THE EVALUATION OF SUB-SYSTEMS METHODS FOR MEASURING THE LATERAL HEAD IMPACT PERFORMANCE OF CARS

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ABSTRACT

The EEVC Side Impact Test Procedure includes the measurement of head impact with the EUROSID dummy. It was recognised that this would evaluate only a limited range of the potential head contact locations within the vehicle. EEVC commenced a study of accident analysis and the evaluation of potential head impact sub-systems tests. Three alternative headforms have been appraised and the effect of free flight and linearly guided impacts have been examined. The objective was to develop a simple, repeatable and representative sub-system test procedure.

This paper presents progress of the EEVC study and the initial results of the test programme. Proposals are made for a possible test method and for a future validation test programme.

INTRODUCTION

The EEVC developed a new impact test procedure for the evaluation of the protection afforded to struck side car occupants in the event of a side impact to the passenger compartment. The final presentation of this test procedure was given in the EEVC paper to the Twelfth ESV Conference in 1989[1]. EEVC developed a new dummy for use with the test procedure (EUROSID) since there was no dummy available at that time suitable for use in side impact testing. The dummy was designed to be able to detect injury risk in the four areas of the body which were most frequently injured at AIS 3 or greater: the head, chest, abdomen and pelvis.

The test procedure is intended to evaluate the protection for a restrained occupant. Under these conditions, the area of the vehicle which impacts the occupant is in most cases confined to the area adjacent to that body area in the normal seating position and these are the areas that are evaluated in the test procedure. However this is not true for the head. Accident studies demonstrated that the area of the vehicle struck by the head is considerably wider than that adjacent to the head. In many cases of serious injury, the head impacts objects outside the vehicle. However there were a significant number of cases of serious injury to the head from contact with the interior of the vehicle. In typical side impact tests the head of the EUROSID dummy frequently does not make contact with the vehicle interior, passing through the side window which is usually broken before the dummy head reaches it. In those cases where the dummy head does strike the interior, it is at a position alongside the original position of the head. In the EEVC side impact test procedure, the dummy head will not evaluate the wide range of positions that are contacted by occupants' heads in accidents.

The EEVC recognised this situation in the final report of the side impact test procedure[2] and concluded that there was a need to investigate the requirements for a supplementary headform test.

EEVC Working Group 13 are developing a head impact test procedure for evaluating the head protection provided in the range of locations for head impact that have been observed in side impacts based on analyses of detailed accident studies. A three phase research programme has been developed to provide the basis for this test procedure which could be used as a supplement to the current full scale side impact test.

In the first phase, three potential headforms have been evaluated in free-flight impacts to targets representing simplified forms of the internal structures of cars that could be impacted by the head. The second phase will study the relative merits of free flight and linearly controlled impacts, using the preferred headform and the third phase will study the application of the proposed test method to whole vehicles and sub-systems and consider the practical level of improvement possible. One sample of the FMH and AAMA headform was available to the group. Each test laboratory used their own EEVC headform, thus the results for the EEVC tests include an additional level of variability not experienced with the other two headforms.

This paper reports on two accident analyses supporting the need for the work and gives the results of the first phase of the study.

ACCIDENT ANALYSIS

Accident investigations have identified head impact as a very important and common source of serious injury in side impacts. Otte[3] showed that over 47% of injuries occurred to the head of a struck side occupant in a side impact compared with only 30% to a driver in a frontal impact. Thomas et. al.[4] reviewed some UK accident data examining injury distribution and severity of injury in side impact. Thomas was able to determine that 41% of all head contacts were to the side glass, 11% were to the B post and seat belt anchorage, 6% to the header rail and 1% to the A post. NHTSA has recognised the importance of head impact and has developed its own subsystems test, although this is intended to cover front impacts and rollover in addition to side impacts. They estimate that 19% of head injuries would be affected if the contacted surfaces were padded.[5]

Table 1 Severity of head injury in TRL and Hannover accident samples (side impacts).

DATA BASE	TRL		Hannover	
AIS	1-2	3-6	1-2	3-6
Sub totals	227	81	285	51
Total	*308*		*336*	

In order to identify better the problems of head impact in side impacts, the data bases to which the working group have access have been interrogated. This analysis has concentrated on examining the severity of head injury against the areas of the vehicle interior that have been identified by the accident investigators as being contacted by the head. The two data bases examined are from TRL, the Co-operative Crash Injury Study (CCIS)[6], and the Hannover data base from Germany[7]. The analysis was restricted to side impacts with a direction of impact coded as 2, 3 or 4 o'clock and 8, 9 or 10 o'clock. The data were examined for both struck-side and non struck-side occupants with and without an occupant seated along side. Table 1 shows the size of the accident sample from which the working group analysis has been made. Tables 2 and 3 give the distribution of injuries against contacts as coded in the data for both struck-side and non struck-side occupants. These results indicate that between 40 and 60 per cent of head contacts were to the interior of the vehicle.

Table 2 Single Head Impact Contacts - Non struck-side occupant with impact on opposite side.

Contact	TRL		Hannover	
	AIS 1-2	AIS 3-6	AIS 1-2	AIS 3-6
A Pillar			5	
B Pillar		2	6	2
Windscreen	1			
Window frame and roof rail	1	1	7	4
Glass	6		9	2
Door	3	3	20	8
External object		1		
Other Contact	1			
Not Known	6			
Total number of cases	*18*	*7*	*47*	*16*

The two data bases show slightly different patterns of contact injury but this can easily be attributed to differences in accident collection strategies. Even so there is a clear indication that the B pillar and structure around the side window is an important area for injury producing contacts. The data also clearly show that potential contacts can occur over a large area of the side of the vehicle. The full scale impact test only evaluates injury severity for the head at one contact location, if

Table 3 Single Head Impact Contacts - Restrained struck-side occupants

CONTACT	TRL		Hannover	
	AIS 1-2	AIS 3-6	AIS 1-2	AIS 3-6
A Pillar	6	2		
B Pillar	21	9	50	21
Windscreen	7	1		
Window frame and roof rail	6	3	33	6
Glass	76	2	120	4
Facia	3	1		
Door	7	6	83	4
Roof	3	2		
Light	1		1	
Steering Wheel	2	1		
Sun visor	1			
Rear Window	1			
Ejection		1		
Other Occupants	4		1	
External object	12	35		
Other Contact	1	3		
Not Known	57	7		
No Contact	1	1		
Total number of cases	*209*	*74*	*238*	*35*

head contact occurs at all in the particular test. The large area of possible head injury contacts shown in these studies strongly indicates that there is a need for additional impact evaluations, in order to reduce head injury risk in accidents.

HEADFORM EVALUATION

The aim of the research programme is to develop a reliable and sensitive subsystems head impact test procedure that can be used to reduce the severity of head injury in side impacts. Three headforms are currently available that could be used for evaluating the interior surfaces of vehicles. One is specified for use in the proposed ECE pedestrian test procedure[8] (called EEVC headform in this paper) another is based on the Hybrid III dummy head and is specified for use in FMVSS 201 test procedure[9] and is referred to as the FMH. The third headform, which, like the EEVC impactor, is also spherical, is called the AAMA headform in this report[10]. In order to determine which of the three headforms would be preferred for use in this test procedure, a comparative test programme has been developed within the Working Group.

The objectives of the first phase of the programme are to assess the three head forms in free flight impact by investigating :-

C sensitivity to changes in the structure impacted
C repeatability
C reproducibility

In addition to these parameters, other aspects of the headforms, such as details regarding handling, could be assessed.

The Annex to this paper describes in detail the configurations of impact used in the phase 1 programme.

For an impactor to be useful for determining variations in injury risk it must be able to discriminate between different paddings and be able to detect changes in any underlying yielding or non yielding structure and the presence of any hidden hardspots. Two types of test have been used to study these attributes. The first was based on a rigid surface onto which paddings with different characteristics were attached. In order to determine if the head forms could identify any hidden hard objects, this simple test was enhanced by adding a rigid object, in the form of a 10 mm square section steel bar, below the surface.

It was recognised that, in practice, the impactor would be likely to be used to evaluate padding fixed to yielding structures. Therefore some impact tests were included to check the ability of the head forms to discriminate paddings on a surrogate deformable B-post manufactured specifically for this test programme. For added realism, tests to modified B-posts, weakened by incorporating large holes, were performed to determine the relative effects on these head forms.

Impact tests to the B-pillar simulations were performed at 6.7 m/s while those to the padded rigid surfaces were performed at 2.5 m/s to keep the responses to within reasonable limits.

The simplest test to perform would be a perpendicular impact. However it was recognised that not all surfaces would be impacted normal to their surface in accidents. Therefore additional tests at 45E were performed to determine whether it would be necessary to include an angled impact test into the test procedure in order to be able to distinguish between different structural designs or whether the simple perpendicular impact would be sufficient to characterise the performance at that position. In addition offset tests, where the axis of the impact was not in line with the hidden structure changes, were performed to determine the head forms sensitivity to impact position.

The padding materials were chosen and manufactured specially for this evaluation in order to represent different yet typical automotive paddings. The padding thickness covering the B posts and plain rigid surfaces was 10 mm thick while that for the padded surfaces with a rigid hard spot was 25 mm thick. The stiffness of the B posts sections was calculated to be representative of real B posts and to allow deformation without complete collapse of the pillar. In order to standardise the impact surfaces characteristics all test surfaces were covered with a flexible vinyl covering.

In order to make some assessment of impact repeatability, all of the tests were performed twice except for the three simple certification drop tests from 376 mm onto a rigid surface which were replicated three times with each head form.

PHASE 1 TEST RESULTS

Phase 1 tests can be split into three types. Firstly 'certification' type tests based on tests that are used to verify that the response of dummy heads are within prescribed limits. The second type of tests were very simple flat surface tests which have been designed to evaluate the sensitivity of the head forms to different padding systems and the presence of hidden hard spots buried within the padding. The third test series was closer to the 'in vehicle' situation. These last tests are similar to the second type but in these, the padding was attached to a yielding surrogate 'B post'.

All of the following tables present the data in a similar manner. Since each test was performed more than once the mean value of the repeated tests is present along with the range expressed as a percentage of the mean.

Apart from Table 4, which gives the results of the certification type tests, the mean measurements are then compared for two test conditions. The difference between the mean for the second test condition from the first test condition is expressed as a percentage of the first mentioned mean test result. Since the head forms were instrumented with accelerometers the values of peak acceleration (g) and Head Injury Criteria (HIC) are presented. All data were filtered at Channel Filter Class 1000.

Each test configuration is categorised by a two digit code. The first character refers to the configuration type and the following letter refers to impact alignment. Full details of the configurations and coding are presented in the Annex.

Table 4 shows the results of the certification tests and Tables 5 - 18 the results of the free flight tests into different surfaces.

Certification tests

Table 4 Certification (and repeatability) tests of the head forms

Headform	AAMA	EEVC	FMH	AAMA	EEVC	FMH
	Peak Accel. (g)			HIC		
TRL mean	240.9	251	233	803	863.4	682.3
TRL Std. deviation	24.9	15.9	3.7	130.6	103	22.3
TRL Coef of var (%)	**10.3**	**6.3**	**1.6**	**16.3**	**11.9**	**3.3**
TNO mean	251.3	245.7	227.9	784.8	791.2	608.8
TNO Std. deviation	6.3	4.0	7.5	29.2	22.7	18.9
TNO Coef of var (%)	**2.5**	**1.3**	**3.3**	**3.7**	**2.7**	**3.1**
BASt mean	240.1	218.7	236.4	737	661.9	675.2
BASt Std. deviation	3.5	3.8	2.5	13.4	16.1	11.8
BASt Coef of var (%)	**1.5**	**1.7**	**1.1**	**1.8**	**2.4**	**1.7**

Note - Three repeat tests.
- Single sample of AAMA and FMH head forms

Each head was dropped three times onto the rigid surface, configuration 1a. The results of these tests are presented in Table 4. Apart from indicating conformance to certification requirements the data can give some measure of repeatability under this simple controlled condition. The coefficients of variation for the test results are given in Table 4, although, as these are based on only three results, they cannot be regarded as reliable.

Effect of Padding

Tables 5 - 11 compare the sensitivity of the headforms to different types of padding. Table 5 compares the responses of the headforms in tests with two padding types supported on a flat rigid plate in perpendicular impacts (configuration 2a)

Table 5 Configuration 2a Discrimination of padding material in perpendicular impact

Headform	AAMA	EEVC	FMH	AAMA	EEVC	FMH
	Peak Accel. (g)			HIC		
Polyurethane mean	165.2	95.8	144.3	518.3	201.2	430.9
Polyurethane range	*1.9%*	*4.4%*	*2.1%*	*2.9%*	*10.4%*	*2.1%*
Polypropylene mean	242.7	151.2	200.6	959.5	395.4	684.3
Polypropylene range	*0.3%*	*1.2%*	*1.3%*	*1.3%*	*2.3%*	*3.0%*
Percentage variation from Polyurethane	**47%**	**58%**	**39%**	**85%**	**97%**	**59%**

Tables 6, 7, 8 and 9 show the responses in the presence of a hardspot hidden within the padding in perpendicular and angled impacts (configurations 3a, 3B, 3c and 3d)

Table 6 Configuration 3a Discrimination of padding material in perpendicular impact with hardspot

Headform	AAMA	EEVC	FMH	AAMA	EEVC	FMH
	Peak Accel. (g)			HIC		
Polyurethane mean	82.4	70.3	90.6	231.4	160.9	283.1
Polyurethane range	*2.9%*	*0.3%*	*1.8%*	*0.7%*	*0.1%*	*1.7%*
Polypropylene mean	132.2	74.9	121.1	356	145.1	318
Polypropylene range	*12.3%*	*17.1%*	*10.3%*	*18.0%*	*21.7%*	*13.0%*
Percentage variation from Polyurethane	**60%**	**7%**	**34%**	**54%**	**-10%**	**12%**

Table 7 Configuration 3c Discrimination of padding material in perpendicular impact with offset hardspot

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Polyurethane mean	86.9	70.8	90	247.9	163.8	273.6
Polyurethane range	*0.9%*	*1.4%*	*1.1%*	*0.8%*	*2.1%*	*2.7%*
Polypropylene mean	142.5	71.9	109.5	405.2	140.6	281.3
Polypropylene range	*3.6%*	*11.4%*	*15.7%*	*7.1%*	*16.6%*	*17.4%*
Percentage variation from Polyurethane	**64%**	**2%**	**22%**	**63%**	**-14%**	**3%**

Table 8 Configuration 3d. Discrimination of padding material in oblique impact with hardspot.

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Polyurethane mean	40.1	18.7	43.2	52.9	6.7	45.0
Polyurethane range	*4.4%*	*1.0%*	*4.3%*	*12%*	*0.8%*	*11.1%*
Polypropylene mean	170.8	58.3	108.9	585.9	90.0	246.2
Polypropylene range	*0.2%*	*7.7%*	*4.9%*	*1.3%*	*12.4%*	*8.1%*
Percentage variation from Polyurethane	**326%**	**212%**	**152%**	**1008%**	**1243%**	**447%**

Table 9 Configuration 3B Discrimination of padding material in oblique impact with offset hardspot

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Polyurethane mean	37.6	30.3	38.2	47.9	21.1	39.2
Polyurethane range	*37.2%*	*26.1%*	*32.2 %*	*84.8%*	*78.2%*	*78.1%*
Polypropylene mean	24.7	10.6	20.9	25	2.6	13.8
Polypropylene range	*37.7%*	*10.4%*	*17.2 %*	*80.8%*	*26.9%*	*44.9%*
Percentage variation from Polyurethane	**-34%**	**-65%**	**-45%**	**-48%**	**-88%**	**-65%**

Tables 10 and 11 compare the responses between padded and unpadded B-pillar simulations.

Table 10 Configuration 4a and 5a Discrimination of padding on B-post in perpendicular impact

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Unpadded mean	143.9	112.6	144	926.1	495	924.9
Unpadded range	*5.21%*	*8.0%*	*3.5%*	*12.0%*	*21.6%*	*3.0%*
Padded mean	148.8	161.5	123.4	1054.3	1183.3	669.1
Padded range	*4.2%*	*10.3%*	*2.8%*	*7.8%*	*15.4%*	*7.8%*

Table 11 Configuration 4B and 5B Discrimination of padding in oblique impact on B post

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Unpadded mean	108.9	78.5	104	567.4	219	414.9
Unpadded range	*8.2%*	*17.7%*	*5.6%*	*17.6%*	*41.4%*	*14.4%*
Padded mean	108.9	135.0	108.1	548.0	815.6	430.3
Padded range	*6.0%*	*5.3%*	*4.1%*	*7.3%*	*9.0%*	*5.1%*
Percentage variation from Unpadded	**0%**	**-72%**	**-4%**	**3%**	**-272%**	**-4%**

Table 12 Configuration 3a and 3c Discrimination of position of hardspot in perpendicular impact

Headform	AAMA	EEVC	FMH	AAMA	EEVC	FMH
Polyurethane padding	Peak Accel. (g)			HIC		
Direct hardspot mean	82.4	70.3	90.6	231.4	160.9	283.1
Direct hardspot range	*2.9%*	*0.3%*	*1.8%*	*0.7%*	*0.1%*	*1.7%*
Offset hardspot mean	86.9	70.8	90	247.9	163.8	273.6
Offset hardspot range	*0.9%*	*1.4%*	*1.1%*	*0.8%*	*2.1%*	*2.7%*
Percentage variation from direct hard spot	**5%**	**1%**	**-1%**	**7%**	**2%**	**-3%**
Polypropylene padding						
Direct hardspot mean	132.2	74.9	121.1	356	145.1	318
Direct hardspot range	*12.3%*	*17.1%*	*10.3%*	*18.0%*	*21.7%*	*13.0%*
Offset hardspot mean	142.5	71.9	109.5	405.2	140.6	281.3
Offset hardspot range	*3.6%*	*11.4%*	*15.7%*	*7.1%*	*16.6%*	*17.4%*
Percentage variation from direct hard spot	**8%**	**-4%**	**-10%**	**14%**	**-3%**	**-12%**

Table 13 Configuration 3d and 3B Discrimination of hard spot in oblique impact.

Headform	AAMA	EEVC	FMH	AAMA	EEVC	FMH
Polyurethane padding	Peak Accel. (g)			HIC		
Direct mean	40.1	18.7	43.2	52.9	6.7	45.0
Direct range	*4.4%*	*1.0%*	*4.3%*	*12%*	*0.8%*	*11.1%*
Offset mean	37.6	30.3	38.2	47.9	21.1	39.2
Offset range	*37.2%*	*26.1%*	*32.2%*	*84.8%*	*78.2%*	*78.1%*
Percentage variation from direct oblique hard spot	**-6%**	**62%**	**-12%**	**-10%**	**215%**	**-13%**
Polypropylene padding						
Direct mean	170.8	58.3	108.9	585.9	90.0	246.2
Direct range	*0.2%*	*7.7%*	*4.9%*	*1.3%*	*12.4%*	*8.1%*
Offset mean	24.7	10.6	20.9	25	2.6	13.8
Offset range	*37.7%*	*10.4%*	*17.2%*	*80.8%*	*26.9%*	*44.9%*
Percentage variation from direct oblique hard spot	**-86%**	**-82%**	**-81%**	**-96%**	**-97%**	**-94%**

Effect of Hardspots within Padding.

Tables 12 and 13 compare the results for impacts directly over with results for tests just adjacent to hardspots hidden within the padding, supported on rigid plates for perpendicular and angled impacts. Two types of padding were used in each condition.

Effect of Angled Impact

Tables 14 and 15 compare the perpendicular and angled impact responses in the presence of a hidden hardspot within the two types of padding and Tables 16 and 17 compare the responses in perpendicular and angled impacts to the unpadded and padded B-pillar simulations.

Table 14 Configuration 3a and 3d Effect of angle of impact to padded surface with hardspot in direct impact

Headform	AAMA	EEVC	FMH	AAMA	EEVC	FMH
Polyurethane padding	Peak Accel. (g)			HIC		
Perpendicular mean	82.4	70.3	90.6	231.4	160.9	283.1
Perpendicular range	*2.9%*	*0.3%*	*1.8%*	*0.7%*	*0.1%*	*1.7%*
Oblique mean	40.1	18.7	43.2	52.9	6.7	45
Oblique range	*4.4*	*1*	*4.3*	*12*	*0.8*	*11.1*
Percentage difference from perpendicular	**-51%**	**-73%**	**-52%**	**-77%**	**-96%**	**-84%**
Polypropylene padding						
Perpendicular mean	132.2	74.9	121.1	356	145.1	318
Perpendicular range	*12.3%*	*17.1%*	*10.3%*	*18.0%*	*21.7%*	*13.0%*
Oblique mean	170.8	58.3	108.9	585.9	90.0	246.2
Oblique range	*0.2%*	*7.7%*	*4.9%*	*1.3%*	*12.4%*	*8.1%*
Percentage difference from perpendicular	**-85%**	**-84%**	**-81%**	**-96%**	**-98%**	**-95%**

Table 15 Configuration 3c and 3B Effect of angle of impact to padded surface with hardspot in offset impact

Headform	AAMA	EEVC	FMH	AAMA	EEVC	FMH
Polyurethane padding	Peak Accel. (g)			HIC		
Perpendicular mean	86.9	70.8	90	247.9	163.8	273.6
Perpendicular range	*0.9%*	*1.4%*	*1.1%*	*0.8%*	*2.1%*	*2.7%*
Oblique mean	37.6	30.3	38.2	47.9	21.1	39.2
Oblique range	*37.2%*	*26.1%*	*32.2%*	*84.8%*	*78.2%*	*78.1%*
Percentage difference from perpendicular	**-57%**	**-57%**	**-58%**	**-81%**	**-87%**	**-86%**
Polypropylene padding						
Perpendicular mean	142.5	71.9	109.5	405.2	140.6	281.3
Perpendicular range	*3.6%*	*11.4%*	*15.7%*	*7.1%*	*16.6%*	*17.4%*
Oblique mean	24.7	10.6	20.9	25	2.6	13.8
Oblique range	*37.6%*	*10.4%*	*17.2%*	*80.8%*	*26.9%*	*44.9%*
Percentage difference from perpendicular	**-83%**	**-85%**	**-81%**	**-94%**	**-98%**	**-95%**

Table 16 Configuration 4a and 4B Effect of angle of impact to unpadded B-post

Headform	AAMA	EEVC	FMH	AAMA	EEVC	FMH
	Peak Accel. (g)			HIC		
Perpendicular mean	143.9	112.6	144	926.1	495	924.9
Perpendicular range	5.2%	8.0%	3.5%	12.0%	21.6%	3.0%
Oblique mean	108.9	78.5	104	567.4	219	414.9
Oblique range	*8.2%*	*17.7%*	*5.6%*	*17.6%*	*41.4%*	*14.4%*
Percentage variation from perpendicular	**-24%**	**-30%**	**-28%**	**-39%**	**-56%**	**-55%**

Table 17 Configuration 5a and 5B Effect of angle of impact to padded B- post.

Headform	AAMA	EEVC	FMH	AAMA	EEVC	FMH
	Peak Accel. (g)			HIC		
Perpendicular mean	148.8	161.5	123.4	1054.3	1183.3	669.1
Perpendicular range	4.2%	10.3%	2.8%	7.9%	15.4%	7.8%
Oblique mean	108.9	135	108.1	548	815.6	430.3
Oblique range	*6.0%*	*5.2%*	*4.2%*	*7.1%*	*8.7%*	*5.1%*
Percentage variation from perpendicular	**-27%**	**-16%**	**-12%**	**-48%**	**-31%**	**-36%**

Effect of Weakening to B-Pillar.

Table 18 compares the responses of the three headforms between perpendicular impacts to the padded B-pillar simulations with and without a hole cut into the sheet metal below the impact point

Table 18 Configuration 5a and 5aN Sensitivity to presence of hole in the padded B-pillar

Headform	AAMA	EEVC	FMH	AAMA	EEVC	FMH
	Peak Accel. (g)			HIC		
Without hole mean	148.8	161.5	123.4	1054.3	1183.3	669.1
Without hole range	*4.2%*	*10.3%*	*2.8%*	*7.9%*	*15.4%*	*7.8%*
With hole mean	146.1	150.9	125.7	1011	1049	651.2
With hole range	*0.3%*	*3.1%*	*3.5%*	*1.4%*	*5.7%*	*2.6%*
Percentage variation from without hole	**-2%**	**-7%**	**2%**	**-4%**	**-11%**	**-3%**

PHASE 1 DISCUSSION

Phase 1 of the test programme allows many comparisons to be made some of which can be viewed as being of more importance than others.

The AAMA and EEVC head forms are both half spherical balls whereas the FMH head form is of an irregular shape with a clearly defined impact area. Some difficulties were experienced in using the FMH head form in respect of orientation within the test laboratories propulsion systems. It was felt that some difficulties might be encountered when testing complex vehicle interiors due to this lack of symmetry and the test houses ability to be able to fire the head form from existing propulsion systems without major changes. In the hard spot tests the FMH could be aligned in a number of different orientations each possibly giving a different response. In order to simplify the tests and to reduce variability a particular orientation of head form to hard spot was adopted.

Several evaluation criteria must be addressed when determining which of the three head forms is the better one.

Sensitivity

Sensitivity can be assessed by examining combinations of test conditions and the ability of the three headforms to discriminate between the different conditions

a) Sensitivity to padding in simple padding tests

The tests have shown (Table 5) that each of the head forms can discriminate between the selected materials. The indicated changes were of the order of 47% to 97% depending upon the chosen assessment parameter and head form. The EEVC head form indicated the greater difference and the FMH the least for both parameters.

b) Sensitivity to padding in the presence of a hard spot..

In the perpendicular impacts, the AAMA headform showed the greatest sensitivity to padding material and the EEVC headform the least. The HIC measured with the EEVC headform showed the opposite trend from the peak acceleration and the opposite trend to the other two headforms with both parameters

In the oblique impact tests directly to the hardspot (Table 9) all three heads showed a very large increase in response when changing from polyurethane to polypropylene padding but when testing with the hardspot offset from the impact point (Table 8), this change resulted in a decrease in response for all headforms. In this instance the EEVC headform showed the greatest sensitivity.

c) Sensitivity to presence of padding on B-post

In the perpendicular tests, only the FMH showed a reduction in response when the B-post was padded compared with the unpadded condition. (Table 10) The HIC, measured with the EEVC headform showed a considerable increase.

In the oblique tests, only the EEVC headform indicated a reduction in response (Table 11). The other two headforms indicated little difference.

d) Sensitivity to presence of hidden hardspot

In the perpendicular tests the AAMA headform showed the greatest sensitivity to the presence of a hardspot, but it indicted a reduction in response when impacting directly over the hardspot although the change was not very large. The FMH was the only headform consistently to indicate an increase in response when directly impacting the hardspot area.

In the angled impact with polypropylene padding, all three headforms demonstrated a large and similar reduction in response when impacting away from the hardspot. However, with the polyurethane padding, the EEVC headform indicated an increase. The other two headforms again showed a decrease, as would be expected, the FMH being slightly the more sensitive.

e) Sensitivity to angle of impact

In the tests with hardspot within padding, all three headforms showed the same sensitivity to angle with polypropylene. Overall, the FMH showed least sensitivity to angle with polyurethane padding. For the test procedure, it is probably desirable to be fairly insensitive to changes in angle.

In the unpadded B-post tests the AAMA headform showed least sensitivity, the EEVC and FMH being fairly similar. In the padded B-post tests the FMH showed least sensitivity for peak acceleration and the EEVC with HIC, although the differences are probably not significant.

f) Sensitivity to weakened B-post

The EEVC headform showed the greatest sensitivity to the presence of a hole in the B-post although the difference between the two B-post results were not very large.

Repeatability

Repeatability is a very important assessment parameter for any test device. All of the head forms have been tested more than once in each of the configurations. This allows some assessment to be made of head form repeatability. All the test results include an indication of repeatability as shown by the range of the responses for a single test condition expressed as a percentage of the mean response. This range value comparison as such is not very robust since it is based for most tests on only two values. However, a consistent difference between headforms over all tests would allow some judgement to be made on this aspect of performance. An initial assessment of repeatability has been made by ranking the headforms by percentage range for each test condition for both peak head acceleration and HIC. For the purposes of this assessment, the headforms were given equal ranking if the differences in the percentage range for two headforms were less than one quarter of the average range for those two headforms. i.e. the rankings were similar if :

$$\frac{[Head\ A\ range\ (\%)\ \&\ Head\ B\ range\ (\%)]}{[Head\ A\ range\ (\%)\ \%\ Head\ B\ range\ (\%)]\ (\ 0.5} < 0.25$$

The assessment methodology has been applied to the data partitioned between perpendicular and oblique impact directions. No headform appeared to perform consistently better regarding repeatability than the others using this assessment technique. In perpendicular impacts the AAMA appeared to be better than the FMH headform which in turn was better than the EEVC headform, for both peak g and HIC measurements. For oblique impacts the FMH head form was better than both the AAMA and EEVC head forms for peak g and HIC. In these oblique tests, the EEVC head form was better than the AAMA as assessed by peak g but the trend is reversed when assessed by HIC. Overall the data do not show that one head form was notably better than the other two.

Further more detailed analysis of these results will be made before the headform for use in Phase II is selected. This preliminary analysis suggests that there is little to choose between them. If further analysis confirms this conclusion, other reasons, such as potential harmonisation, may dictate the choice of headform for future work.

CONCLUSIONS

The test programme was designed to evaluate the three head forms in a series of well controlled experiments, aimed at testing attributes thought to be important in a sub systems procedure. The initial analysis of the results have shown that there is little to choose overall between the three headforms-

1. The EEVC headform was more sensitive at distinguishing between paddings in the simple padding test and for detecting the presence of a weakened hole in the B-post
2. The AAMA headform was overall more sensitive to padding material in the tests involving the presence of a hidden hardspot.
3. Only the FMH gave a consistent and expected response to the addition of padding to the B-post
4. Only the FMH was consistently able to detect the presence of a hidden hardspot within the padding material.
5. None of the headforms was markedly superior to the others for repeatability in the interim analysis. Those differences that were observed suggest that the FMH and AAMA headforms are a little better than the EEVC, particularly for HIC, which is important if this is the parameter selected for evaluation.

FUTURE WORK

After further detailed analysis of these results, the preferred headform will be selected for the next Phase of the study. As mentioned above, the test programme consists of three phases. Phase II aims to examine the affect of linearly guided compared with free flight projection and Phase III will examine the performance of the preferred headform and projection system in vehicles. In due course the results of these other two phases will be published.

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Current members -

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Mr Adrian Roberts - Transport Research Laboratory (Sec.)
Mr Flavio Fossat - Fiat Auto S.p.A.
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Observer
Mr John Green - Rover Group

REFERENCES

1. R Lowne; EEVC Working Group 9 Report on the EEVC Side Impact Test Procedure. Proc 12th ESV Conference, Göteborg, May 1989, pp950-53.

2. EEVC; EEVC Report on the Side Impact Test Procedure. EEVC. April 1990.

3. Otte D. et al; Residual Injuries to Restrained Car Occupants in Front and Rear Seat Positions. 11th ESV Conference, Washington. 1987.

4. Thomas P. et. al; Side Impact Regulations - How do they relate to real world accidents? 12th ESV Conference, Göteborg, Sweden 1989,

5. NHTSA, Preliminary regulatory impact analysis: New requirements for passenger cars to meet a dynamic side impact test: FMVSS 214, Page IIIA-3, DOT HS 807 220, January 1988.

6. Transport Research Laboratory - 'Co-operative Crash Injury Study' (CCIS) - 1983 onwards. A large accident and injury study with several sponsors. TRL, Crowthorne, UK.

7. Otte D: Deformation Characteristics and Occupant Load Capacity in Lateral Impacts for Nearside Belted Front Car Passengers. SAE Paper 933126, 37th STAPP Car Crash Conference1993.

8. J Harris: EEVC WG10; Proposals for test method to evaluate pedestrian protection for cars. Proc 13th ESV Conference. Nov 1991 paper S3-O-06. pp293-302.

9. National Highway Safety Administration Federal Motor Vehicle Safety Standards ; Head Impact Protection. FMVSS 201.

10. Ramanujam N. N. et al: Preliminary Free-Motion Headform Testing of Vehicle Upper Interior Surfaces. SAE Paper 911216. Government/Industry meeting, Washington 1991.

ANNEX

PHASE 1 TEST PROGRAMME

a) Base line tests.

Three impact tests with each of three head-forms on three impact surfaces (rigid surface drop test - to duplicate cadaver and headform test certification conditions {Configuration 1a}, a simulated steel B-pillar {Configuration 4a} and a padded simulated steel B-pillar {Configuration 5a}). All impacts normal to the impact surface from a drop height of 376 mm.

b) Affect of angles of impact.

Three impacts to each of the two B-pillar simulations with each of the three head-forms, all at 45° to the normal to the surface (Configurations 4B, 5B). plus three flat surface padded tests {Configuration 2b}. Impact velocity 2.5 m/s.

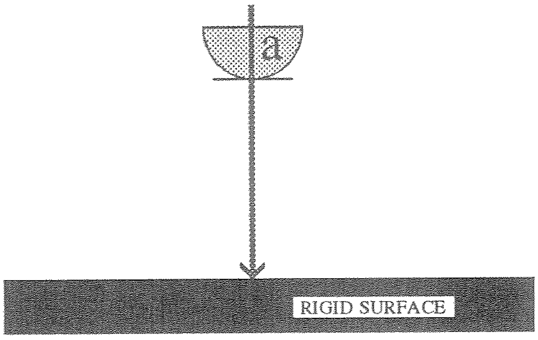
c) Sensitivity to hard spots, holes and padding.

Two impacts with each of the head forms onto padded surfaces with a hidden hardspot with two stiffnesses of padding and two impact positions on each padded surface (one over the hardspot {Configuration 3a} and one adjacent to it {Configuration 3c}), also test {Configuration 3B and 3d}. Two tests onto paddings with different characteristics {Configuration 2a}. The depth of the hard spot is 10mm with a padding cover of 10-12mm thick. Impact velocity 2.5 m/s.

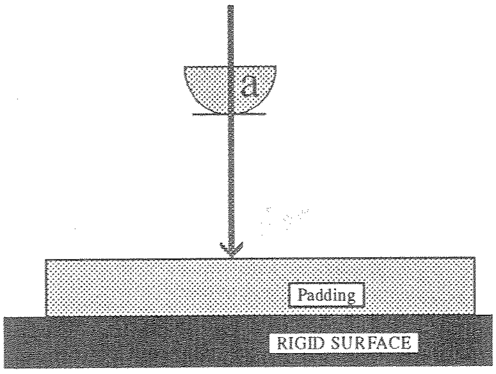
A modified 'padded B post' will be impacted with each of the three head forms, test configuration 5a. The modification to the 'B post' will consist of a 45mm diameter hole in the profiled section of the fabrication, with the hole centred below the point of impact. Each padded 'B post hole test' will be repeated once. Impact velocity 6.7 m/s.

Test Configurations

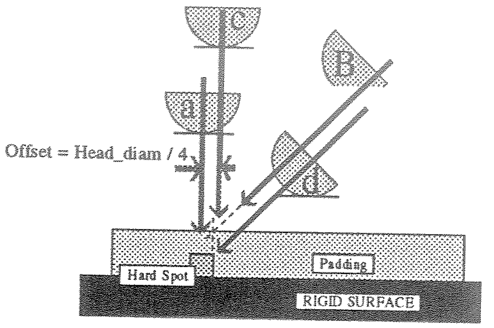
Angles of impact are 90° and 45° to the rigid surface, the arrows indicating the direction of impact. In the tests shown with lower case letters, the arrow represent the axis of the impactor. - Upper case letters indicate the point of contact of the headform with the surface, and the arrow direction shows the direction of impact only and does not indicate the central axis of the impactor. (None of the configurations is shown to scale).



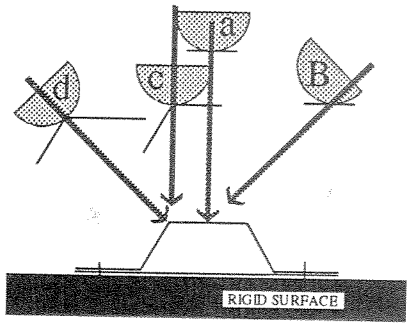
Test Configuration 1 - Rigid Surface



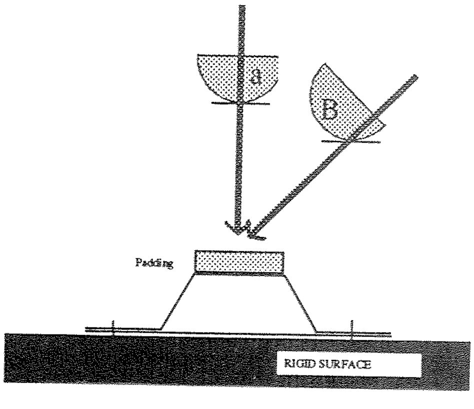
Test Configuration 2 - Padded Surface



Test Configuration 3 - Padded Hard Spot



Test Configuration 4 - Unpadded B Post



Test Configuration 5 - Padded B Post