Speeding up the Pedestrian Protection CAE Process

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1 Introduction

Pedestrian protection is increasingly important to the design and development of the front end of vehicles. The various protocols, impactors and methods relating to pedestrian protection mean that the CAE process can be complex and time consuming. Arup has developed various tools to aid in this process which are used internally within Arup when working on automotive consultancy projects as well as being available externally in the Oasys LS-DYNA® environment software. These tools are available for both head and leg impact analyses. This paper describes the tools and also how they are used on real world projects.

There are various parts of the pedestrian protection CAE process that potentially can be slow/time consuming. These include:

- Calculating zone boundaries.
- Determining target points.
- Positioning and depenetrating the impactor in multiple (often hundreds) locations.
- Creating LS-DYNA input models.
- Post-processing multiple analyses.
- Summarising the results
  - Point calculation/star rating.
  - "Area of HIC" calculations.

The tools that Arup have developed to aid in the above are as follows:

- Mark-Up
  - Calculate zone boundaries based on regulatory and consumer test protocols.
  - Specify a grid of target points within calculated boundaries.
  - Specify target points based on available space below the bonnet.

- Multi-model build
  - Position impactor automatically to all specified target points + depenetrate.
  - Automatically create all input decks for LS-DYNA.

- Post-processing
  - Automatically produce individual reports per analysis.
  - Automatically produce summary report with points/area calculation.

2 Mark-Up

The mark-up tool within Oasys PRIMER can be used to identify impact zones relating to various protocols (including EuroNCAP v8). The tool will work out the various reference lines that form the bounds of the impact zones (fig 1).
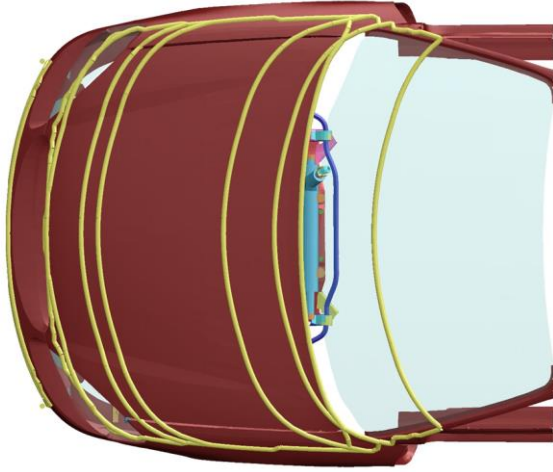

Fig.1:   Zone boundary calculation.

The zones are calculated using default values for various inputs (for example side reference line angle, or wrap around distances). These inputs can all be modified during markup for sensitivity studies.

Once the impact zones are determined, the tool can be used to create target points for head/leg impacts in a number of ways:

- Automatically creating a grid of target points over the zones based on specified spacing (fig 2).
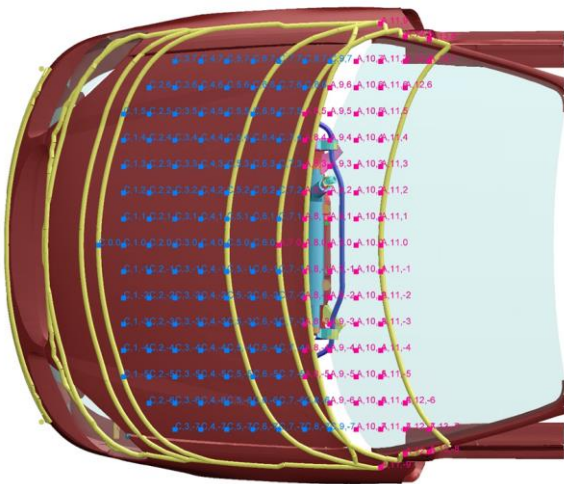

Fig.2:   Grid of points.

- Manually create target points at specified locations. This can be done by either clicking directly on the A-surface, or by selecting a "hard point" below the surface. In the latter case, the tool will project the coordinate of the specified hard point back to the A-surface along the line of flight of the impactor to create the target point (fig 4).

- Automatically determine "hard points" below the bonnet based on packaging space and create an appropriate target point on the outer surface of the bonnet based on impactor line of flight (figs 3/4).
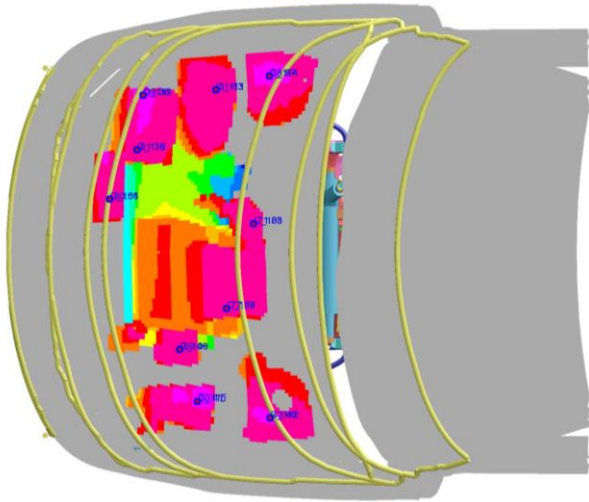

Fig.3: "Hard point" calculation.
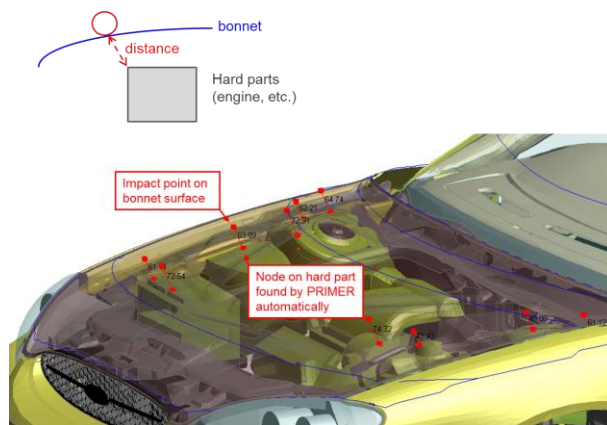

Fig.4: Projecting "hard point" back to bonnet surface.

- Create "robustness points" surrounding specified target points to investigate the sensitivity of impacting at particular locations (fig 5).
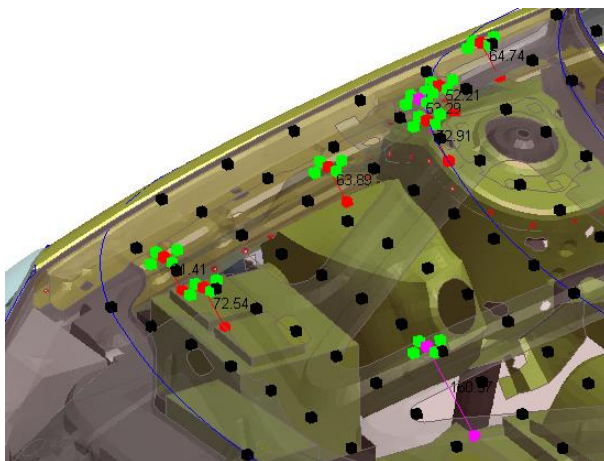

Fig.5: "Robustness" points.

3 Multi-Model Build

Once target points have been specified, the next stage is to build multiple models automatically based on those target points. This is done by:

Moving the impactor to each target point in turn.
Depenetrating the impactor according to set rules.
Outputting models to run in LS-DYNA with *INCLUDE_TRANSFORM definitions to move the impactor model to the calculated starting positions.

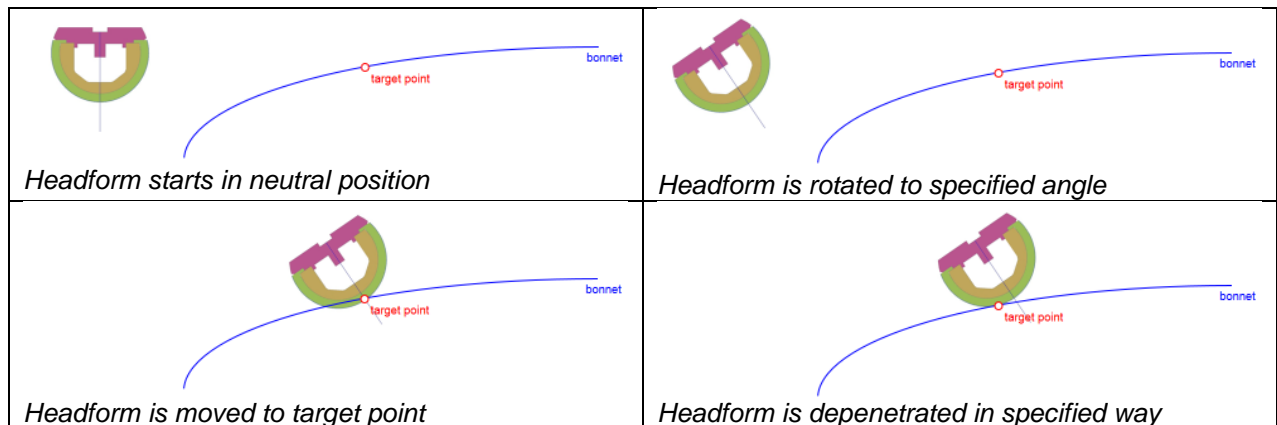*Fig.6: Multiple build of many LS-DYNA models based on target points.*

Headform starts in neutral position

Headform is rotated to specified angle

Headform is moved to target point

Headform is depenetrated in specified way

Fig.7: Positioning and depenetrating the impactor.

There are various options available during the multiple model build process. The user may wish to position the impactor such that the central point of the impactor lines up with target point along the line of flight, or they may wish to position such that the initial contact point is as close as possible to the target point.

There are also various options for how the output files are written. The default is to write a series of master decks containing *INCLUDE_TRANSFORM and *DEFINE_TRANSFORMATION definitions that reference the impactor in its neutral position. There are also options to write each impact point as a separate *CASE definition.

4 Post-Processing

The final stage is to post-process the many individual LS-DYNA® analyses that are created. Reports can be created automatically using built in templates within Oasys REPORTER. This reduces the time required to manually post-process many runs. Various features are available:

Produce individual report for each impact.
Produce a summary report of all individual impacts.
For EuroNCAP grid method plot results and calculate points scored.
Create contour plots and "areas of HIC" calculations based on multiple impacts (Head impact - GTR9).
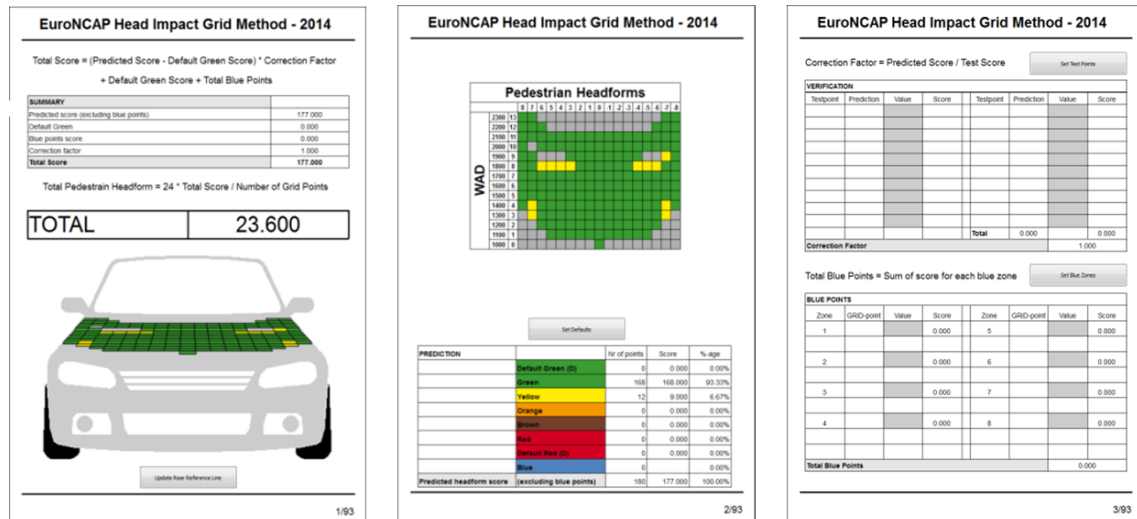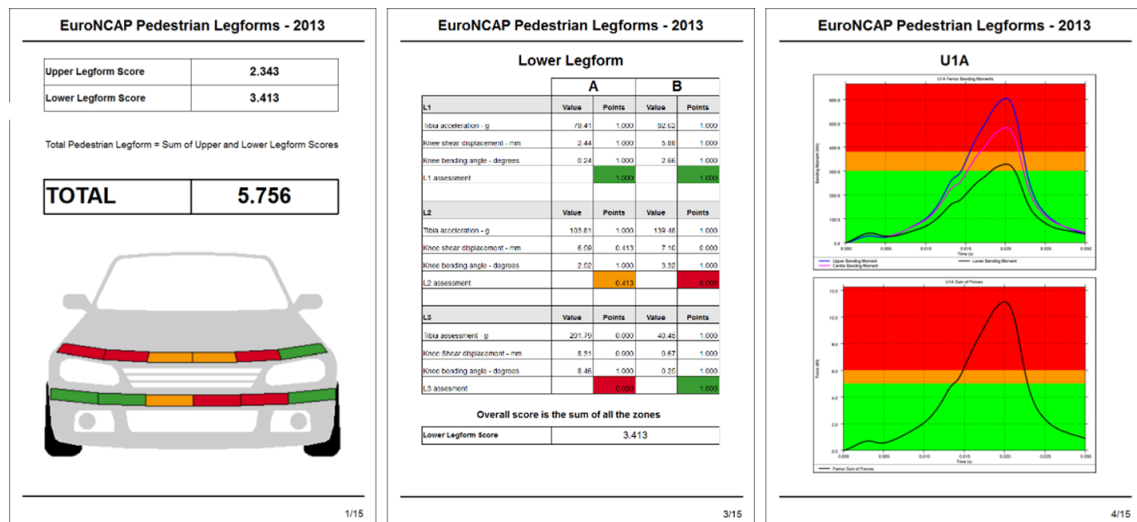

Fig.8:   Collated EuroNCAP headform results.

Fig.9:   Collated EuroNCAP legform results.

For the protocols which specify that percentage areas of the bonnet surface must be below certain HIC values, there is a report template for taking a grid of HIC data and interpolating/extrapolating the results to produce a contour of HIC results within the zone boundaries. Area percentages are also given for particular ranges and targets (fig 10).
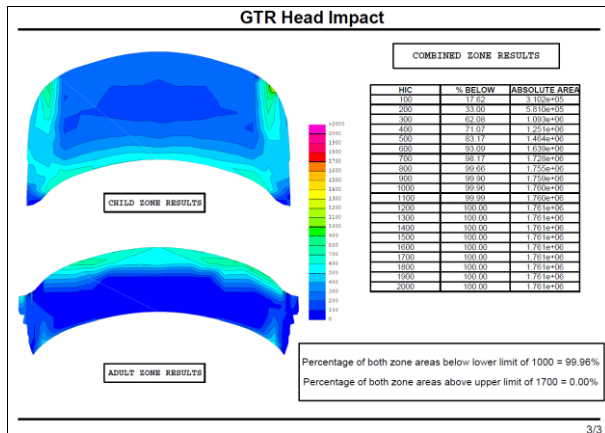
GTR Head Impact

COMBINED ZONE RESULTS

HIC	% BELOW	ABSOLUTE AREA
100	17.62	3.102e+05
200	33.00	5.810e+05
300	62.08	1.093e+06
400	71.07	1.251e+06
500	83.17	1.464e+06
600	93.09	1.638e+06
700	98.17	1.728e+06
800	99.66	1.755e+06
900	99.90	1.759e+06
1000	99.96	1.760e+06
1100	99.99	1.760e+06
1200	100.00	1.761e+06
1300	100.00	1.761e+06
1400	100.00	1.761e+06
1500	100.00	1.761e+06
1600	100.00	1.761e+06
1700	100.00	1.761e+06
1800	100.00	1.761e+06
1900	100.00	1.761e+06
2000	100.00	1.761e+06

CHILD ZONE RESULTS

ADULT ZONE RESULTS

Percentage of both zone areas below lower limit of 1000 = 99.96%

Percentage of both zone areas above upper limit of 1700 = 0.00%

3/3

Fig.10: Contour of HIC results.

5 Summary

The pedestrian tools that Arup have developed help the user produce models quickly, and spend less time post-processing results. The tools are currently available in the Oasys LS-DYNA® environment software suite, and have been used successfully on various vehicle programs, from high performance sports cars to bespoke multi-person transportation vehicles.

When using these tools we have been able to speed up input into the design process, and have more time to investigate issues and solutions. The tools are also useful in the initial stages of development for investigating concepts relating to styling, materials, design and packaging.

6 Literature

- Oasys® PRIMER 12.1 User Manual. Ove Arup & Partners Ltd: Solihull, UK, 2015
- LS-DYNA® Keyword User's Manual, Version 971. Livermore Software Technology Corporation (LSTC): Livermore, CA 94551-5110, USA, May 2007