EVALUATION OF SECONDARY RISK WITH A NEW PROGRAMED RESTRAINING SYSTEM (PRS2)

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ABSTRACT

The new safety standards or car assessment programs for passive safety lead to the stiffening of car bodies. Consequently, the loading of occupants increases, generating a higher injury risk to the thorax. To avoid this increase in undeformed cars, more efficient restraining systems have to be developped. But the improvement of performances should not increase out-of-position (OOP) risks, in particular to the neck and thorax of adults and to children.
This paper deals with the development of a new restraining system combining a belt with 4 kN force limiter and an airbag with pressure limitation. In order to have a biomechanical evaluation of real protection on human beeing, the OOP injury risk is studied by Post Mortem Human Subject (PMHS) experiments.

THE PROGRAMED RESTRAINING SYSTEM

This system was presented by Bendjellal, 1997 [1]. It consists on 3 main components for the optimisation of thorax restraint : the pretensioner, the belt load limiter and the air-bag. The pretensioner and the belt load limiter are designed to restraint the thorax as soon as possible but with a load which complies with human tolerance (4 kN). Then, the airbag is designed to contribute actively to the thorax restraining while avoiding agressiveness of the deployment. This leads to an increase in the generator power, associated to an elaborated airbag-folding which reduces the punch out and to a pressure limitation in the airbag.

OUT-OF-POSITION INJURY RISKS

In order to evaluate the real OOP injury risk and to generate biomechanical data, a test protocole on PMHS was elaborated with and realized by CEESAR. Four static tests have been conducted up to now with PMHS and can be compared with Hybrid III tests conducted in the same conditions.

Test method - The subject is seated on a Renault Megane seat, leaning over the steering wheel equiped with PRS2 Airbag. Two positions of the occupant were used. In the first position (Figure 1), the forehead rests on the steering wheel rim and the chin is on the top of the airbag module. In the second position (Figure 2), the nose was located on the module.

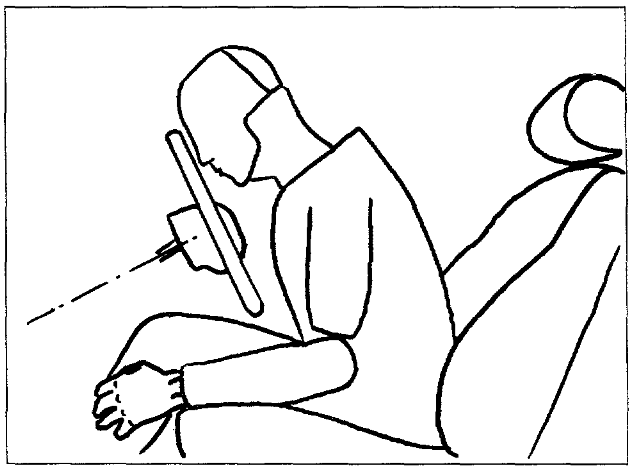

Figure 1 : Occupant relative position to steering whell in static air bag deployment OOP tests. Position forehead on rim.

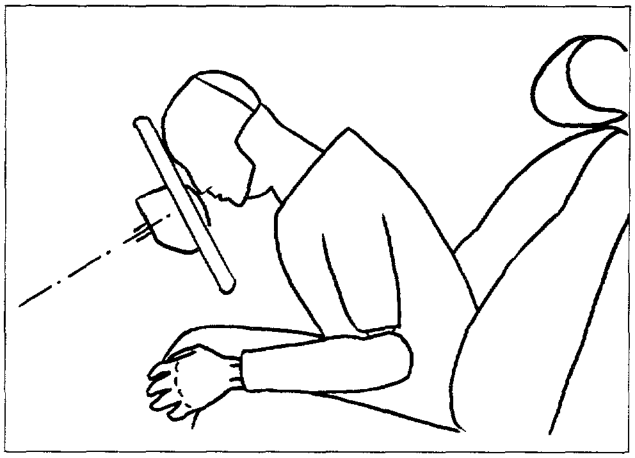

Figure 2 : Occupant relative position to steering whell in static air bag deployment OOP tests. Position nose on module.

Preparation of subjects - The subjects are fresh cadavers from the Anatomical Donor's service of the Anatomical Laboratory of the Saints-Pères Faculty, Paris V. The vascular system is re-pressurized through a bi-carotid injection of a solution of formaldehide, water and china ink. The pulmonary volume is re-established.
For the Hybrid III, tests were performed with and without neck shield (FTSS n° 103 9006).

Instrumentation - The subjects are equiped with a 12-acceleration array fastened to the occiput of the head in order to measure 3 linear and 3 angular head accelerations. 3-axes accelerations are measured at T4, T12 and sacrum level. Thoracic deflection is measured with a chest band at level T5. Vascular and pulmonary pressures are also measured.
For Hybrid III, measurements include 3-axes head, thorax and pelvis accelerations, neck loads, head and thorax angular velocity and chest deflection (potentiometer).
The airbag pressure is measured as well as steering wheel forces

Test results - Table 1 gives the subject characteristics, Table 2 the test results with HIII and PMHS in the position with the nose on the module and Table 3 test results with HIII and PMHS in the position with the forehead on the rim.

DISCUSSION

OOP injury risk with PRS II - For the PMHS tests, three subjects were tested in the first configuration (forehead on rim) and one subject in the second one (nose on module).
In the forehead/rim position, two subjects sustained AIS2 thoracic injuries, while the third one just sustained a slight burn on the forearm (AIS1). It is to be noted that these two subjects where repectively 76 and 81 year old men, the first one having metastases on the ribs. No injuries were observed to the neck, nor to the head.
In the nose/module position, the subject sustained no injuries.
The results of these 4 tests are satisfying and suggest that the airbag folding as well as the pressure limitation worked well.

Neck injury analysis- For the nose/module position, the kinematic is similar for the PMHS and the HIII : the head has a movement of extension from the begining of the deployment, while the thorax goes backward. However, the head acceleration is the double with PMHS compared to HIII.

For the forehead/rim position, the head kinematic is different on PMHS and HIII. Indeed, for PMHS the head is pushed upward at the begining of deployment, without extension. The thorax goes backward, pulling the head which goes in extension when the thorax comes in contact with the seat-back. On the contrary, for HIII, the head goes in extension from the begining of deployment to the end of test. As a consequence, it is difficult to associate neck injury on PMHS to neck measurements on HIII for these tests.

Thoracic injury criteria - For the two test conditions, the kinematic of the thorax is similar for PMHS and HIII. More, the air bag pressure is comparable and the thorax accelerations are on the same range. On the contrary, the thorax deflections are in the range of 13 to 18,5 mm for HIII, against 63 to 73 mm for PMHS, or 50 to 60 mm if we reduce chest compression by 13 mm to take account for the effect of compression of the flesh covering the thorax. The Viscous Criterion (VC) are in a ratio of 10 between HIII and PMHS. It can be conclued that HIII is more stiff than PMHS in these test conditions.
These data, for the test conditions discussed here, lead to a 50% risk of AIS2 and 0% of AIS3 in the range of 50 to 60 mm of internal deflection, for males in the range of 54 to 81 years. If we refer to Mertz analysis [2] of Neathery data (distributed chest impacts), the same range of deflections is associated to a risk between 10% and 40% of AIS3+. It is to be noted that these figures refer to cadaver data.

CONCLUSIONS

A preliminary investigation to evaluate the risk of neck injury with the PRS II air bag was performed, using the Hybrid III 50° percentile dummies and 4 subjects (PMHS). Two occupant/steering wheel positions, i.e. forehead on rim and nose on module, were used. The air bag pressure control worked in all tests. For the PMHS, only two AIS2 thoracic injuries and a slight burn on the forearm for one subject (AIS 1) were found during the autopsies. In addition, no neck injuries were found. These data appears to be satisfying at this stage of analysis; further investigations with the Hybrid 5° percentile and a more in-depth analysis of the PMHS test data remain to be performed to increase the knowledge in the field of human behaviour and tolerance in OOP conditions.

AKNOWLEDGMENTS

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REFERENCES

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3- Mertz H.J. : « Anthropomorphic Test Devices « Accidental Injury - Biomechanics and Prevention, A.M.Nahum and J.M.Melvin, eds, Springer - Verlag , New York, 1993.

TABLE 1 : Subject characteristics and injuries

	PMHS 500	PMHS 501	PMHS 503	PMHS 505
WEIGHT (kg)	68	96	78	70
HEIGHT (m)	1,72	1,76	1,75	1,68
Buste (m)	0,945	0,91	0,90	0,875
CHEST WIDTH (seating position) (m)	0,200	0,235	0,200	0,210
AGE (years)	54	73	76	81
SEXE	Male	Male	Male	Male
Cause of death				
HEAD	No injury	No injury	No injury	No injury
NECK	No injury	No injury	No injury	No injury
THORAX	No injury	No injury	R3-5 Fx on left side R3-5 Fx on right side AIS = 2	R3-4-5 Fx on left side R3-4-5-10 Fx on right side AIS = 2
Comments			metastase on ribs	

TABLE 2 : Test results with HIII and PMHS (nose on the module)

	Limits		Nose on the module: HIII 997	Nose on the module: HIII 998 with neck shield	PMHS 501
HEAD	1000	HIC 15 ms (t1-t2)	113 (23-38)	98 (24-39)	436 (3-9)
	80	Acc 3 ms **(g)**	44	38	81
		max Rotation **(deg)** (ATA)	84	81	8
	60	Ext neck/thorax (deg) (film)	61	56	
NECK	3.1/ -3.1	Fx Upper neck **(kN)** (tmax)	0.84 (34) / -0.19 (53)	1.1 (35) / -0.1 (155)	
	4.0/ -3.3	Fz Upper neck **(kN)**(tmax)	1.55 (33) / -0.3 (10)	1.27 (29) / -0.12 (11)	
	190/ -57	My Upper neck condyles (Flex/Ext) **(Nm)** (tmax)	49 (11) / -33 (59)	77 (36) / -26 (61)	
		Fx Lower neck **(kN)** (tmax)	6.94 (11) / -1.38 (21)	5.08 (48) / -1.52 (6)	
		Fz Lower neck **(kN)** (tmax)	1.36 (33) / -0.15 (16)	1.1 (8) / -0.23 (11)	
		My Lower neck **(Nm)** (tmax)	19 (343) / -97 (37)	17 (343) / -100 (9)	
THORAX	60	Acc 3 ms **(g)**	15	17	T4 = 24 T12 = 9
	76	Déflection **(mm)**	15 (9%)	13 (8%)	63 (19%)
	1	VC **(m/s)**	0.058	0.045	0.47
PELVIS	60	Acc 3 ms (g)	3	3	5

TABLE 3 : Test results with HIII and PMHS (Forehead on rim)

	Limits		Forehead on rim: HIII 995	HIII 996 with neck shield	SPHM 500	SPHM 503	SPHM 505
HEAD	1000	HIC 15 ms (t1-t2)	44 (25-40)	52 (26-39)	295 (8-12)	71 (7-15)	34 (31-46)
	80	Acc 3 ms **(g)**	29	35	46	38	27
		max Rotation **(deg)** (ATA)	69	64	26	8	15
	60	Ext neck/thorax (deg) (film)	48	40			
NECK	3.1/ -3.1	Fx Upper neck **(kN)** (tmax)	0.2 (6) / -1.11 (31)	0.14 (5) / -0.73 (27)			
	4.0/ -3.3	Fz Upper neck **(kN)**(tmax)	2.09 (9) / -0.02 (330)	1.78 (35) / -0.01 (-93)			
	190/ -57	My Upper neck condyles (Flex/Ext) **(Nm)** (tmax)	8 (326) / -62 (32)	3 (332) / -39 (28)			
		Fx Lower neck **(kN)** (tmax)	3.11 (45) / -0.47 (33)	2.51 (36) / -2.50 (37)			
		Fz Lower neck **(kN)** (tmax)	1.77 (9) / -0.43 (11)	2.02 (35) / -0.03 (212)			
		My Lower neck **(Nm)** (tmax)	50 (11) / -128 (9)	21 (10) / -100 (7)			
THORAX	60	Acc 3 ms **(g)**	15	15	T4 = 24 T12 = 14	T4 = 28 T12 = 17	T4 = 20 T12 = 11
	76	Déflection **(mm)**	17 (10%)	18.5 (11%)	72 (28%)	73 (26.2%)	63 (24.9%)
	1	VC **(m/s)**	0.08	0.106	0.66	1.06	0.92
PELVIS	60	Acc 3 ms (g)	5	4	6	4	5