MSC/CONSTRUCT – Features and Capabilities
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Abstract

For design engineers and analysts MSC/CONSTRUCT[1)] provides an exceptionally fast and easy-to-use, conceptional design tool consisting of two options:

- MSC/CONSTRUCT TOPOLOGY is the topology optimization option, which distributes material within a design space envelope based on the optimum load paths.
- MSC/CONSTRUCT SHAPE is the non-parametric shape optimization option, which homogenizes the stress distribution (Fully Stressed Design).

Both of these options are FEM-based and use an efficient optimality criteria technique. In the optimization cycle MSC/NASTRAN is used as the analysis engine. This guarantees reliable results and highest performance.

MSC/CONSTRUCT V2.5 was released in Q3/98. Major highlights are:

1. A graphical user interface within MSC/PATRAN
2. A restart option
3. High performance improvements which significantly increase the throughput
4. An automatic shape basis vector generation for MSC/NASTRAN's SOL 200 by MSC/CONSTRUCT

Especially items 3. and 4. will be presented by customers‘ real life examples.

1. The Product

1.1 Introduction

Design decisions made during the early phases of a product design have far-reaching effects on both product performance and manufacturing costs. Often these decisions are made under severe time pressure on the basis of past experience (Figure 1).

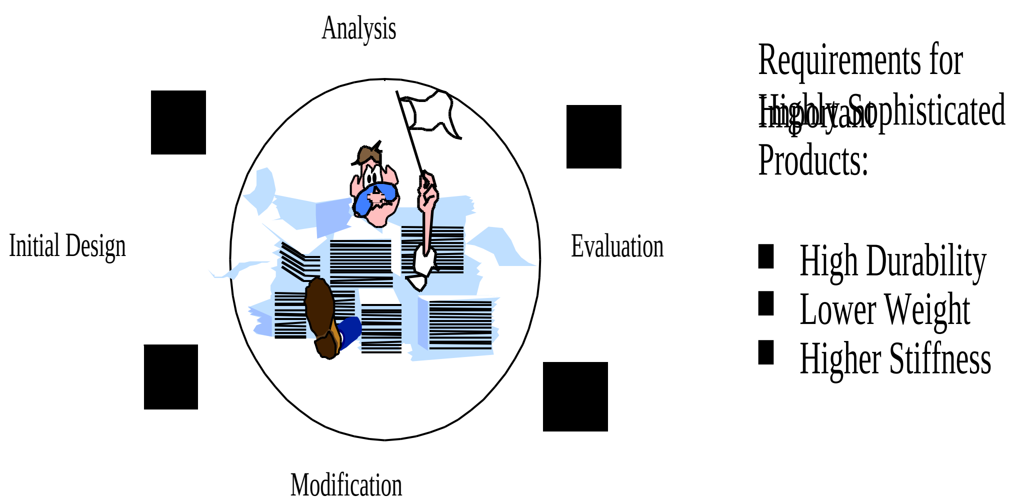


Figure 1: Reduction of Cost and Development Time

In this respect, MSC/CONSTRUCT helps to overcome bottlenecks. It provides analysts, as well as design engineers with fast and easy-to-use design optimization technology:

- Encouraging cost-effective design decisions in the early phases of a product’s life cycle
- Supporting the design of lightweight structures, avoiding overdesign and saving material
- Saving time in the design-build-test scenario

1.2 Topology and Shape Optimization Using MSC/CONSTRUCT

MSC/CONSTRUCT contains both ***Topology*** and ***Shape*** optimization (Figure 2).

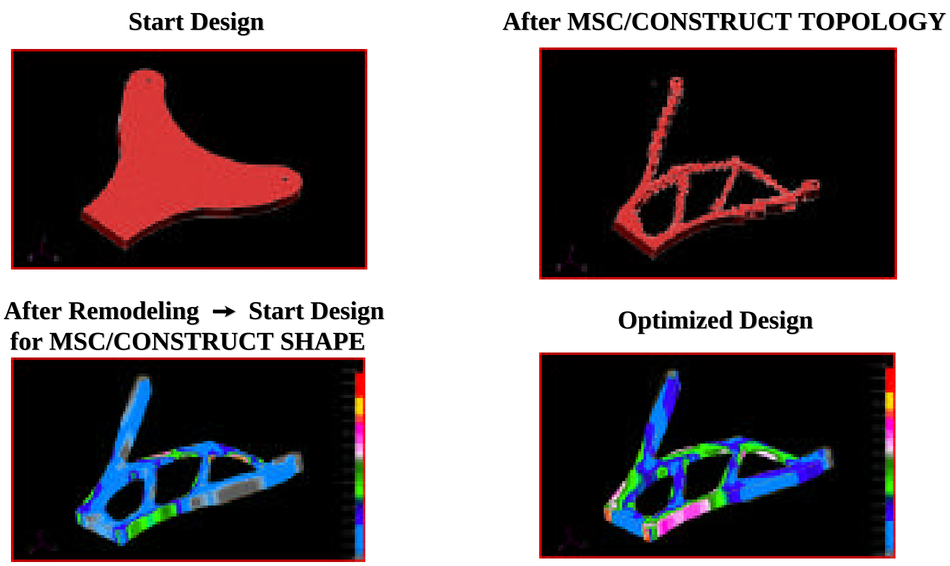


Figure 2: MSC/CONSTRUCT Capabilities

Topology optimization does not change node locations. It removes material from the defined design space, which has to be considered as a geometric space envelope containing the final design proposal. The suggested design gives an indication of the optimal strain energy distribution. For the optimization process, groups of finite elements can be constrained by excluding, freezing or prioritizing them, which helps to achieve a feasible design. The result of topology optimization can be used as a trial design for an initial CAD representation (Figure 3). A smoothed topology optimized finite element model may be used as an initial design for shape optimization or for any other subsequent simulation analysis.

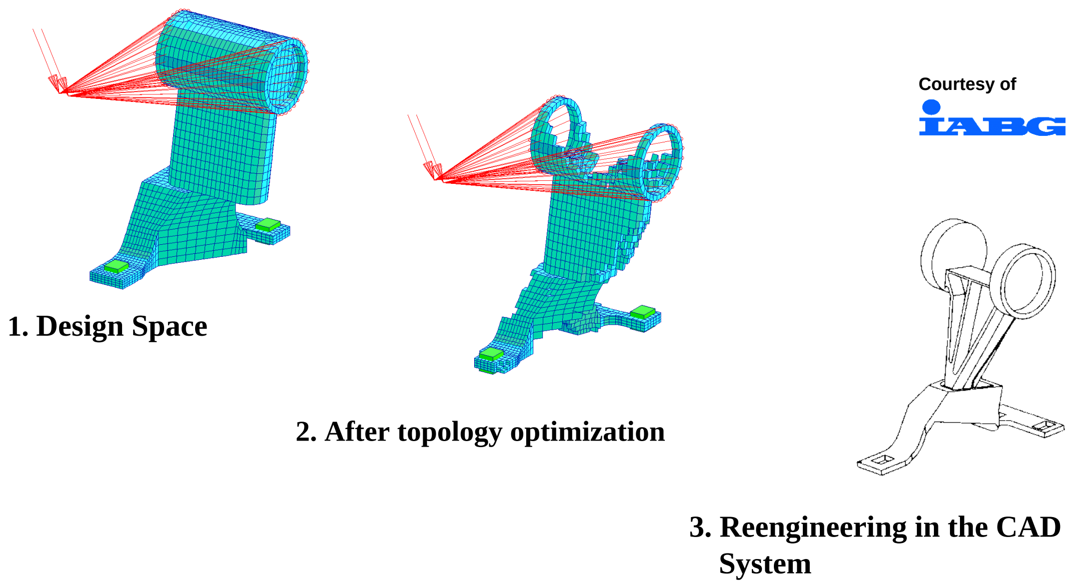
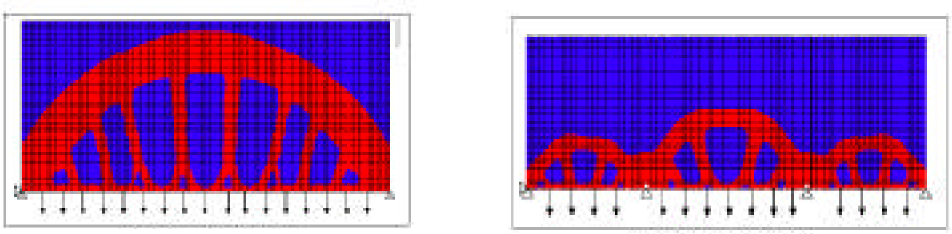


Figure 3: Topology Optimization of An Arm-Rest

The consequences of changed boundary conditions for a design can easily be investigated. Figure 4 shows the design proposal of the optimizer for two different supports of a plate under vertical loading. In both cases the design space was defined as a rectangle.

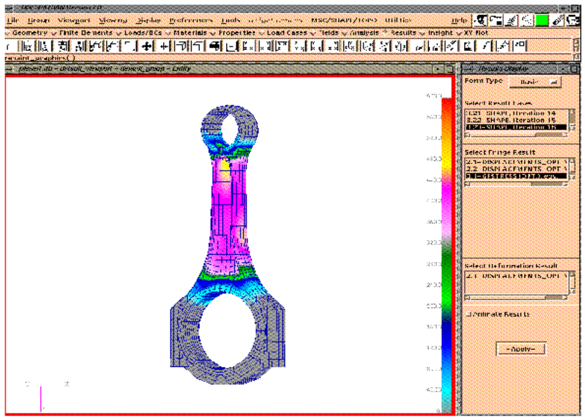


Boundary Condition Case 1 Boundary Condition Case 2

Figure 4: Topology Optimization of a Plate

Shape optimization modifies the node locations of the specified design nodes based on the calculated stress levels. It homogenizes the stress distribution according to the specified stress objective function (Figure 5). The method itself is not gradient-based using sensitivities, but based on optimality criteria (Fully Stressed Design). Therefore, the user does not need to specify allowable shape changes via shape basis vectors, which makes it fast and easy-to-use.

The movement of the nodes can be restricted (specification of the absolute value, node coupling, etc.), e.g. for the approximation of „manufacturability“ constraints.



Start:
Nonparametric FE Model

Objective:
Stress Homogenization

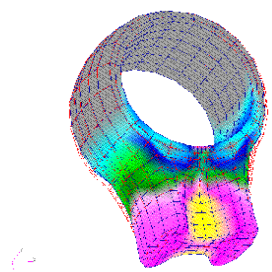


Figure 5: Shape Optimization of A Conrod

Non-parametric shape optimization saves preprocessing time and, therefore, manpower or costs. It provides a higher flexibility for the exploration of the complete design space, as the solution is not limited by the selection of the design variables (Figure 6).

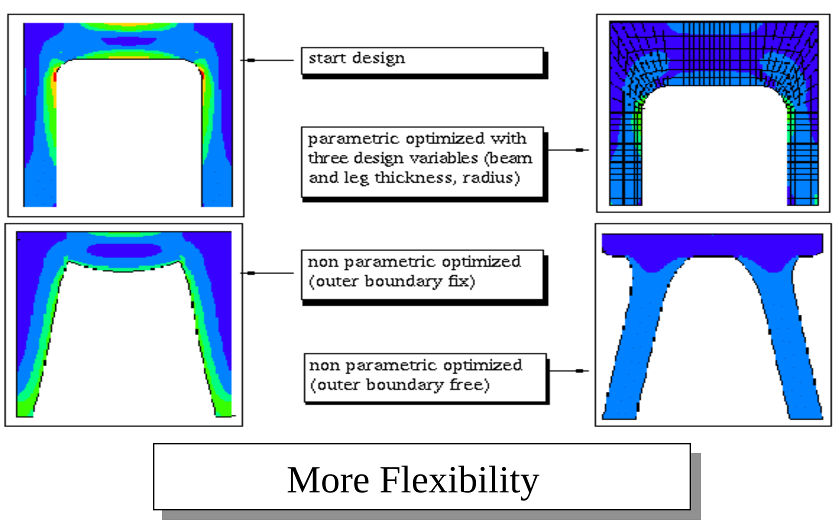


Figure 6: Parametric Versus Non-Parametric Shape Optimization

MSC/CONSTRUCT constraint features enable the design intent to be maintained during the optimization process. Among other options, fixed location constraints can be used to maintain mounting or loading point locations. Geometric limits may be specified or the unique feature of collision control may be applied to ensure that parts do not clash or overlap. Coupling constraints may be used to maintain the „manufacturability“ of the design.

1.3 MSC/CONSTRUCT, MSC/NASTRAN, and MSC/PATRAN

MSC/CONSTRUCT is closely integrated with MSC/NASTRAN and MSC/PATRAN, allowing management of data flow and program execution without any user intervention (Figure 7). MSC/CONSTRUCT works in optimization cycles, where each cycle consists of one MSC/NASTRAN and one MSC/CONSTRUCT run. The first MSC/NASTRAN analysis determines initial design performance. MSC/CONSTRUCT then creates a modified design based on the selected load-stress hypothesis and submits a new design for another MSC/NASTRAN analysis. The optimization loop continues until convergence is achieved. The integration of MSC/NASTRAN as the analysis engine guarantees reliable results and highest performance, especially for very large FE-models (500.000 elements and more).

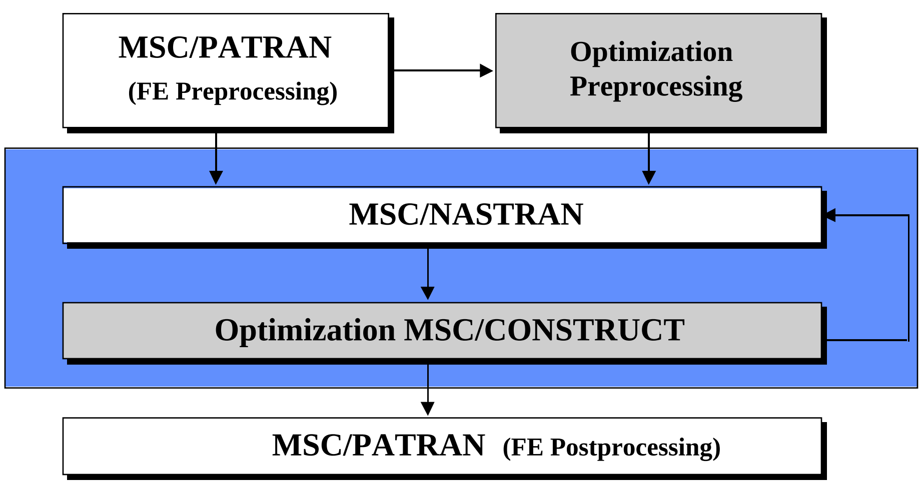


Figure 7: The Optimization Process

MSC/CONSTRUCT complements the sensitivity based shape and sizing optimization capabilities in MSC/NASTRAN. It may be used to rapidly investigate concepts and suggest design proposals. MSC/NASTRAN is then applied further downstream in the design process for more complex analysis requirements and constraints (Figure 8).

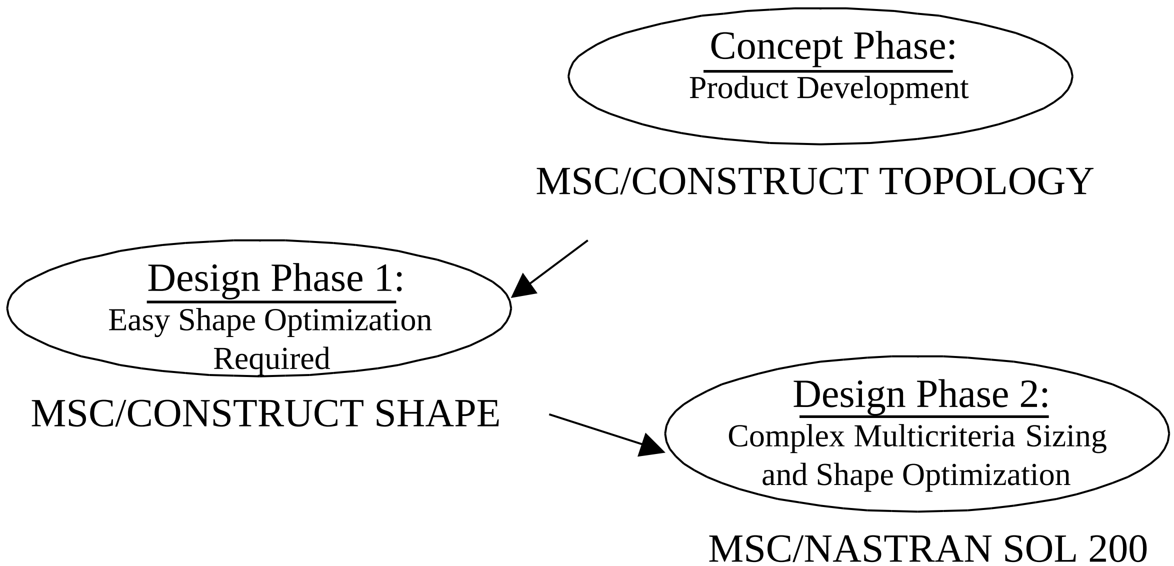


Figure 8: MSC/CONSTRUCT and MSC/NASTRAN

2. What is New in MSC/CONSTRUCT V 2.5?

The new release of MSC/CONSTRUCT V2.5 has been shipped.

2.1 Graphical User Interface

MSC/CONSTRUCT V2.5 now has a graphical user interface within MSC/PATRAN, which supports the generation of the parameter file necessary for the control of the optimization process.

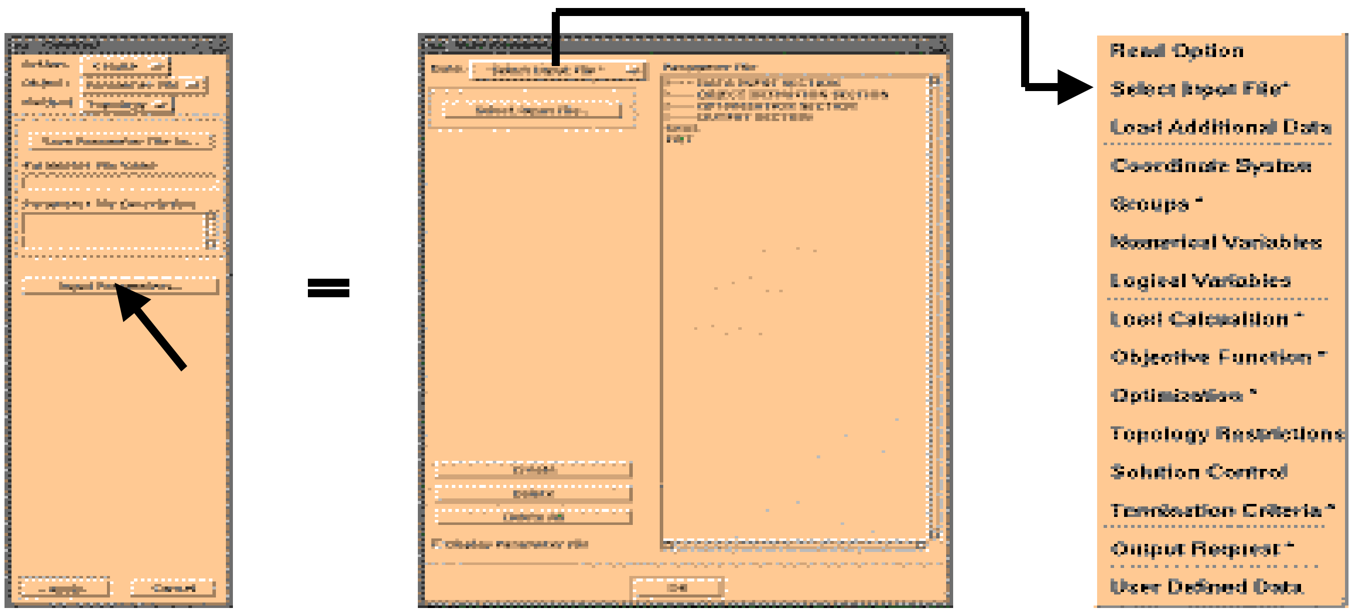


Figure 9: Graphical User Interface

Furthermore, postprocessing within MSC/PATRAN is possible with a fast results reader.

2.2 Restart

The new restart capability is especially important for large problems. This capability allows the results to be checked during the optimization process. It also helps avoid the re-run of a job from scratch when jobs are suspended for any reason.

2.3 Performance Improvements

The achieved performance improvements of the complete process are highlighted below using real-life examples. They always consist of two parts: performance improvements of MSC/NASTRAN, as well as improvements of the optimizer itself.

2.3.1 Topology Optimization of a Pump Lid

Figure 10 shows the topology optimization of a pump lid. The client's original design failed due to cracks. Therefore, a complete re-design was necessary. Starting from a CAD representation, the design space and frozen areas were defined. The FE-model had approximately 70.000 DOFs. The optimizer needed 23 iterations for a specified volume reduction of 90%. The new design proposal for the stiffening measures is also shown in figure 10.

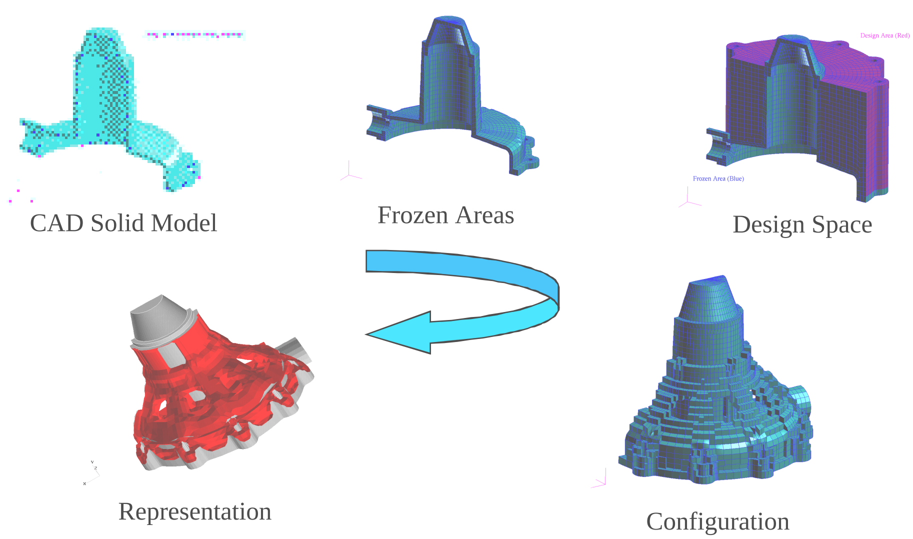


Figure 10

A performance comparison of MSC/NASTRAN V70.5 and MSC/CONSTRUCT V2.5 versus MSC/NASTRAN V70 and MSC/CONSTRUCT V2.0 showed a speed-up of 2x on a SGI R10000/180 (Table 1). Within MSC/NASTRAN the iterative solver was used.

Time per Iteration				Total Time		
MSC/CONSTRUCT V2.0	MSC/CONSTRUCT V2.5	MSC/NASTRAN V70	MSC/NASTRAN V70.5	MSC/CONSTRUCT V2.0 MSC/NASTRAN V70	MSC/CONSTRUCT V2.5 MSC/NASTRAN V70.5	Time Reduced
126 sec	48 sec	345 sec	205 sec	11304 sec	6072 sec	46 %

Table 1: Performance Comparison

2.3.2 Topology Optimization of A Bonnet

A topology optimization of a bonnet was performed by the company Pininfarina[2)] (Italy). Due to pedestrian impact safety requirements one design goal was to make the bonnet more compliant in the center area. An existing FE-shell model was used with about 330.000 DOFs. During the optimization, MSC/CONSTRUCT checked which stiffening measures could be left off while maintaining the torsional stiffness (Figure 11).

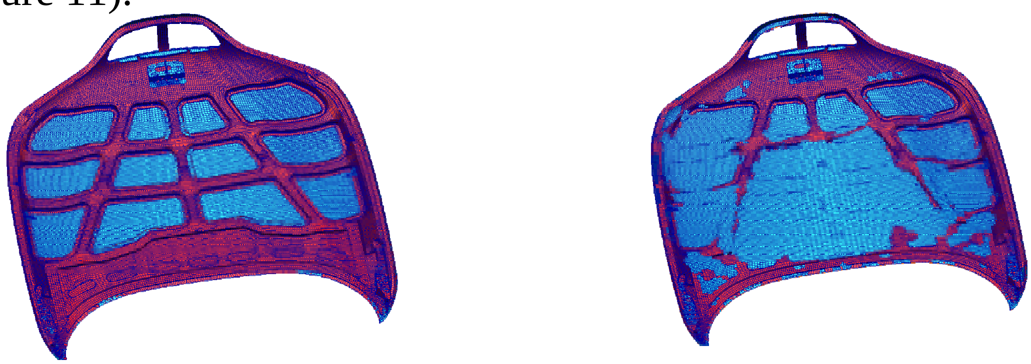


Figure 11: Topology Optimization of A Bonnet

Comparing the new versions of MSC/NASTRAN and MSC/CONSTRUCT with the previous ones resulted in a speed-up of about 3.8x (Table 2) on an HP workstation.

Time per Iteration				Total Time		
MSC/CONSTRUCT V2.0	MSC/CONSTRUCT V2.5	MSC/NASTRAN V70	MSC/NASTRAN V70.5	MSC/CONSTRUCT V2.0 MSC/NASTRAN V70	MSC/CONSTRUCT V2.5 MSC/NASTRAN V70.5	Time Reduced
355 sec	122 sec	2076 sec	520 sec	31603 sec	8346 sec	73 %

Table 2: Performance Comparison

2.3.3 Topology Optimization of A Fender

BMW used topology optimization for a check where stiffening measures would make sense on a fender in a wheel housing. For a correct introduction of the boundary conditions the complete assembly had to be considered (Figure 12). In this case, there were five loading conditions and three different constraint sets.

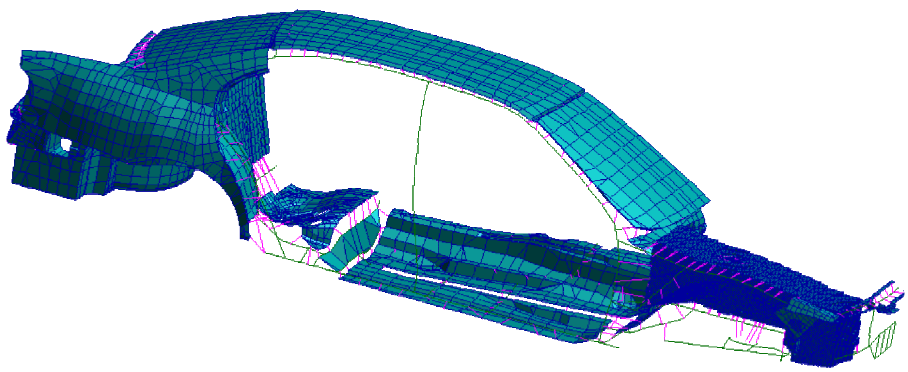
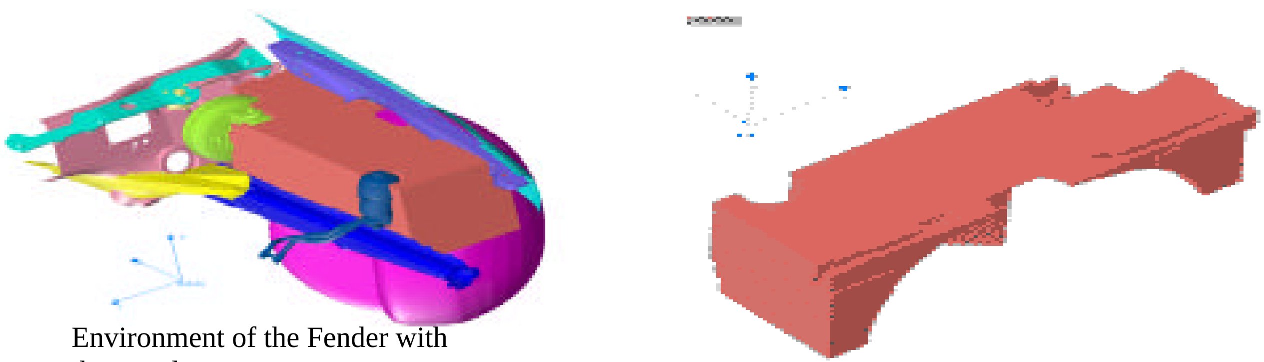


Figure 12: Topology Optimization of A Fender

The design space was defined in a CAD system (CATIA) and meshed using VOXEL technology (Figure 13). VOXEL technology normally is applied in collision investigations when putting together assemblies. It leads to a facetted FE-mesh, which is completely sufficient for topology optimization. The HEX-elements are of ideal quality, meaning equal side-length and 90° interior angles. They are extremely easy to generate. The required fine resolution resulted in 290.000 DOFs.



Environment of the Fender with the voxel space

Figure 13: Meshed Design Space Using the VOXEL Technology

Using VOXEL technology again, the end-result of the topology optimization could easily be transferred back to CAD. This procedure will also be presented by Mr. Ingo Raasch[3)] (BMW) during this conference.

Model after Optimization

Optimized Model in CATIA

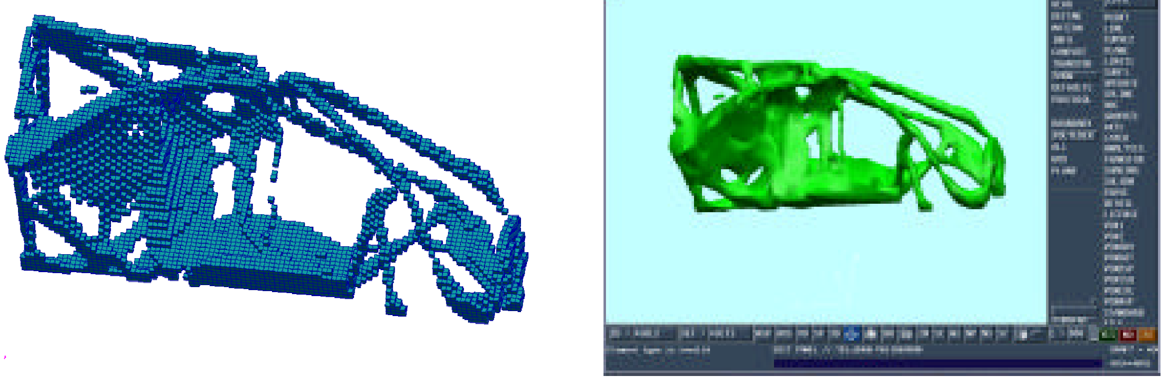


Figure 14: Results Transfer Back into CAD

Table 3 shows a speed-up of 18% for the complete run on SGI R10000/180. The speed-up of the optimizer was 7x. The run times for MSC/NASTRAN V70 and V70.5 were in the same order of magnitude.

Time per Iteration				Total Time		
MSC/CONSTRUCT V2.0	MSC/CONSTRUCT V2.5	MSC/NASTRAN V70	MSC/NASTRAN V70.5	MSC/CONSTRUCT V2.0 MSC/NASTRAN V70	MSC/CONSTRUCT V2.5 MSC/NASTRAN V70.5	Time Reduced
1625 sec	238 sec	14400 sec	13459 sec	464581 sec	390311 sec	18 %

Table 3: Performance Comparison

2.3.4 Evaluation of MSC/CONSTRUCT by AUDI

Our German client AUDI[4)] also evaluated MSC/CONSTRUCT V2.5 and MSC/NASTRAN V70.5 and compared the performance with MSC/CONSTRUCT V2.0 and MSC/NASTRAN V69. For a typical job mix for topology optimization, speed-ups were verified between 3x and 4x for the complete optimization process on SGI.

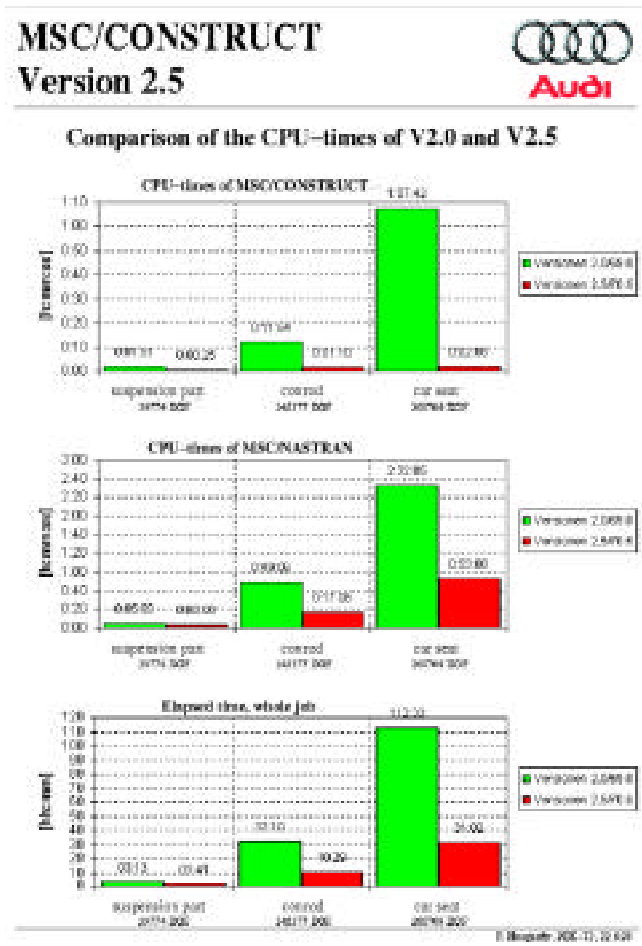


Figure 15: Performance Comparison at AUDI

2.4 Shape Basis Vector Generation for MSC/NASTRAN SOL 200 by MSC/CONSTRUCT

Shape optimization within MSC/NASTRAN SOL 200 is gradient-based and allowable shape changes have to be defined by shape basis vectors. The numerical optimization algorithm then determines the best linear combination of these shape basis vectors. These shape basis vectors can be defined manually, which is time consuming, or defined via auxiliary structures, which sometimes is difficult to control.

Other optimization approaches are the optimality criteria based ones, such as those implemented in MSC/CONSTRUCT. They have the advantage of generating new shapes without the necessity of shape basis vectors. Their disadvantage is their lack of handling arbitrary, robust objective functions and constraints.

Therefore, using MSC/CONSTRUCT for the shape basis vector generation can help significantly to exploit the rich optimization capabilities of MSC/NASTRAN and automate that process. Shape optimization with MSC/CONSTRUCT results in an optimum shape in terms of a homogenous strain distribution and delivers a corresponding displacement vector, which describes the change from the original shape to the optimum shape.

For each design node, this displacement vector can be generated either after each optimization iteration or just at the end of the run and written out via DVGRID entries. Subsequently, these can be used as shape basis vectors for SOL 200.

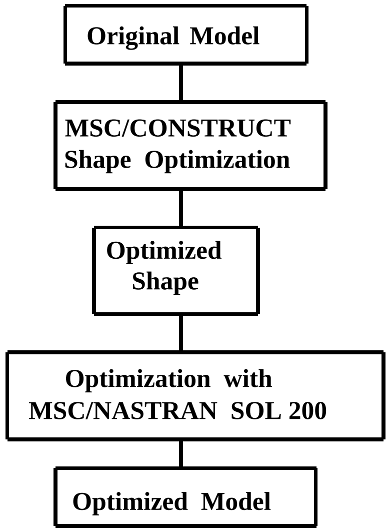


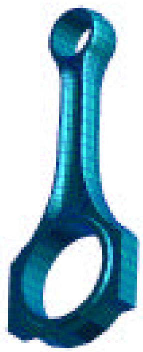
Figure 16: Generation of the Shape Basis Vectors

In several examples, this procedure was verified. The conrod example in Figure 17 proves that MSC/NASTRAN SOL 200 delivers the same shape changes as MSC/CONSTRUCT for linear statics, when using MSC/CONSTRUCT with the corresponding optimized shape via DVGRID entries.

However, this does not mean that SOL 200 will just re-do the MSC/CONSTRUCT run. Rather, SOL 200 would be able to make a much more refined shape optimization considering all kinds of constraints in the area of structural, multi-disciplinary optimization, using these shape basis vectors generated in a much more automated way.

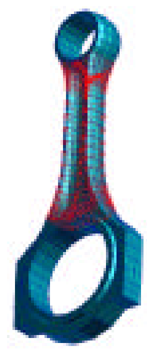
This procedure also was successfully applied by BMW and results presented during this conference by Mr. Ingo Raasch[3)].

Example: CONROD



GRIDs	4576
HEXAs	3484
DOFs	13215
DVGRIDs	739

Surface nodes of MSC/CONSTRUCT
= DVGRID entries for SOL 200



SHAPE CHANGE:

MSC/CONSTRUCT MSC/NASTRAN/SOL 200

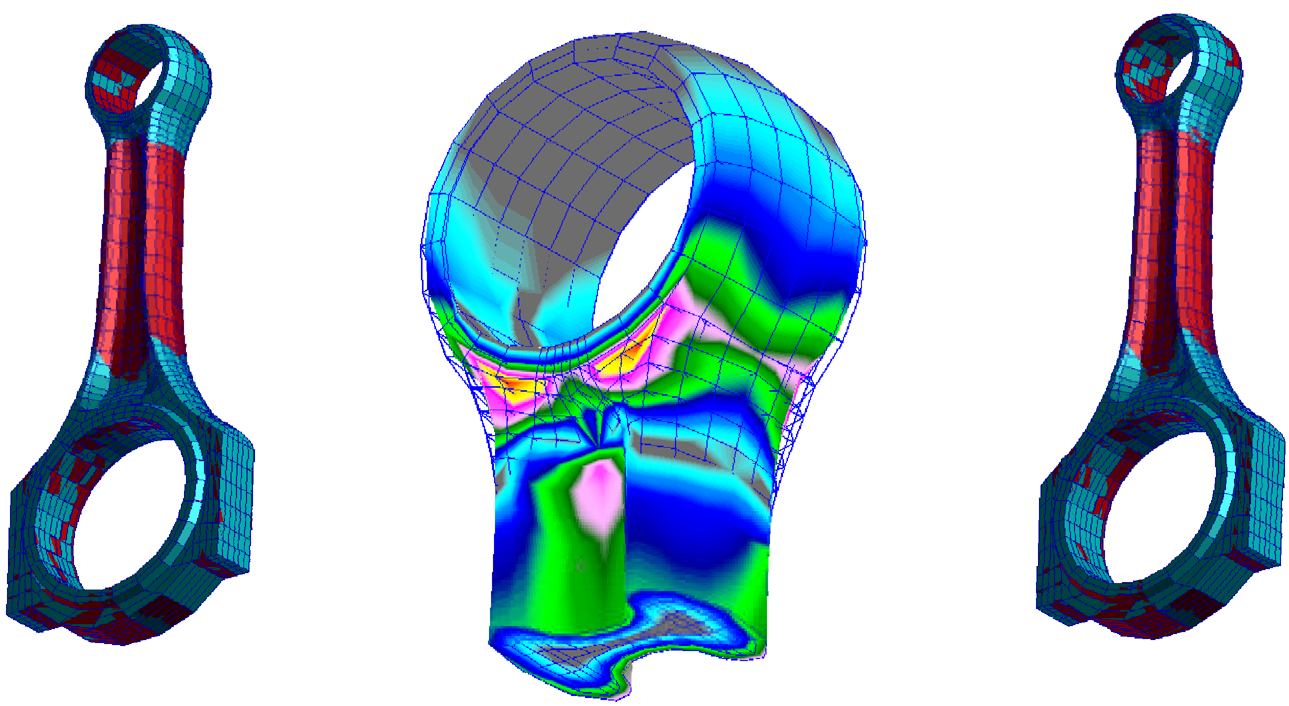


Figure 17: Coupled Shape Optimization Using MSC/CONSTRUCT and MSC/NASTRAN

3. Conclusion

MSC/CONSTRUCT is an optimization package for topology and non-parametric shape optimization. It is fast and easy-to-use and enables engineers to explore the available design space in a more generic way, as opposed to gradient-based techniques.

Important ease-of-use improvements were introduced in MSC/CONSTRUCT V2.5, including an MSC/PATRAN graphical user interface and a restart capability. The performance improvements compared to the previous version are significant. An automated generation of the shape basis vectors for MSC/NASTRAN enables a much more convenient usage of shape optimization within SOL 200.

4. References

1) MSC/CONSTRUCT User's Manual, Version 2.5
The MacNeal-Schwendler Corporation
Los Angeles, CA
September 1998

2) Müller, O.
HIPOP, HIgh Performance OPtimization, a European funded project within ESPRIT – High Performance Computing and Networking, Progress Report, PRO 7-12

3) Raasch, I.
Usage of Optimization Tools in the Design Process at BMW
Proceedings of the MSC User's Conference, October 1998

4) Hougardy, P.
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