CHAPTER 9 : TECHNICAL FEASIBILITY

9.1 PREAMBLE

The mandate of the IHRA pedestrian safety working group is to develop test procedures to improve the protection of pedestrians (and other vulnerable road users) struck by cars, while meeting technical feasibility constraints of cars manufacturers, and customers properties.

In Europe, tests have been carried out on actual cars according to the procedures developed by the EEVC WG10/WG17, in the framework of EuroNCAP activities.
Tests results clearly demonstrate that no car currently sold in Europe can meet these requirements, which are the tentative basis of a European Union Directive on Pedestrian Protection.

Some observers claimed that since a few cars got 60 to 75% of the EuroNCAP "points" needed to get a four stars rating, it should not be too difficult to close the gap between the EEVC requirements and the already achieved results. However, a careful review of these cars showed:

1. that getting 4 stars in a EuroNCAP rating was far from meaning that a car would pass the EEVC requirements (simply because the objectives of a regulation, on one hand, and of NCAP, on the other one, are different: **regulation** = rating for determining whether a car passes or fails; **NCAP** = rating for ranking.)
2. that the best currently available techniques have been used to get these results, and,
3. that no significant improvement towards betters ones could be expected from these techniques.

It is also clear that the technical feasibility of solutions to be implemented on cars to meet the proposed requirements was never assessed as it was not a mandate of the working group.

<u>**Conclusion**</u>

The technical feasibility of solutions was never assessed, and no car, even the most recent ones, using the best currently available techniques, could meet the EEVC requirements. There are therefore strong reasons to think that there is a serious problem linked to the feasibility of solutions complying with these proposed requirements.

The above stands true for all EEVC tests procedures and requirements, however, the following review is devoted to head-form impacts, which are the subject of the current developed IHRA test procedures.

9.2 HEAD IMPACT PROTECTION: TESTS CONDITIONS, REQUIREMENTS, AND CORRESPONDING SOLUTIONS - STATE OF THE ART.

An overview of the currently known impact test procedures concerning head impact velocities, head impact protection requirements, and corresponding technical solutions (or impacted surfaces), leads to the following summarised conclusions :

- For the various existing Frontal Impact Test Procedures (FITP, including regulations and X-NCAP ones), it is clearly impossible to consistently meet an HIC less than 1000, without **implementing air bags on steering wheels. This stands true as soon as the test speed is over 50/60km/h, depending on impact configuration, and even if advanced type seat belts** are provided, which strongly minimise the head to steering wheel impact speed.

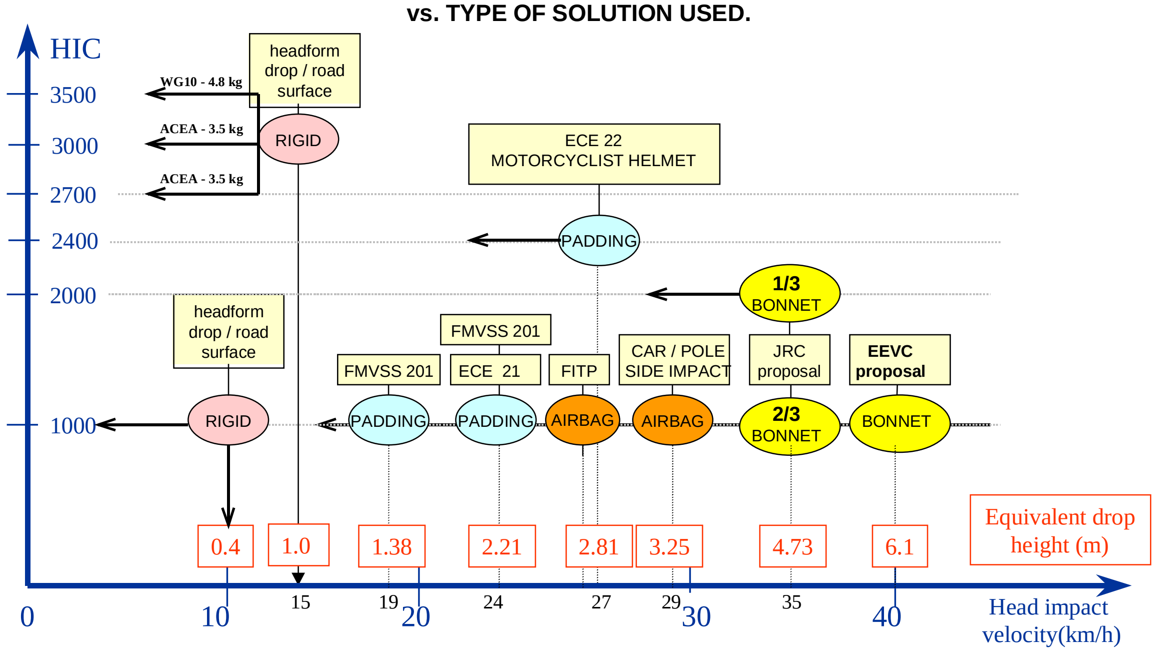
- Regarding FVMSS 201 (free flying head-form impacts against passenger compartment internal fittings at a velocity of 19 or 24 km/h), solution to meet the requirement of HIC below 1000 is to add padding to the inner side of all pillars and roof rails.

- For the car to pole side impact, the only solution to get a HIC below 1000 at an impact velocity of about 29 km/h is to **fit the car with curtain type side airbags.**

- ECE 21 (internal fittings), which requires a higher limit of the head acceleration of 80g (not exceeding 3 ms), for an impact velocity of 24 km/h, needs padding of the internal fittings. For higher speeds, it is clear that we must refer to frontal impact test procedures, and **need front passenger airbags.**

- For the ECE 22 regulation on motorcycle helmets, which are tested at 27 km/h and must meet an HIC below 2400, a " padding" **is needed.**

HEAD IMPACT VELOCITIES & PERFORMANCE CRITERIA, vs. TYPE OF SOLUTION USED.



<u>Consistently and confidently "passing" a legislative requirement like HIC less than 1000, at a head impact velocity of 40 km/h, with a "padding type" solution (car bonnet) seems to be out of reach. "State of the art" solutions to pass HIC less than 1000 at impact velocities of 25 to 29 km/h are airbags or other new developments…..</u>

9.3. PEDESTRIAN HEAD-FORM TO BONNET IMPACT TESTS - FEASIBILITY OF EEVC WG17 REQUIREMENTS - REVIEW OF AVAILABLE RESULTS.

Recently, some European Institutes (participating to EEVC activities) tried to demonstrate the feasibility of solutions meeting EEVC/WG 17 proposed requirements, by:

- testing existing cars according to these procedures, and by
- modifying these cars, to tentatively meet corresponding requirements.

Reference is made mainly to two recent communications, which were published at the last ESV Conference in Amsterdam in June 2001.

The first one is a publication from BAST (1), which describes the changes brought to a "representative" small family car. Changes done were limited to avoid modifying components relevant to occupants' safety. Tests have been carried out according to the EEVC procedure and tools, firstly on a standard car, and then on a modified one. Test results were compared Regarding the head-forms impacts on the bonnet, it was found that the minimal theoretical deformation distance should be 53 mm for the child head-form, and 63 mm for the adult one ; these calculations are based on the most "optimistic" deceleration pulse. In this research program, the necessary deformation distance was achieved by artificially raising the bonnet before impact, through the mocking-up of an active system (springs) increasing the height on its rear part by 80 mm.

The thickness of the outer sheet metal part or "skin" of the bonnet was also reduced from 0.75 mm to 0.5 mm**. This means that the Research Institute deliberately accepted that a lot of "customers oriented properties" of the initial bonnet (e.g. dent resistance, etc.) would no longer be met**

For the adult head-form these modifications improved somewhat the results, but on a total of 6 tests on the bonnet of the modified car, the HIC values are still above 1000 for 3 of them. For the child head-form, some results were also improved, but once again, it was not possible to achieve HIC below 1000 in all points.

- **The second one** was published by TNO and DSM (2) also at the 2001 ESV Conference.

This study was devoted to the development of new concepts for a vehicle front end, with the following objectives:

- to decrease the mass of the vehicle front (ECOFRONT project), but also
- to meet severe requirements for passive safety of both car occupants and vulnerable road users outside. Developments relevant to pedestrian safety only are described below.

Activities were mainly based on computer simulations, the results of which were validated, essentially through sub-component testing.

The following strategy was developed to meet the EEVC WG17 requirement for the child head-form to bonnet tests, i.e. HIC below 1000:

1. to provide for necessary clearance under the bonnet, and to move bonnet hinges outside of the EEVC WG17 impact area,
2. by changing the material properties of the bonnet "skin", optimising it via successive computer simulations, using a MADYMO FE model. More concretely, the concept of a "sandwich type" material was used, i.e. a thin sheet metal part for the outer part of the bonnet, "bonded" to an inner layer of frangible composite material. It was expected that

such a concept would give the most favourable shape to the head-form deceleration signal, in order to minimise the HIC value.

The Research Institute also carried out simulation activities, to verify that a few major functional properties of the bonnet would still be met in addition to the compliance with the EEVC WG17 requirements.
The results show that the geometrical shape of the exterior, the vehicle type and the “package” design are very important.
The main conclusion of this study is that pedestrian safety cannot be achieved with immediate modifications on existing cars, or in-production cars, but has to be considered at the very first step of the design process of a vehicle, since it severely limits degrees of freedom in packaging and styling developments. Furthermore, should slight changes to bonnet design be needed during the development, they might appear as being unfeasible, due to the conflicts between test requirements and functional ones.
Anyway, even with the “sophisticated” material used no **actual** bonnet, but only a **“virtual”** one was produced, at the time the study was published. No physical evaluation of this bonnet could then be performed, and no final results demonstrating actual compliance with EEVC WG17 were available. It is to be further stressed that suitability of the proposed material to Automobile Industry needs is still to be investigated.

- **A more recent** communication from BAST (3) relates to «A Vehicle Front Optimised for Pedestrian Protection». It describes the results of a study commissioned to BAST by IKA to modify a Sedan and a MPV, to have them meeting the EEVC WG 17 requirements, without compromising occupant protection and vehicle design.

For the head-forms to bonnet impacts, the same strategy as described above was followed:

1. use of an “active” bonnet , with the suggestion to determine the head impact area in the “raised” or “activated” position,
2. use of a thin bonnet “skin” for the child head impact zone (0.5 mm).
   Once again, the results are not as satisfactory as expected: some impact locations didn’t meet HIC 1000, in both the adult and child head impact areas. It is also to be stressed that solutions tested in the framework of this project wouldn’t meet numerous customers’ requirements, let alone existing regulations. Furthermore, considerable additional activities are to be conducted regarding the triggering and “operation” of active bonnets.

- **The Honda Civic**, with a 1.4 L engine, which has recently been tested as part of the Euro-NCAP programme achieved the highest pedestrian protection rating of any car tested (3 stars, 26 points out of 36). A test programme was conducted by TRL consisting of a series of pedestrian tests, using the WG17 test methods to establish the level of conformity of the Honda Civic with the EEVC requirements. Tests were also carried out with a 3.5 kg head-form to establish the level of conformity of the Honda Civic with the requirements of the first phase of the Negotiated Agreement with ACEA. In addition, a limited programme of changes to the vehicle design was carried out with the intention of improving its performance. The revised features were re-tested to determine if any changes (improvements) to the pedestrian protection had been achieved.

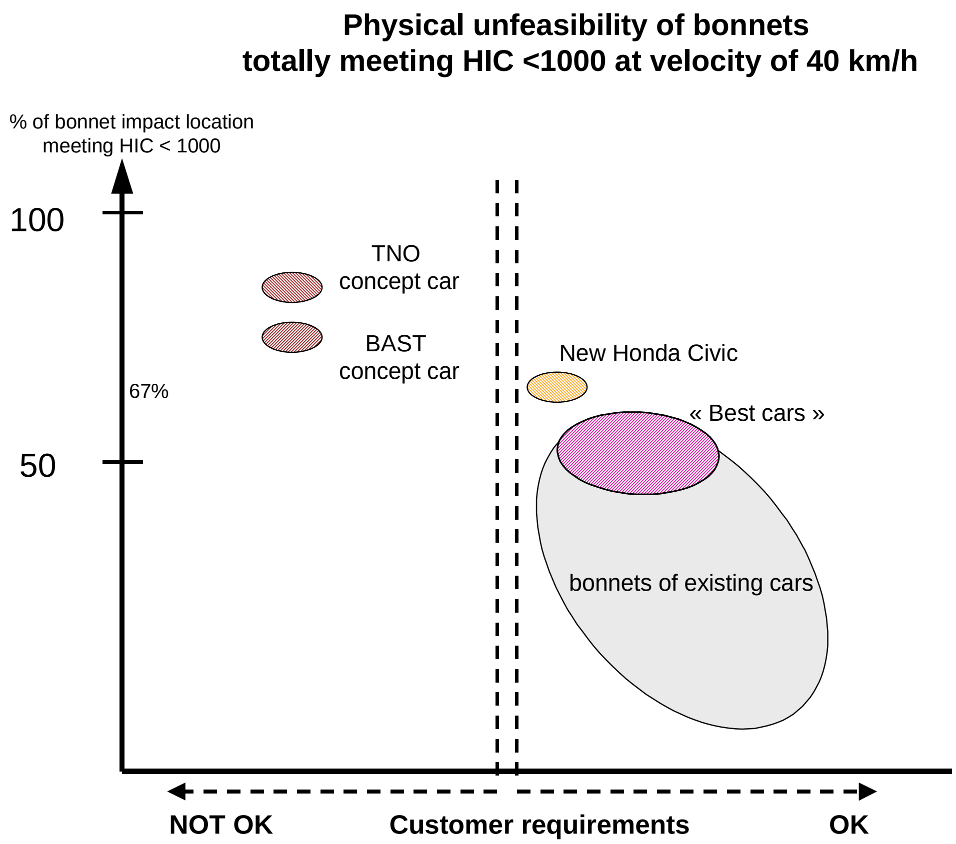
The modifications made by TRL to the Civic bonnet to wing edge joint gave improved results reducing the HIC from 2023 to 1216 at one site and from 1775 to 1507 at the second. These modifications were considered to be compatible with existing manufacturing methods, to have no detrimental effect on the vehicle functionality and have very small additional costs. **This doesn't reflect the package space required for the larger engine sizes. Furthermore, a practical design for the wiper motor spindle and the bonnet hinge, that could meet normal customers' requirements, has not been found.**

However, this study shows that, even after improvements, HIC values of 1500 are still measured and it is not possible to achieve consistently and confidently HIC lower than 1000 in all points, as proposed by EEVC. Due to scatter of measurements a design target of HIC 800 is customary in Industry. Moreover, it should be stressed that new Honda Civic is only representative of cars with short bonnet and in particular that there is no adult head impact area.

Conclusions

Research institutes attempted to "design" bonnets according to EEVC WG17 procedures and requirements. All studies were based on following common strategies:
1. Provision for sufficient clearance between the bonnet and hard spots underneath, either through the use of a revised packaging, or by assuming availability of an active bonnet.
2. Amendment of properties of bonnet "skin" and design, to maximise chances of getting good HIC, all other things being equal.
3. In some cases, change in other functional properties of the bonnet due to above modifications was assessed, and some efforts were devoted to preservations of these functional properties. In other cases, the compromise used was clearly oriented to meeting HIC requirement, with "unreasonable" solutions.
4. All the above actions were mainly dedicated to the bonnet surface, but it is clear that there are major difficulties linked to the design of elements such as the bonnet hinges and latches, etc., which would have to both meet their functional requirements, on one hand, and be pedestrian friendly, on the other one.
More, information from suppliers indicate that impacts in the area below WAD 1000 mm will involve the headlamps assembly area (IHRA/PS/222). Even if the headlamps would be free mounted, the measured HIC value of a child head-form impactor would be influenced only by inertia effect and it would be very difficult to achieve low HIC values. This is the conclusion of a publication at the 2001 ESV Conference entitled "New headlamp concepts as key to optimisation of vehicle front ends in consideration of pedestrian protection".
Bonnet design with two head-form impactors of 3.5 and 4.5 kg will lead to higher bonnet due to the needed under bonnet clearance. This would result in higher CO_2 output due to the increased air drag for those vehicles which is contradictory to other global requirements (IHRA/PS/223).

Results of studies demonstrated that even with extreme solutions, not meeting other functional properties of the bonnet, HIC below 1000 could not be consistently and confidently achieved on the whole bonnet head impact area. A sufficient clearance between the bonnet and the hard spots underneath is a necessary condition, but it is not, and by far a sufficient one. Classical designs of bonnets, using currently available (or not) "tricks", can't presently and won't in the future allow for compliance with HIC below 1000, when head-form impact speed is 40 km/h. The only solution which seems to give an answer to HIC 1000 according to EEVC test procedure is then outside air bags.



9.4 PEDESTRIAN HEADFORM TO WINDSCREEN IMPACT TESTS - FEASIBILITY OF EEVC WG17 REQUIREMENTS.REVIEW OF AVAILABLE RESULTS.

The IHRA head-form impact test procedure aims to involve the whole windscreen and windscreen frame, so, including also the A-pillars. It is clear that the A-pillars are part of the important components of the structure of the car, and that they must insure their indispensable functionality, as they are at least, the link between the car structure and the car roof.

A document presented by TRL at the 8th IHRA meeting, deals with this problem (IHRA/PS/139). Component tests were made on a special test rig made to simulate A-pillars of
real cars. Prototypes were made, trying to keep their "essential functional characteristics, but even after components tests have been carried out, and then also tests on actual cars fitted with the best prototypes, results showed that the HIC values could be somewhat reduced in some parts, but that they could anyway never fulfil the limit of HIC below 1000.

Conclusion

To meet HIC below 1000 at 40 km/h in a reliable and confident manner is physically impossible with classical solutions. They have been demonstrated to fail, currently, and there is little hope left they would pass in the future.
The only solution, if requirements are left as they are, is to implement outside air bags. These airbag systems need to have reliable sensor techniques to make sure that the airbag will work correctly, i.e. inflation in time, consideration of pedestrian stature and weight, no faulty inflation…. These techniques are not available at the moment or in the near future.

References

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(4) G.J.L. Lawrence, B.J. Hardy and W.M.S. Donaldson, "Costs and effectiveness of the Honda Civic pedestrian protection, and benefits of the EEVC and ACEA test proposals", April 2002.