EEVC/CEVE

European Experimental Vehicles Committee

EEVC Working Group 9

Report on the Side Impact Test Procedure

Presented to the Twelfth ESV Conference, Gothenburg, Sweden, May 1989

Paper No 89-5A-O-23

EEVC WORKING GROUP 9 REPORT ON THE EEVC SIDE IMPACT TEST PROCEDURE

Prepared on behalf of EEVC Working Group 9 by R W LOWNE

Abstract

The EEVC first proposed a Test Procedure for Side Impact protection at the Fifth ESV Conference. Since that time the test procedure has been further developed, a specification for a mobile deformable barrier produced and a dummy specifically for use in lateral impacts has been developed. These have been reported at previous ESV Conferences. Over the last two years it has been possible to evaluate the test procedure because Production Prototypes of the dummy, EUROSID, and satisfactory examples of the deformable barrier face have been produced.

EEVC Working Group 9 has been created to support the development of the test procedure, including the dummy and MDB face and to consider the implications of the use of component test procedures and mathematical modelling in legislative testing. This report describes the current status of the test procedure, including some results of tests performed to this procedure using the new dummy and the MDB faces and draws conclusions from these tests and tests comparing the EEVC and NHTSA Barriers.

Introduction

EEVC first proposed a procedure for the evaluation of the performance of vehicles in side impacts at the Fifth ESV Conference in 1974(1). The proposals were in general terms but included the evaluation of the performance of the vehicle by the use of dummies.

The proposals were further developed at the Ninth ESV Conference (2). This revised procedure was to impact a stationary target car at 50 km. per hour with a mobile barrier, to the front of which was attached a deformable face. The trajectory of the mobile barrier was to be perpendicular to the longitudinal axis of the target car and the centre of the barrier face was to be aligned with the R-point of this vehicle (Figure 1). The deformable barrier face was intended to have crush characteristics based on test results with a number of European cars and was sub-divided into six blocks, each with its own force/deflection characteristics (Figure 2). The performance of the car would be judged by the readings taken on a dummy. Since that time, the procedure has been further developed, three designs of Mobile Deformable Barrier faces have been produced and a dummy has been produced specifically for use in side impact tests (EUROSID).

A major review of the original proposal was made at the 11th Experimental Vehicles Conference , 1987 (3) following test experience with early versions of the Mobile Deformable Barriers (MDBs) and the Component Prototype version of

EUROSID. The main parameters of the test procedure were confirmed with the exception that the height of the barrier face was raised from 250mm. to 300mm. and a proposal was made to permit excursions from the barrier force specification during the first 150mm of crush. Further testing to the EEVC procedure has followed using the Production Prototype EUROSID and later versions of the MDB faces.

EEVC Working Group 9 was created in 1988 to support the development of the test procedure, including the dummy and the MDB. The Working Group was also asked to examine the implications of the use of mathematical models in association with sub-systems or component tests for legislative testing and an assessment of the possibilities and difficulties of this approach is contained in section 5 below. This paper reports recent experience with side impact testing to the EEVC procedure.

Eurosid

Twenty four Production Prototype EUROSIDs have been produced for evaluation by a wide range of test institutes and the experience gained from this testing is being used to produce the specification and design of the first production version of the dummy. Some improvement has been made to the biofidelity of the dummy and problems with some of the instrumentation have now been eliminated. The details of the status of EUROSID are presented in another paper given at this Conference(4).

In the view of EEVC the production version of this dummy will provide an adequate tool for assessing the likelihood of injury from side impacts and is sufficiently reliable and consistent for use in the proposed side impact regulation dynamic test.

Mobile deformable barrier face

Mobile Deformable Barrier (MDB) faces constructed from rigid polyurethane foam and designed to meet the EEVC specification have been extensively tested by government and industry in both Europe and North America. Two designs have been developed within the EEVC, one manufactured by Fritzmeier GmbH and the other by Kenmont Ltd. A further design has been produced by UTAC in France. Although each appears to have satisfactory characteristics, none of them fully meets the original EEVC specifications (1). Further studies are planned to reconcile the performance of the barrier faces and the performance corridors.

Working Group 9 is considering the possible advantages of specifying the design of the barrier face in addition to a performance requirement.

Experience with the test procedure

The EEVC Test Procedure specifies two side impact dummies; one in the front seat and one in the rear seat, both on the struck side. However, in order to improve photography of the inside of the vehicle, only the front dummy was used in these tests.

Reproducibility

Side impact tests have been performed at three institutes on the same model of target vehicle; a small two door hatchback passenger car. The same make of MDB face was used for all tests.

Table 1 shows the results for these tests and Table 2 presents the effect of applying the proposed EEVC Performance Criteria to the results. The main inconsistency is in the pubic symphysis force, but these tests were performed using a pubic symphysis transducer which is now known to produce erroneous results. A new force transducer is now specified for EUROSID (See Ref 4).

Table 1
Test results on a Small Passenger Car
Performed at Three Test Institutes

Test Institute	BASt	BASt	TRRL	Ford
Parameter				
HEAD				
HIC	448	758	275	267
THORAX				
Peak Rib Deflection (mm.)	30.5	35.0	33.5	36.0
Peak Viscous Criterion (m/s)	0.6	0.7	0.5	0.7
Max. TTI	138	132	132	-
ABDOMEN				
Force > 4.5kN. @39mm. (Switch contact)	no	no	no	no
PELVIS				
Peak Ilium force (kN.)	1.9	2.7	2.5	2.6
Peak pubic symphysis force (kN)	7.3	8.1	11.2	10.3
MDB Peak longitudinal accel.(g)	14.2	14.3	15.3	15.5

With the exception of the HIC values which are all well below the criterion level, it can be seen that the results are very consistent for full scale tests suggesting satisfactory reproducibility for the test procedure.

Table 2
Results of Applying Proposed EEVC Test Criteria to Test Results on a Small Car Performed at Three test Institutes

Test Institute / Parameter and Proposed Criterion	BASt	BASt	TRRL	Ford
HEAD				
HIC (1000)	pass	pass	pass	pass
THORAX				
Peak Rib Deflection (42mm)	pass	pass	pass	pass
Peak Viscous Criterion(1.0) (m/s)	pass	pass	pass	pass
ABDOMEN				
Force > 4.5kN. @39mm. (Switch contact)	pass	pass	pass	pass
PELVIS				
Peak Ilium force (10kN)	pass	pass	pass	pass
Peak pubic symphysis force* (10 kN)	pass	pass	fail	fail

* original transducer with known errors

Sensitivity

Tests to determine the effect of barrier impact speed have been performed at two Laboratories, BASt(5) and TRRL(6). The results are shown in Table 3.

There is a general progression in the value of the parameters with increase in speed. This is more noticeable with the vehicle used in the BASt tests, which was a small hatchback car, than with the TRRL tests, which used a medium size hatchback.

TRRL has performed tests to investigate the effect of the mass of the Mobile Deformable Barrier on the injury parameters (6). The results of the tests, which were performed using a medium size hatchback car, are shown in Table 4. The barrier masses selected are those proposed for the EEVC (950kg) and the NHTSA (1350kg) test procedures.

Table 3
The Effect of the Impact Speed of the
Mobile Deformable Barrier on the Measured Dummy Parameters

Parameter			
		BASt	
Impactor speed (km/h)	45	50	55
HIC	167	265	-
Peak Chest Deflection (mm.)	30.0	38.5	44.5
Peak Pubic Symphysis Force (kN)	4.4	4.7	5.6
Peak Ilium Force (kN)	0.9	1.0	1.2
		TRRL	
Impactor Speed (km/h)	41	50	61
HIC	145	792	905
Peak Chest Deflection (mm.)	45.0	48.0	47.0
Peak Viscous Criterion (m/s)	1.0	1.3	1.4
Maximum TTI	135	169	218
Peak Pubic Symphysis Force (kN)	5.3	6.9	13.5
Peak Ilium Force (kN)	1.2	2.5	1.9

Table 4
The Effect of MDB Mass on Dummy Transducer Readings

Barrier Face	EEVC	EEVC
Barrier Mass (kg)	950	1350
Dummy	EUROSID	EUROSID
HIC	792	434
Peak Chest Deflection (mm.)	48.0	46.0
Peak Viscous Criterion (m/s)	1.3	1.3
Maximum TTI	169	167
Peak Pubic Symphysis Force (kN)	6.9	6.9
Peak Ilium Force (kN)	2.5	1.9

There do not appear to be any systematic differences between the results with the different barrier masses, at least with the vehicle model tested.

Comparison of EEVC and NHTSA Test Procedures

BASt, TNO and TRRL have reported tests aimed at establishing the effects of the differences between the test procedures proposed by EEVC and NHTSA (5,7,6). These results are summarised in Table 5. In all the tests quoted below, the dummy used was EUROSID to permit the effect of the test procedure, rather than the dummy, to be examined.

Table 5
Comparison of EEVC and NHTSA Test Procedures

	BASt	
Test Procedure	EEVC	NHTSA**
Barrier Face*	EEVC	EEVC
HIC	265	160
Peak Chest Deflection (mm.)	38.5	37.5
Peak Pubic Symphysis Force (kN)	4.7	3.6
Peak Ilium Force (kN)	1.0	0.7

* 250mm ground clearance for both tests.
** MDB mass 1100kg.

		TNO	
Test Procedure	EEVC	EEVC	NHTSA
Barrier Face	EEVC	EEVC	NHTSA
HIC	115	240	611
Peak Chest Deflection (mm.)	40.0	39.5	27.5
Peak Viscous Criterion (m/s)	0.5	0.5	0.4
Max TTI	121	128	136
Abdomen Switch Contact	yes*	no	yes
Peak Pubic Symphysis Force (kN)	3.23	4.21	16.62
Peak Ilium Force (kN)	0.87	1.26	1.01

* switch contact force set at 4kN instead of 4.5kN

		TRRL	
Test Procedure	EEVC	NHTSA	Car-Car
Barrier Face	EEVC	NHTSA	Car
HIC	792	-	254
Peak Chest Deflection (mm.)	48.0	30.0	53.0
Peak Viscous Criterion (m/s)	1.3	0.6	1.7
Max TTI	169	123	143
Abdomen Switch Contact	no	no	no
Peak Pubic Symphysis Force (kN)	6.9	15.8	6.6
Peak Ilium Force (kN)	2.5	-	1.3

The BASt tests, in which EEVC barrier faces were used for both tests, indicate that the crabbed test at 54km/h impact speed and 1100kg barrier mass is slightly less severe than the 50 km/h perpendicular impact with a barrier mass of 950kg. but the differences are small.

The TNO and TRRL tests, which used different target car models, suggest that the NHTSA test procedure is likely to be less severe to the thorax area but more severe to the pelvis. The TRRL tests indicate that the EEVC test procedure gives closer results to the car to car test than does the NHTSA test procedure, at least for the models of target and bullet cars used.

Mathematical models for side impact testing

WG9 is now is currently evaluating proposals to use the prediction of mathematical models, usually supplemented by component tests to provide the input data, as an alternative to whole vehicle impact testing as a means of assessing the occupant safety of a vehicle. This would have advantages for the vehicle manufacturer if these predictions could be available at an early stage in the design process whereas full scale testing can only take place when prototypes are available. The advantage is somewhat less when component tests are required to provide input data since whole vehicle structures will be required.

The mathematical modelling approach also has the potential advantage that the evaluation of the vehicle for a range of occupant sizes, seat positions and impact speeds would be more practical than if whole vehicle tests were required each time. Depending on the technique used, a range of impacting objects such as trucks, rigid poles and rigid walls could be simulated in addition to simulating car to car impacts. The mathematical simulation part will, of course, be repeatable although any sub-systems testing will add variability.

However, the use of mathematical models is not straightforward and their ability to reproduce adequately the dynamics and reactions of a barrier impacting a car containing a dummy have yet to be demonstrated. Even if this approach is shown not to be sufficiently well developed to be applied in a legislative test to a new vehicle model, it might prove to be suitable for evaluating small design changes to approved models or to extend approval to a wider range of vehicle trim levels and specifications without the need for further dynamic tests.

The use of mathematical models to understand and reproduce the behaviour of vehicle in side impacts is still in its infancy but some lessons have been learnt from attempts to do so. CCMC have proposed a test procedure in which a vehicle bodyshell and other necessary body and trim parts are loaded externally by a deformable face and internally by a rigid body block representing the occupant. A computer model uses these data as input to predict the behaviour in a dynamic test(8). This procedure is being modified to allow the computer to control continuously the rams for the deformable face and the dummy (computer in-the-loop). WG9 will be interested to consider this procedure when it is available and fully specified. Based on experience to date of mathematical models of side impact and the experience of full scale tests, WG9 have drawn the following interim conclusion:

1. The use of a mathematical model/ subsystem test approach to vehicle side impact legislative testing would have the advantage of being able to approve a vehicle earlier on in the design stage than current whole vehicle tests on completed vehicle. The time advantage gained depends on the complexity of the mathematical model and on the proportion of the vehicle necessary for the sub-system or component test.

2. A mathematical model approach would allow the performance of a vehicle to be assessed under a wider range of conditions than the single test condition of a full scale test.

3. The use of mathematical models is not straightforward and their ability to reproduce adequately the dynamics and reactions of a barrier impacting a car containing an occupant have yet to be demonstrated.

4. The model of the occupant must be sufficiently detailed to be able to predict likely modes of injury in lateral impacts and to give the correct load transfer between vehicle and occupant and between the major body parts of the occupant.

5. The sub-systems test procedure must be closely specified and must adequately represent the collapse of the vehicle under dynamic conditions.

6. The procedure for deriving the input data and for operating the model, including the dynamic correction factors, must be uniquely defined and must not rely on expert interpretation.

7. The procedure must be fully validated over a wide range of conditions which differ from those for which the model was calibrated.

8. The difference in the costs of testing a vehicle for final approval between full scale vehicle impacts and a mathematical model/subsystems test approach is not likely to be as great as might be supposed, although testing for development purposes could prove to be much less by using the latter approach.

9. Taking into account the present status of mathematical modelling and the time required to develop, validate and evaluate test procedures, WG9 considers that it will be 5 to 7 years before a mathematical model/ sub-systems test approach could be considered seriously for legislative testing. It might prove practical for it to be used earlier for supplementary testing or Conformity of Production testing.

Conclusions

1. The EEVC test procedure appears to give reproducible results; tests at three different laboratories gave similar results on one vehicle model.

2. The results are sensitive to impact speed of the mobile barrier but do not appear to be very sensitive to the barrier mass within the range tested (950 - 1350kg).

3. For the same barrier face, the perpendicular impact mode seems to be slightly more severe than the crabbed mode but the differences are small.

4. The NHTSA test procedure (using EUROSID) appears to be slightly less severe to the thorax area but more severe to the pelvis. The test results with the EEVC procedure were closer to those of a car-to-car test than were the results using the NHTSA test procedure.

5. The EEVC Test Procedure appears to be able to discriminate between different models of vehicle and would encourage the design of vehicles with improved protection for occupants in side impacts.

6.Mathematical models for side impact simulation in association with sub-systems tests are not sufficiently well developed or proven for their use as the main legislative test in the near future.

References

1. EUROPEAN EXPERIMENTAL VEHICLES COMMITTEE, *The Future of Car Safety in Europe.* Proceedings of the 5th. ESV Conference, London, 1974.

2. EUROPEAN EXPERIMENTAL VEHICLES COMMITTEE WORKING GROUP No 6, *Structures: Improved Side Impact Protection in Europe*, Proceedings of the Ninth ESV Conference, Kyoto, 1982.

3. EUROPEAN EXPERIMENTAL VEHICLES COMMITTEE ON SIDE IMPACT (CESARI D, AND I NEILSON), *Further Consideration of the European Side Impact Test Procedure*, Proceedings of the Eleventh ESV Conference, Washington, 1987.

4. ROBERTS A K, *Status Report of the EUROSID Dummy*. Proceedings of the 12th. ESV Conference, Goteborg, Sweden 1989

5. GLAESER K-P, *Results of Full Scale Tests with EUROSID under Different Test Conditions*. Proceedings of the 11th ESV Conference, Washington, 1987.

6. HOBBS C A, *The Influence of Car Structures and Padding on Side Impact Injuries*. Proceedings of the 12th. ESV Conference, Goteborg, Sweden, 1989.

7. DeCOO P, A VERMISSEN, E JANSSEN and J WISMANS, *Evaluation of European and USA Draft Regulations for Side Impact*. Preceding of the 11th ESV Conference, Washington, 1987.

8. RICHTER. R, H OEHLSCHLAEGER, R SINNHUBER and R ZOBEL. *Composite Test Procedure for Side Impact Protection*. SAE Paper 871117; SAE Govt./Industry Meeting, Washington, DC May 1987

Appendix

Members participating in EEVC Working Group 9 meetings;

J Bloch
G Ferrero
P Hoekstra
E G Janssen
R W Lowne (chairman)
A Pastorino
A K Roberts (secretary)
G D Suthurst

D Cesari
K-P Glaeser
C A Hobbs
M G Langdon
D Matthes
E Pullwitt
W Sievert

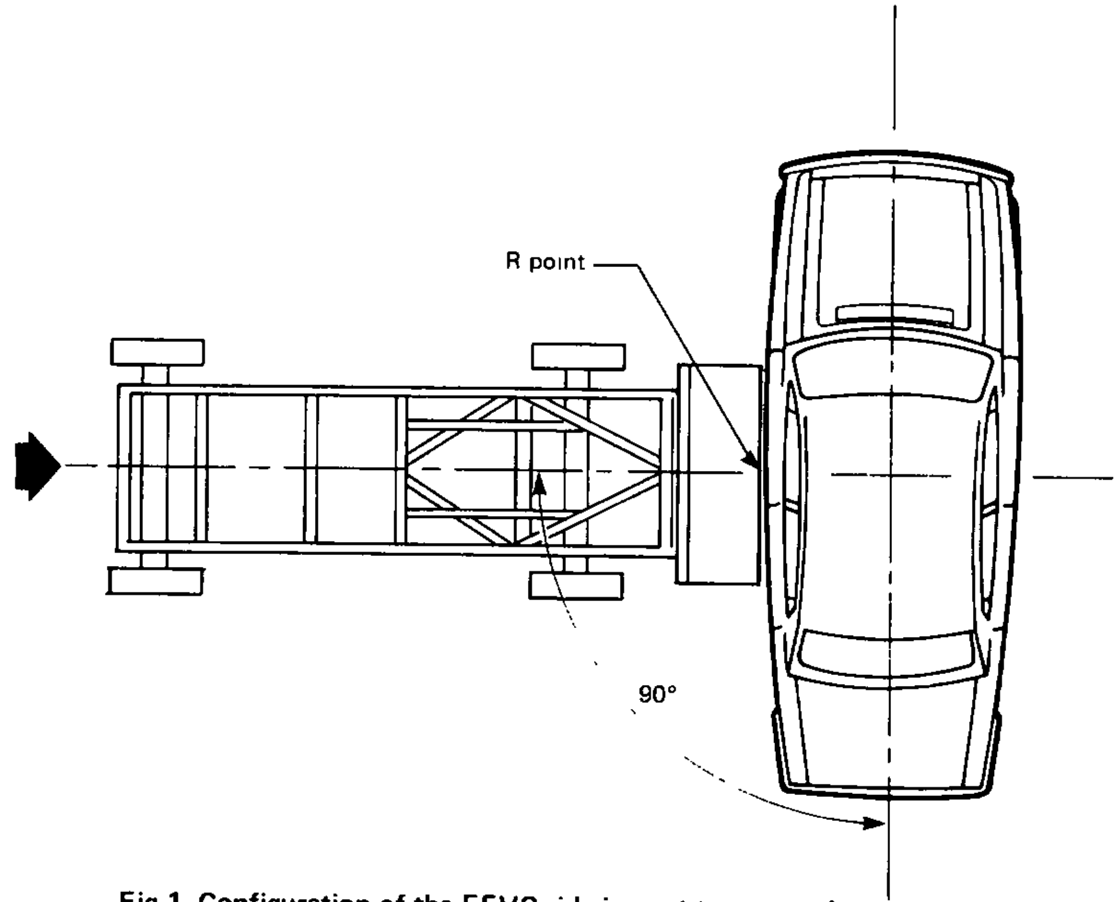

Fig.1 Configuration of the EEVC side impact test procedure

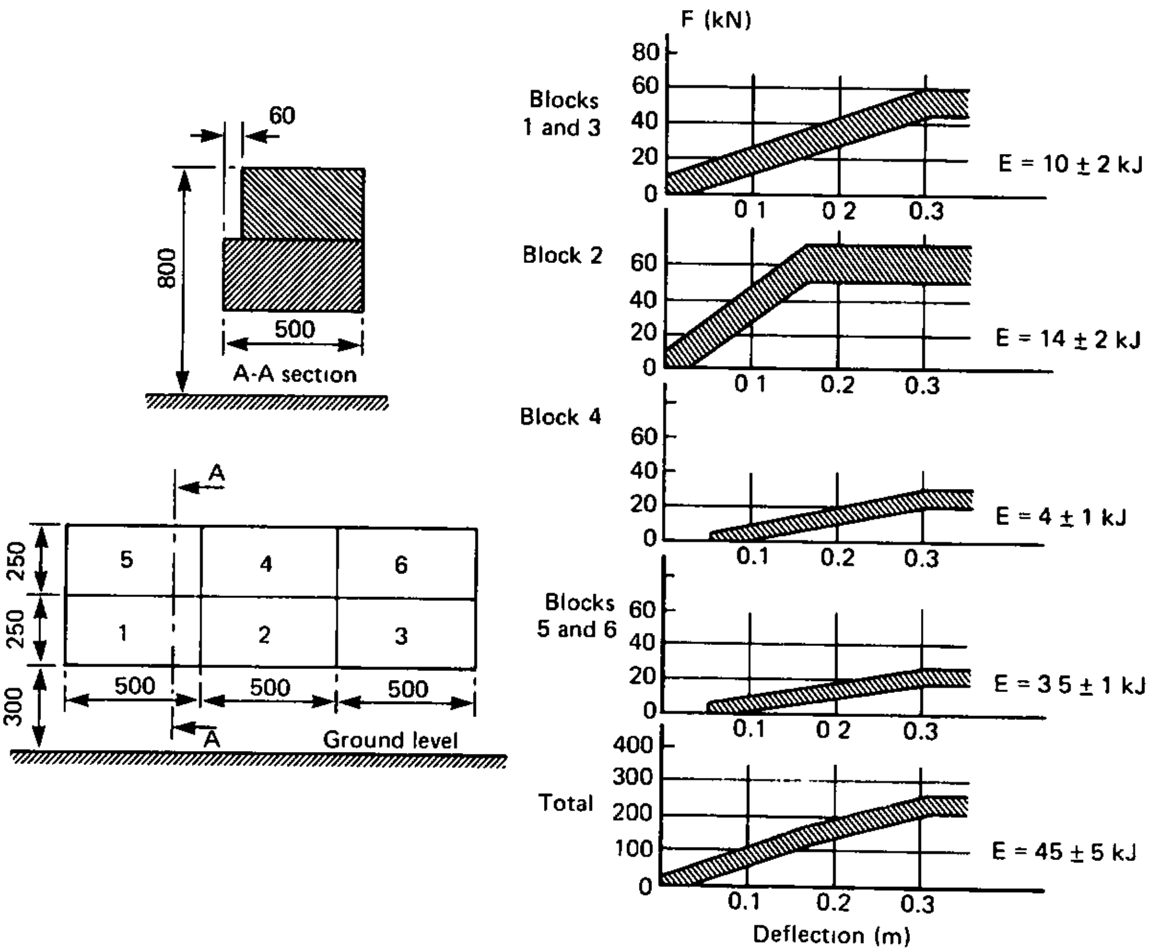

Fig.2 Main characteristics of the EEVC mobile deformable barrier