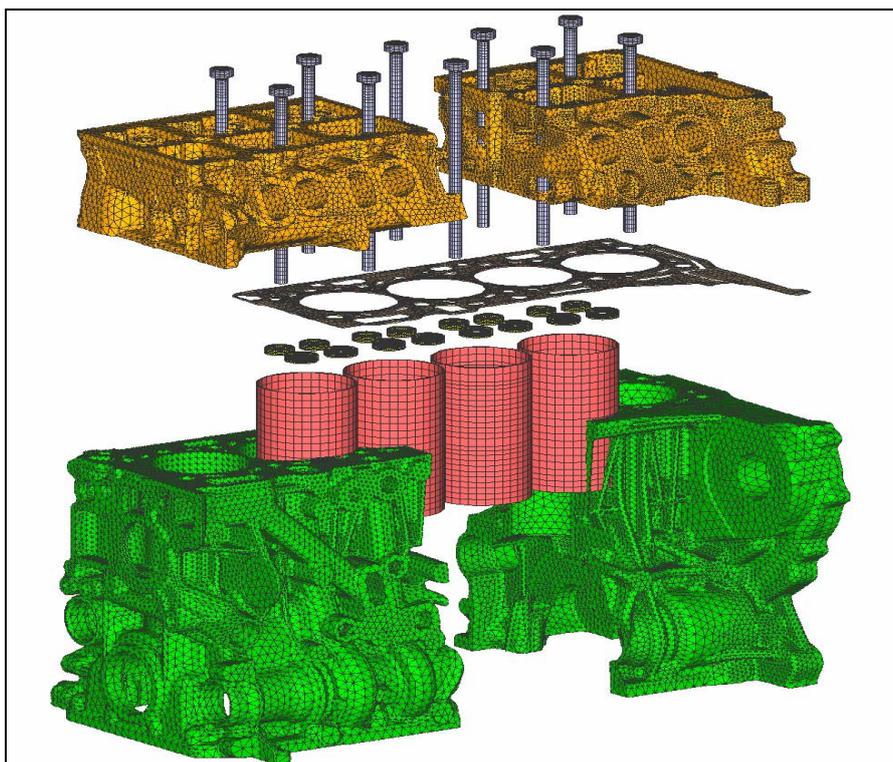


## USAGE OF ANSA'S AUTOMATED VOLUME MESHING-METHODS IN THE RAPID PRODUCT DEVELOPMENT PROCESS OF DIESEL ENGINES

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**ABSTRACT** - In order to stay successful in today's competitive markets, it is necessary to set high end standards in the product development process of diesel engines and it is also essential to reduce the development time of new products.

Despite a further increase of power and torque, the weight of the new 4 and 6-cylinder diesel engines of BMW has been significantly reduced and high quality and low emission standards have been achieved.

In this respect, state of the art CAE-simulation methods play an important role in today's development processes at BMW and therefore "New Automated Volume Meshing Methods of ANSA" are a milestone for rapid and successful application of the virtual product development.

Some years ago, it was not possible to create complete engine FE-volume models within a reasonable time range. Hand made meshes took up to 10 weeks of pure meshing time and thus model changes, design variants or optimization loops were nearly impossible to handle, because of the enormous time consumption. ANSA's new automated meshing methods allow an effective creation of complex volume meshes, e.g. for complete cylinder heads or crankcases models, within one or two days and so give a benefit of weeks to build up complete engine models.

As a result of this fast possibility to build up not only segment models but also complete simulation models, effects like global bending, non-uniform temperature distributions, a.s.o. could be taken into account for the numerical optimization of engine parts.

Finally these “New Automated Volume Meshing Methods” allow an effective and rapid virtual product development and guarantee excellent results in component durability calculation and quality despite of increasing engine power and weight reduction.

TECHNICAL PAPER -

## 1. INTRODUCTION

In order to stay successful in today’s competitive markets, it is necessary to set high end standards in the product development process of diesel engines and it is also essential to reduce the development time of new products.

Despite a further increase of power and torque, the weight of the new 4 and 6-cylinder diesel engines of BMW has been significantly reduced and high quality and low emissions standards have been achieved.

On the example of the New BMW 4 Cylinder Diesel Engine the usage of ANSA’S automated volume meshing-methods is shown on a overview of special applications. The experiences, advantages and benefits of the meshing functionalities in the rapid product development of our new diesel engines are presented on examples out of the complete range of FEM-simulation, like structural and fatigue analysis, optimization / morphing, dynamic & acoustic analysis and also CFD-analysis and CFD-optimization.

### Usage of ANSA’S automated volume meshing-methods:

State of the art CAE-simulation methods play an important role in today’s development processes at BMW and therefore “New Automated Volume Meshing Methods of ANSA” are a milestone for a rapid and successful application of virtual product development. Some years ago, it was not possible to create complete engine FE-volume models within a reasonable time range. The former 2,5 cylinder models had a low level of details and discretisation:

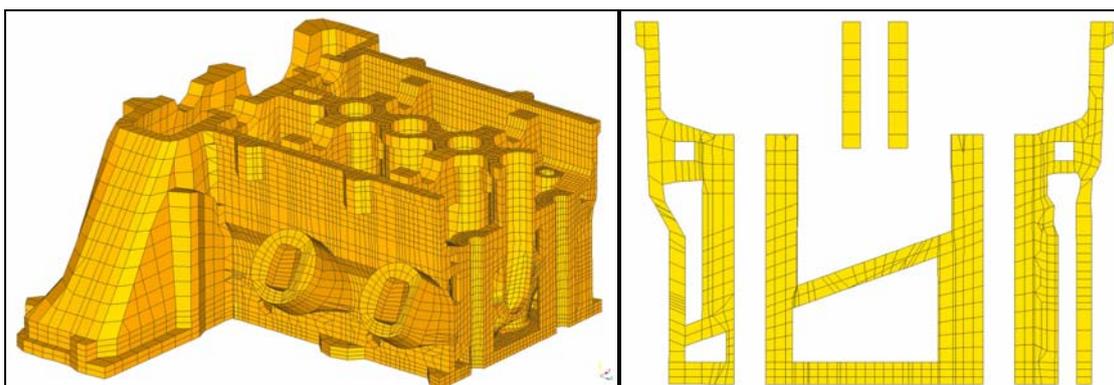


Figure 1: „manually“ created solid mesh

Hand made meshes took up to 10 weeks of pure meshing time and thus model changes, design variants or optimization loops were nearly impossible to handle, because of the enormous modelling time.

ANSA’s new automated meshing methods allow for an effective creation of complex volume meshes, e.g. for a complete cylinder head or crankcase model, within one or two days and give a benefit of weeks to build up complete engine models.

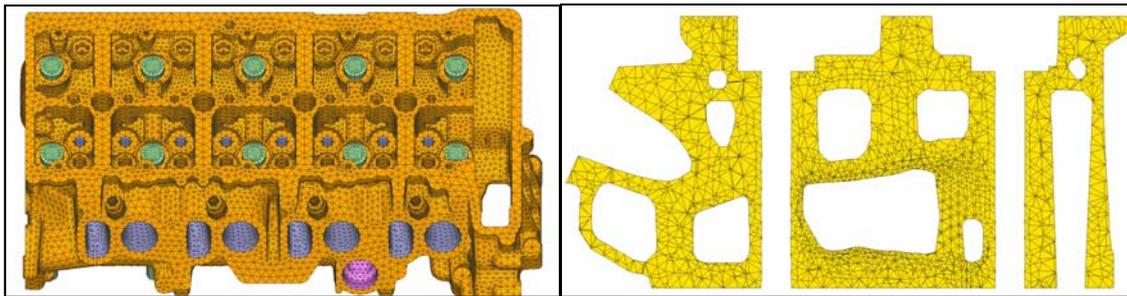


Figure 2: "automatically" created ANSA mesh

Using of ANSA's functionalities for the meshing process like, direct and part structured CAD import, geometry cleanup and surface improvement using macro create, element quality improvement using "RESHAPE" (with optimized reshape parameters), the local mesh refinement for critical areas and a finish element quality check of the volume mesh, gives us high quality meshes with a high level of details and discretisation within some hours or at maximum within some days.

As a result of this fast possibility to build up not only segment models but also complete simulation models, effects like global bending, non-uniform temperature distributions, a.s.o. could be taken into account for the numerical optimization of engine parts.

Complete engine model:

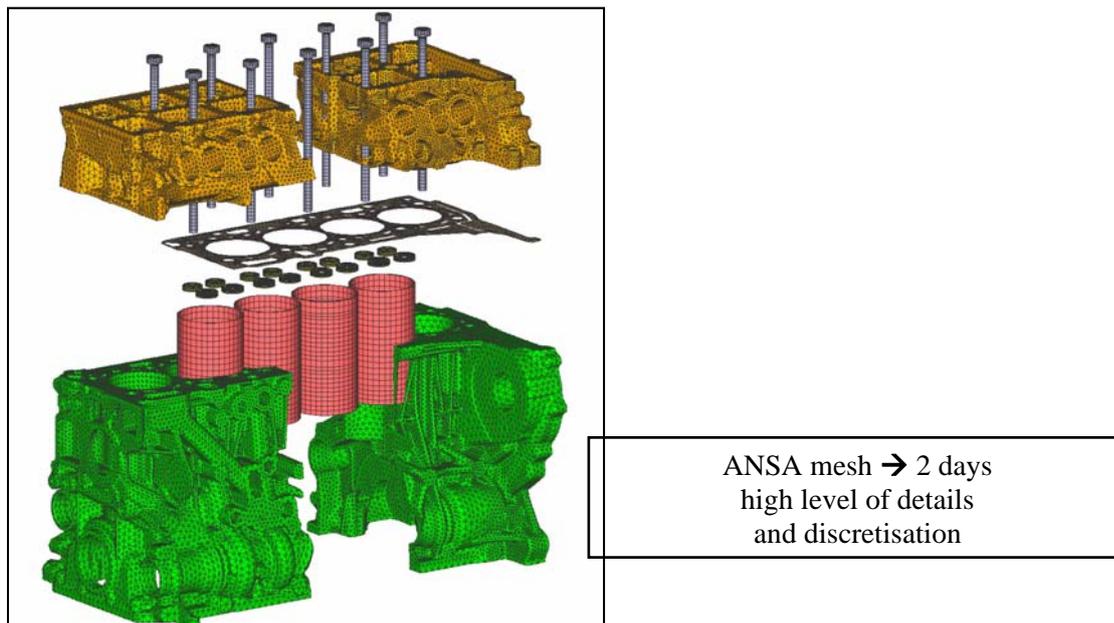


Figure 3 complete engine model:

One example of the big benefit of using complete engine models is the cooling flow optimization. A loop between 3D-coolant simulation in STAR CD and resulting heat transfer coefficients which are used for the thermal calculation in ABAQUS, provide us a non-uniform temperature field of the engine as basis for a cooling flow optimization with the target of reduction of the maximum engine part temperatures.

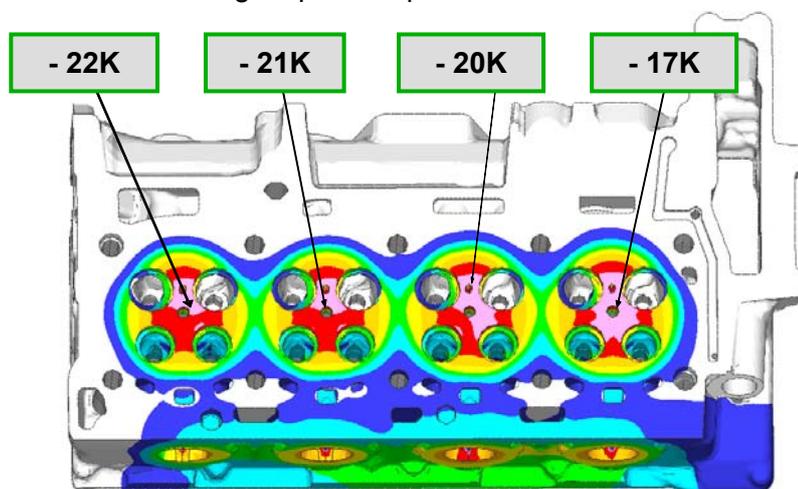


Figure 4: temperature optimization result

Using ANSA's new automated meshing methods more than 20 cylinder head optimization variants could be evaluated in the optimization process and the optimal design gives us an increased heat transfer coefficient of factor 3.5 in the critical areas and a benefit of more than -20K in the hot areas of the cylinder head. This optimized cylinder head water-jacket geometry is verified and measured in a lot of engine test runs and is now the basis for the New BMW-4 Cylinder Diesel Engine.

#### Submodel technique-fatigue analysis-optimization:

The complete engine model calculation, takes into account non-uniform temperature field, mounting loads (set rings, liners, pre-tension of the bolts) and the combustion load cases of each cylinder.

However, despite the excellent possibilities of ANSA to create highly efficient meshes with strong variations of mesh size dependent on the curvature, the global meshes are sometimes still have to be too coarse for a high precision fatigue analysis. In this case the sub-model technique of ABAQUS is an effective way to use very fine meshes for best discretisation to detect the critical areas of all engine parts.

Based on the global results of the whole engine model, which do not contain unrealistic boundary effects at cutting planes or symmetry faces (typical for only partial engine models), a submodel analysis can now be performed at any position of the analyzed engine. It is carried out by transferring the already accurate deformation-results of the global model to the boundary faces of the submodel. Similarly the temperatures are mapped to the complete submodel.

Based on the accurate stress distribution of the submodel mean-stress and stress amplitude are calculated and used for the fatigue analysis with FEMFAT (MAGNA). If critical areas are detected, use can be made of another feature of the submodel technique: providing a sufficient submodel size and as long as the global stiffness does not change too much, an optimization with TOSCA (FE-DESIGN) including several loops can be carried out purely on the submodel. As a consequence, no contacts and major nonlinearities like gaskets are contained in the model, which leads to a dramatic speedup in the FE analyses. For instance also the whole cylinder head can be used as a submodel with a very exact discretisation (extremely fine mesh for the water jacket) for fast, but highly accurate results. Of course, the final design has to be verified by a global analysis to get safe and robust engine parts.

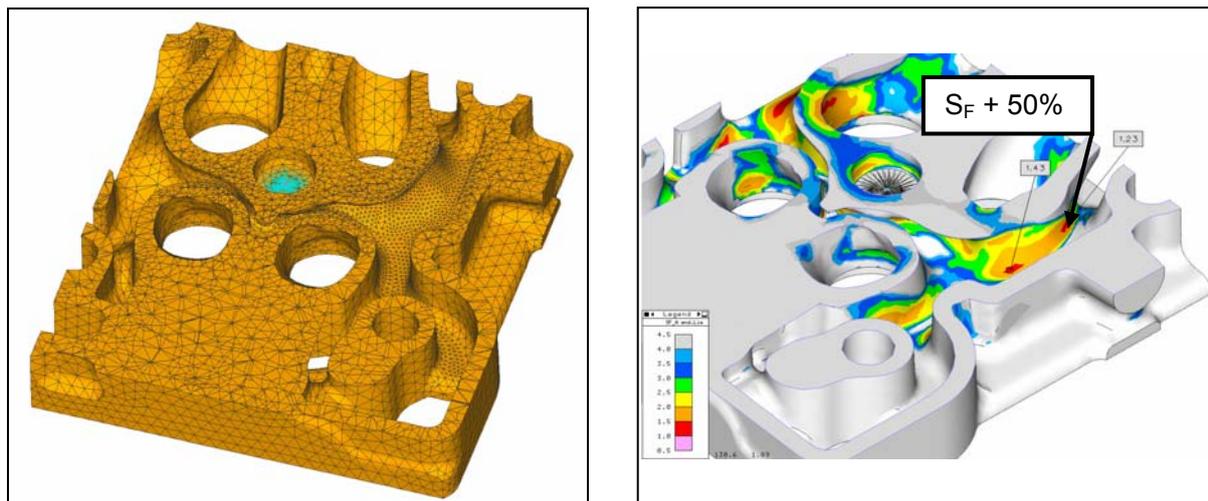


Figure 5: Submodel technique, TOSCA shape-optimization

Structural dynamics and acoustics:

In the years before "manually" created shell / solid meshes take an of the enormous time consumption of up to 12 weeks to get an acceptable dynamic-model of a power train-unit. Special transition elements between shell an solids had to be used for the connection and also the flexibility for changing engine parts or variants was low and spent a lot of time.

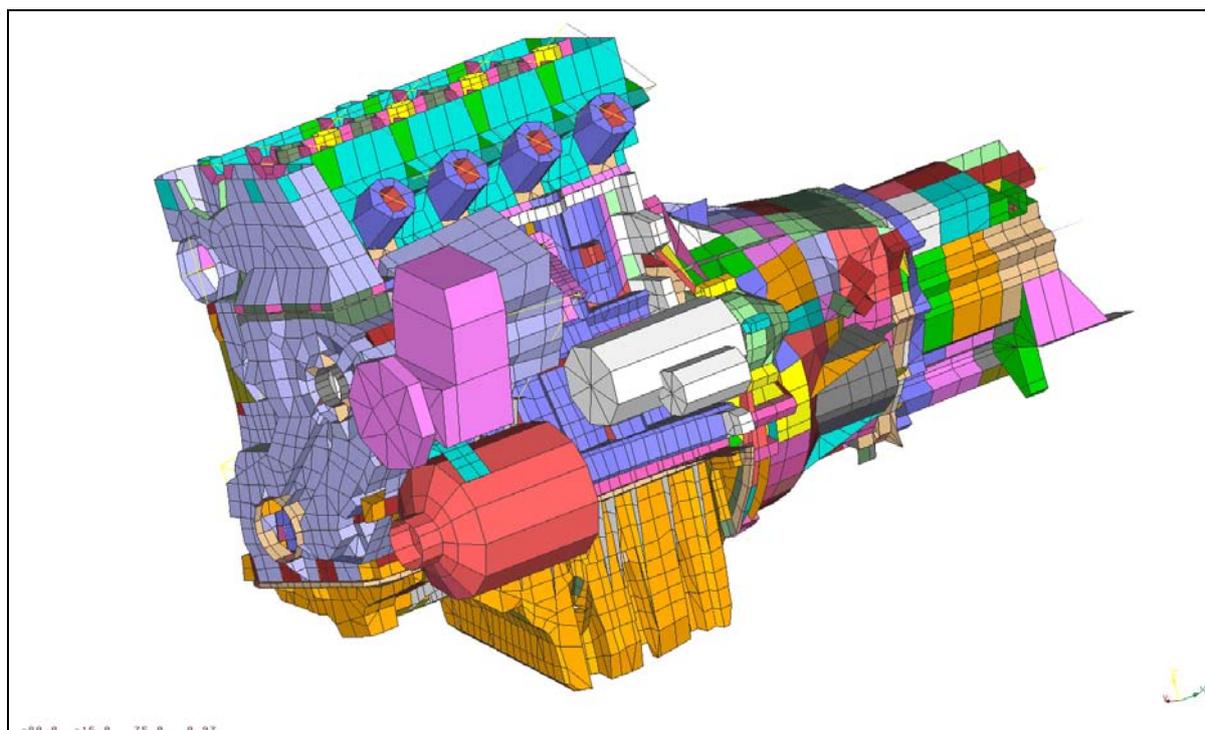


Figure 6: "manually" created shell / solid meshes

ANSA's new automated meshing methods gives an effective creation of all complex volume engine parts, a high flexibility for model changes, variants and optimizations. The complete meshing time for the a power train-unit will be reduced per factor 10!

To obtain a power train-unit model a lot of engine parts need to be modelled. When all the necessary machine elements are meshed with ANSA they are assembled using a separate Tool which allows a detailed modelling of all the screw connections which are holding the engine together. An according model of a 4 cylinder diesel engine is shown in the following figure.

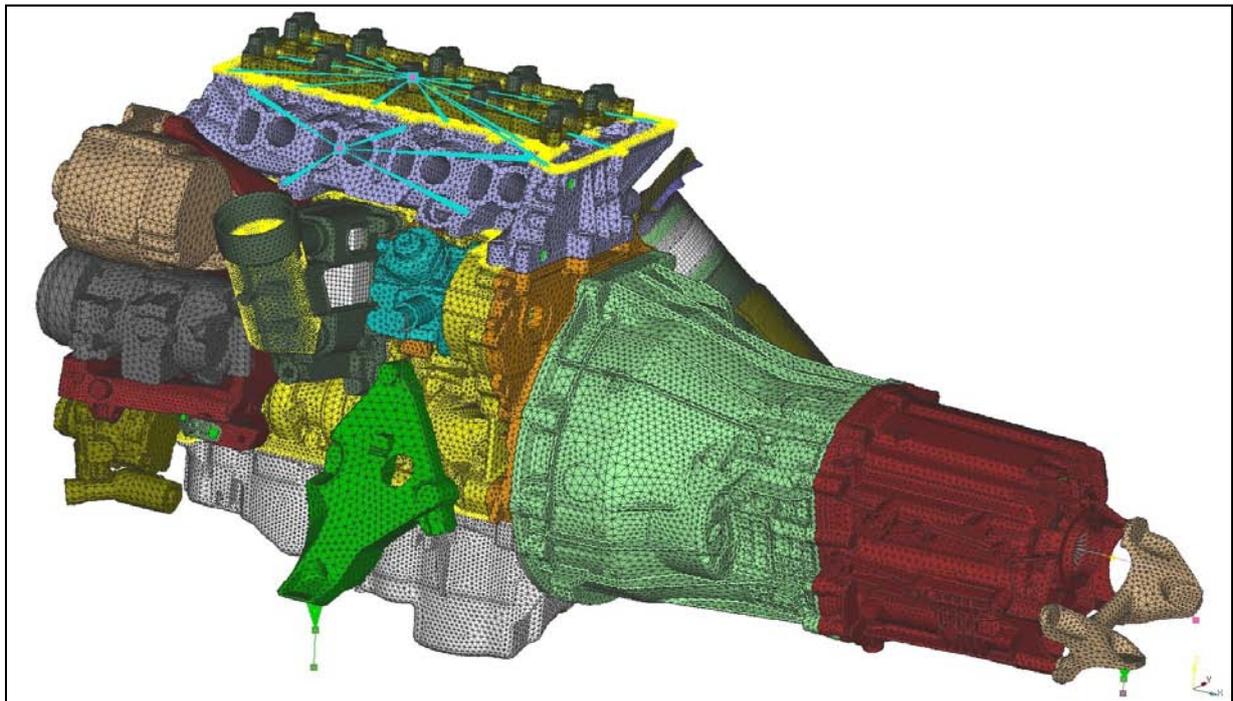


Figure 7: "automatically" created ANSA mesh

At the outset a normal mode analysis is performed. The global modes are of great interest in this respect to acquire the dynamic behaviour of the model. Based on the modal basis an engine speed-up run simulation is performed where the complete power train-Unit model is passed through the hole engine speed array.

The result of such investigations are Campbell-Plots which are a useful assistance to specify engine speeds where the acoustic behaviour of the corresponding engine is worth to be investigated more precisely. Finally a modal frequency response analysis for the selected engine speeds is conducted to get for instance, amongst others, the surface distribution of the structure-borne noise indicators.

### ANSA-meshing methods for CFD analysis

Low meshing time and a high level of discretisation is necessary for accurate and fast results in the 3D-CFD-analysis. ANSA's CFD-mesh algorithm are used to define boundary layers on the surfaces for better discretisation, mixed elements (prism, tets, pyramids) for transition layer and quads (hexahedral elements) to fill the rest of the volume to decrease the degree of freedoms and to increase the calculation speed.

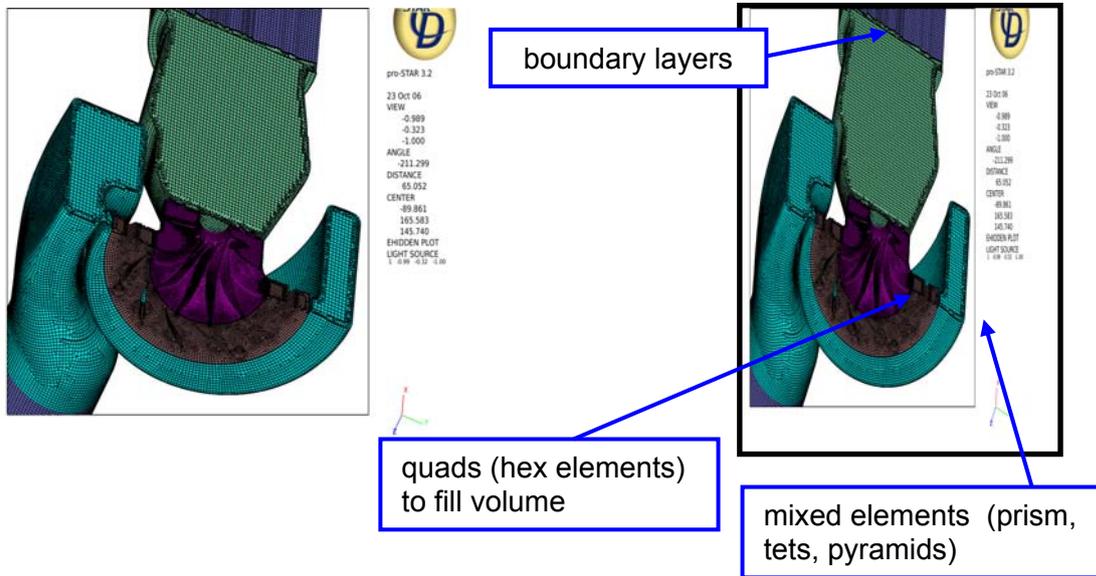


Figure 8: ANSA CFD -model

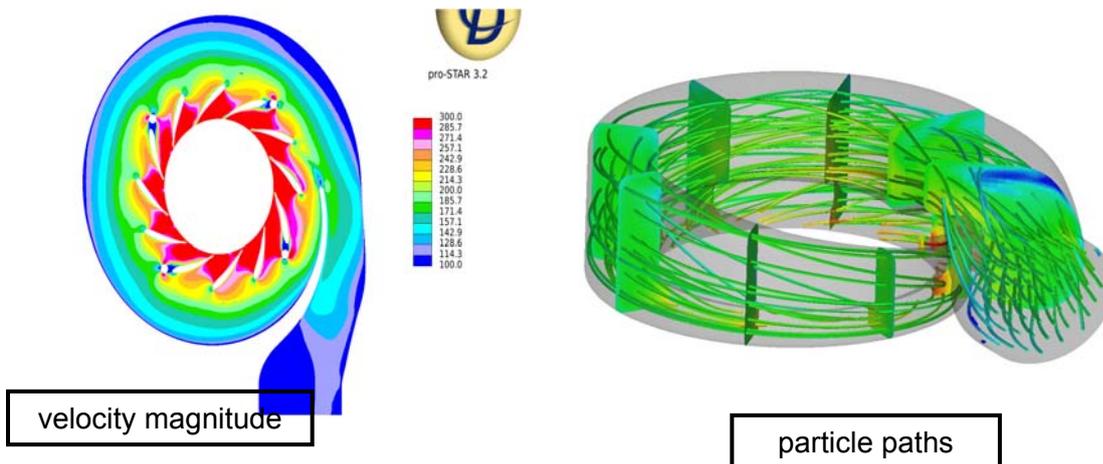


Figure 9: 3D-CFD analysis StarCD

Optimization using ANSA-Morphing:

Highly three dimensional effects of fluid dynamics leads the simulation engineer to the problem of a huge number of influence variations. An effective method of shape improvement is using the morph option in combination with an automatic optimization, e.g. modeFRONTIER. The ANSA morphing creates based on the parameterizes CFD-mesh (parameters are set on the edges of the morphing boxes) a huge amount of meshes with different geometries. All these geometries are automatically calculated in STAR CD and parallel evaluated by the free optimization algorithm in modeFRONTIER to reach the optimum target option.

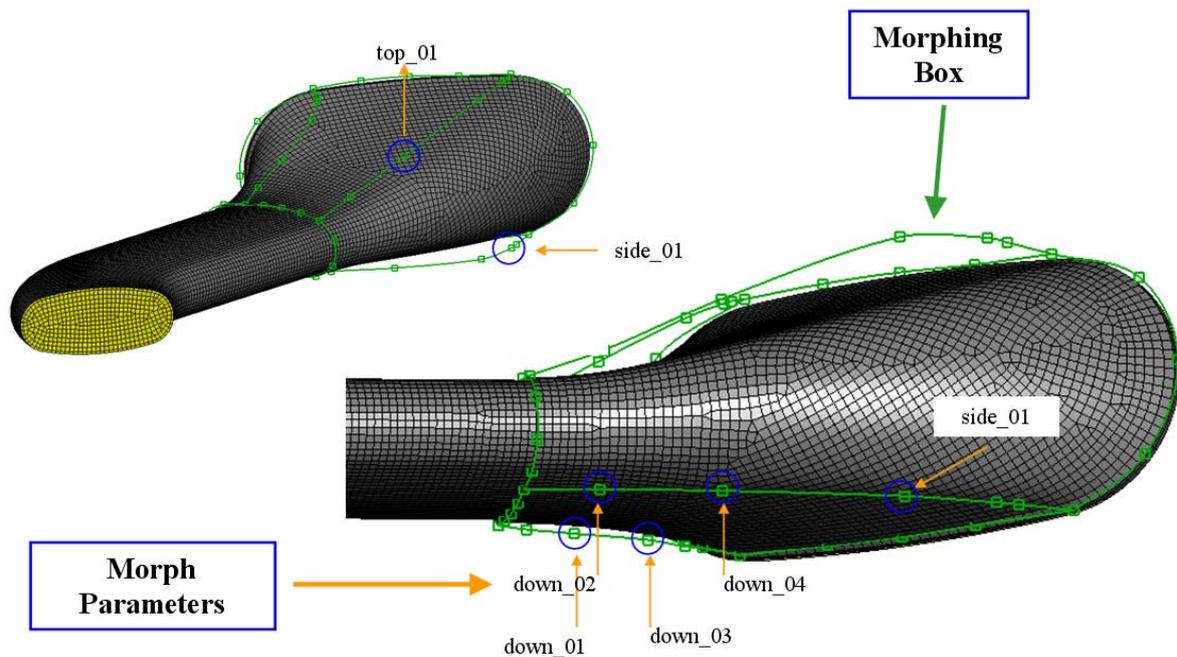


Figure 10: ANSA Morphing

In the current example an inlet to a catalyst is object of an optimizing, see figure above. For that purpose six morph parameters have been defined in ANSA, which can be modified in batch mode. Therefore you need an ANSA translation respectively a Session File. Important is of course to check quality of mesh, because there is a limit of morphing range. In modeFRONTIER a UNIX script in processing the necessary steps as follows:

- ANSA mesh loading
- Morphing with Output Parameters of Optimization (Target Options are Reduction of Pressure Drop and Improvement of Velocity Uniformity Index)
- CFD Simulation in STAR CD
- Determination of Input values for modeFRONTIER
- Definition of Output Parameters for ANSA Morphing

Mesh size is 250 000 cells and one optimization loop needs about 30 minutes (4 processors parallel). After 250 loops the run have been stopped and as result pressure drop and uniformity index were improved.

## 2. SUMMARY

ANSA is an effective tool for a rapid virtual product development process. Using the functionalities of ANSA gives a maximum reduction of meshing time and complex meshes with a high level of discretisation as guaranty for accurate and fast results. Model changes, design variants and optimization loops can be done in a rational time range of some hours or days. ANSA can be used in the complete range of FEM, like structural and fatigue analysis, optimization / morphing, dynamic & acoustic analysis and also CFD-analysis and CFD-optimization.

Finally these “New Automated Volume Meshing Methods” allow an efficient and rapid virtual product development and guarantee excellent results in component durability and quality despite increasing engine power and weight reduction.

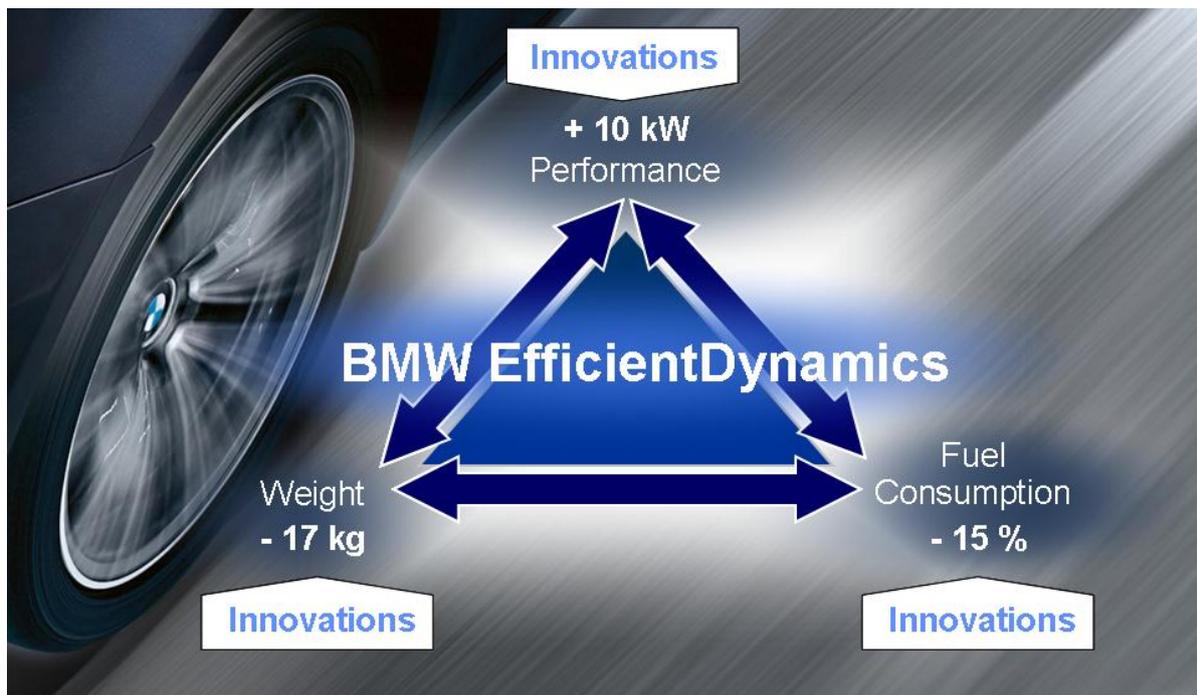


Figure 11: BMW efficient dynamics-The New BMW 4-Cylinder DIESEL Engine

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