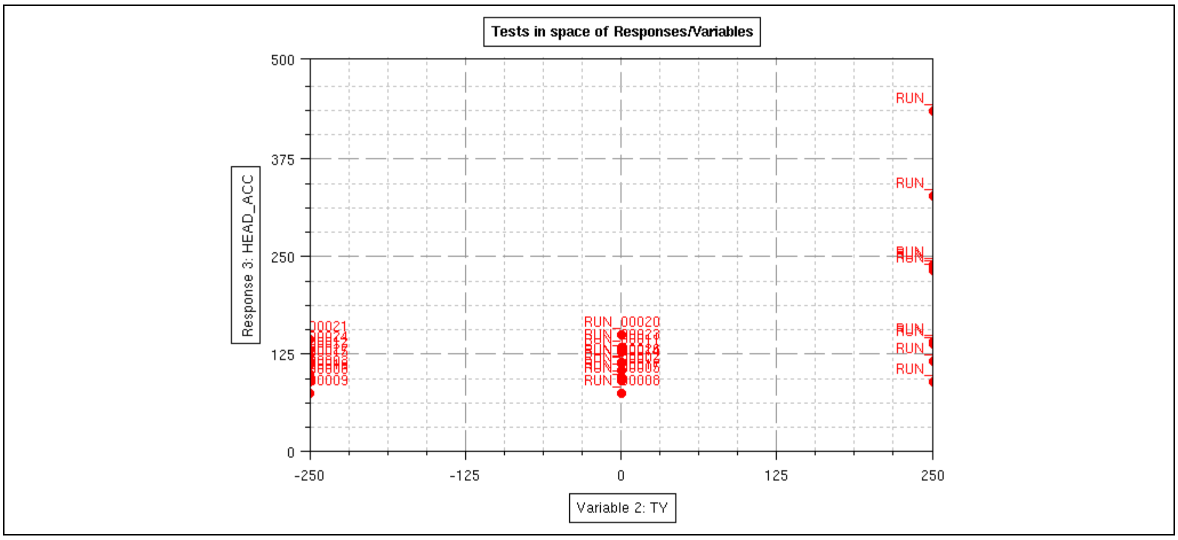
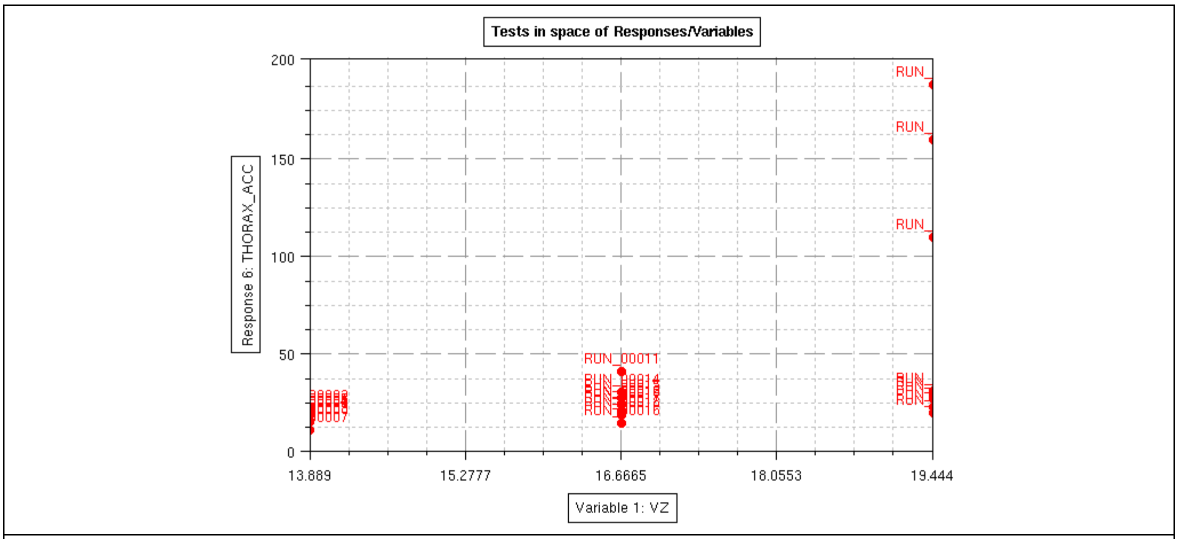
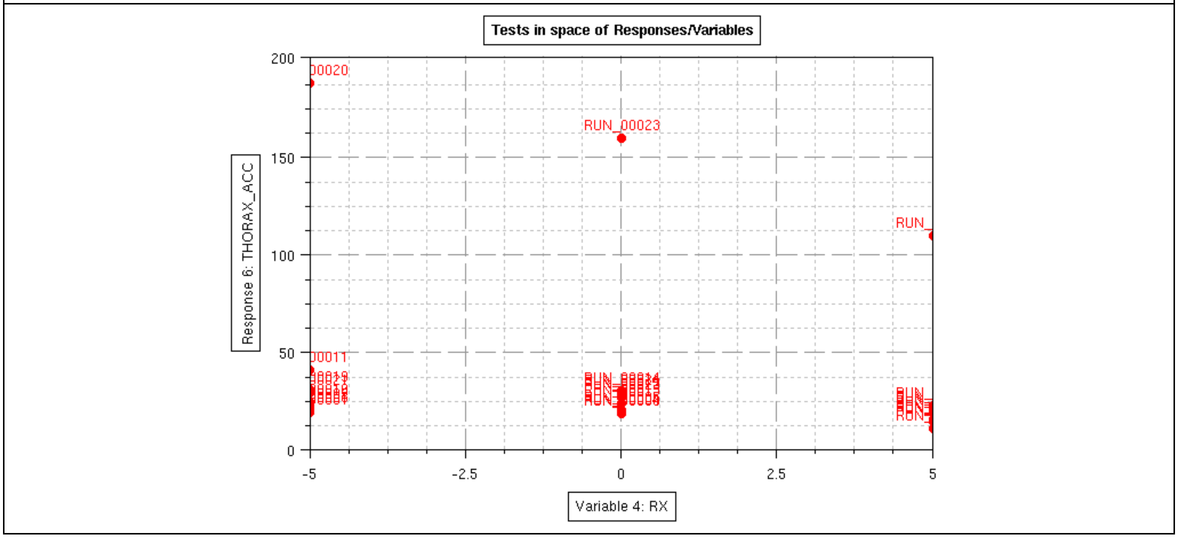


Figure A15 - Head Resultant Acceleration (signal analyzed up to 120ms)

Figure A14 and A15 comparison clearly shows the main problem about the hard impact configuration for studies covering the 120 ms time range. Runs 7, 13, 16, 19 and 22 are very well included in a normal behaviour until 60 ms, but are outliers when considering 120 ms.





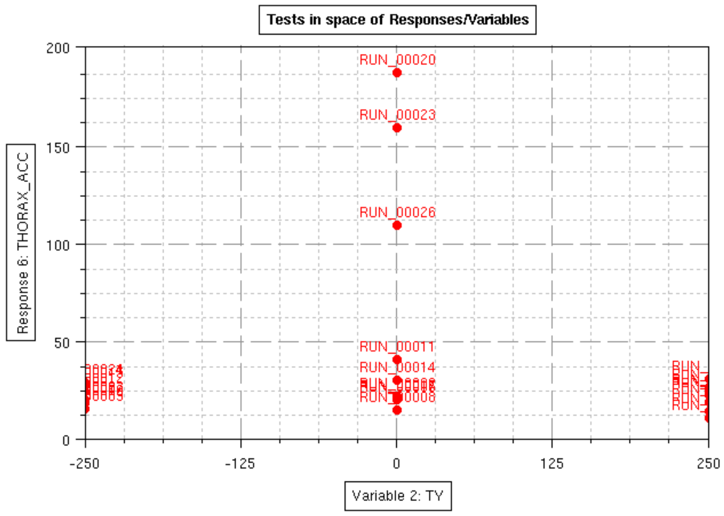
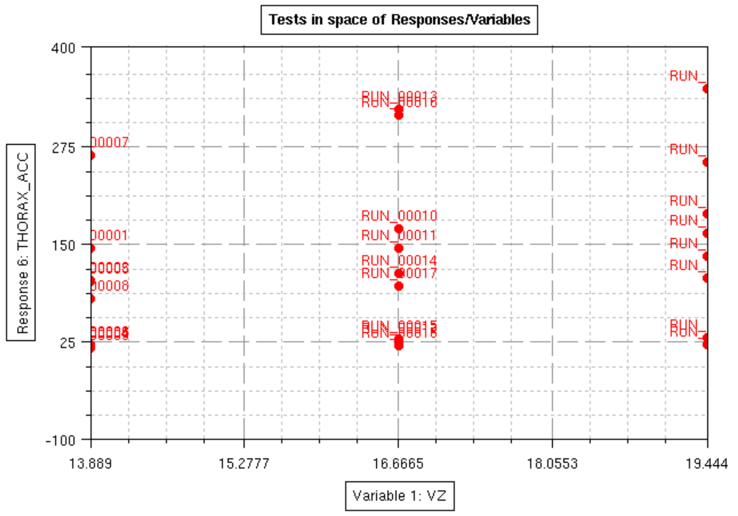
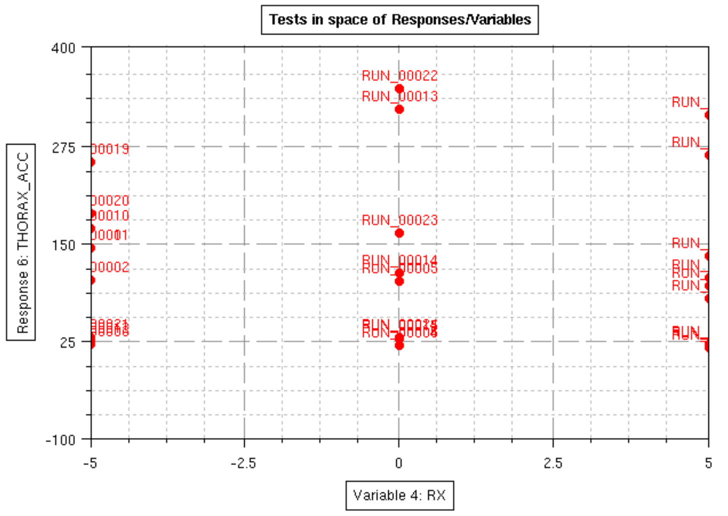


Figure A16 - Thorax Resultant Acceleration (signal analyzed up to 60ms)

As it was already stated in the previous chapter, impact directly on the pole at high speed induces large thorax acceleration peaks (runs 20, 23 and 26 on figure 16).





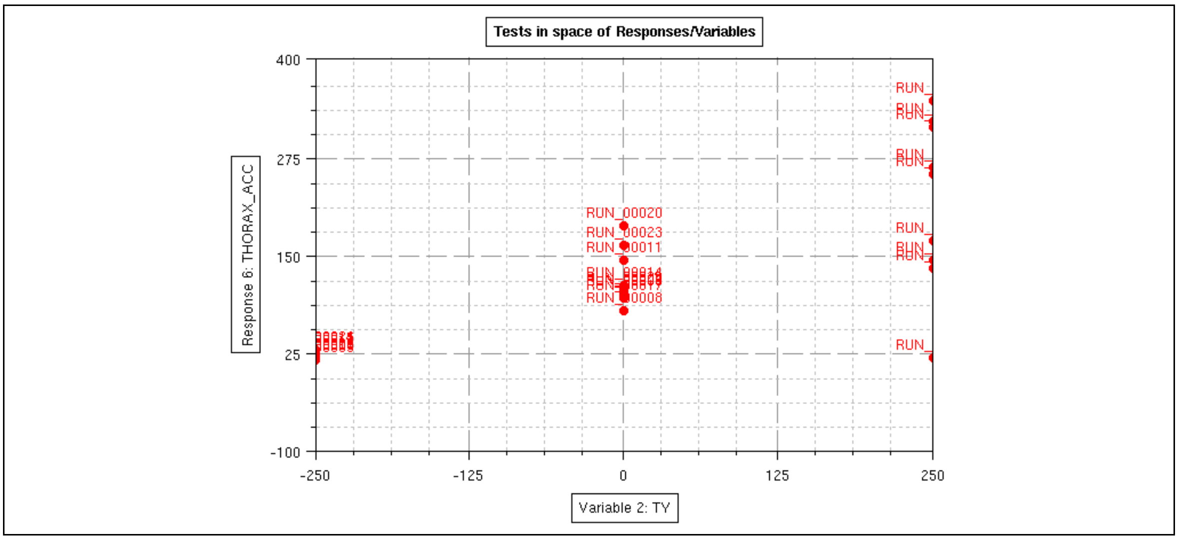
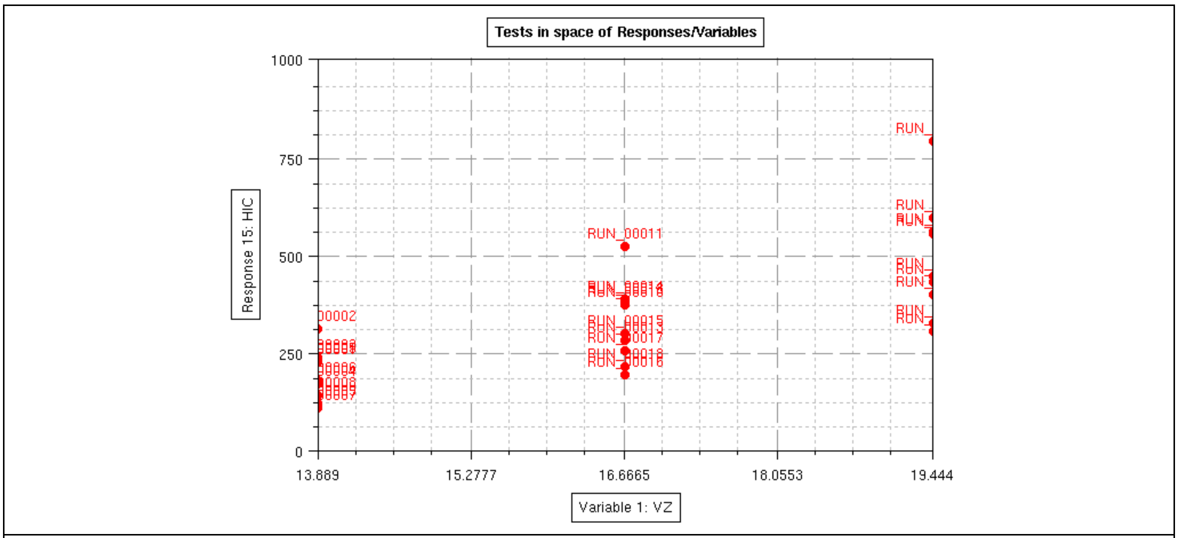
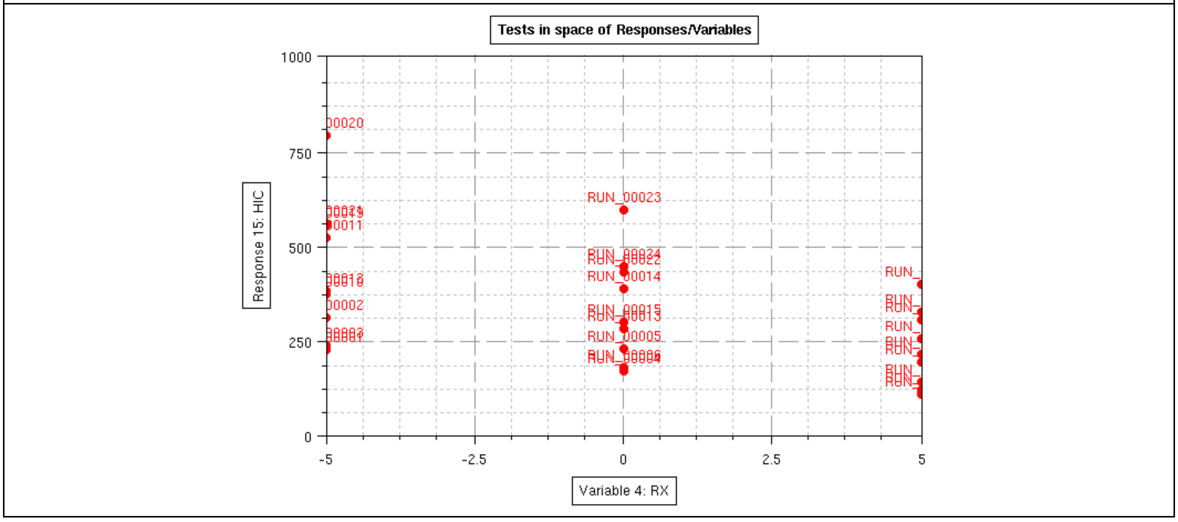


Figure A17 - Thorax Resultant Acceleration (signal analyzed up to 120ms)

On a larger range of study (from 0 to 120 ms), thorax acceleration peak is very sensitive to impact location (figure A17) and its value dispertion is rised.





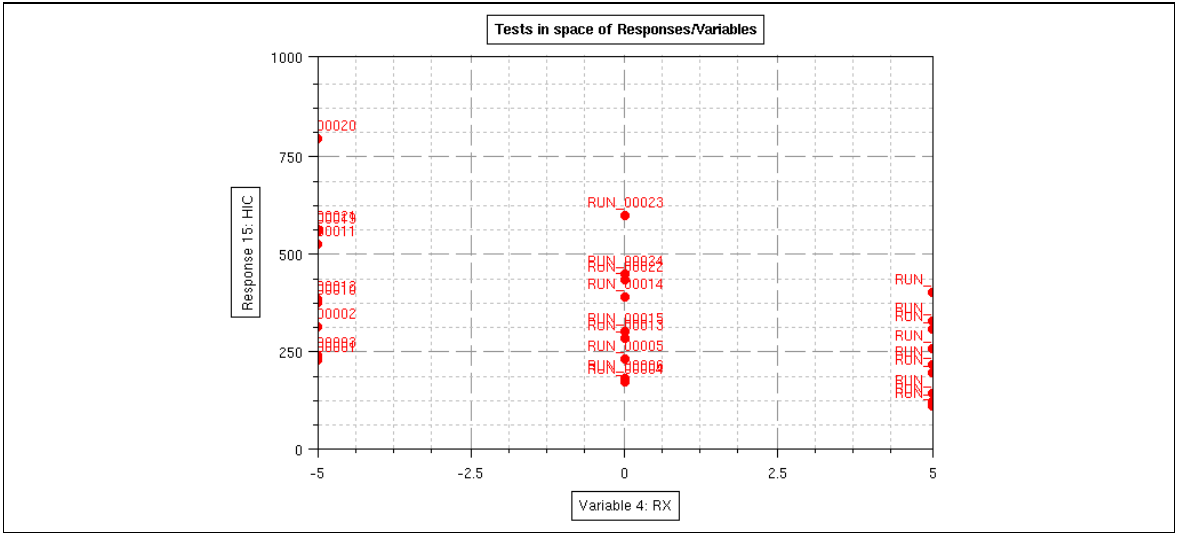
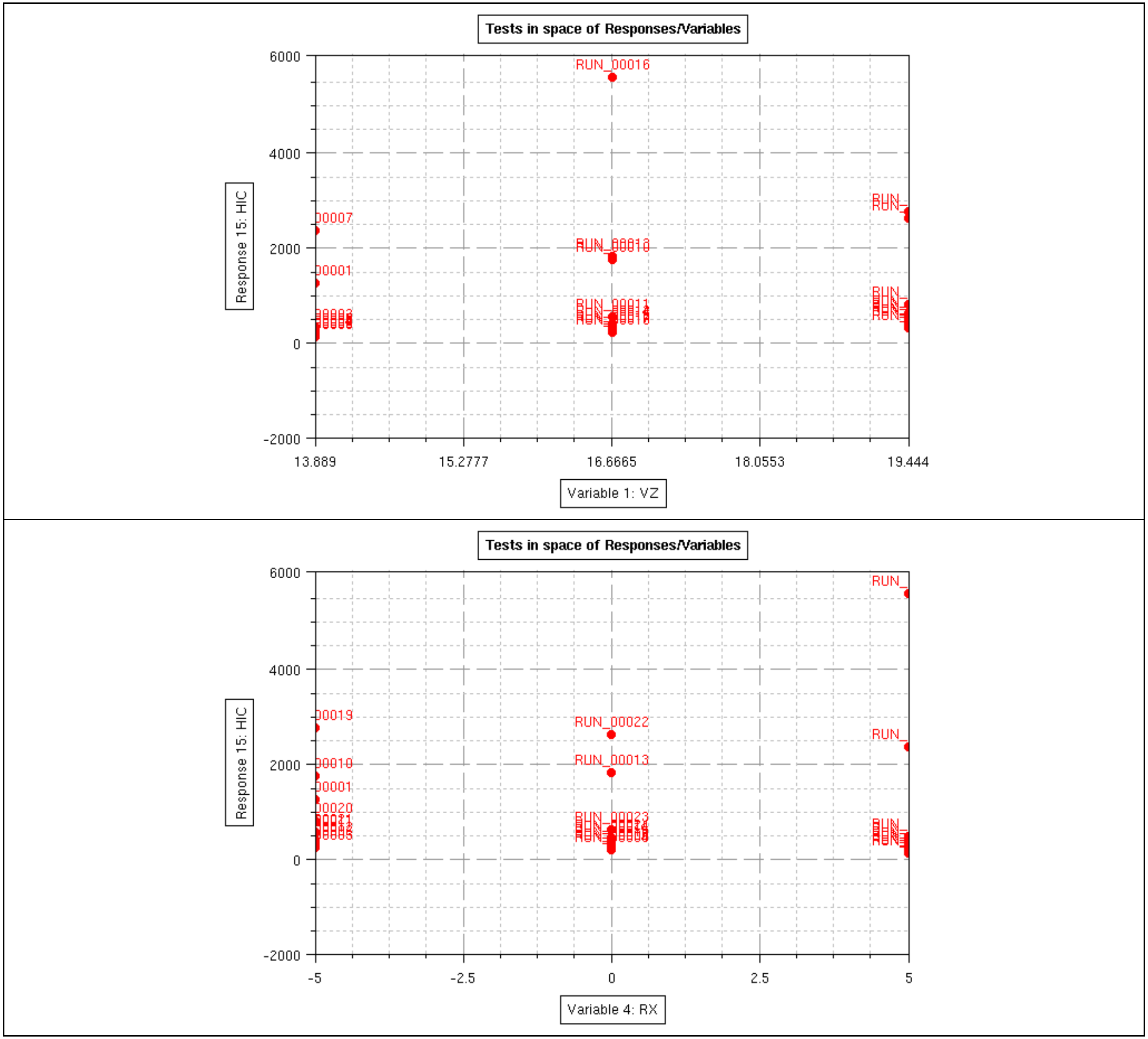


Figure A18 - HIC value (signal analyzed up to 60ms)



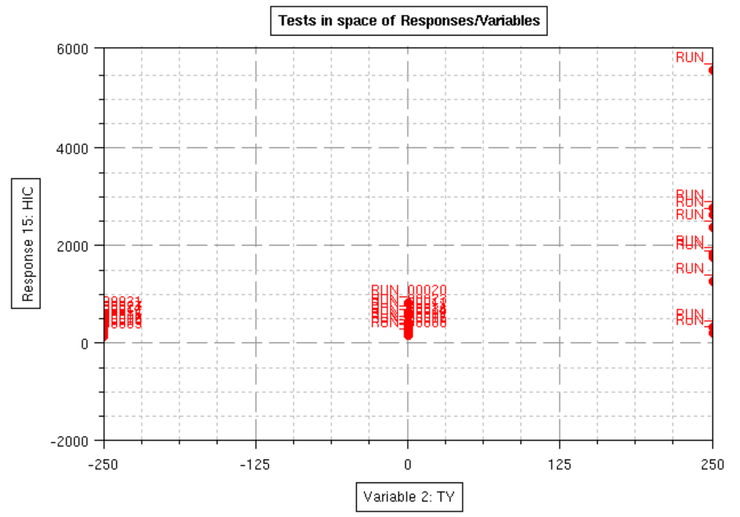
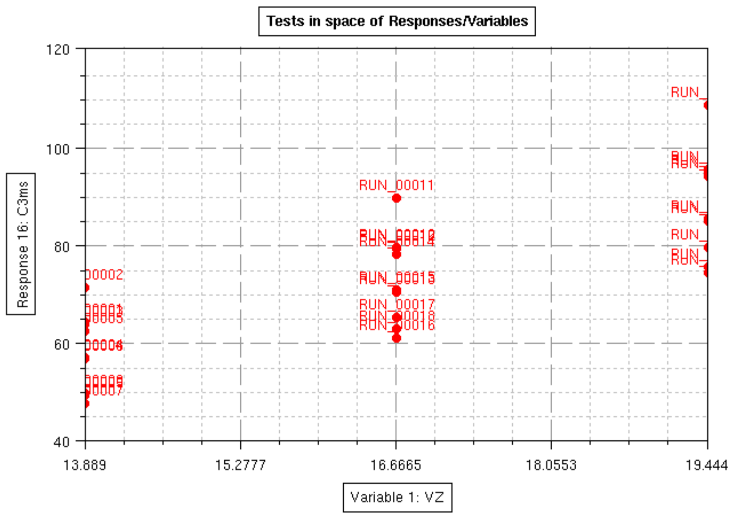
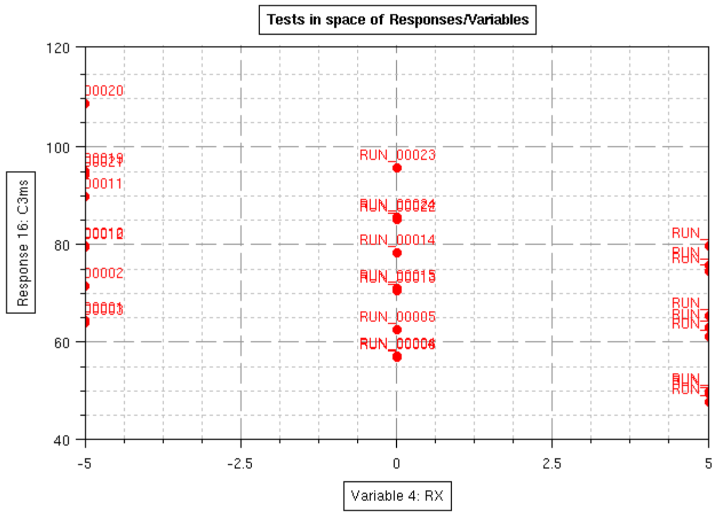


Figure A19 - HIC value (signal analyzed up to 120ms)

On a 120 ms study, run 16 excepted, HIC is not sensible to impact angle variations or impact speed. However the impact location induces a great variability (Figure A19). As it was stated, impacting before the pole induces a late hard impact which has an influence on HIC values.





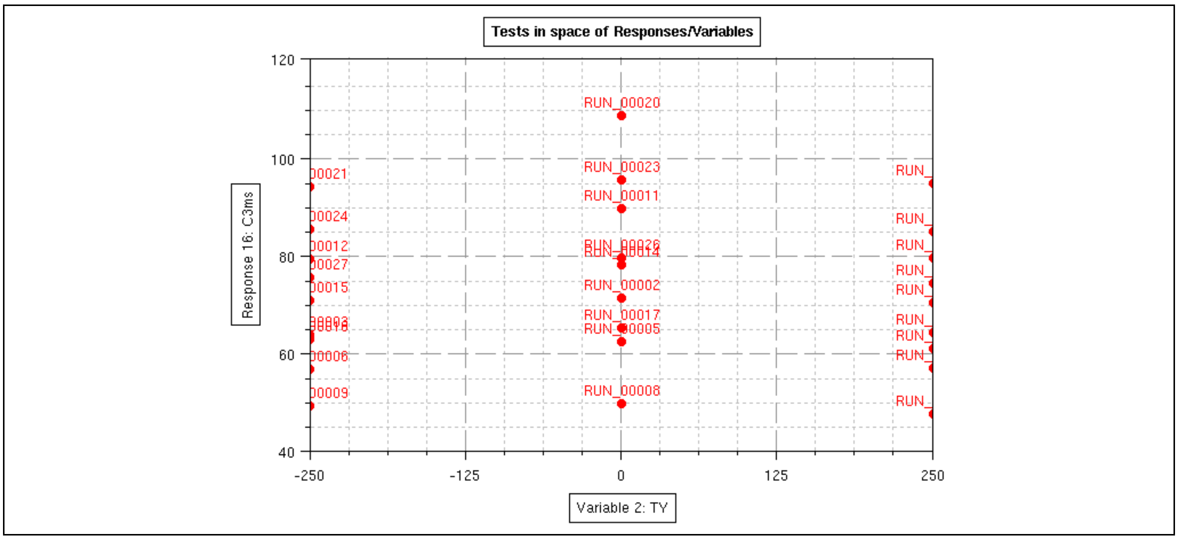
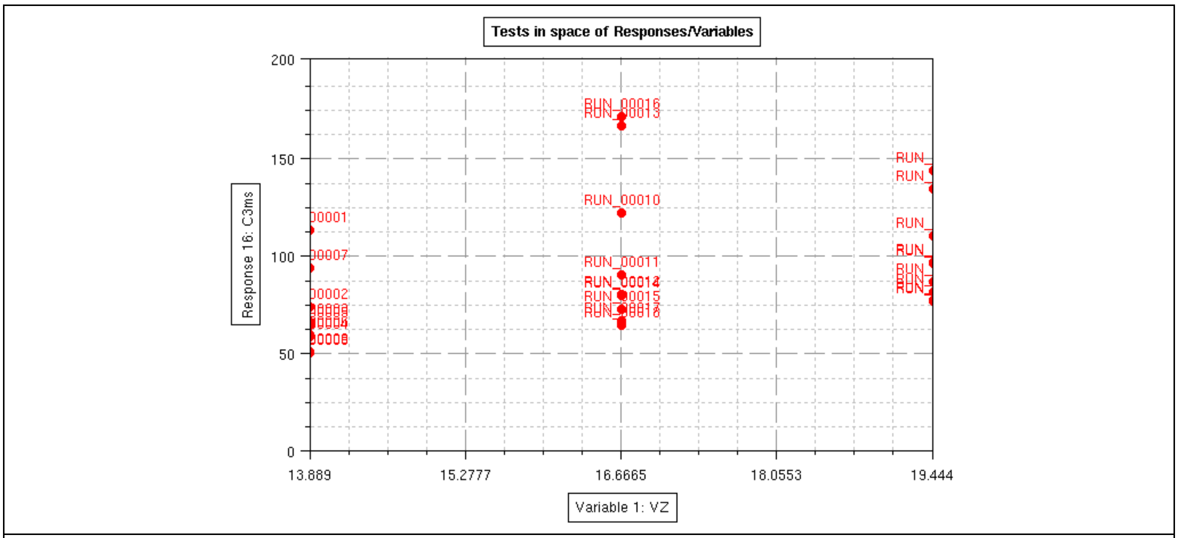
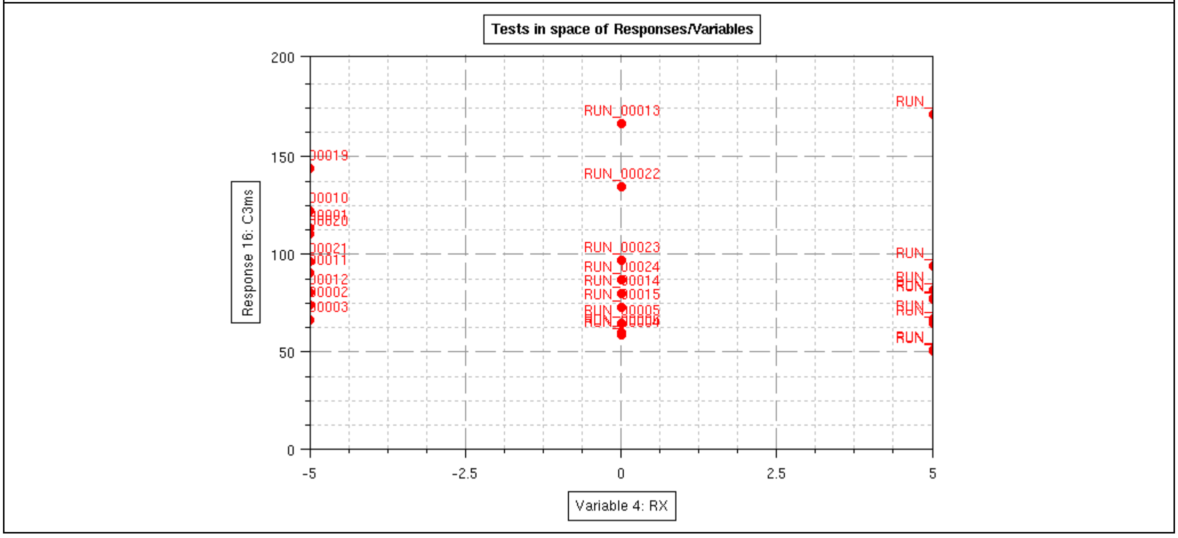


Figure A20 - Head 3ms value (signal analyzed up to 60ms)





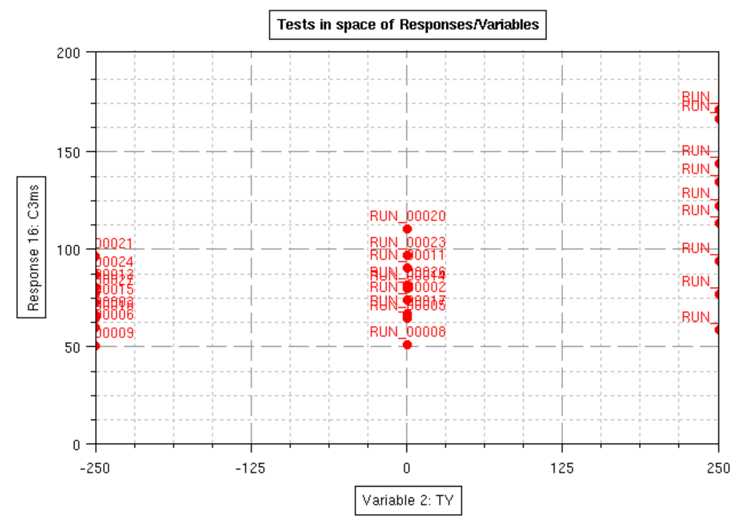


Figure A21 - Head 3ms value (signal analyzed up to 120ms)

As for HIC and head peak acceleration, conclusions on Head 3ms are different for the short or long time range (comparison of Figure A20 and A21).

- ***Statistical Analysis***

Tables A4 and A5 indicate statistical moments of the responses.

Responses over 120 ms	**Minimum**	**Maximum**
HIC	120.8	5521.6
Head 3ms	49.643	169.92

Responses over 60 ms	**Minimum**	**Maximum**
HIC	109.8	789.7
Head 3ms	47.17	108.18

Table A4 - Responses Range

Responses over 120 ms	**Mean**	**Standard Deviation**	**| SDev / Mean |**
HIC	922.04	1204.77	1.307
Head 3ms	89.88	32.57	0.362

Responses over 60 ms	**Mean**	**Standard Deviation**	**| SDev / Mean |**
HIC	334.24	164.20	0.491
Head 3ms	72.83	15.43	0.212

Table A5 - Statistical Moments

To illustrate the dispersion, histograms below show frequency of HIC and 3ms values over the 27 jobs performed.

It clearly shows that the HIC value of 5521.56 (run 16) is an outlier.

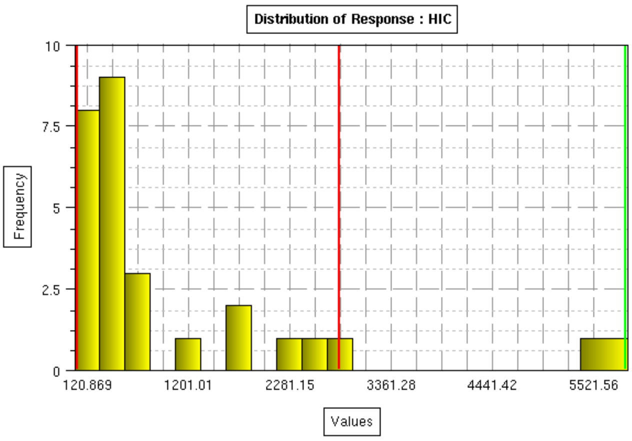


Figure A22 - HIC distribution

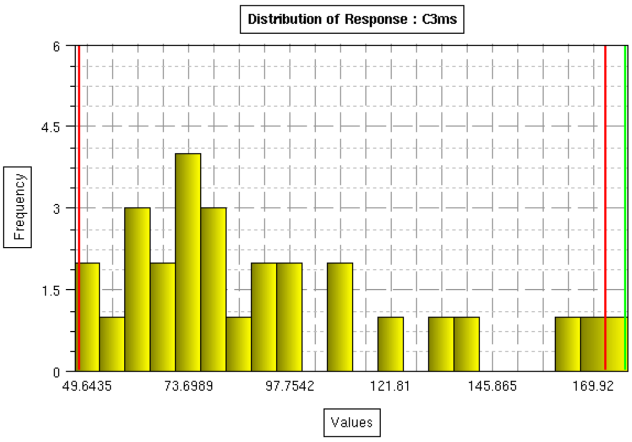
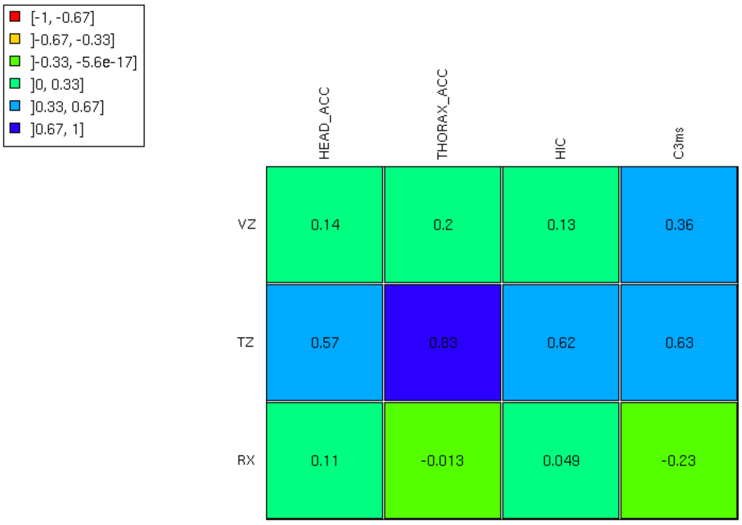


Figure A23 - Head 3ms distribution

- ### *Correlation Analysis*

Table 6 displays the linear correlation between responses and variables.



🟥 [-1, -0.67]
🟨]-0.67, -0.33]
🟩]-0.33, -5.6e-17]
🟩]0, 0.33]
🟦]0.33, 0.67]
🟦]0.67, 1]

	HEAD_ACC	THORAX_ACC	HIC	C3ms
VZ	0.14	0.2	0.13	0.36
TZ	0.57	0.83	0.62	0.63
RX	0.11	-0.013	0.049	-0.23

Table A6 - Linear correlation between responses and variables

Impact location point (variable TZ) is the most important parameter, it is greatly correlated to each studied responses. However Head 3ms is also correlated to speed (variable VZ).

Figures A24 & A25 below present the graphs (biplots) obtained applying ADVISER's postprocessing feature (Principal Component Analysis in the Data Mining module).

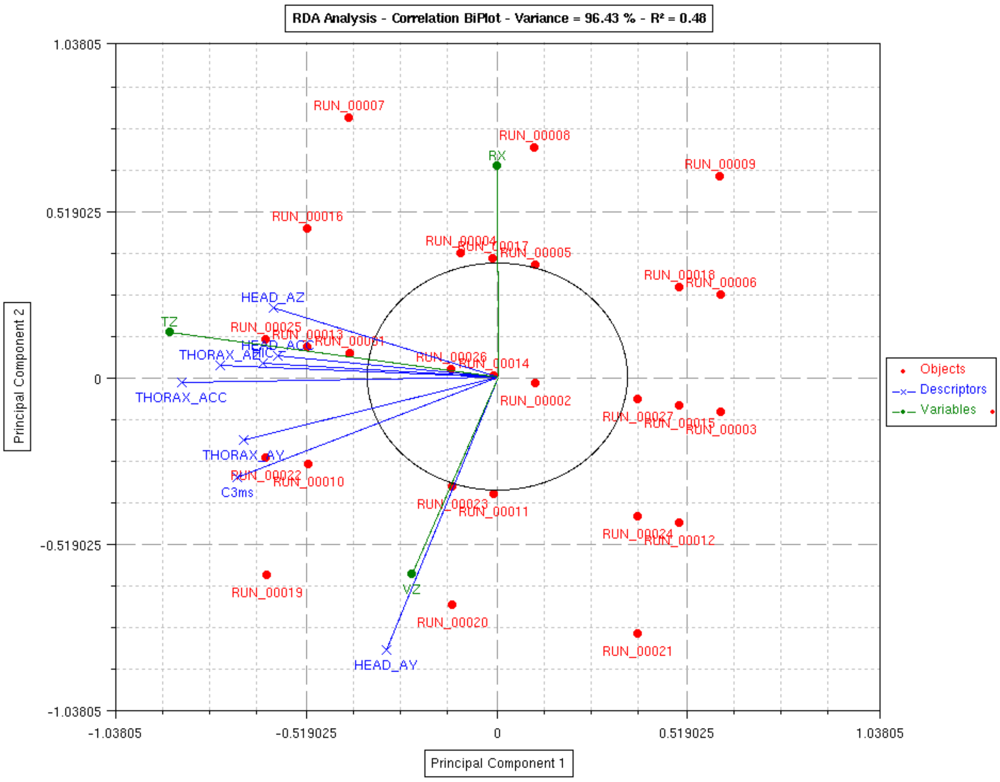


Figure A24 - PCA correlation biplot

Figure A24 analysis leads to two main statements:

- Head acceleration is highly correlated with speed (VZ)
- All the others responses are correlated with impact location (TZ)

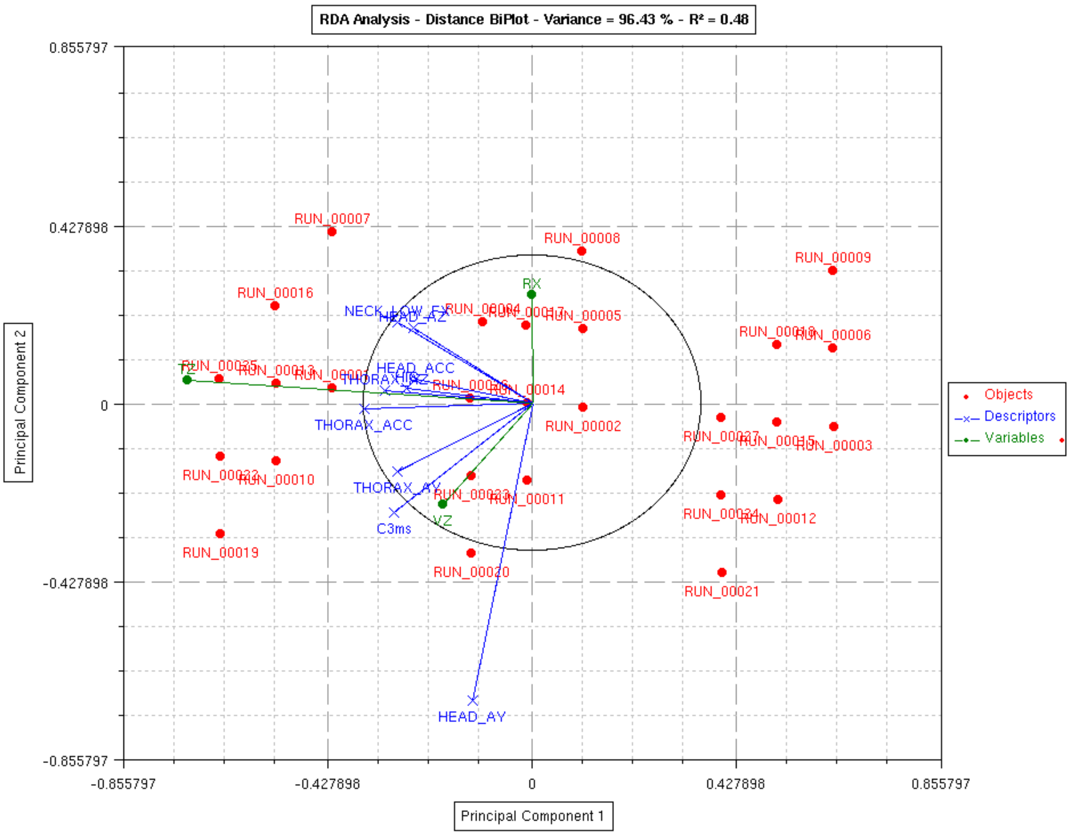


Figure A25 - PCA distance biplot

Figure A25 analysis leads to confirm that the impact location is the most influent parameter. Angle (RX) and velocity are then of equivalent importance.

5. Analysis synthesis

Three main statements which can be deduced form the previous study:

- First of all, two end configurations are possible, sliding along the barrier or “hard impact” on the pole. The second configuration mainly influencing the responses after 60 ms by generating very variable results.
- Secondly impact point location is the most important parameter. It is correlated to every response and change the global behaviour of the simulations.
- At last, speed is increasing responses sensitivity. It increases the two others parameters influence, inducing a higher variability between tests.

On criteria, the two less scatters due to unknown variables are head resultant acceleration and HIC (which are obviously strongly related).

6. Conclusion

The main objective of Task 4.2.3 is to propose a new standard for impacts of motorcyclists versus road infrastructure.

First of all we have shown that performing two test series, one with a face up dummy, one with a face down dummy, is not necessary. The differences between the model responses in the two cases are very limited.

Then, by using the chosen configuration (as defined in Deliverable 4.2.2), we analyzed the influence of velocity, impact angle and impact point location on the outcome of the tests.

A parametric study based on these three parameters was performed and analyzed. An ADVISER table was built to post-process the results and has shown that:

- the study range has an influence on the responses analysis;
- impact location point is the main parameter and induces high variations on responses;
- velocity is increasing responses' sensitivities to the two others parameters.

Moreover, head resultant acceleration and HIC are the most independent injury criteria which can be used.

In conclusion, we recommend to pay attention to the impact location point setting and speed specification when the new standard tests for impacts of motorcyclists versus road infrastructure will be devised in order to obtain stable results.