COMPOSITE MODEL BUILDING FOR AUTOMOTIVE CAE

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ABSTRACT – Composite materials are being more heavily utilised in the automotive industry. These lightweight and durable materials are being used on a wider basis and are supporting advances in developing optimal structures.
It is clear that in the future composite materials will become more widely used in mainstream automotive engineering.

Penso are at the forefront of this innovation, developing as a company and working together with major OEM's and material suppliers to deliver innovative and ground breaking solutions.

CAE Model build plays a major part in the development of both design and engineering. Accurate analysis drives the development process forward, delivering performance with real world value. This is particularly crucial with an expensive resource such as carbon composites.

Using the correct tools and procedures is essential; improving techniques and enabling effective control of model data.

BETA CAE Systems S.A. software has played a key part in this process by helping with model build efficiency within both its pre and post processing capabilities. Handling all relevant model data during the process and maintaining run information is crucial.

Iterative runs and analysis are a major component of product development. The advanced scripting tools developed at Penso enable rapid model build which enhance productivity and allows a wider search envelope to fully validate designs and understand failure modes.

These advances help Penso to deliver structural performance results in rapidly decreased timescales which were previously deemed to be unachievable.

TECHNICAL PAPER -

1. INTRODUCTION

Penso is an award winning engineering and manufacturing consultancy based in the UK, with ambitious growth and development plans. Penso are also the UK sole supplier of Beta software applying the full Ansa/Meta software suite in the delivery of our engineering services.

As the Automotive industry develops and pushes forward the boundaries of technology, composite materials are at the forefront. Although not a new concept in the mainstream application for structural Automotive engineering is relatively untried and uncommon. Penso were approached by an external customer with a demanding project brief to engineer and manufacture an automotive car body structure (BIW) using carbon fibre composite materials. The structure had to meet class leading weight and stiffness target and be delivered to a demanding timeline.

The final result of the project delivered six manufactured monocoque body structures (bolted tubs and rear frames) fully engineered and analysed.

This paper details the contribution of the software tools and processes to achieve the final vehicle construction.

2. MODEL BUILD

NVH analysis was performed on the body structure, this comprised of;

- Tub (including roof structure and tunnel closers front and lower)
- Rear Frame (including cross brace)
- Front Sub frame
- IP
- Battery tray (not including cover)
- Windscreen and Rear bulkhead glazing
- Suspension Brackets
- Powertrain brackets (excluding rear powertrain lower)
- Pedal box bracket

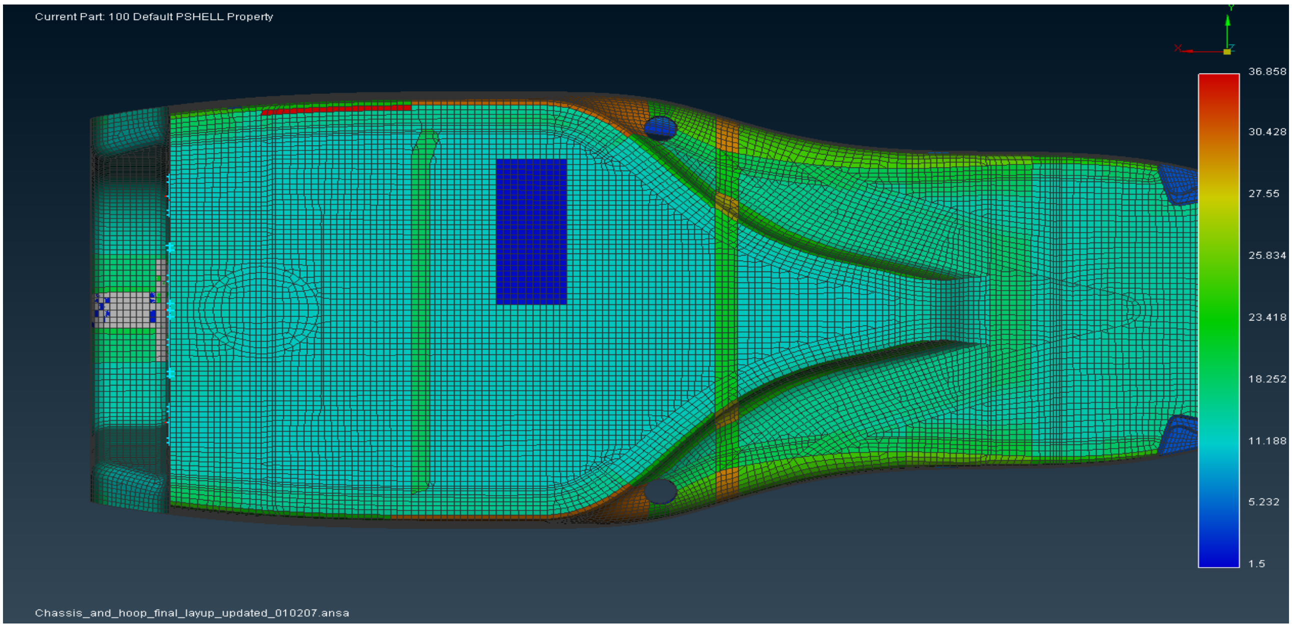

Figure 1: Monocoque tub in an FE model showing laminate layers.

The class leading structural targets required many development iterations. Running multiple analyses runs is time consuming and can jeopardise development timing. A solution to this was the development of advanced scripting tools to automate repetitive processes. Scripting is a computer language that can be used as an automatic way of applying set boundaries or conditions to a model, without the need to manually apply the same job. Beta software has the ability to use and create very powerful scripts. Penso would use both native Beta scripts and in-house Penso developed scripts during the course of this project.

A general procedure was followed during the model build process which was:

- A common mesh was used for NVH, durability and crash models.
- Panels were meshed to A-surface with shell elements oriented accordingly.
- Ply boundaries were cut into the mesh, including staggered boundaries >10mm.
- Layup defined using ANSA LAMINATE tool.

- Material orientation was manually defined (generally oriented in –X direction).
- Holes <6mm closed with node at centre point.
- Holes 6-12mm modelled with 6-8 nodes.
- At least 2 elements across flanges (1:6 aspect ratios permitted).

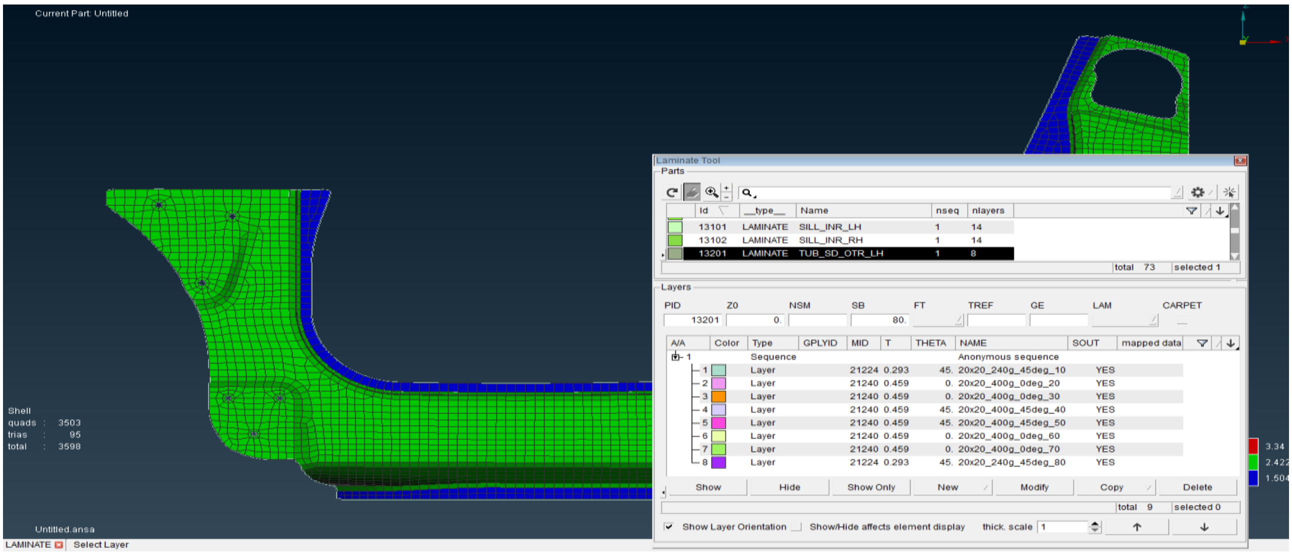

Figure 2: Laminate tool lay out.

A complexity of composite materials is that each laminate panel can have unique ply (individual layers) constructions.
The number of ply's and their orientation is specific to each panel and often varies across a panel; different areas of the panel have different ply stack-ups.
To manage this complexity Penso developed a script which could match ply's over a specific area. This script allows the user to select the stack-up they require and then apply it to a specific area on a panel. This saves valuable time and is a more accurate method than applying the layer to the required part of the panel via the laminate tool.

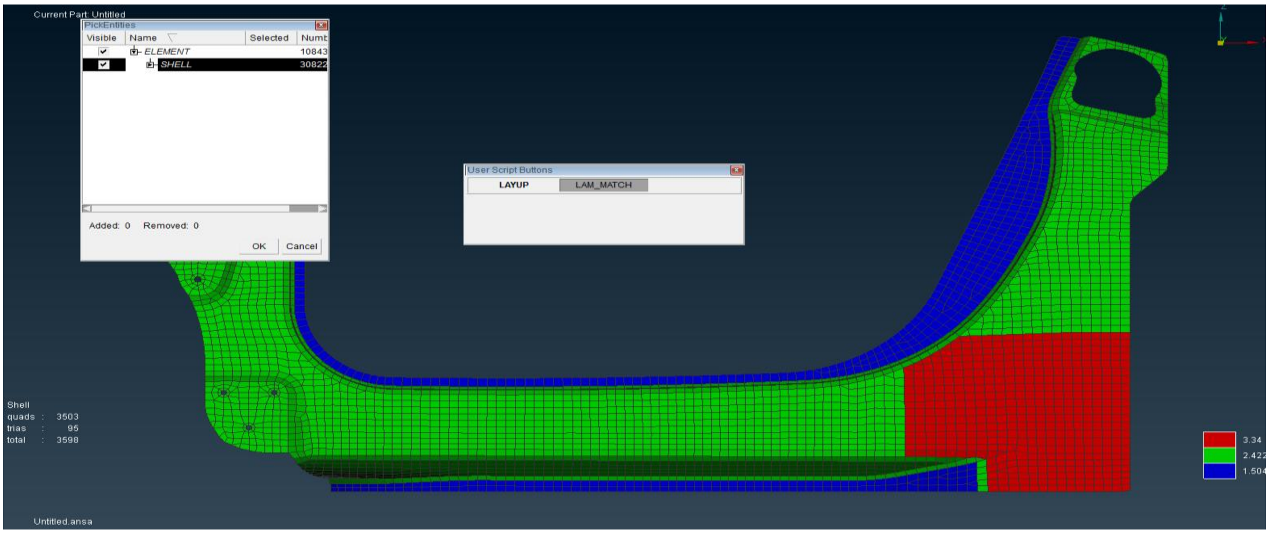

Figure 3: Penso script for layup.

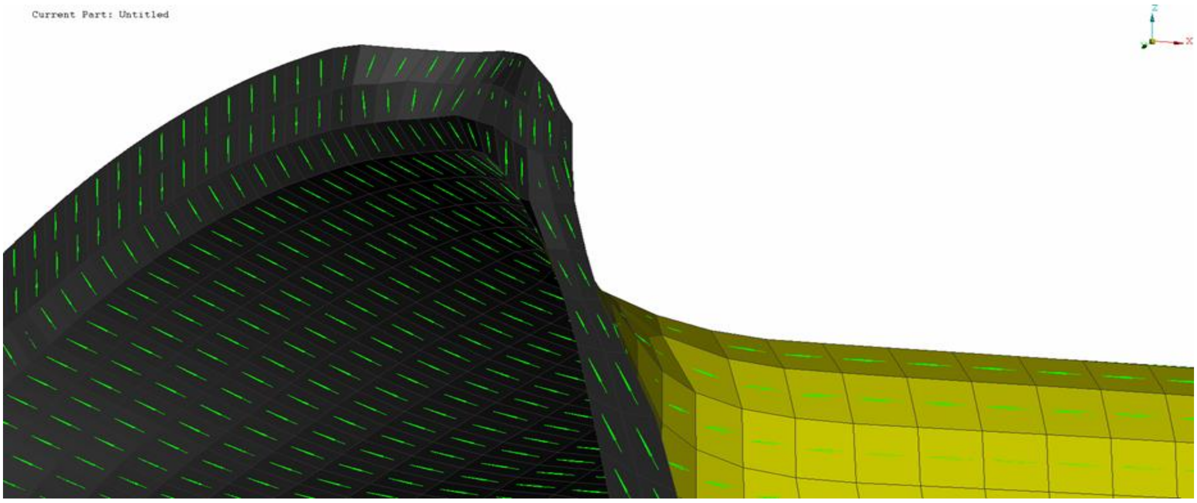

Figure 4: Material orientation.

A significant problem with model building using composite materials is material orientation. Composite materials are orthotropic, having different mechanical properties in different directions. Understanding and controlling the direction of the material is very important.

The rapid development on this project required the team to assess multiple CAD models, with each change in geometry the material orientation needed to be redefined. Penso decided the quickest and easiest way of dealing with this on a regular basis was to apply the results mapper tool. This laid the existing material orientation over the new geometry.

Bonding strips and adhesive were used to connect the panels together, along with traditional methods of panel connections. The Adhesive thickness was defined based upon the joint condition:

A-surface to A-surface, 0.5mm
A-surface to B-surface, 0.75mm
B-surface to B-surface, 1.0mm
Film adhesive, 0.2mm

Adhesive faces were also used where the flow and shape of the panel did not allow a natural flow for a bonding strip. Although this is not ideal for everyday application, it solved the issues faced in certain situations.

A script was created to automatically calculate the number of shell and solid elements in both the tub and the rear of the vehicle. The script also calculated the mass for both areas of the vehicle, as well as the total mass of the vehicle. This script was used to aid with the post processing analysis of the development within the project.

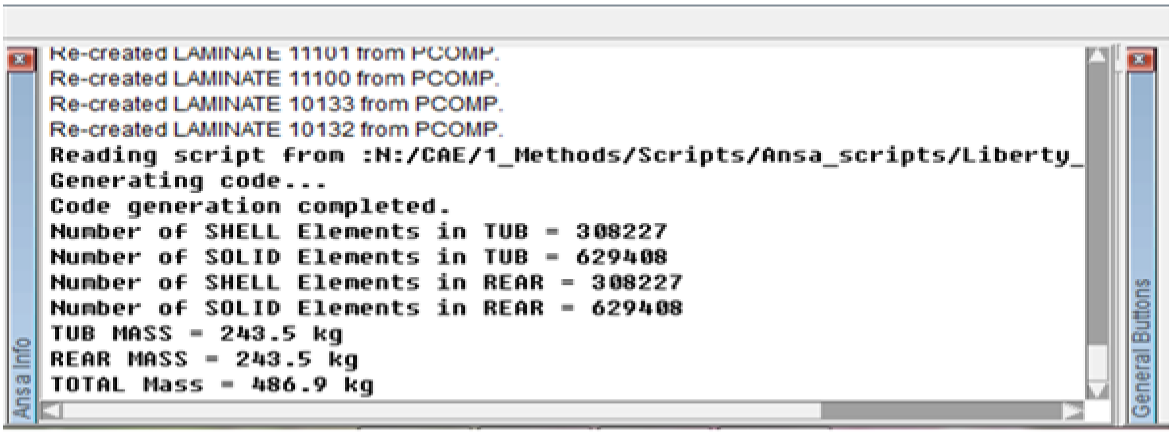

Figure 5: Penso scripting tool for mass and elements.

3. OPTIMISATION

Optimisation of stiffness was critical to the development of the structure, as the project had zero physical prototypes; the first off vehicles were expected to be fully running. The targets set for analysis were high; many were unique and never achieved on a road car before.

The Hoffman failure index was used in optimization for durability loading. The target for the project was to be obtaining a nominal target of 0.6. Values over 1.0 were deemed a failure. Further investigation is on-going at Penso to investigate the failure indices applicability for mainstream automotive application.

Scripting and session files were also created to aid with the calculating and application of the bending and torsional stiffness of the tub and the rear. This helped to maintain a consistent data measurement

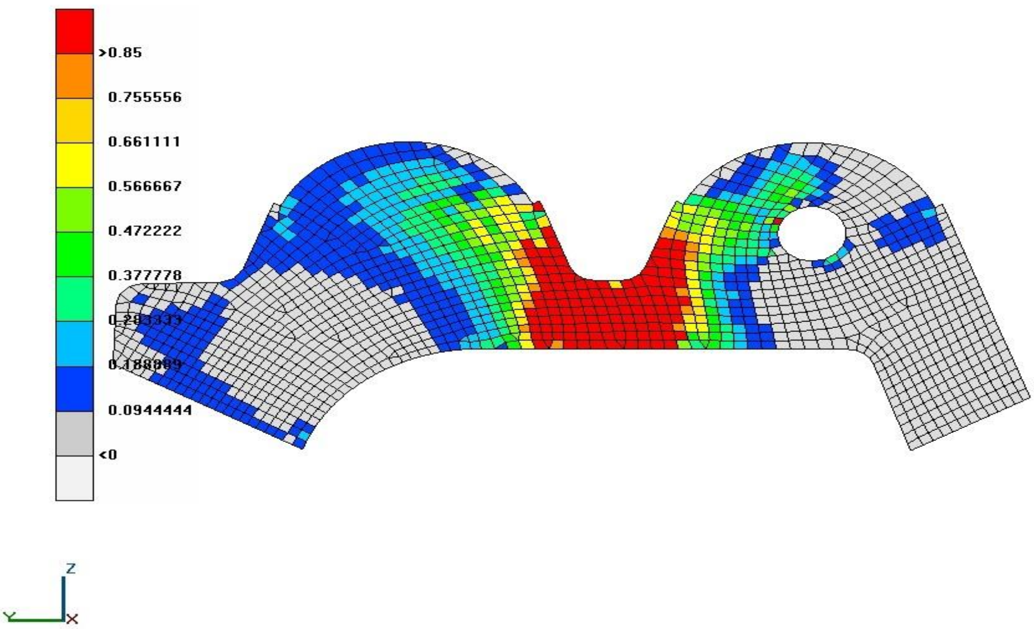

Figure 6: An Area of the Hoffman failure index Results.

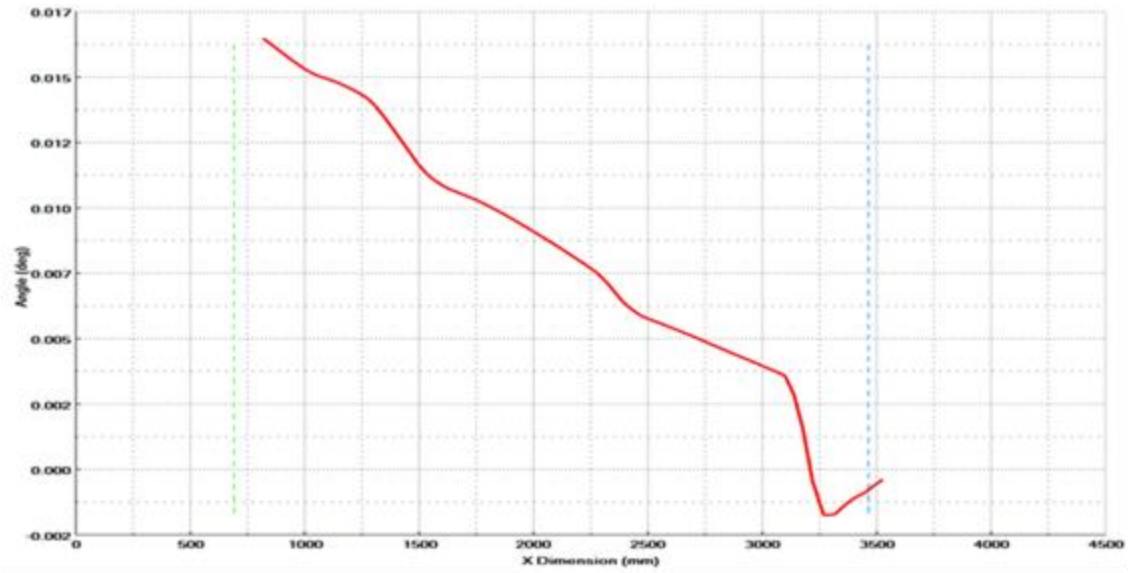

Figure 7: A Graph produced from the script session.

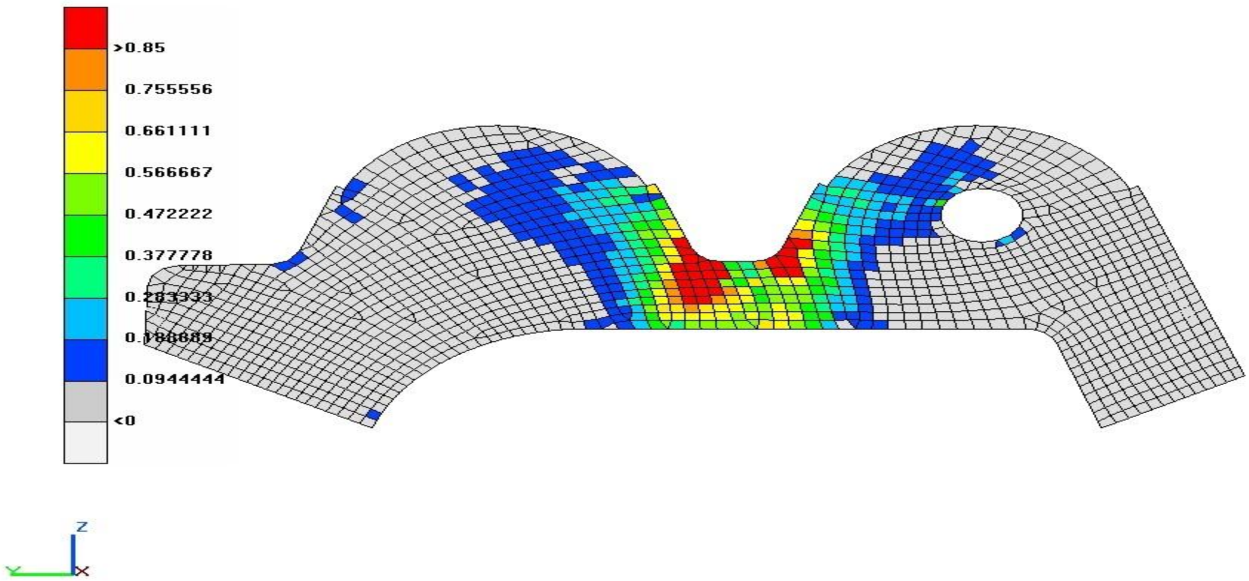

Figure 8: A visual improvement of the Hoffman failure index.

An automated composite tool bar has been created in Meta in conjunction with this project. Feedback was given from both Penso and Beta with regards to this, and what materialised was a new feature which is prevalent in the newest versions of Meta.

4. POST PROCESS

Global torsional stiffness
Opposing vertical forces are applied to the two front suspension rocker brackets. Loads are applied via CBAR elements connected to RBE3 elements. Z displacements were measured at 4 points; Torsional stiffness was calculated using these values. The measurement points align with the wheel centres and are positioned away from the load application points to reduce the influence of any local deformation.

Vertical forces were applied to the sill edges at the wheel base midpoint. Loads are applied via RBE3 elements. The RBE3 elements only attach to the sill edges to prevent excessive local deformation of the sill. Z displacements were measured at two points on the floor edge. Bending stiffness was calculated using these values. The displacement points are positioned away from the load application points to reduce the influence of any local defamation.

Torsional Stiffness Calculation

Torque, T= DL x FT

σfront = tan-1((dz1 + dz2) / D1)
σrear = tan-1((dz3 + dz4) / D2)
σtotal = σfront - σrear

Torsional Stiffness, KT = T / σtotal

Bending Stiffness Calculation

Displacement, dzmid= (dzmid_1 + dzmid_2) / 2

Bending Stiffness, KB = dzmid / (2 x FB)

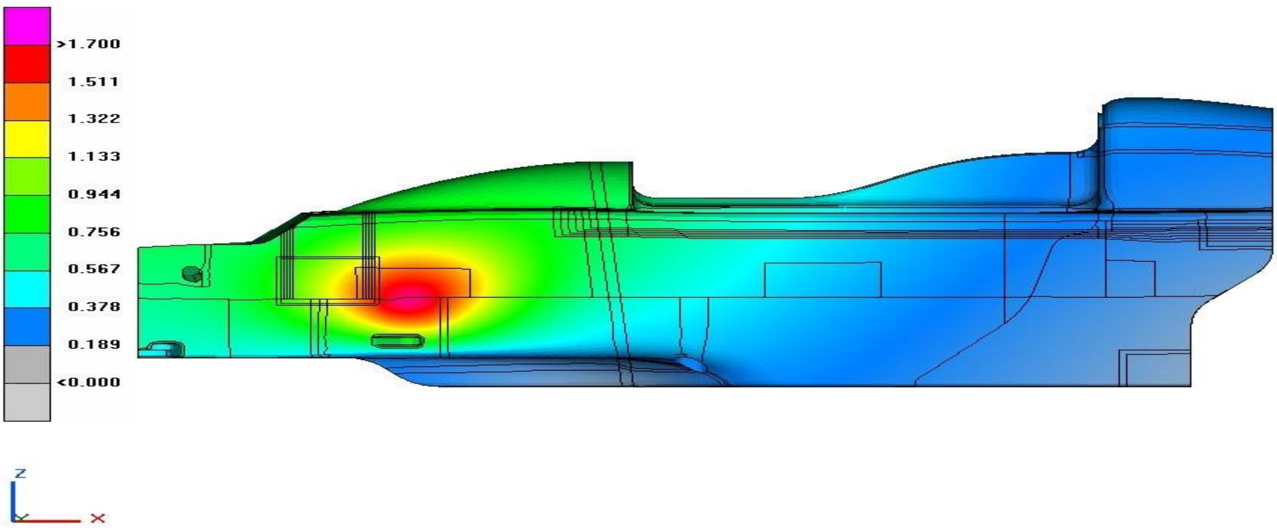

Figure 9: Visualisation of loading.

Local stiffness
Individual 1000N loads were applied in X, Y and Z at each hard point.

Front suspension	Lower wishbone front
	Upper wishbone rear
	Rocker arm pivot
	ARB fixing
	Steering column
	Steering rack
	Shock absorber
Rear suspension	Lower wishbone front
	Upper wishbone rear
	Rack control arm
	ARB fixing
	Shock absorber
Powertrain	Front Powertrain upper
	Front Powertrain lower
	Rear Powertrain front
	Rear Powertrain rear
Other	Pedal box
	Brake booster

Local Stiffness values are calculated using the strain energy method. Strain energy values were extracted from the .f06 file.

Constraints
Global torsional stiffness
The body is constrained at the rear suspension damper brackets with SPC's connected via RBE2 elements. The body is also constrained vertically on the sub frame lower edge centreline.

Global bending stiffness
The body was constrained with SPC's at the front suspension rocker brackets and at the rear suspension damper brackets.

Layup Books.

Layup books were created via post processing to record and report each individual panel. Each layup book showed the fibre direction, centre line and honeycomb ribbon direction for each panel. The final layup books were delivered in MS PowerPoint, displaying all the iterations and resin layup for each panel. This data is generated via Ansa scripting.
Each slide also shows a representation of the resin, weight, weave and fibre within each panel. This was of great benefit to the manufacturing team, as they were able to use the layup books as a guide whilst applying the material for prototypes. They helped to show the weight, resin, weave and fibre in a straightforward and consistent way.

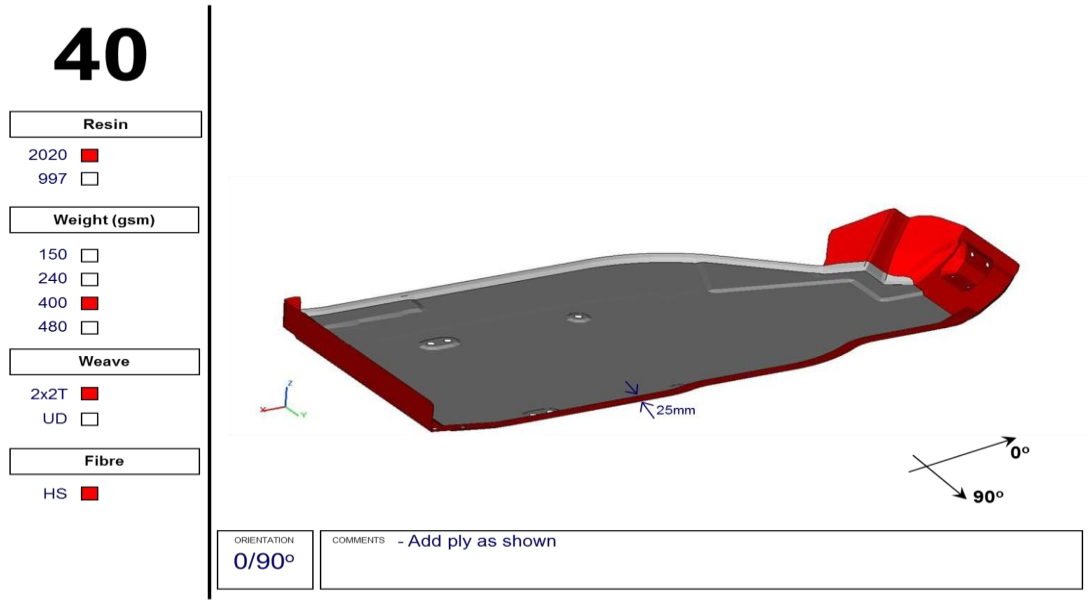

Figure 10: An example of a layup slide.

These layup books helped to keep a log and record of each individual panel and were easier to explain any issues that could occur to partnering companies. It also aided manufacturing of the tub and rear.

LAYUP BOOK GENERAL PROCEDURE

The procedure for the layup books was repeated for each panel and each run:

- Set up Laminates in ANSA
- Output .nas file for each laminate
- Create Images of each ply
- Create any additional images required (detail/views/core/inserts/capping plies/gluefilm)
- Import ply images into CLOTH_template
- Import additional views
- Import other images into appropriate templates (Core/Gluefilm etc…)
- Manually set OP Number / Ply Data / Comments / Orientation on each slide
- Add GENERAL_template above Operations
- Add dimensions and CL on each slide as required
- Highlight all the materials used in the Layup book
- Insert the Interface regions image from CAD
- Add COVER_template as first slide
- Manually set Part Name/ID/Issue/Rev/Footer/Analysis model reference
- Insert thickness plot
- Paste in CURE_CYCLE template as the last slide
- Save file and Archive earlier version

5. IMPROVEMENTS

Penso approached the project by ignoring draping effects to improve processing time, studies showed only a small benefit, however a draping tool would be used to append any change in geometry. A change could be made to the geometry and a draping tool could be used to re-apply the laminate to the geometry. This would save the time it takes to reapply the layers and the material orientation. This would also save time for writing a script.
As mentioned earlier in the paper, more analysis on the Hoffman failure index would need further analysis for durability.

A further advance in the automation between CAD, CAE and manufacturing is always an area that could be improved. Although this is a general statement that could be applied to most companies, with procedures that are untried and untested it is even more important for the development of the processes used. If Penso are to use these procedures on a consistent basis, then optimizing procedure is crucial.

6. CONCLUSION

Although the development of the six fully functional monocoque tubs and rears would seem the project was successful, it was not without its difficulties. Penso has achieved something special and potentially ground breaking with this project. However maintaining and improving procedures developed during this process are vital if manufacture becomes common. Beta software can be a vital tool in the step from engineering to manufacture. Development of any process is vital to progression and advancements in engineering and with revolutionary projects, this is even more prevalent.

REFERENCES

- All figures and calculations provided are supplied by Penso Consulting.