

Session H3.2

AUTOMATED BUILT-UP & ANALYSIS OF NVH MODELS WITH ANSA / μETA PACKAGE

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ABSTRACT - Among the requirements of nowadays vehicles development, NVH defines one of the main attributes ensuring driving comfort with respect to the passenger's welfare. The use of the Finite Element Method (FEM) is becoming more and more important on this field, providing a means for simulating and improving the perceptions of a model, and thus, complementing efficiently the laboratory results.

The creation of reliable models that will deliver accurate results is a strenuous, time-consuming and error-prone process due to the particular requirements of NVH analysis and the communication bottlenecks, naturally existing between the different engineering teams that need to share information and be updated. Moreover, building such models efficiently implies that tedious tasks should be conducted fast, without errors and with the minimum user-interaction, assuring repeatability.

This paper presents an integrated process workflow using the ANSA/μETA Software Package, distributed by BETA CAE Systems S.A., for the development of NVH simulation models and the evaluation of the analysis results. The Data Manager tool imports and handles all different components with their suitable template-based representation and automatically looks after the versioning of parts, thus ensuring that the model will be always updated. The whole process of building up the model is controlled and monitored through the Task Manager, which includes all individual tasks of the workflow in a step-wise manner. Using the Data and the Task Managers, results in the NVH-simulation becoming a repeatable and cost-efficient procedure, assuring at the same time the high quality of the model.

TECHNICAL PAPER -

1. INTRODUCTION

The build up of an NVH model is a tedious and time-demanding task resulting in most time spent by the engineer for the preparation of the model instead for the analysis itself. This fact arises as a combination of various parameters such as:

- The large amount of CAE data that impose a need for their sufficient management.
- The data are collected from different sources. Different parts of the model are delivered to the NVH analyst from different departments. Thus, the demand for efficient management becomes more crucial.
- Data related to parts are not of the same type. It could be that for some parts the actual geometry exists (typical example could be the BiW) while for others only a pure FE mesh exists (this is the case with the power-train in many cases). Moreover, in some cases parts exist in the form of reduced models (e.g.: modal models, lumped masses, etc).

- Meshing requirements for NVH analysis differ significantly from other disciplines, thus prohibiting the use of the same model with other disciplines. Therefore, it is necessary that in any case, a model mesh dedicated to NVH should be built-up.
- Communication between engineers coming from different disciplines narrows even more the existing bottlenecks towards building up an NVH model.
- On top of the aforementioned issues, the quality of the model should be assured in any case and this imposes even more strict demands on the creation of the NVH model.

As a consequence of the high level of complication, the process is prone to errors, which in turn prolongs further the completion of the model and jeopardises its quality.

To address the increasing demands for better quality models completed in shorter time and with the minimum interaction from the engineer, BETA CAE Systems S.A. introduced two tools embedded within ANSA: the Data Manager and the Task Manager.

The Data Manager is a pool containing all necessary information and data used during the CAE-cycle:

- Parts are stored and retrieved based on their version and their different FE attributes (e.g. meshed with 10mm element size, 20mm element size, etc.). Consequently, the engineers can easily handle / modify the model and, on the same time, it is ensured that the model is always up to date.
- Predefined settings for the creation of different FE attributes for each part.
- Library items that can be considered as templates used for boundary conditioning, connecting subassemblies and application of output requests.
- Auxiliary Components added in particular load cases, like crash test dummies, impactors etc.

The Task Manager is the tool that automates the building up of the model. All individual tasks of the workflow are included in the Task Manager in a step-wise manner. In this way, the Task Manager is able to control the process through:

- Taking into account the order with which tasks should be accomplished.
- Taking into account the dependencies between tasks. Dependency between tasks means that if a last change in the model affects the result of a previously executed task, then the task stops and the user is notified by the Task Manager so as to take action.
- Running and checking automatically all tasks that can be run without user interaction.
- Notifying the user when a task fails to be executed due to modelling mistakes or lack of information.

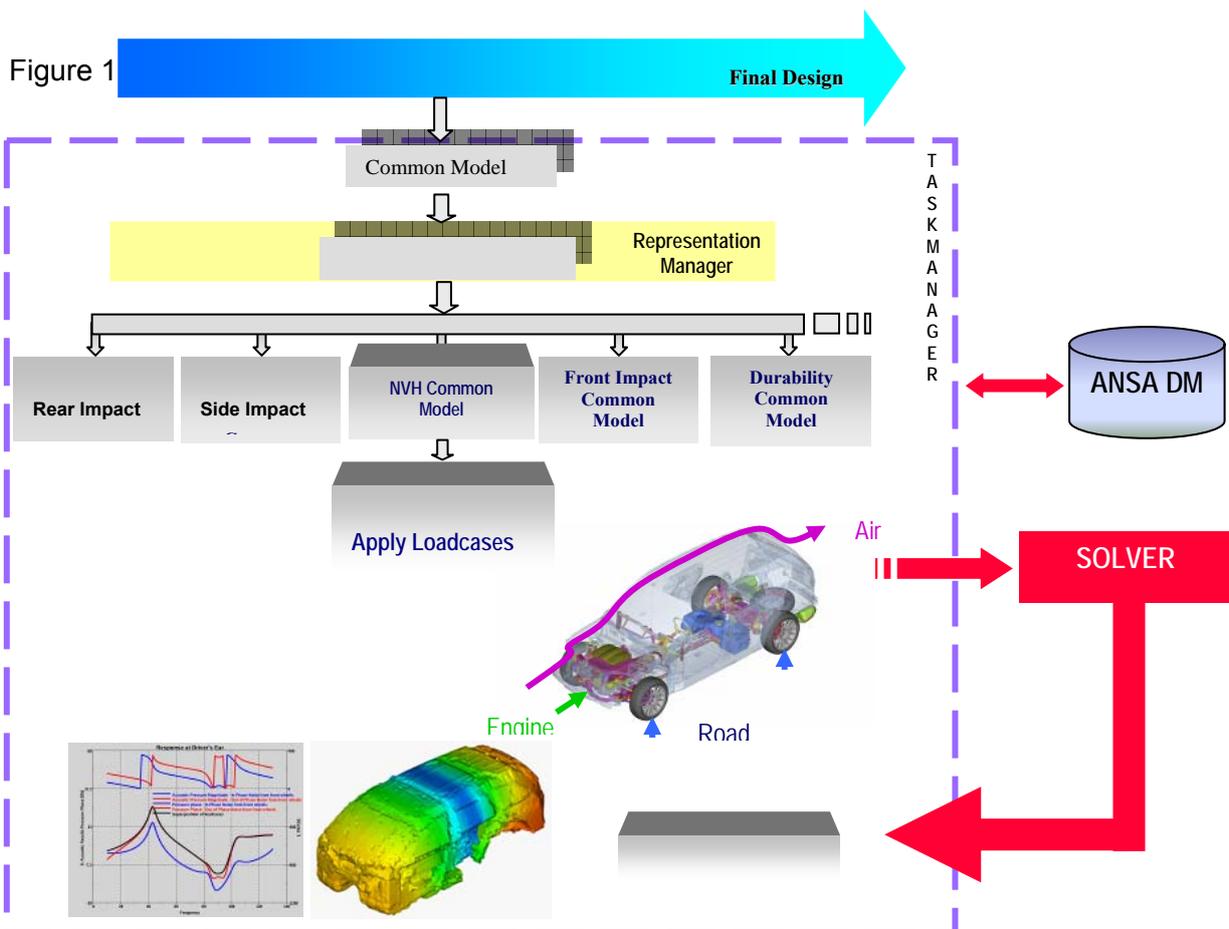
This paper outlines an integrated process workflow for the built-up and evaluation of results of an NVH model using the ANSA/μETA package. In this case, this process (the building-up of an NVH model) is looked upon as a part of a broader CAE process, which involves the deployment of both the Data and the Task Managers in cooperation. Therefore, in order to deliver a complete overview of the workflow, it is necessary to refer also to the preliminary work, which precedes the building-up of a discipline specific NVH model.

2. OVERVIEW OF THE COMPLETE PROCESS

Figure 1 displays schematically the overview of the complete simulation process workflow (1). It is evident from this figure that the build up of a model actually is comprised by three phases that are clearly reflected on the following respective groups of tasks of the Task Manager:

- The Common Model creation: this phase contains all information that is common to all disciplines.
- The Discipline Common Model creation: at the end of this phase, the model includes all information that is common to the specific discipline.
- The Load case definition: at the end of this phase, the model is ready to run. During this phase, all information that is related to a specific load case is added to the Discipline Common Model.

The core of this paper is related to the tasks involved in the build up of an NVH model therefore, it refers to the Discipline Common Model and the NVH Loadcase (which also includes running the solver and post-processing the respective results). However, prior to presenting the building-up of the NVH model, it is necessary to clarify issues related to the prerequisite work.



3. PREREQUISITE WORK

3.1. How to build a task (2, 3)

The tasks are built in an easy and simple way inside ANSA and are stored in the ANSA DM. Each task consists of task items, which reflect the steps of the workflow that should be executed. These tasks, when created, are model independent. All model related data are imported from the ANSA DM during the execution/update of each task item.

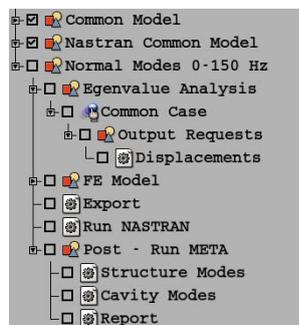


Figure 2 - Task items in ANSA's Task Manager

3.2. Preparation of the Common Model (CM) (2)

First the model hierarchy must be imported. The model hierarchy is read from the VPM tree file or any other source file that includes such information (2). This file (which is usually exported from CAD Systems) contains the model hierarchy and engineering information (like thickness, material, weight). A preview of this tree is given through the VPM Tree Editor, which furthermore allows filtering/modification activities. Through this editor a Download list (D/L-list) can be exported and this works as an input file for the CAD data import. Each part of the model that exists in a CAD format is translated into an ANSA database, which in turn is stored in the ANSA DM. During the translation procedure, engineering information is interpreted according to the D/L-list.

Other parts or subassemblies, which exist only in FE mesh, are also saved in corresponding ANSA databases stored again in the ANSA DM.

After all parts of the model have been stored in the ANSA DM, they are merged into an ANSA models.

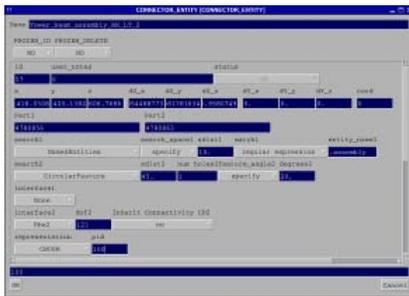
The task that should be used is also loaded into ANSA and now it is necessary to establish the association between the task items and the parts of the model.

3.3. The Common Model concept (2, 3)

The Common Model (CM) is the first phase towards the building up of the complete ready-to-run model. As its name implies, the CM includes all model data that are common to all disciplines. It is the common starting-point for the creation of any specific discipline model.

A CM consists of the following entities, which also correspond to respective task items in the Common Model task group:

- **Sub models:** These can be as many as necessary depending on how it is decided to split the model into sub-assemblies. As described in the previous paragraph, the association of the Task items with the Model entities is based on the sub-models. The sub-models can include either geometry of parts as they are translated from the CAD files or complete sub-assemblies in FE-Mesh that will be used as they are in the analyses (eg: power-train that comes as a complete assembly to be included in the analysis).
- **BiW Connections:** The connection information is read from an XML, VIP, VIP2 or any other ASCII file.
- **Model Assembly data (Generic Connectors):** These data include information for the connectors between sub-assemblies. The means to pass this information is the definition of Generic Connectors. These are ANSA entities, created by the CAE expert once for each model and are mesh-density independent. A Generic Connector is defined through the following card (Figure 3) and contains information about:



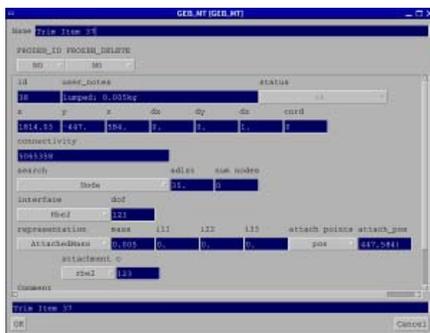
WHERE it is located

WHAT to connect

HOW to connect (this information is not included in the Common Model – this is the information that should be specified at a later phase, when the Discipline Common Model is created, since this information is discipline dependant).

Figure 3

- **Model Trimming data (Generic Mass Trim Items):** These data include information about the added mass that should be applied on parts. The means to pass this information is the definition of Generic Mass Trim Items. These are ANSA entities, created by the CAE expert once for each model and are discipline-independent. A Generic Mass Trim Item is defined through the following card (Figure 4) and contains information about:



WHERE it is located

WHICH entities affects

HOW to apply the mass: (this information could be included either during the Common Model phase or, in case it is discipline dependant, during the Discipline Common Model phase).

HOW MUCH mass to apply

Figure 4

3.4. How to establish the association between the model and the task items (3)

The association between the model and the task items is based on the names of the sub-models and is achieved through the ANSA Part Manager. Each sub-model of the Common Model Task group corresponds to one Group of the Part Manager with the same name. Therefore, when the Common Model Task group is loaded in ANSA, Empty groups corresponding to the sub-models task items, are created in the Part Manager with the same names. Then, when all parts of the model have been merged into ANSA, the user links inside the ANSA Part Manager the existing Parts and Groups to the respective Empty sub-models groups.

The association between task items and the model entities is established. Figure 5 depicts this process.

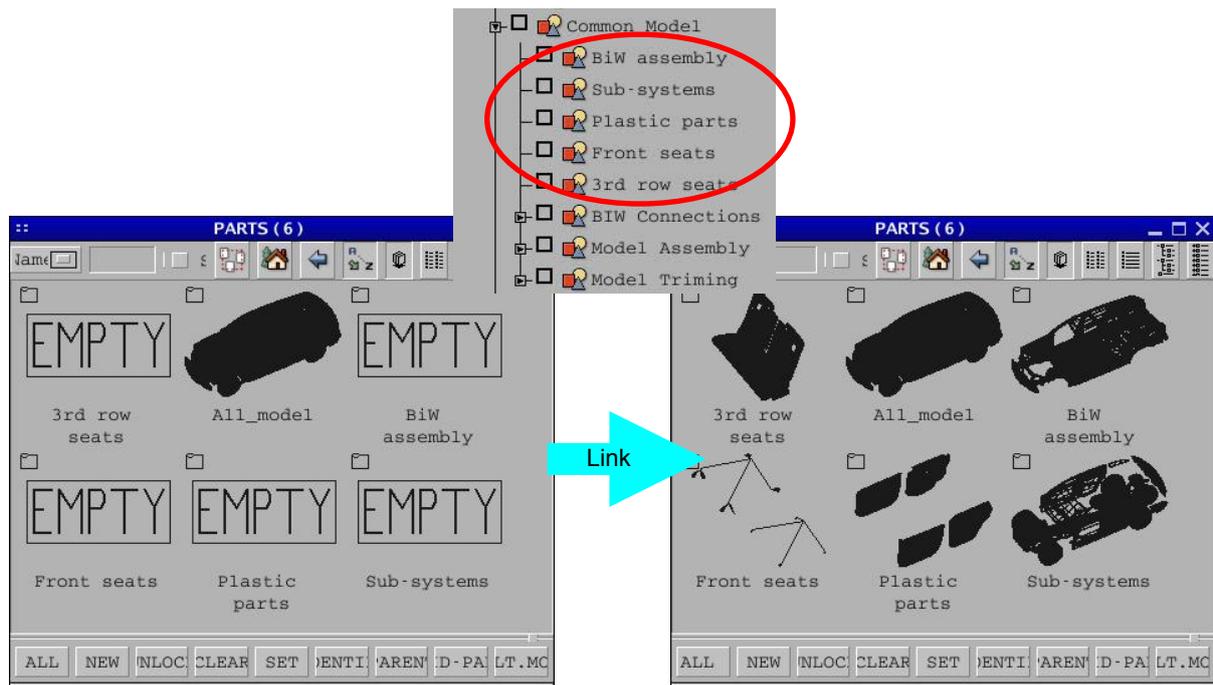


Figure 5

As soon as all the above data have been imported / specified in ANSA and the association between the task items and the model entities has been set-up, the Common Model definition phase is accomplished.

This Common Model can now be saved as an ANSA database and this will constitute the starting point for the build up of any Discipline Specific Common Model.

3.5. The Representation concept (2, 3)

The term “representation” for parts in ANSA defines the actual modelling characteristics attributed to a part within a complete model.

The solving time for an analysis depends on the number of elements / degrees of freedom that appear in the model. Thus, to keep the solving time to the minimum required without risking the accuracy of the results, the model is represented with fine mesh in areas of interest and with coarsen mesh in areas indifferent to the particular analysis (in between there are areas with transition mesh). Areas of interest are the components of a model, for which their behaviour is important to be captured with high accuracy. This is the concept behind the representation management of parts.

For example, one part could be meshed with element size 20 when included in an NVH model, while the same part could be meshed with element size 10 when included in a crash model. It could also be the case that the same part could be included within a model only as a lumped mass. All these modelling variations of the same part are called “representations”. Figure 6 shows two possible representations for a door.



Figure 6

All possible meshing representations of each part can be created once and in an automatic way using the ANSA Batch Meshing features and saved in the ANSA DM through the ANSA Part Manager.

4. BUILDING THE NASTRAN NVH COMMON MODEL

4.1. General

The Common Model database is opened in ANSA and the build up of the Discipline Common Model (in this case the NASTRAN NVH Common Model) commences.

Two distinctive sections can be identified during this phase.

The first section is related to applying the proper modelling attributes to the already existing entities according to the NASTRAN NVH discipline. That is the application of the proper representation on each existing sub-model and the realisation of the existing connections, connectors and mass trim items according to NASTRAN NVH specifications.

The second section of this phase is related to importing any other sub-models, connections, connectors or trimming items that are specific only to NASTRAN NVH (e.g.: Heavy Air Seats) as well as to include actions related to NASTRAN NVH such as the creation of Acoustic Cavity, the execution of Model checks, the creation of a report etc.

All actions and entities that are related to this second section are reflected on the task items of the Nastran Common Model task group. This Task group is also saved in the ANSA DM and it is loaded when the building of the NASTRAN NVH Common Model begins.

4.2. Apply Representations

The application of representations on the parts / sub-models of the model is controlled through the Representation Manager. This process is depicted in Figure 7.

As the Task Manager starts running one by one the task items, the user applies for each sub-model task item the appropriate representation through the Representation Manager. Examples of several types of representations are shown below:

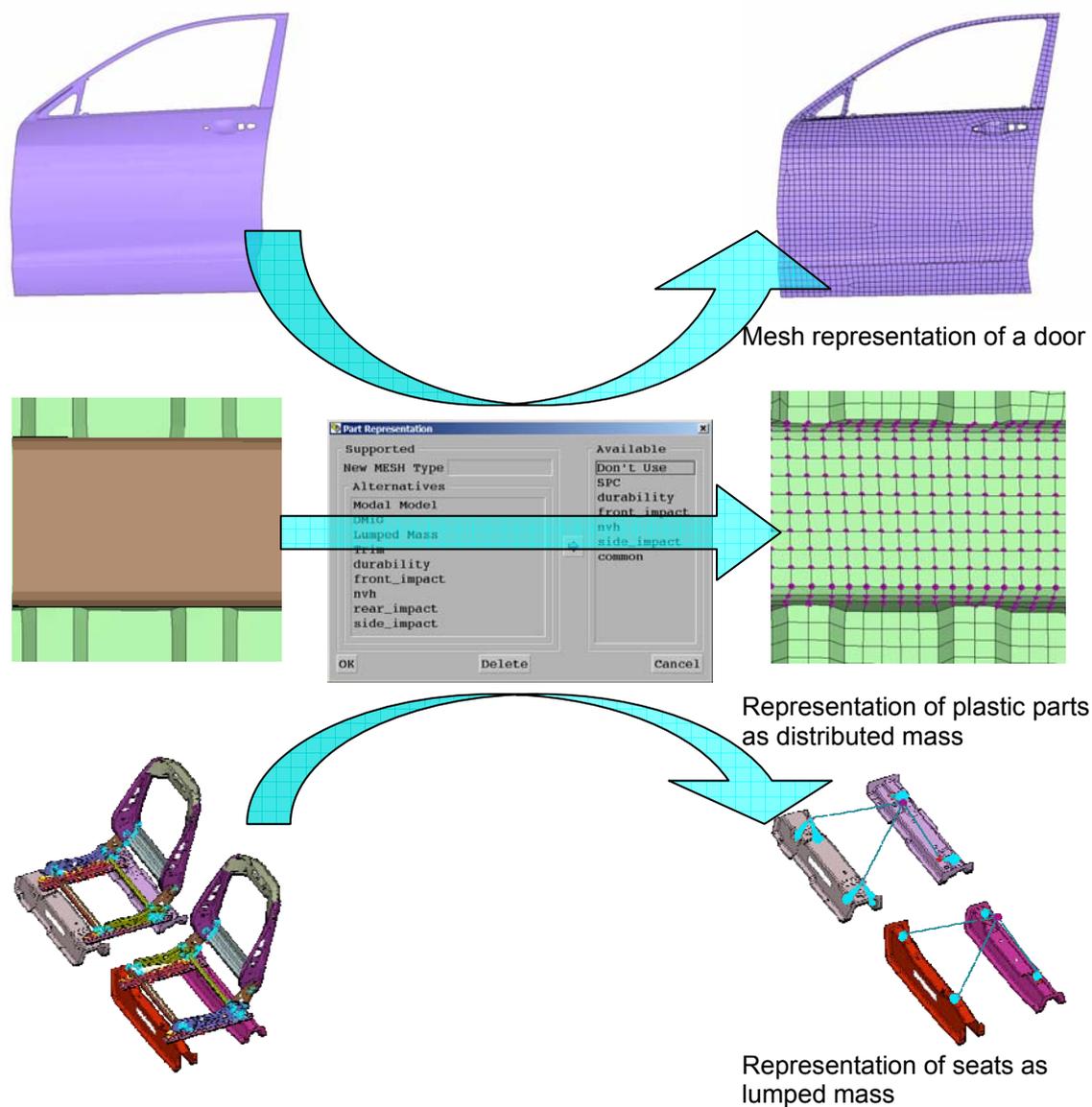


Figure 7 - Application of representations

4.3. Realisation of connections

As soon as the Task Manager reaches the task items that are related to connections, the Connection Manager is invoked and the user may select how each connection type should be realised. Typical examples of the realisation of several connection types are depicted in Figure 8.

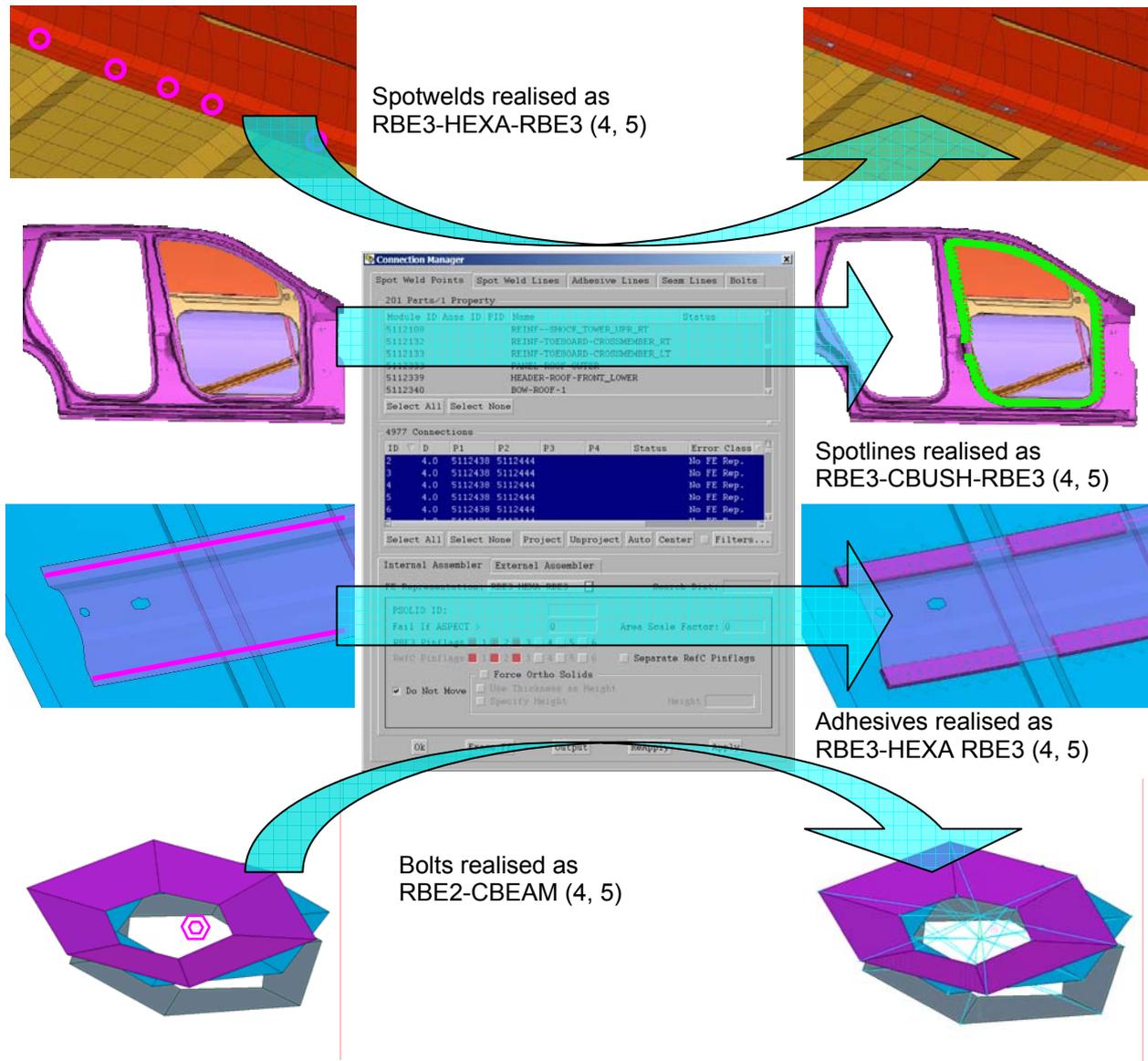


Figure 8

4.4. Realisation of Connectors

After the connections have been applied, the task continues with the realisation of Connectors. The realisation of connectors does not request user interaction and it is done automatically according to the definition of each connector. User interaction is necessary only if the realisation of a connector fails. In this case the task is stopped and the user is notified to take action. Only after the connector is realised, the Task shall continue.

The definition of connectors can be achieved either through one of the standard options, that exist within the Generic Connector card or through a library item. A library item is created once, stored in the ANSA DM and can be used as a template for a similar case (2).

As an example, Figure 9 shows 2 connectors that are realised with CBUSH elements. The library item is a simple CBUSH, which has parameterised properties, therefore, can be easily adjusted to different cases. This library item has unit length and should be aligned with the Ox axis. The interfacing of the CBUSH to the connected parts, in this case, is achieved with RBE2's and this information is also included within the definition of the Connector.

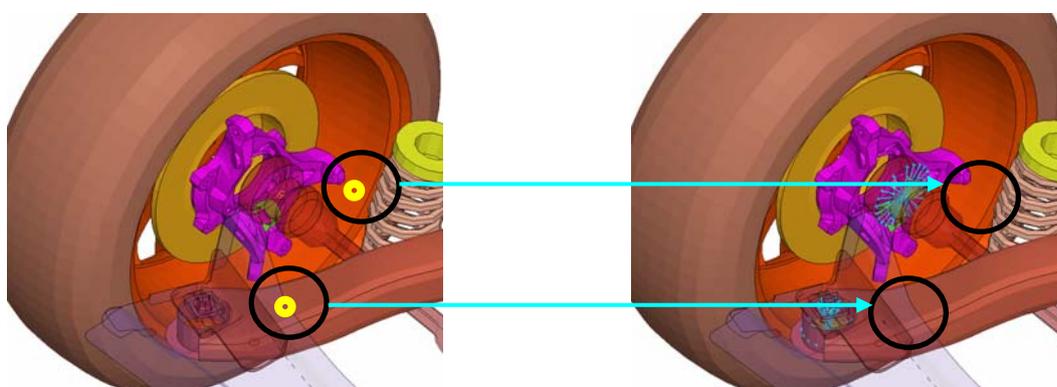


Figure 9

4.5. Realisation of Mass Trimmings

Next, the Mass Trim task items are realised. Similar to the connectors case, the realisation of the Mass Trim items does not request user interaction and it is performed automatically according to the definition of each Mass Trim item. User interaction is necessary only if the realisation of a Mass Trim item fails. In this case the task is stopped and the user is notified to take action. Only after the Mass Trim item is realised, the Task shall continue.

The realisation of Mass Trim items can be achieved either through one of the standard options that exist within the Generic Connector card or through a library item. A library item is created once, stored in the ANSA DM and can be used as a template for any similar case (2).

As an example, Figure 10 shows a Mass Trim item that is realised as a non-structural mass representing the mass of the paint of a part.

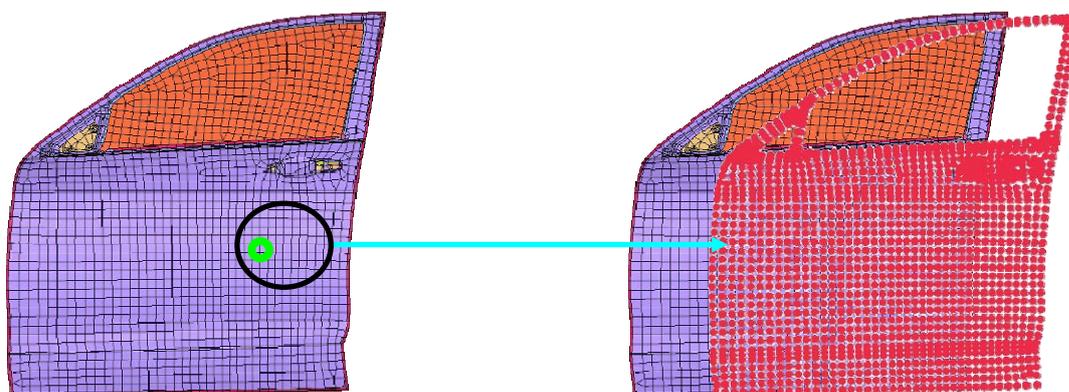


Figure 10

At this stage, the first section of the NVH Common Model phase is finished. The respective task items are checked in the Task Manager (Figure 11) indicating that the tasks were executed successfully.

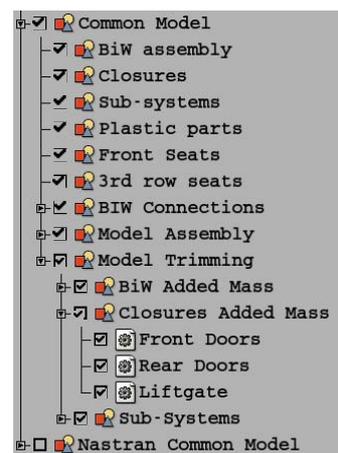


Figure 11

4.6. Importing NVH added components

At that point, the second section of the NVH Common Model commences. The Nastran NVH Common Model group of tasks includes additional sub-model task items. In this way, components specific only to NVH, such as the Heavy Air seats (Figure 12), are added for the needs of the Acoustic cavity analysis.

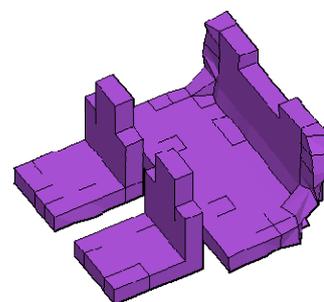


Figure 12

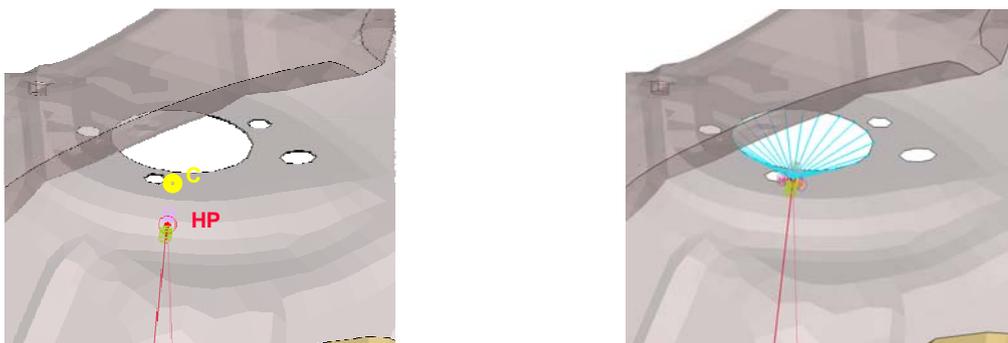
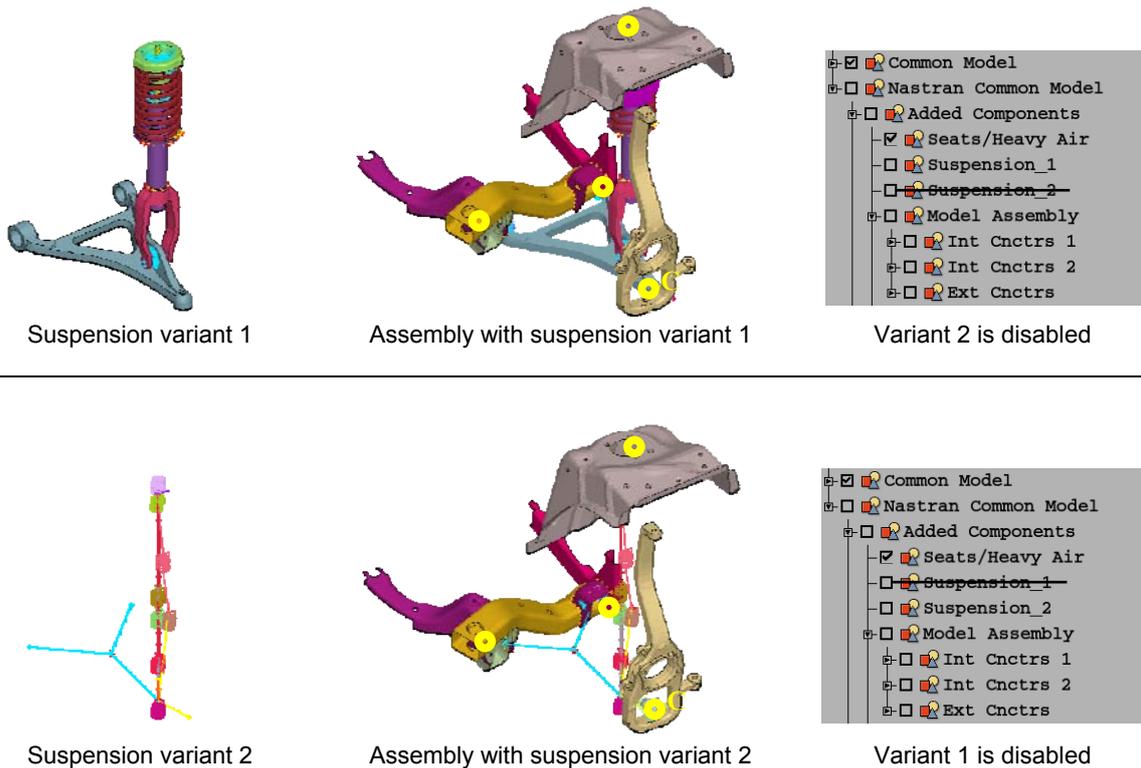
4.7. Using sub-modelling variants

One of the merits deriving from the use of the Task Manager is the easy and fast inclusion / exclusion of sub-model variants within the same model. A typical example that is depicted in Figure 13 is the suspension.

The suspension variant 2 replaces the suspension variant 1. Both suspension variants are included in the Task Manager as different sub-models but only one is enabled at any time. Both suspensions are connected to the rest of the model through the 4 connectors also appearing in Figure 13.

The substitution is achieved by simply disabling variant 1 in the Task Manager and enabling variant 2. The Task Manager automatically identifies variant 1 and excludes it from the visibility as well as from the model but it does not delete it. That means that this variant can be retrieved later if necessary. At the same time, variant 2 is brought to visibility and included in the model.

The variant suspension 2 is automatically connected to the rest of the model through the connectors. At that point, it should be mentioned that it is possible to connect the new suspension automatically even if its original dimensions do not fit to the connecting locations. This is possible with the use of Hard Points which are actually entities defined in ANSA and having several nodes assigned to them. These assigned nodes are dependent from the Hard Point therefore they follow the movement of the Hard Point as a rigid body.



Detail of the top section of the suspension. Originally, variant 2 did not fit to the connector's location. This problem is resolved by using Hard Points that actually stretch the variant suspension so that to reach the connector's location.

Figure 13

4.8. Preparation of Output locations

The next step towards the completion of the Nastran NVH Common Model is the preparation of the output locations. This is achieved through the following three task items:

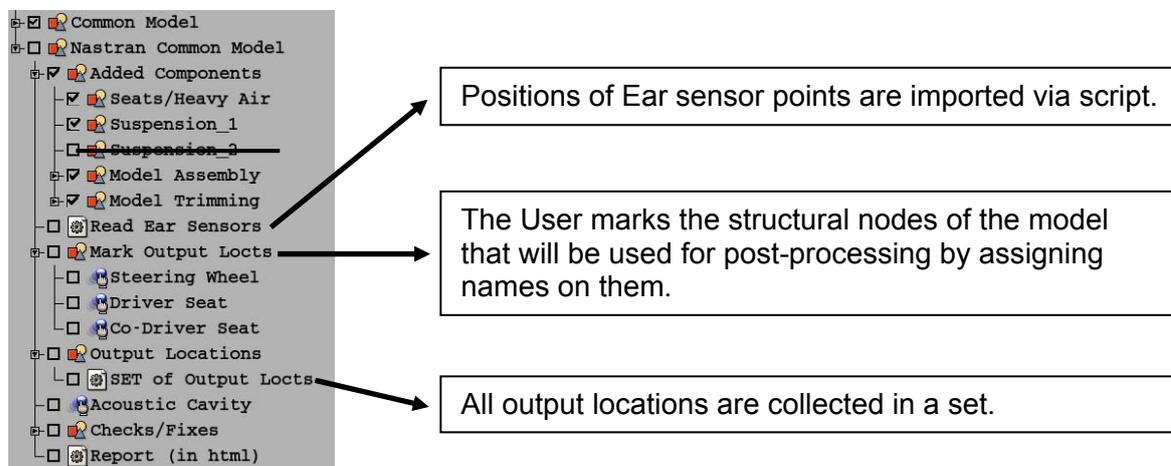
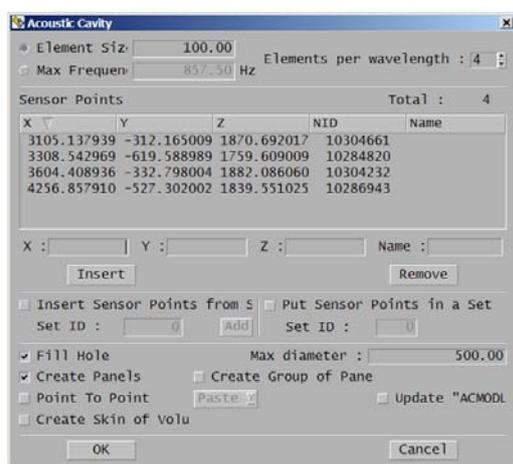


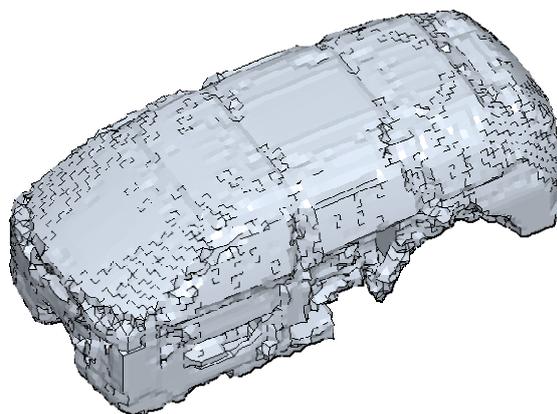
Figure 14

4.9. Creation of the Acoustic Cavity

When the Task Manager reaches the Acoustic Cavity task item, the respective ANSA tool (4) is automatically invoked and the user is prompt to specify all necessary parameters for the creation of the Acoustic Cavity mesh (5, 6) (Figure 15). It should be mentioned here, that it is assured that the Ear sensor points, which were previously imported, will consist nodes of the cavity mesh.



ANSA Acoustic Cavity tool



Acoustic Cavity mesh

Figure 15

4.10. Checks and Reporting

The last task items before the completion of the NVH Common Model are:

- The performance of checks and the consequent fixes of possible modelling problems. The following checks are included in this case study: Units System conformity, Model data and Dependency errors (4, 5).

- Final reporting on the NVH Common Model. A report with general information on the model is created automatically by ANSA in HTML format. The information that should be included in the report is fully controllable.

4.11. Storing the NVH Common Model in the ANSA DM

As soon as the NVH Common Model is completed, it can be stored in the ANSA DM. In this way, this model can be retrieved from the ANSA DM by other engineers and can be used as the starting point for the building-up of NVH models for specific loadcases.

It should be emphasised that if the NVH Common Model is correct, then all NVH loadcases can be easily built starting with loading this NVH Common Model in ANSA. During the building-up of any NVH loadcase, it is ensured that if any action affects the integrity and correctness of the NVH Common Model, the user is notified and the affected task items become unchecked (dependencies between task items).

5. BUILDING AN NVH LOADCASE: EXTRACTION OF NORMAL MODES

5.1. Preparation of the NASTRAN Model for Normal Modes extraction

The NASTRAN Load Case task related to the extraction of Normal Modes of the BiW between 0-150 Hz is loaded from the ANSA DM (Figure 16).

Since it is requested to calculate the Normal Modes only for the BiW parts, several sub-models should be disabled for this analysis from the Task Manager (Figure 17).

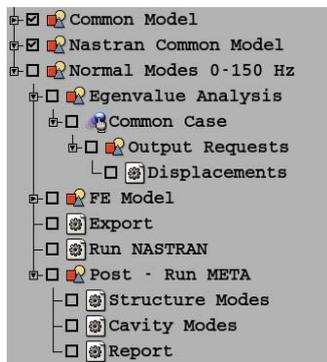


Figure 16

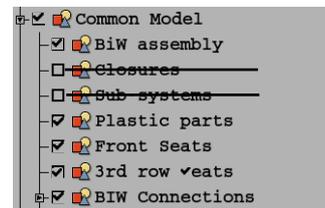


Figure 17

The Output requests, the exporting of the deck in NASTRAN format and the initiation of the solver via script are all actions performed through respective tasks in the Task Manager.

5.2. Post-Processing of the Normal Modes results

After the solver has run successfully, the post-processing is initiated through respective task items. These task items actually execute a script that launches μETA to run a μETA session file (7), which could be previously stored in the ANSA DM.

Alternatively, μETA can be launched in a listening mode, thus running as a server. In this way, μETA can execute directly μETA commands dictated by the Task Manager without a session file.

For this case study, μ ETA was run with three different session files (corresponding to three task items). The first animates the structural modes one by one and could also record these animations in a video file (Figure 18). The second animates the cavity modes and could also record them in a video file (Figure 19). Finally, the third session creates automatically an HTML report for a first assessment of the results (Figure 20). In this report, the zero modes have been identified from the rest normal modes and plotted in a bar chart. Therefore, this report provides directly a fundamental indicator of the correctness and integrity of the model (6, 8). For example, if the zero structural modes are more than 6, then this would possibly imply a modelling problem or the existence of misconnected parts. Consequently, the user can decide fast and effortlessly whether to proceed with further post-processing of Normal Modes results and then to build other NVH loadcases, or to discard the Normal Modes results and return to ANSA to correct the NVH model.

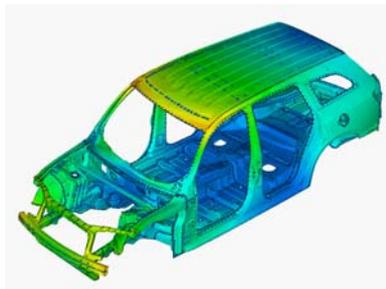


Figure 18

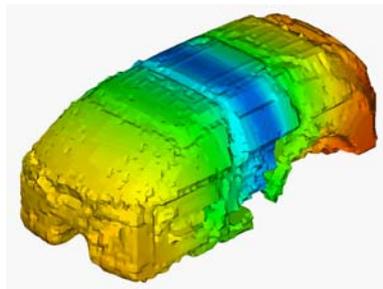


Figure 19

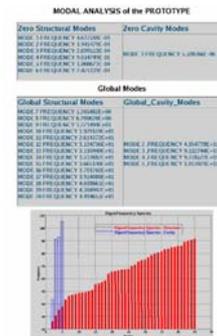


Figure 20

It should be mentioned, at this point, that μ ETA could also run these session files in batch mode without the Graphical User Interface being present.

6. BUILDING AN NVH LOADCASE: FREQUENCY RESPONSE ANALYSIS FOR ROAD NOISE

6.1. Preparation of the NASTRAN Model

After the completion of the post-processing of the Normal Modes and the evaluation of the results as being acceptable, the workflow continues with the building-up of a second NASTRAN Load Case related to the Frequency Response Analysis for the Road Noise.

The corresponding task is loaded from the ANSA DM (Figure 21).

For the needs of this analysis, the representation of each tyre is changed to that of a Modal model of a tyre (Figure 22). This Modal model is also stored in the ANSA DM and it is applied through the corresponding task of the Task Manager.

Following the inclusion of the Modal Model for the tyres in the model, four different subcases are defined. These subcases correspond to in-phase and out-of-phase loading of the front and the rear wheels respectively.

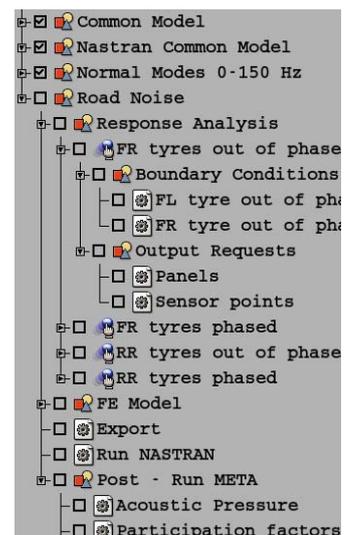


Figure 21

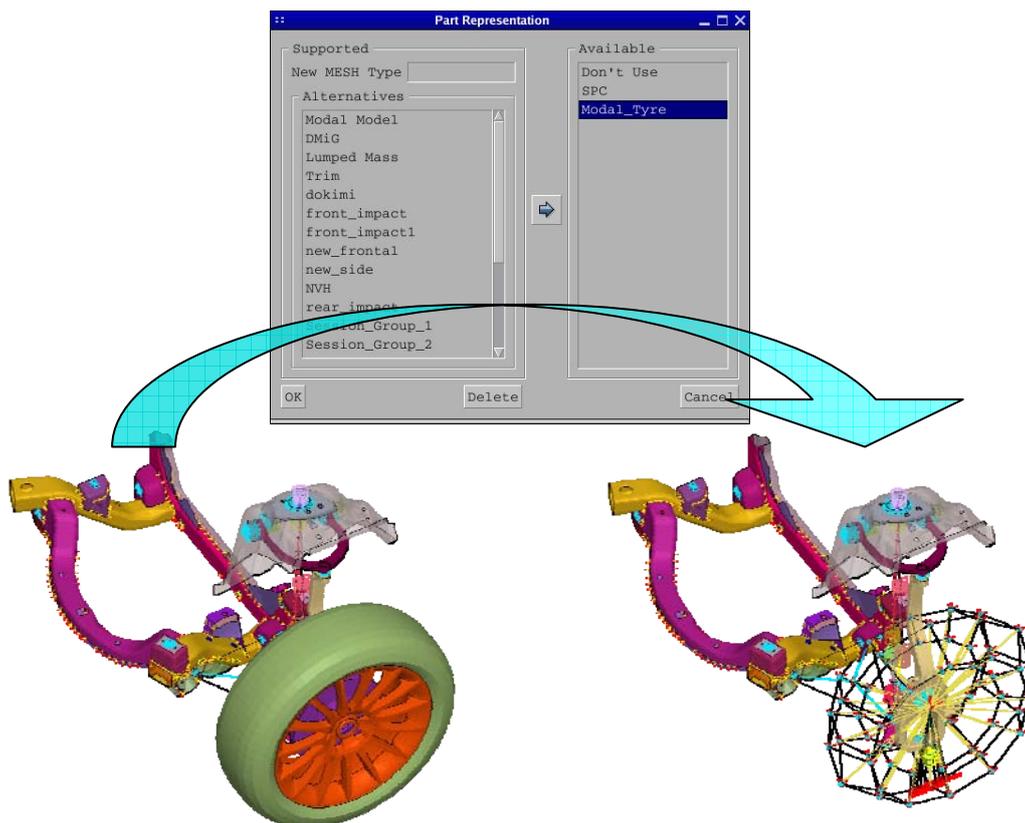


Figure 22

Each group of task items that correspond to a subcase includes the necessary items for the definition of the boundary conditions as well as the output requests for that subcase.

The boundary conditions are frequency dependant loads that apply on the tyres so as to represent the road noise entering the structure from the contact surface between the tyre and the road (Figure 23).

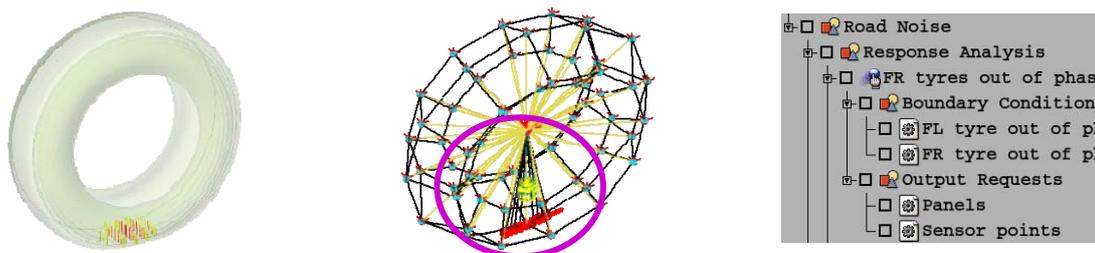


Figure 23

The output requests are related to the definition of panels and the sensor points.

Finally, the deck is exported in NASTRAN format and the solver is initiated via script.

6.2. Post-Processing of Frequency Response results

After NASTRAN has run successfully, the last items that correspond to the post-processing of the results with μETA, are executed. The first task item is related to the creation of a 2Dplot for the Acoustic Pressure results (Magnitude and phase) at the “ear” sensor points. The Acoustic Pressure magnitude accounting for a combination of loadcases is also calculated and displayed in μETA (7) (Figure 24).

The second task runs a μETA session that displays in contour plot the grid participation factor results of the structural panels that define the cavity (7). Through this session file, the areas that exhibit high grid participation are identified and exported as a set of elements (Figure 25). This set is then retrofitted back to ANSA so as to take measures in order to improve the dynamic behaviour of the model, thus, a closed loop for the improvement of the model can be established.

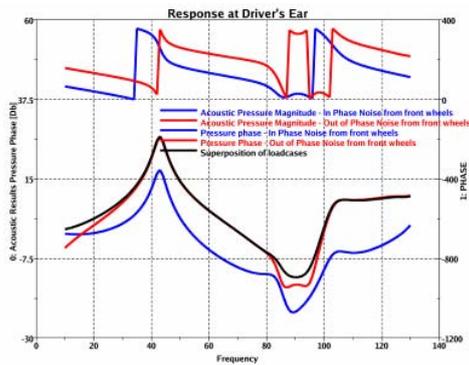


Figure 24

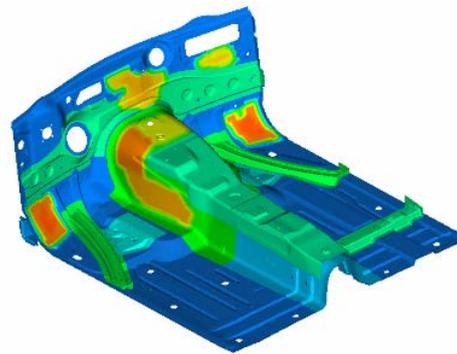


Figure 25

In order to improve the damping characteristics of a panel the user may either add some new features (beads, embosses, etc) using the ANSA Morph tool (Figure 26), or apply a damping patch through the Damping patch tool of ANSA (8) (Figure 27). In the first case, a new study version of the part(s) is created and is stored in the ANSA DM. In the second case, the creation of the damping patch could also be a part of the Task.

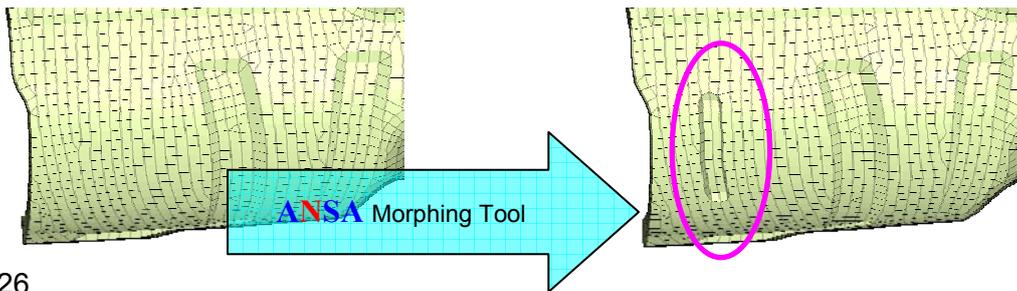
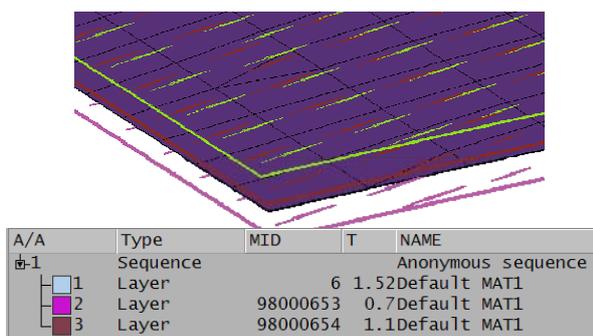
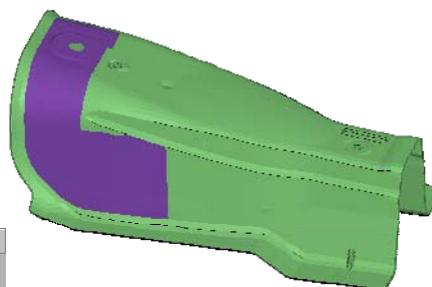


Figure 26



Damping Patch Tool – Damping Patches are represented and created as Composite materials



The Damping Patch is applied

Figure 27

7. CONCLUSIONS

The use of the Task Manager in association to the ANSA DM environment is certainly beneficial in many aspects for the realisation of the CAE cycle. The main merits that a CAE team can gain from the deployment of these tools within the workflow, are:

- The process of building up a model becomes repeatable.
- The quality of the model is assured and the errors, which are naturally involved with a complicated process, can now be avoided.
- The use of the ANSA DM and the Task Manager assists the user in avoiding certain repeatable actions since it minimises the user interaction.
- The engineer becomes more familiar with the model and in the same time dives deeper but easier in the whole CAE process.
- The CAE turnaround time is significantly reduced.
- The whole process is taking place inside ANSA and there is no hopping between different tools thus, saving time, simplifying the building up of a model and avoiding bottlenecks in the cooperation of different software products. When deploying several types of software for such complicated process, the bottlenecks arise mainly from compatibility issues as well as from the fact that it is not possible to establish dependencies between different actions throughout the whole CAE process.

REFERENCES

- (1) Georgios Nikolaidis, Dimitrios Zafeiropoulos, Konstantinos Ntamagkas, "Building Discipline Specific FE-Models with the Common Model Concept", BETA CAE Systems, 2nd ANSA & μETA International Congress, June 14-15, 2007
- (2) BETA CAE Systems, "ANSA Data Management Users Guide", ANSA v12.1.2 Documentation, 2007
- (3) BETA CAE Systems, "ANSA Task Manager Users Guide", ANSA v12.1.2 Documentation, 2007
- (4) BETA CAE Systems, "ANSA Users Guide", ANSA v12.1.2 Documentation, 2007
- (5) MSC Software, "MSC.Nastran 2004 Reference Manual", MSC.Nastran Documentation, 2004
- (6) MSC Software, "Advanced Dynamic Analysis User's Guide", MSC.Nastran Version 70, Documentation of MSC.Nastran 2004
- (7) BETA CAE Systems, "μETA PostProcessor v.5.4.0 User's Guide", μETA v.5.4.0 Documentation, 2006
- (8) Juan Jesus Garcia, Ismael Fernandez, Javier Iturbe, Ines Lama, "Fundamentals of Automotive NVH", Applus IDIADA, Course on NVH, May 2007