

# NEW APPROACH ON PROCESSING LARGE SCALE COMPUTER TOMOGRAPHY DATA IN CONJUNCTION WITH HIGH-END CAE PRE-PROCESSING

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ABSTRACT –

Simulating “reality” is a key motive behind all CAE activities and a typical slogan for advertising simulation software. The expert knows this implies two assumptions: First of all we have to know how “reality” looks like in detail. The general process defines the product via CAD and then a) a CAE model is derived and b) via the built to print process a physical model is manufactured. Naturally there are differences due to tolerances or even mistakes between the simulation model and the physical model.

Second, beside producing simulation results in any geometrical detail there is in general a geometrically limited feedback from physical testing. Differences in the global correlation between physical and virtual test (simulation) can only be fully explained and finally resolved when being able to correlate the simulation and physical model before test and after test on every desired geometrical and material level.

In order to finally add this capability to improve CAE based design BMW started to add computer tomography (CT) to the correlation process. Not focusing only on micro CT resolving material structures we also focus on parts and assemblies up to our final product - full vehicle systems.

As hardware was recently developed to resolve these issues the crucial task to process CT data in correlation with CAE and CAD data is the crucial bottleneck. This is due to different data definitions, it's immense amount of data and it's complexity to interpret material and geometry. In order to apply such methods and read, process, reduce, reconstruct and visualize the CT for the engineer new features have been developed by BETA CAE Systems in ANSA, with the challenges given by BMW.

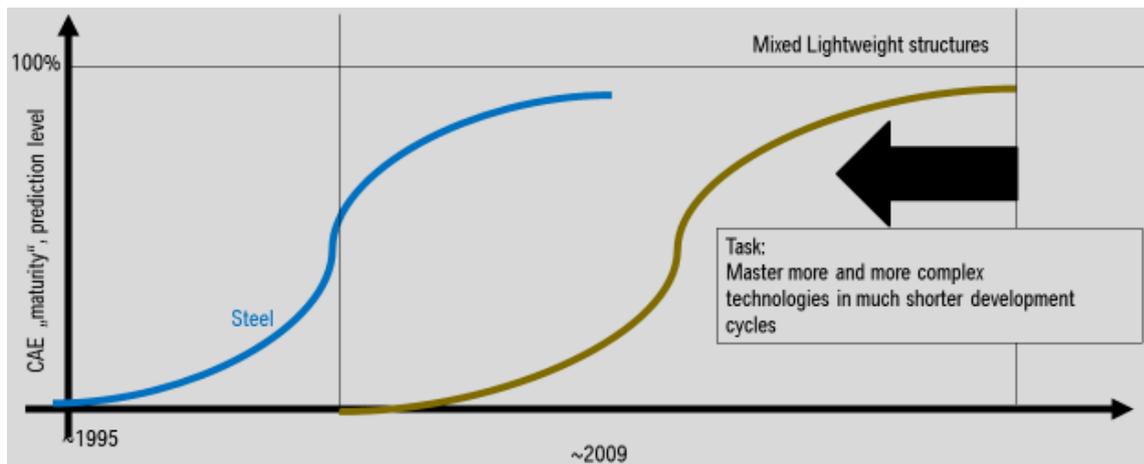
TECHNICAL PAPER -

## 1. INTRODUCTION

Redefining the state of the art in structural design from vehicle generation to generation requires a constant development of existing tools as well as the introduction of new generations of processes.

With BMW I3 and I8 BMW entered the mass production in vehicle development of carbon fiber reinforced plastics in primary structures. Historically we know the problematic of interpreting simulation results and hardware results accordingly. The exponentially increased technical complexity of a multi material structural design and all it's associated joining techniques as well as entire new vehicle architectures in conjunction with a short development time required to look for new techniques to improve the correlation methods between virtual and physical design.

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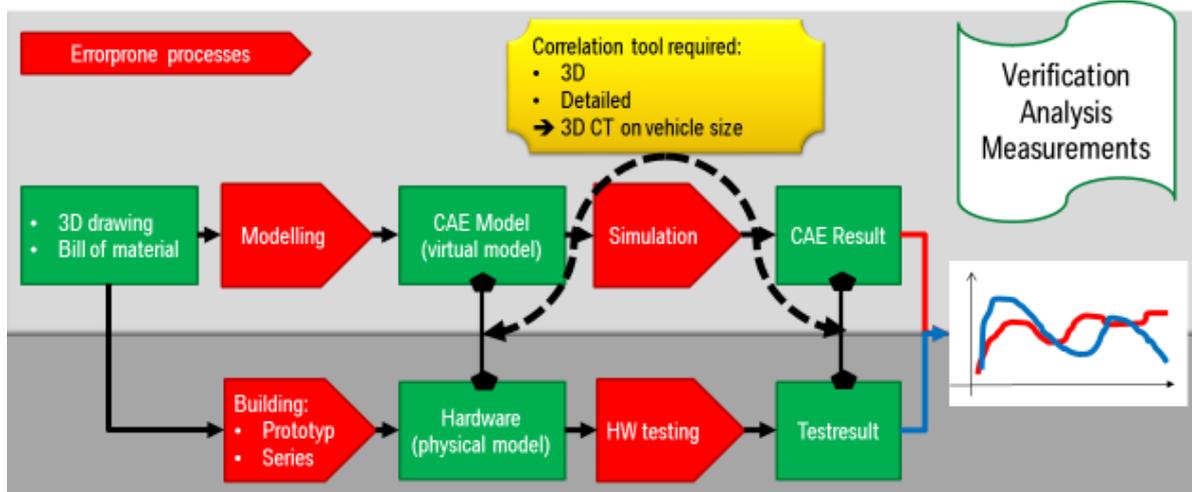
When looking at the total process chain from design to testing, let it be virtual or physical we see several steps which introduce either abstraction or even mistakes which are the key source for non conforming results between hardware test and virtual testing by simulation. Starting from a 3D CAD drawing the virtual process chain consists of:

1. Finite element model generation: Including geometric abstraction, material modelling
2. Load case setup and simulation per se.

The hardware process chain consists of:

1. Building and joining and assembling the individual parts.
2. Hardware test setup and execution.

Correlating final test results in hardware and simulation and to interpret them correctly includes the knowledge of the levels of abstraction introduced before and the possible error sources.



For example possible „errors“ on the virtual side can include wrong abstraction level, either too detailed or too rough, insufficient material models and/or data, as well as mistakes in the setup of loadcases and errors introduced by the simulation per se. Simulation errors could be numerical ones such as bad round offs as well as instable situations.

Possible “errors” on the hardware side can be simply bad manufacturing, damages on the hardware, last minute changes in materials supply due to unavailability of certain materials in prototyping, not mature process of bonding etc. . On the hardware testing side all kind of things can go wrong and the smallest errors, because of unseen are the worst: bad position of crash barriers, poorly fixed accelerometers etc. .

So in order to track down all sources of error and to give the engineer the opportunity to draw the right conclusions from his work every single step in the above process must be available to any detail of inspection and correlation.

In order to achieve this we need to compare built hardware on full vehicle size in pre-test configuration in geometrical details with the comparable finite element model. The comparison must include the size and geometry of parts, joining such as spotwelds, seam welds and glueing as well as the detail of non structural but package relevant parts.

Also the comparison of the final test result must not be limited to some accelerations and few displacement points instead the whole collective of the geometry must be available for an efficient inspection. For example it does not make much sense to wonder about different dummy acceleration values if the fundamental behaviour of the front structure is different to either significant different engine compartment package or a different behaviour of front longitudinal buckling due a different failure mode of screws.

This can only be achieved if the hardware is digitalized sufficiently. In our means to the engineering degree of millimeter level. Fortunately by the advances of the EZRT of Fraunhofer in Fürth (5),(6) a 3D computer tomography (CT) up to full vehicle size is possible today. A resolution at approximately 0.33 millimeter for full vehicle level is achievable.

However the results of CT are in general gray scale pictures or cross sections and it's assembly is called a "CT volume" consisting of "voxels". These gray scale pictures are not much use for the engineer who has his CAD and CAE environment and his data available in polygonized form.

Therefore it is absolutely necessary to implement a transition and conversion from gray scale images back to a CAD/CAE like data format preferable in the environment of the engineer.

## 2. STATUS OF PROCESSING CT DATA IN ANSA

In order to convert CT data (volume) into structured geometry several steps are necessary. Beside the simple technical aspects necessary to execute we will point out also the special complexity concerned with a full vehicle CT.

### 2.1 Facts around a full vehicle CT:

An upper size of a full vehicle can be estimated by 6000mmx2000mmx2000mm.

Assuming a maximal resolution of 0.33mm we have 9 voxels per mm<sup>3</sup>. Which leads to  $6 \cdot 10^3 \cdot 2 \cdot 10^3 \cdot 2 \cdot 10^3 \cdot 9 = 2.16 \cdot 10^{11}$  voxels.

Assuming only one byte per voxel, providing 256 gray values, we end up with approximately 216 Gb of voxel data. If we simply would convert 1 voxel to 1 hexahedral element assuming that 1 hexa in average adds also one grid and both will be represented in typical CAE based ascii form with two 100 byte long lines we end up with approximately 20Terabyte of input deck only.

This is orders of magnitude away from what can be handled today.

As several more smart algorithms were developed in the past such as "marching cubes" (1) etc. we want to apply them to extract isosurface of certain gray values representing individual materials. As a matter of fact the gray value in the CT is partly correlated to the x-ray absorption capabilities of the material which is correlated to it's constitution of it's atomic nucleus which correlates to mass. Therefore heavier materials absorb x-ray better and result in whiter gray values. Another part of the gray value results from voxels which are only partly filled with material, such as for example a 30% fillgrade.

### 2.2 Procedures developed in ANSA up today and steps to execute:

When describing the procedure we will simultaneously give performance data of an example I8 RC model which underwent a CT resulting in 4000x1600x1000 voxels with the data provided in DICOM format (dcm) (2), (3).

The hardware/computer had the following characteristics:

Linux CentOS based release 6.6; NVIDIA GeForce GTX 760; core I7, 3.6 GHz; 64 Gb RAM

ANSA attacked the problem from the very beginning by implementing a loop like step-by-step approach to process the large problem out-of-core:

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Without restricting generality we assume the CT volume is stored as a voxel block x-,y-,z-wise. De facto nothing else like a sequence of images.

Step 1: Images are read in ANSA bunches:

Due to the resolution of the dcm-files (1600x1000) and their amount (around 4000 pics), it is not possible to read all images at once on the above machine. For this example, bunches of 500 pics at the time were used.

Step 2: Downsizing of the images during reading

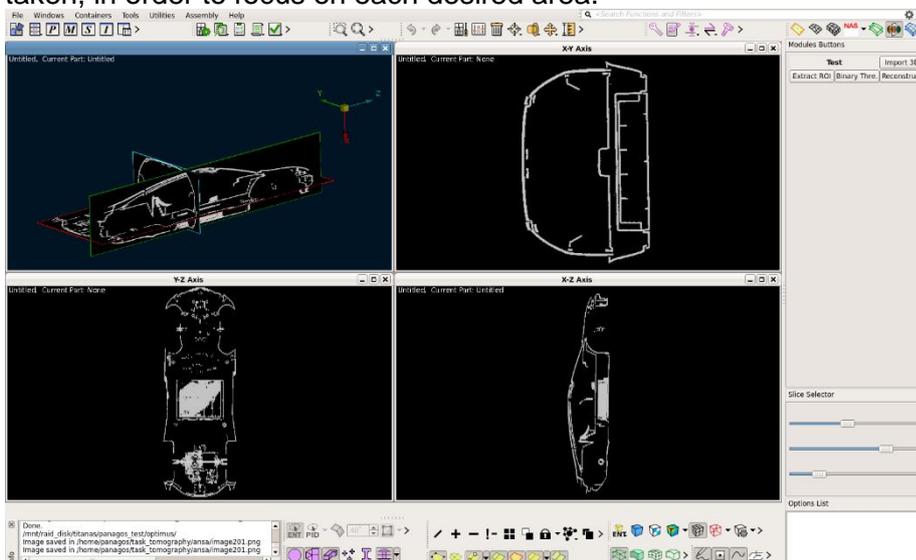
For the above method 125 sections would lead to a model structure of 20 million surface elements which is difficult to handle and too much detail. Therefore the pics were downsized during reading. The downsizing used was by half (but is flexible to adjust), which lead for the same amount of sections to 200.000 surface elements. So a factor 1:2 in the image resolution leads to a factor 1:100 in the produced structure.

Step 3: Visualization of the data

Ansa splits the screen in 4 windows:

- one window shows the current section you are looking at in 3d-space
- the other 3 windows show the current sections in each of the 3 global plane definitions

A slider is served that allows the user to travel along the normal axis of the pictures that were taken, in order to focus on each desired area.



Step 4: Tools are provided in order to remove unwanted areas.

For simplification and or to focus on special areas only the user optionally can specify a box in space, and everything within that box is treated as empty space.

Step 5: Material selection range: Specification of min-max gray scales.

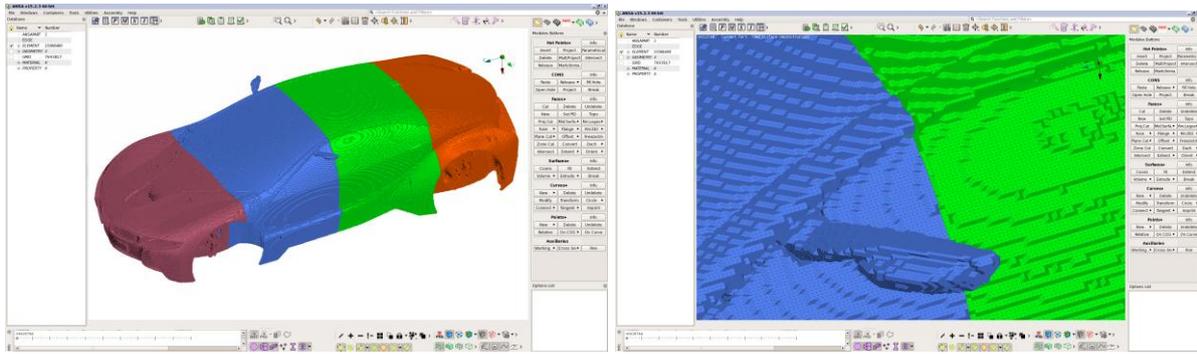
ANSA will consider whatever is below the “min” value as empty space and the rest as material.

Step 6: Application of additional filters

In order to remove small caves (small areas of material within empty space or vice versa small empty spaces within the material), a filter can be optionally applied to disregard those caves.

Step 7: Build a polygonised mesh.

A surface mesh based on the outer boundaries of the regions where material has been identified will be generated, based on the settings applied on the previous steps.



Step 8: Downsize in mesh level.

Standard ANSA meshing functionality based on the reconstruct functionality is applied in order to downsize the mesh even further.

Step 9: Export the mesh.

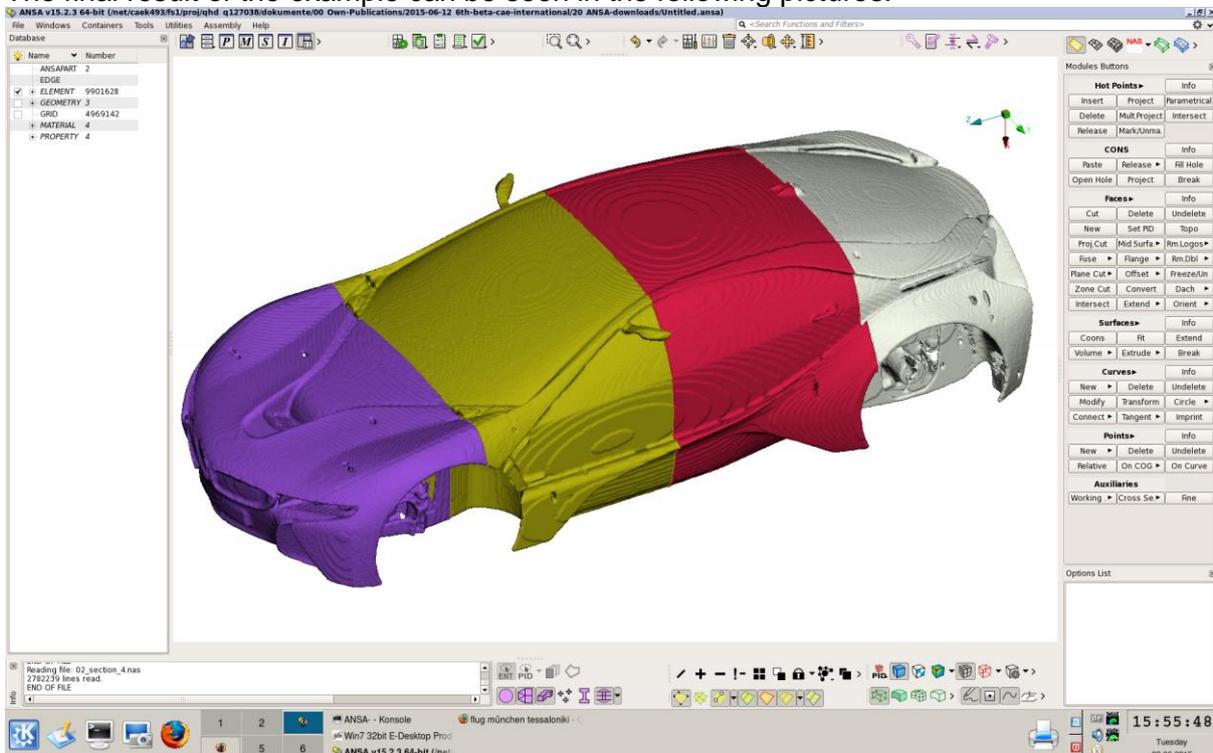
Export either in Nastran (7) format for instance or any other CAE format supported by ANSA. (4)

Step 10: Free space by deleting the current mesh and repeat steps 1-9 each quantum as described in step 1. For the i8 model the 500 pictures were read at a time, so steps 1-9 are applied for each quantum.

Step 11: Stitch the areas together.

Read all the Nastran files produced by step 9 from all the regions and apply standard ANSA mesh functionality in order to connect the meshes together, again based on the reconstruct approach.

The final result of the example can be seen in the following pictures:



### 3. CHARACTERISTICS OF THE FINAL PROBLEM – FULL VEHICLE CT

The approach shown above was implemented by considering in advance the largest possible problems for the automotive industry seen today. These problems as indicated above represent a full vehicle CT analysis with the highest possible resolution.

To increase complexity the models can also appear in an extremely distorted state when focused on processing after “crash test” models.

In the picture below a full vehicle CT of a MINI is shown demonstrating the feasibility of full vehicle analysis. The increased complexity compared to the i8 model is less the increased data size (~300Gb) but more the complex mixture of materials and accumulation of many parts in several areas. The resolution of the problem was 0.4mm.

Also the increase of artefacts and beam hardening effects is an issue which can be addressed by ANSA's filtering technique.

In order to address the problem we assume that the slice wise step approach needs to be replaced by a bounding box wise step approach. Bounding boxes will be either defined as a default or by existing CAD/CAE geometry. Also we estimate that it will be necessary to provide a geometrical overlap of the slices and/or bounding boxes and remind that overlap. This will allow an optimized stitching at the end.



### 4. CONCLUSIONS

In the beginning we outlined the necessity of new approaches like CT and the integration of its data into the CAE process in order to support the role of CAE especially concerning high end complex structures with multi material approaches.

The extension of high end preprocessing tools such as ANSA to support this process offers a wide range of advantages due to the extremely rich basic meshing functionality and file interfaces.

ANSA has shown successfully that it is quickly able to support the functionality necessary to process such complex data.

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The functionality implemented by ANSA recently supports the basic steps demonstrated at the i8 RC model.

Further work has been defined to support even the largest possible problems in computer tomography and core CAE relevant issues for automotive design. Some of the features under development are listed below:

1. Support of additional image formats (png, jpeg, etc).
2. Ability to read sections (sequences of images) by setting as step the data memory size.
3. Capability to isolate regions of interest to partially read the slices in buckets
4. 3d-preview Tools in image level
5. New filters and manual tools to manipulate image data
6. Multiple grayscales for different materials recognition
7. Improvement of surface smoothness
8. Automation capabilities through setting up image treatment templates

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