The Application of Process Automation and Optimisation in the Rapid Development of New Passenger Vehicles at SAIC Motor

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Abstract
As a relatively young automotive company, SAIC Motor has drawn on the expertise of its UK Technical Centre to help in its objective to bring a new range of vehicles to market in an aggressive time frame. CAE has formed an integral part in doing this and the UK technical centre has worked closely with Altair Product Design amongst others to utilise its Engineers' skills as well as the Hyperworks suite of software.

The paper aims to showcase what has been achieved to date, on the Roewe 550 medium car programme - currently on sale in China - and on another current vehicle programme, where processes have been developed further. Several interesting optimisation examples are highlighted in the development of the body structure as well as some key process improvement methodologies which have been jointly developed between SAIC and Altair to streamline the design process.

Keywords: Optimisation, Crash, NVH, Durability, HyperStudy, OptiStruct, Altair Product Design

1.0 Introduction
SAIC Motor is the largest domestic motor manufacturer in China, based in Shanghai. It has joint ventures with VW and GM and has now embarked on the latest phase in its business plan, namely to develop its own range of products and brands.

In order to do this effectively, the UK technical centre was set up to draw on the extensive experience of the UK automotive engineering community. Formally Ricardo 2010, the SAIC Motor UK Technical Centre (SMTC UK) has been key to helping SAIC achieve its goals.

The competitive nature of the automotive industry demands vehicle development times to be continually driven down to ensure early time to market, as well as minimising development costs and the product Bill of Materials costs. A key factor in time scale reduction is the successful implementation of a CAE design driven process and optimisation techniques are essential in minimising cost and weight whilst maintaining performance.

During the Roewe 550 development programme, SMTC UK and Altair Product Design Engineers developed a virtual design of the vehicle within 12 months that required no full prototype testing. Physical testing of the vehicles has latterly proven that the performance predictions from CAE were accurate enough to achieve an efficient design. Learning on this programme has led to further advancements in CAE on the current vehicle programme.

The key factors that enabled the CAE vehicle development within such an aggressive time scale were:

- Consolidated Software Stack
  - HyperWorks dominant (Less fragmentation).
- Extensive Use of Automation
  - Batchmeshing, auto reporting, etc.
- Extensive Use of Optimisation
  - Key timescale reduction technology, not just performance or minimum mass consideration

**Figure 1** shows a generic representation of the CAE vehicle design process. The phases indicate vehicle development stages. Each phase begins with a full CAE model build that ensures all attribute analyses begin at the same design level. As shown, ‘Process Automation – Pre’ is extensively used at these stages to ensure rapid turn around of model creation and ‘Process Automation – Post’ ensures rapid availability of results with minimal analyst interaction.

The performance indicator, shown on the Y axis, is a generic representation of the average performance of all crash, NVH and durability attributes. During a phase, the vehicle performance is developed through routine use of optimisation analysis. In early phases, concept and global optimisation is used to define an efficient base structure. These activities are then ramped down in later phases while local performance optimisation is ramped up as the design becomes more mature.

Through the routine use of optimisation, the objective at the end of phase 3 is to exceed performance targets to allow more scope for mass optimisation during phase 4.
2.0 CAE Process - Roewe 550

2.1 Consolidated Software Stack

Crash, NVH and durability analysis was carried out using a common suite of software tools. Figure 2 illustrates the software solution used for each activity within each of the disciplines. The LS-DYNA solver was used for crash simulations and non-linear durability analyses. Fatigue analysis was carried out using nCode. For all other activities it can be seen that Altair HyperWorks was used.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Activity</th>
<th>Software Solution</th>
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<tbody>
<tr>
<td>Crash</td>
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<td>BatchMesher</td>
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<td>Crash Pre Processing</td>
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<td>Crash Solver</td>
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<td>NVH</td>
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<td>Durability</td>
<td>FE Model Build</td>
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<td>Durability Post Processing</td>
<td>Altair HyperView</td>
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<td>OptiStruct</td>
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<td>HyperStudy</td>
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Figure 2: Vehicle Program Consolidated CAE Software Stack

The consolidated software stack facilitated:
- Ease of model transfer between disciplines: reducing time, volume of data and user error.
- Commonality and therefore familiarity of software package layout for each activity including communication back to SMTC UK and China
• Manning resource transfer between disciplines when required, as analysts were already familiar with the software used in other disciplines.
• Commonality of optimisation tool usage allowing multi-disciplinary optimisation

2.2 Extensive Use of Automation

2.2.1 Process Automation - Pre

Rapid turnaround of model builds was achieved through Altair’s Batch Meshing technology. From Body in White (BIW) CAD data release, body models were built and assembled within 10 days, whilst still providing uninterrupted development support. Figure 3 illustrates the general model build process.

Tools were developed to automate the welding of the BIW through interrogation of the CATIA V5 weld file and Bill of Materials (BOM). The BIW model was welded within minutes and the quality of the weld data could quickly be assessed to ensure that all the welds were realised in the model. This process supports multiple weld representations for different analysis types and codes.

Advances in Altair Radioss NVH solver technology allowed smaller crash type mesh sizes to be handled in NVH runs in reasonable time frames. A common meshing strategy was therefore used for crash and NVH models. These models also formed the basis of durability analysis, with mesh refinement modifications made only in required localised areas. This model commonality significantly reduced model library complexity and facilitated ease of model transfer between disciplines.
2.2.2 Process Automation - Post

Process automation was continuously used throughout the program to post process and report results in a consistent manner without risking user error or introducing differences in the interpretation of the data. Speedy reporting gave feedback to design teams in reduced time scales, allowing design decisions to be made and design iterations cycles to be carried out more quickly.

Post processing automation significantly reduced the number of man hours spent post processing, enabling analysts to focus on more value added activities. Figure 4 shows an example of the types of post processing output for crash analysis results. The data extracted into the report is customised to suit the individual load case through a template file.
2.3 Extensive Use of Optimisation

2.3.1 Concept Optimisation

During the early phases of the development program, Altair OptiStruct was used to investigate and derive design concepts that satisfied available package constraints and loading conditions. Areas of the structure that had not been defined allowed greater design freedom to use optimisation methods such as topology to arrive at an optimum material distribution and size and shape to derive gauges and geometry definition. Two examples of this type of analysis are presented below.

**Figure 5** shows the results of a front end slam panel topology optimisation that was used to define the optimum material distribution under service loading conditions and available package space. The defined load paths, shown, were used in discussions with designers to develop the slam panel design. **Figure 6** shows the results of a crush can size and shape optimisation analysis. The results of this analysis were used in the development of an efficient crush can design.
2.3.2 Global Optimisation

The objective of the global optimisation analysis was to define, early in the design process, critical areas of the structure that required development to improve global stiffness and global modal performance. Figure 7 shows an example of a global discrete gauge optimisation analysis. The objective of the optimisation was to maximise global performance without increasing mass. The gauge contour plot indicates areas of the body structure that contributed significantly to the global performance and therefore areas of further focused design development.

2.3.3 Local performance Optimisation

As the design of the vehicle became more mature, concept and global optimisation activities began to decrease as more detailed, local, design optimisation activities began to increase.
As an example of local optimisation analysis, Figure 8 shows the results of a topology analysis carried out to define a light weight gearbox mount design that met NVH and durability targets.

![Package Space Definition](image1)

![Topology Results – Meeting NVH and Durability Targets](image2)

**Figure 8: Local Optimisation Example – Topology Definition, Gearbox Mount Design**

### 2.3.4 Mass Optimisation

At the beginning of the last phase, many attributes met and exceeded targets. This gave the opportunity to reduce the mass of the structure whilst still maintaining target performance. Also during the last phase, panel tooling was at the sign off stage which limited the possibility of changing panel design and shape, but still allowed the possibility of panel gauge changes. The last phase was therefore the ideal time to carry out mass gauge optimisation analysis on the mature, and performance optimised, body structure.

Many different approaches can be used to carry out gauge optimisation analysis. In all approaches it is essential that relevant attributes from each of the disciplines are taken into account. An OptiStruct optimisation analysis can take into account all linear analysis load cases. Therefore, all NVH and a limited number of durability attributes could be included in the optimisation analysis. Some non-linear load cases could also be represented, however, non-linear analysis such as crash events inevitably require non-linear over check analysis to ensure target performance is maintained.

One approach used during the Roewe 550 vehicle program was to apply OptiStruct sensitivity analysis to identify the least contributing panels for all linear load cases. Figure 9 shows an example plot of the least contributing body structure panels. These panels were then set to the minimum allowable gauge and non-linear load cases screened the performance and increased gauge and/or the material grade where required to achieve target performance. This approach resulted in a significant body structure mass reduction.
2.3 Completion of project

Once the development phase of the project was completed, the project moved on to the validation and production phases. The resulting vehicle passed all of the project performance targets, many of which meet European requirements, demonstrating that the CAE work has played a key role in delivering a successful project.

The Roewe 550 went on sale in China in 2008. Figure 10 shows the production vehicle at launch.

![Roewe 550 production vehicle](image)
### 3.0 Process Developments and Enhancements

Process automation and optimisation methods have been continually reviewed and developed. Some examples of new developments that were used on a current SAIC vehicle program are described in this section.

#### 3.1 Swage Optimisation

Swaging increases panel stiffness and is primarily used to improve NVH attributes but can also be important for crash and durability performance and can present opportunities for subsequent mass reduction activity and requirement for NVH damping material. During the Roewe 550 program, panel swage optimisation was carried out for all major panels. The optimisation method introduced panel swage form with the objective of maximising panel natural frequency. Although this method was found to be successful, a disadvantage was that maximising the panel natural frequency did not always guarantee that peak frequency response levels would be reduced.

An improved method that was used in a current vehicle program was frequency response optimisation. The objective function was specified as minimisation of the maximum frequency response peaks. Example swage and frequency response results are shown in Figure 11. By applying this method to all major body structure panels, benefits in overall Noise Transfer Functions (NTFs) were, in some cases, in excess of 10dB. Figure 12 shows a comparison of baseline and panel optimised Body NTFs at four passenger ear positions.
Figure 11: Panel Swage Optimisation – Frequency Response, MinMax Peaks

Figure 12: Panel Swage Optimisation – Benefits to NTF Performance
3.2 Mass Optimisation

The mass optimisation procedure used in the last phase of the Roewe 550 program was described in Section 2.3.4. During the current vehicle development project an improved approach has been successfully used which yielded additional mass saving benefits.

The approach was based on an iterative process. OptiStruct gauge optimisation was carried out considering all linear load cases and then the optimised gauge line up was over checked by selected non-linear crash and durability analyses. Where required, panels were up gauged and/or material upgraded to meet performance targets. These panels were then frozen and a new OptiStruct gauge optimisation was carried out excluding the frozen panels.

At each step of the process, the manufacturing constraints were considered and forming limits were used to ensure that only feasible gauge changes were made to any individual panel. Forming simulation was repeated for any crash critical panels that were affected during the process. Figure 13 shows a schematic representation of the complete process and Figure 14 shows a typical output from the optimisation.

![Figure 13: Mass Optimisation Process Schematic](image-url)
The process was repeated until OptiStruct optimisation analysis could no longer reduce mass. Figure 15 shows the mass reduction history as a function of iterations. It can be seen that for the last iterations, mass reduction began to converge on a single mass saving value. The process was found to significantly reduce the mass of the body structure by approximately 6% without any detriment to performance.

Figure 15: Iterative Mass Optimisation Approach - Mass Saving History
4.0 Next Steps

Although SMTC has achieved significant results over the last few years, it recognises that there are still many improvements to be made to their CAE processes and methods. Not only do individual processes as outlined in this paper need to be constantly refined and improved, but these processes should be standardised and built in to a robust process management infrastructure to achieve optimum quality and consistency.

SMTC strives to work globally as “One Family” and have set up a joint Virtual Engineering team which encompasses everything from CAE to virtual design, electrical architecture to knowledge based engineering.

SMTC is currently investigating several Database and Process management solutions with the intention of integrating this into the product development infrastructure, including the existing CAD PDM system.

SMTC UK is also investing in IT infrastructure so that the team can start to perform more analysis in-house, providing closer, more immediate support to the design team as well as providing the ability to develop CAE techniques and processes in-house.

5.0 Conclusions

SAIC with Altair Product Design has demonstrated that aggressive vehicle program time scales can be met through effective engagement of a CAE design driven process combined with the utilisation of timescale reduction and optimisation technologies.

Routine and extensive use of process automation and optimisation throughout the vehicle programs allowed vehicle performance and timing targets to be successfully met whilst minimising cost. This has already led to the successful launch of a vehicle product into the market place. Some examples of process automation and optimisation were presented together with examples of new processes and approaches that have been used on the current vehicle program.

Through the continued collaboration of SAIC and Altair Product Design, process automation and optimisation technologies will continue to be developed and enhanced in an effort to further reduce vehicle time to market as well as enhancing a global working culture.

It is anticipated that the rapid development of exciting new SAIC products will continue apace and that the CAE teams both in Shanghai and the UK will be at the heart of the process, whilst working closely with key suppliers such as Altair Product Design.

6.0 References