H-Point Machine and Head Restraint Measurement Device Positioning Tools – Extended Capabilities

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1 Abstract

The H-point of a seat is an important parameter for in the design process of a vehicle, and in particular the design of a seat. This can be estimated empirically, but this method is usually not sufficient to accurately determine how the manikin's position is affected by subtle yet complex interactions within the seat and its trim. To aid this process, Arup have developed a positioning tool kit for use in conjunction with the Oasys PRIMER software [1]. The positioning tool kit calculates the H-Points of the automotive seats, as well as the backset measurement, thus providing the scores of the head restraint.

- **HPM** Positioning Tool is a JavaScript tool for prediction of the H-Point of a seat, based on the SAE J826 regulation [2], used in conjunction with Oasys PRIMER and LS-DYNA® [3]. All pre-simulation positioning of the HPM is completed automatically within Oasys PRIMER, and the output is a ready-to-run LS-DYNA model. Once LS-DYNA has calculated the settling of the manikin using the seat properties, Oasys PRIMER is used for interpretation of the results to report the H-point co-ordinates and back angle of the HPM.
  The HPM Positioning tool follows the SAE J826, which requires the location of the accelerator pedal. The accelerator pedal info is not always available in the early stages of the seat design, and only the location of the ball of foot (BOF) of the right foot might be known. For this case, based on customer requests, the tool has been extended to allow the value of the BOF to be entered instead. Another potential use of this new option is predicting the H-point of a front passenger seat, in which case the BOF is positioned on the floor.

- **HRMD** Positioning Tool is a JavaScript tool for prediction and assessment of seat and head restraint geometries according to the following procedures:
  - IIHS
  - NHTSA
  - EuroNCAP
  - C-NCAP
  - The HRMD Positioning Tool has now been extended to follow the new EuroNCAP Rear Whiplash Test Protocol.

The HPM and HRMD Positioning Tools have been validated through comparison to physical measurements and tests based on Futuris seat data. The tools show good correlation to physical HRMD drops conducted by Thatcham on a seat package. The prediction was shown to consistently lie in within the scatter of the available test data.

2 Introduction

The accurate prediction of the H-Point of a seat is essential for seat manufacturers. It is also important for dummy positioning in crash tests. It is crucial to have this early, before the physical seat is built. Arup have developed a JavaScript based positioning tool kit to predict the H-Point and whiplash performance. The tools work in conjunction with Oasys PRIMER and LS-DYNA.
Some of the benefits are:

- Increased confidence in the H-Point of a new seat design,
- Opportunity to adjust the design,
- Allow for more accurate predictions of whiplash performance and other crash test simulations where dummy positioning is critical.

3 HPM & HRMD Positioning Tools

HPM Positioning Tools – capabilities:

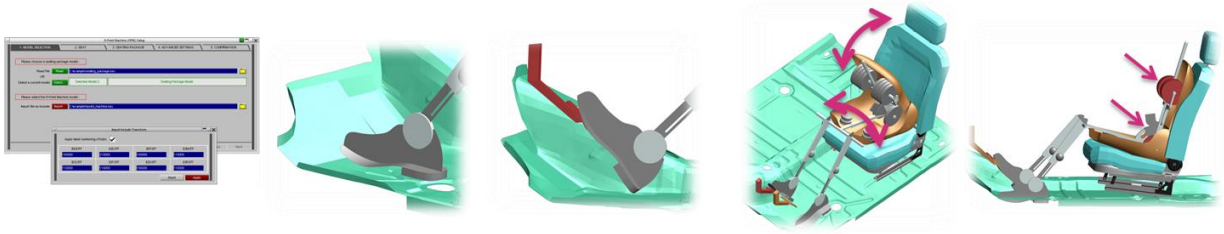
- Determine seat H-Point
- Uses model of industry standard H-Point Machine
- Follows the SAE J826 specification – driver seat
- Outputs ready-to-run LS-DYNA® model
- Interprets results and reports H-Point
- Option added, if accelerator pedal not available.

HRMD Positioning Tools – capabilities:

- Assess head restraint geometry
- Uses HPM model with HRMD extension, except for EuroNCAP Rear seat, which uses just the HPM
- Outputs ready-to-run LS-DYNA® model
- Calculates static scoring for **driver** seat for: EuroNCAP, IIHS, NHTSA & C-NCAP
- EuroNCAP **rear** seat option added.

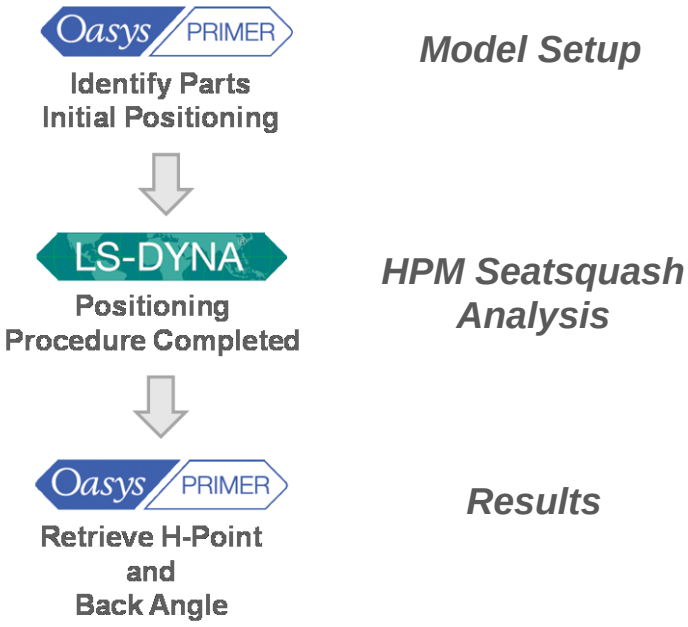
Why use a script for HPM positioning?

- The positioning follows the procedures in SAE Document J826, which is a complex procedure containing multiple steps.
- This is often repeated multiple times.
- It is difficult and time consuming to simulate the procedure.



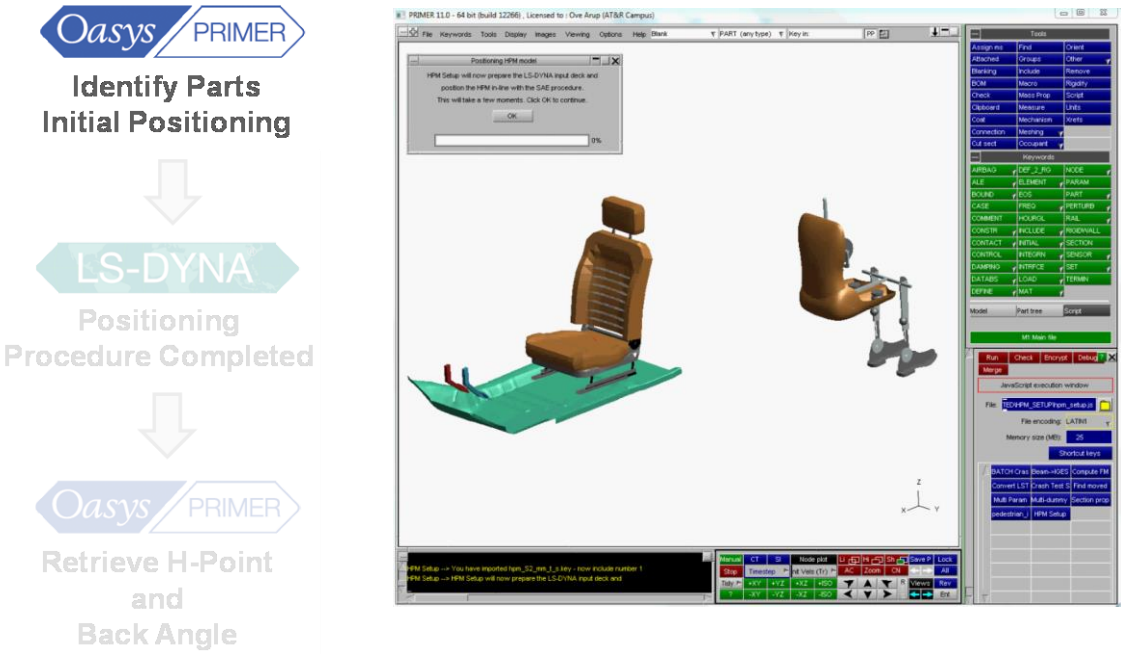
3.1 HPM Positioning Tool

The HPM positioning tool follows the workflow described below:



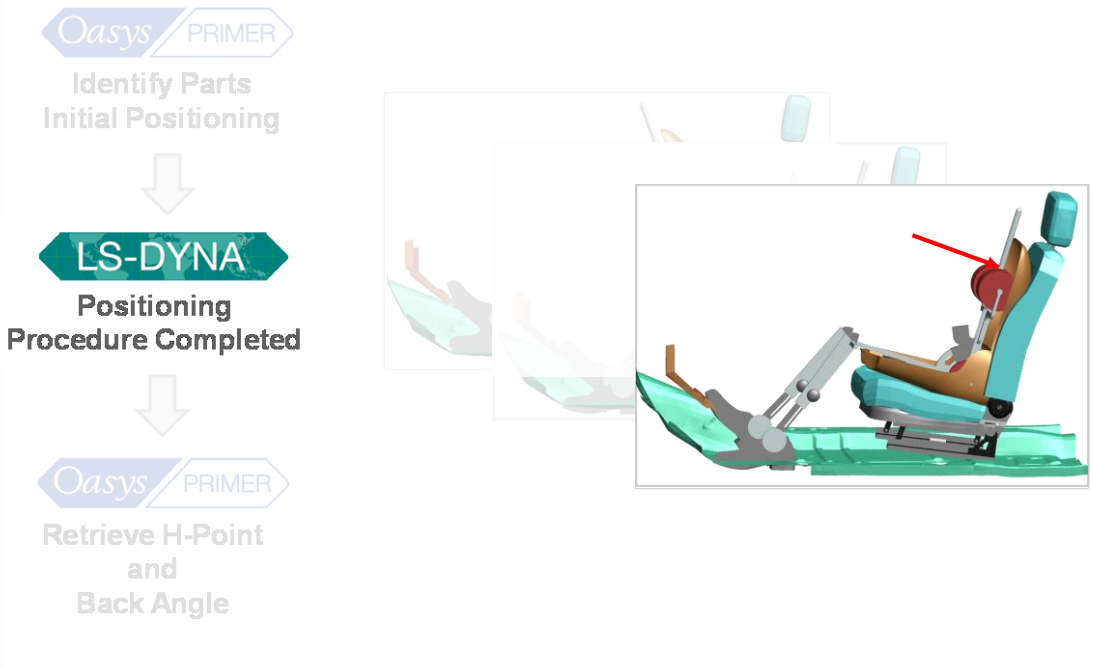
3.1.1 Model Setup

The seat package and the HPM are read into PRIMER and the user is prompted to provide all relevant information, after which the HPM is positioned in a preliminary position. The script also allows for rigidifying the components of the seat package that can be considered undeformable during the HPM drop, as this will reduce the runtime considerably.



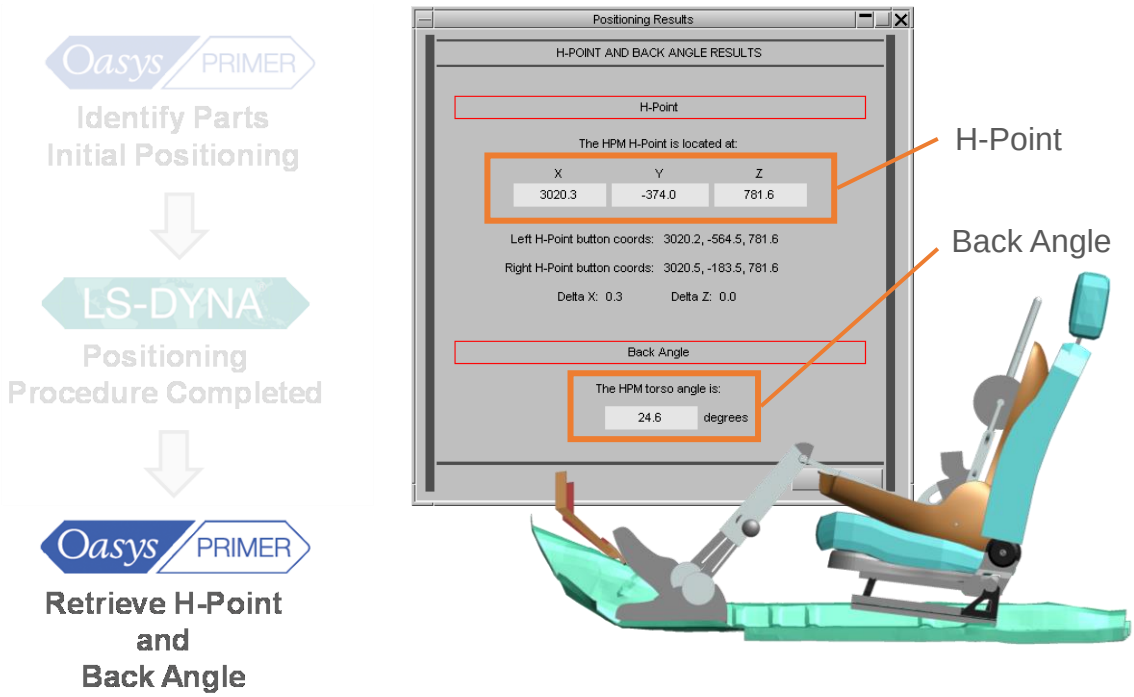
3.1.2 Positioning Procedure Completed

- The model prepared during the Model Setup is run using LS-DYNA. During the run, the *SENSOR_... cards are used to allow a multi-step procedure to be simulated within a single LS-DYNA analysis. The *LOAD_GRAVITY_PART cards are used to simulate the installation of various weights. The analysis termination time needs to be adjusted such that the manikin comes to a full stop.



3.1.3 Results

The results from the LS-DYNA analysis are output to a dynain file, which will contain the final position for each node in the model. To assess the results, both the original model, as it was set up at step one, and the dynain file are read into PRIMER, where the HPM tool will calculate and report the H-point coordinates.

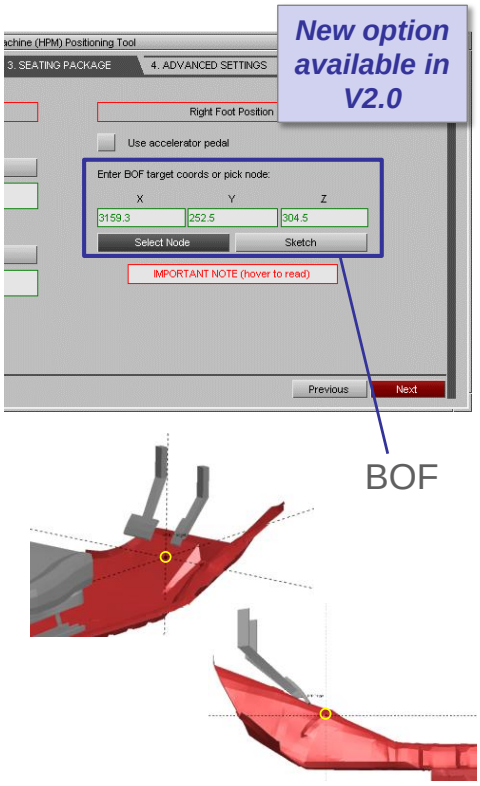


The new version V2.0 of the HPM tool has been extended to allow as input the Ball of Foot (BOF) to be used instead of accelerator pedal.

The HPM Positioning tool follows the SAE J826, which requires the position of the accelerator pedal. The accelerator pedal info is not always available in the early stages of the seat design, and only the location of the ball of foot (BOF) of the right foot might be known. For this case, based on customer requests, the tools have been extended to allow the value of the BOF to be entered instead.

Another potential use of this new option is predicting the H-point of a front passenger seat, in which case the BOF is positioned on the floor.

Please note that even though the tool offers this option, the front passenger seat drop is outside the scope of the SAE J-826 protocol.



4 HRMD - Head Restraint Static Assessment

The position of head restraint relative to head influences the risk of whiplash injury: scoring is better if the head restraint is closer to the head. The position is measured using H-Point Machine with Head Restraint Measurement Device (HRMD) attached.
The static scoring of the HRMD tool for the driver seat is based on:

- EuroNCAP,
- IIHS,
- NHTSA,
- C-NCAP.

A new addition for version V2.0 is the EuroNCAP Rear Seat option. It should be noted that this uses the HPM only, i.e. the manikin without the HRMD, as this assessment is based on geometric measurements of the seat.

The workflow for the HRMD Positioning Tool is very similar to the HPM tool, as explained in the previous section. The inputs that the user will have to make will vary dependent of the specific regulation.

The results are displayed simply and clearly and are formatted in the style relevant to the chosen regulation, as per the picture below. The scores are automatically calculated. Images and sketches of the HPM and head restraint in each position can be reviewed.

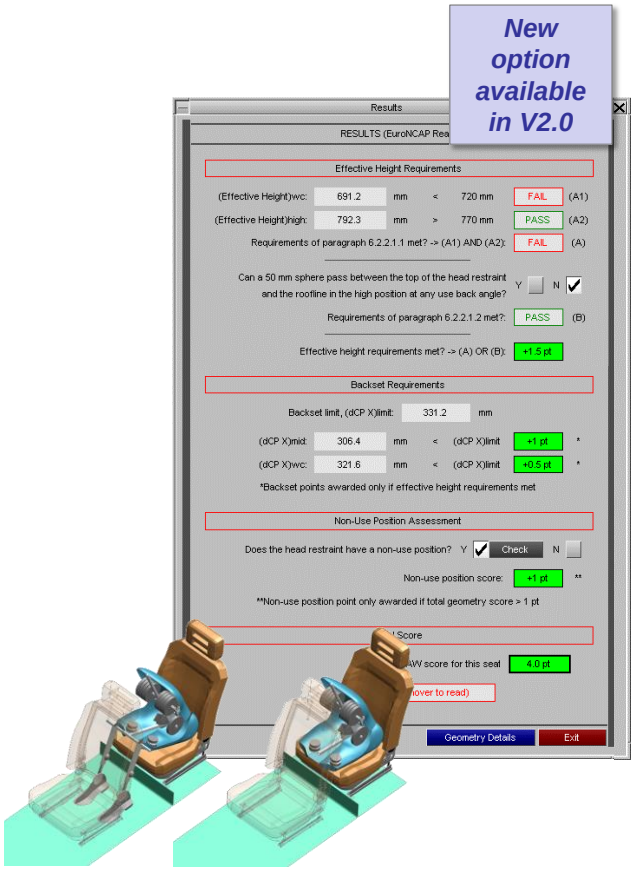
4.1 EuroNCAP Rear Whiplash Assessment

Since 2014, the EuroNCAP Whiplash Assessment includes a static assessment for rear seats; this will award maximum 1.0 point for rear seats.

The HRMD Positioning Tool has been extended to follow this protocol and offers:

- A clear step-by-step guidance to the inputs needed, based on a thorough understanding of the protocol,
- Options of using a manikin without lower legs, if necessary,
- Calculating the geometric assessment and producing the raw scoring for the rear seat/s.

The capability for rear seats virtual assessment is especially valuable, as rear seats tend to be unique for each vehicle.



5 Verification and Validation

5.1 Verification

Extensive verification studies were undertaken, where sensitivity to several variables was monitored, such as: versions of LS-DYNA, units, single versus double precision, SMP versus MPP.
LS-DYNA version R7.0.0 was generally used. However, a comparison was done using 971 R6.1.1 and this showed no significant difference in results. Please note that the models require LS-DYNA 971 R6.0.0 or more recent versions.
The conclusions of the studies are as per below:

- The variation in CAE results for the HRMD tool was in the same order of magnitude as the test variation;
- Units [m, s, kg], [mm, s, t] and [mm, ms, kg] (s1, s2 and s3) were tested. The study showed that the units have no impact on results.
- Double precision gives more consistent results and dummy settles sooner (~3.5-4sec for this particular seat package) when compared to single precision. Based on this, the recommendation is to run double precision.

5.2 Validation

The HPM and HRMD tools have been validated through studies done in collaboration with Futuris, a global company specializing in the design and manufacturing of seating and interior solutions, with products renowned amongst the best in the world.
The validation work focused on the HPM Tool for H-point prediction (SAE-J826) and on the HRMD Tool for backset prediction (Euro-NCAP).
The seat model used for this validation was correlated to multiple load cases: high speed front and rear impacts, low speed rear impact, quasi-static loading in multiple directions. The foam and trim were correlated in isolation as well as part of the complete seat system

5.2.1 Validation – HPM tool (SAE-J826)

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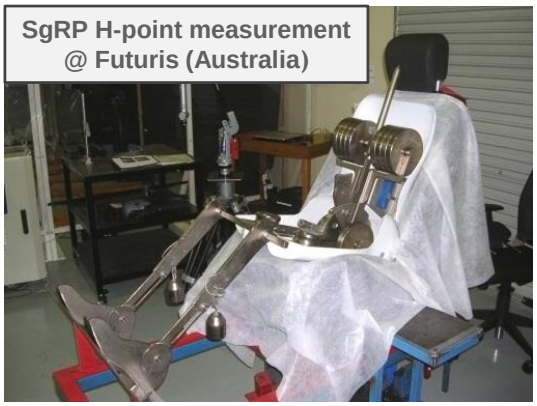

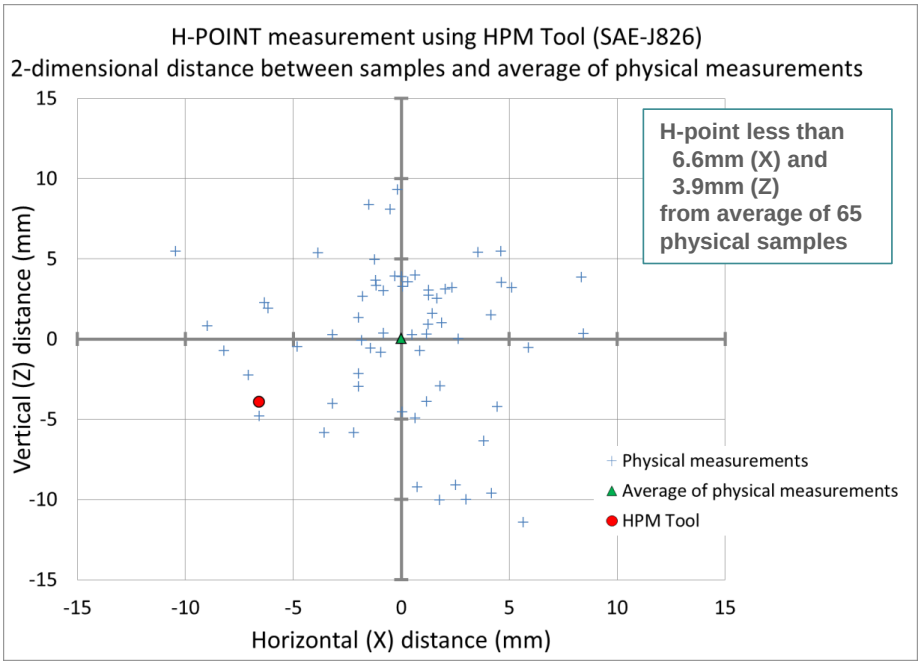

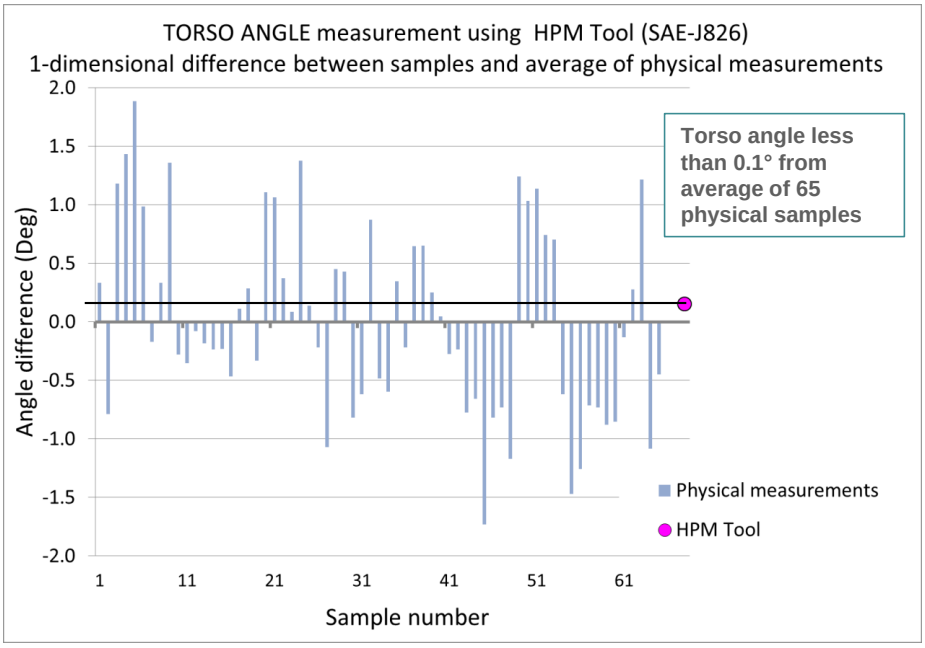

5.2.2 Validation – HRMD tool (EuroNCAP)

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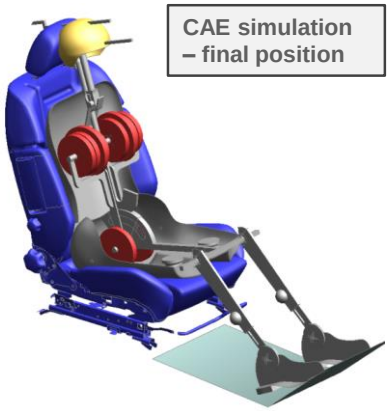

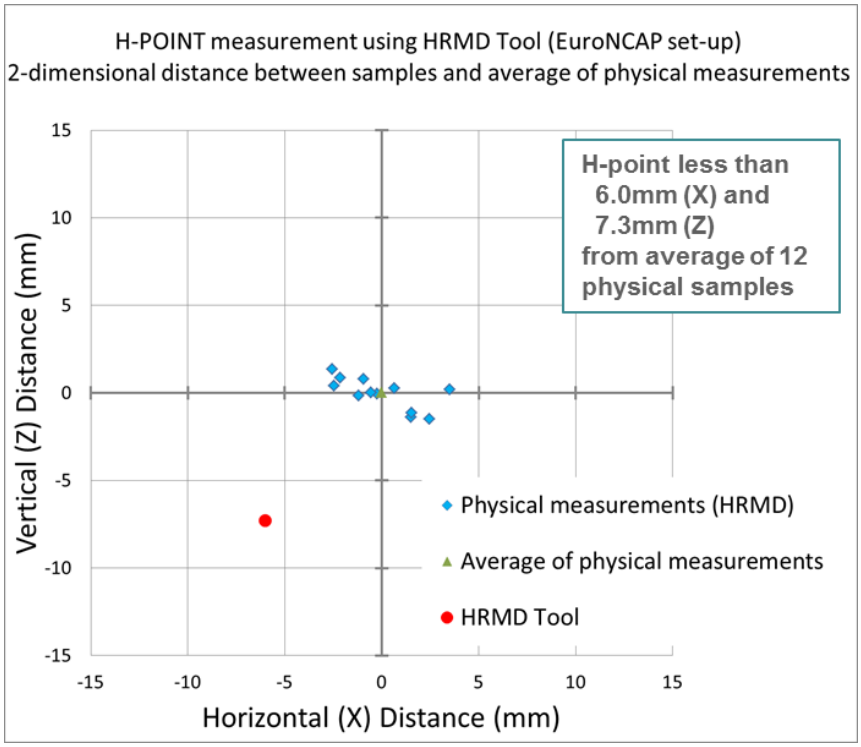

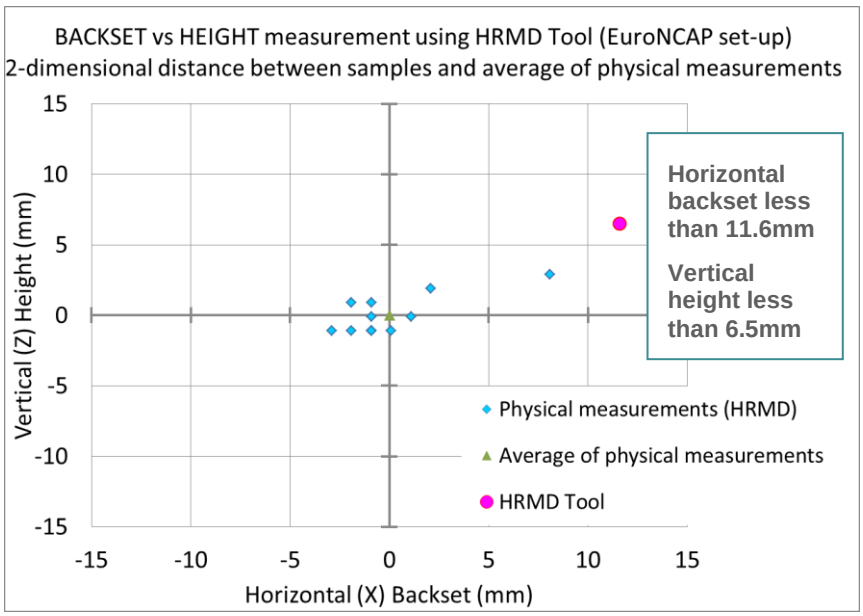

With the seat base and seatback in “Design” position, as per SAE-J826, the HPM tool predicted:

- H-point less than 6.6mm (X) and 3.9mm (Z) from average of 65 physical samples
- Torso angle less than 0.1° from average of 65 physical samples

With the seat base in Mid and the seatback set to 25° torso angle, the HRMD tool predicted:

- H-point less than 6.0mm (X) and 7.3mm (Z) from average of 12 physical samples
- Horizontal backset less than 11.6mm, head vertical height less than 6.5mm from average of 12 physical samples

Considering the tolerance of physical samples (usually H-point ± 10mm), the tools showed very good correlation to physical samples.

6 Summary

Arup have developed the HPM and HRMD Positioning Tool kit that can be used in conjunction with the Oasys PRIMER software [1]. The tool kit calculates the H-Points of the automotive seats, as well as the backset measurement, thus providing the scores of the head restraint. The benefits of the tools can be summarized as follows:

- More confidence in Design H-Point;
- Tuning the seat model trim characteristics to obtain the same response as the physical seat;
- Understanding variability of H-Point position to seat parameters;
- More confidence for dummy positioning in safety loadcases, e.g. Front impact, Side impact, Whiplash analysis;
- Automated tool for predicting the static score for seat head restraint EuroNCAP driver and rear seat, C-NCAP, IIHS & NHTSA;
- Opportunity to adjust the seat/package design.

7 Literature

[1] Oasys® PRIMER12.1 User Manual. Ove Arup& Partners Ltd: Solihull, UK, 2015

[1] SAE International: “J826 NOV2008 Devices for Use in Defining and Measuring Vehicle Seating accommodation”, Revised 2008-11

[1] LS-DYNA® Keyword User’s Manual, Version 971. Livermore Software Technology Corporation (LSTC): Livermore, CA 94551-5110, USA, May 2007