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Application area of CAD-parametric optimization

- **Improvement**
  - Existing products can be improved.
  - Products can be modified for further applications
- **Development**
  - In an early product state a (nearly) virtual development is possible.
  - With coupling of FEA and OptiSLang an innovative product can be developed before a real sample exists.

At Brose several products were handled with OptiSLang with a number of parameters between 3 and 22.

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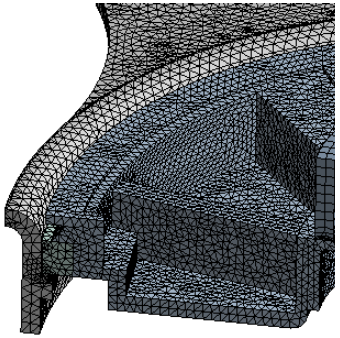
Strategies of parameterization

- **Direct Interface between CAD and FE**
  - For sensitivity and robustness of existing products.
  - A direct optimization of the design in the CAD-system is possible.
  - Our experience: recommendable up to 9 parameters.

- **CAD interface + FEM applicable simplifications**
  - If CAD-model needs modification for effective meshing.
  - If partial design correction is needed.

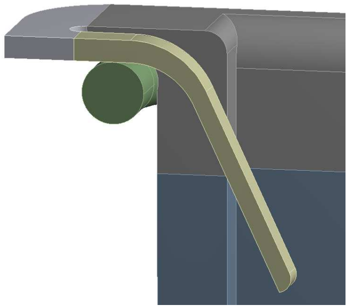
- **Complete new geometry with ANSYS DesignModeler**
  - For more complex CAD-Models.
  - For complete new development before any CAD model exists.

Concrete examples



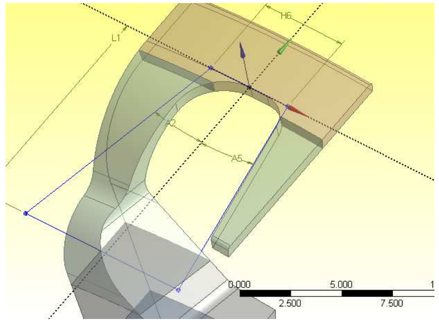
"very simple"

Additional rib with 3 parameters



"more complex"

Simple 3D part with 8 parameters



"advanced"

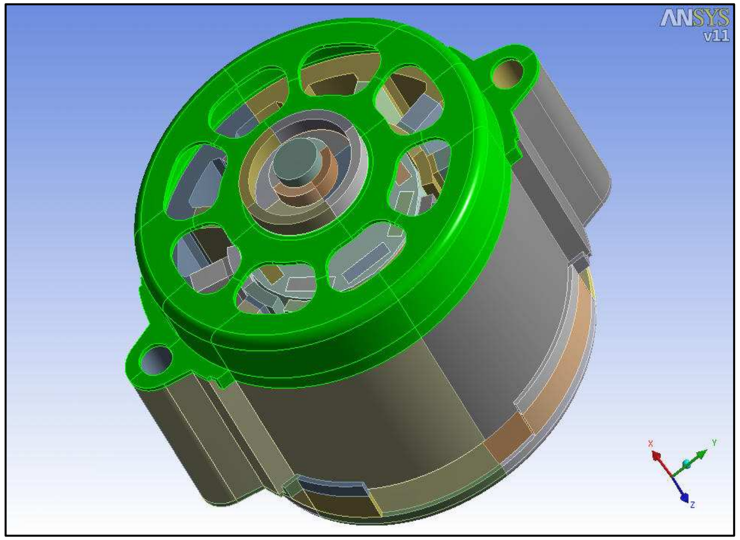
DM Geometry with

15 parameters, geometric constraints are needed to check wall thickness.

Product improvement

Example: Bearing shield of a motor

- Problem: On the test bench (shaker) the excitation of an eigenfrequency of the motor causes a mechanical overload of the bearing shield (resonance).



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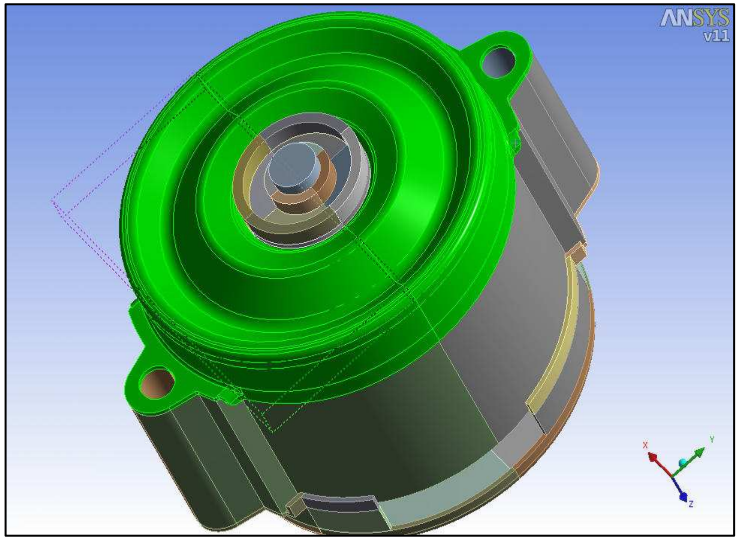
Product improvement

- Correction: By increasing the stiffness of one bearing shield the motor eigenfrequency must be increased, to avoid dynamic overstressing.
- For increasing stiffness a parametric FE-model is generated in the ANSYS Workbench environment. This model is used for optimization with OptiSlang.



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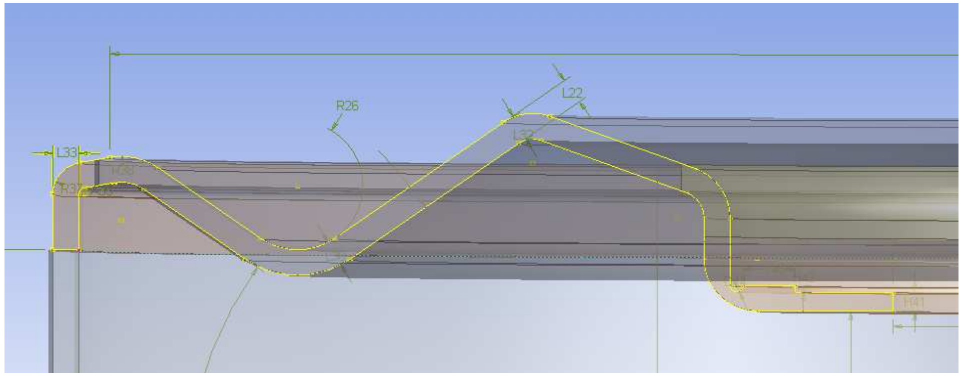
Product improvement
Parametric FE - model

- **A parametric geometry is generated with the ANSYS DesignModeler. Instead of the original plane area 4 angles are designed, which form a circular stiffening corrugation . The geometry includes 8 parameters:**

- DS_angle1
- DS_angle2
- DS_angle3
- DS_ angle4
- DS_Radius1
- DS_Radius2
- DS_Radius3
- DS_ distance



- **The FE–model is meshed with quadratic hexahedrons in a high quality.**

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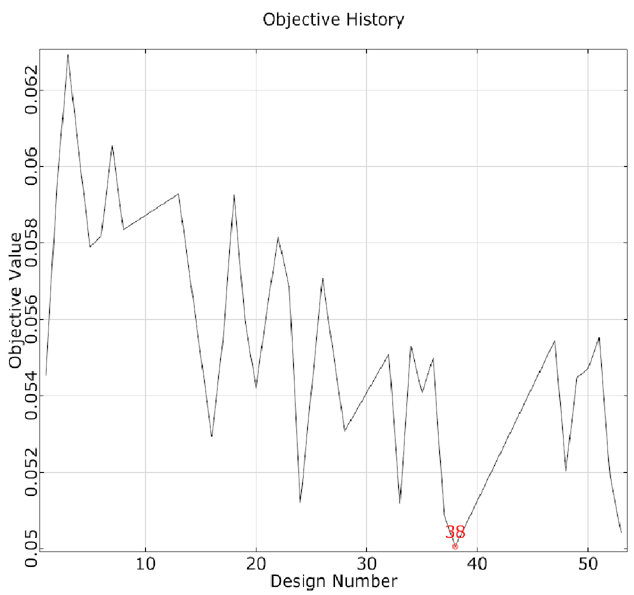
Product improvement

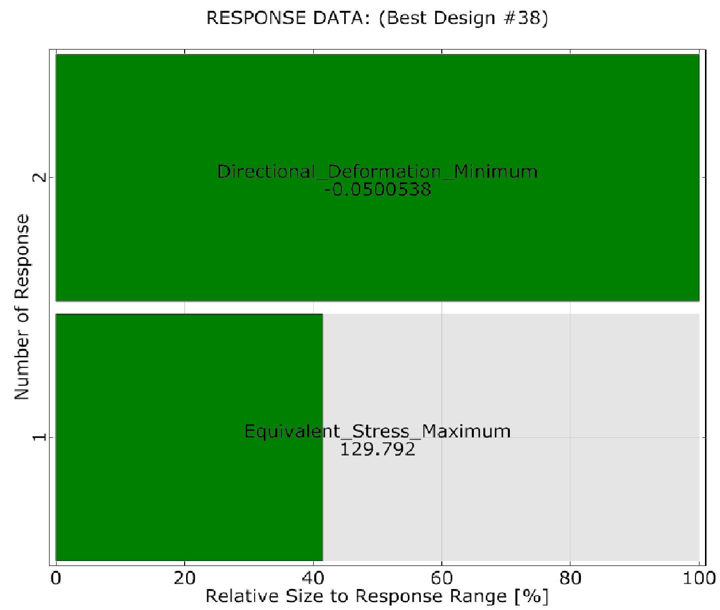
- Tools for optimization:
- FE solver ANSYS (Workbench environment)
- Original CAD model ProE, modification and parameterization DesignModeler
- Optimization OptiSLang
- To minimize calculation time the FE model is loaded in the linear elastic region.
- A sensitivity analysis was made to check the relevance of parameters .
- Method: Adaptive Response Surface Method (ARSM).
- Objective: Deformation in axial direction abs(Directional_Deformation_Minimum)

Product improvement

After 53 calculated designs the optimization runs into invalid geometries, regeneration failures occur.

At this point the best Design 38 is deformed by 0,05mm at a load of 200N, regarding the original design this is an increasing of the stiffness by a Factor 4!





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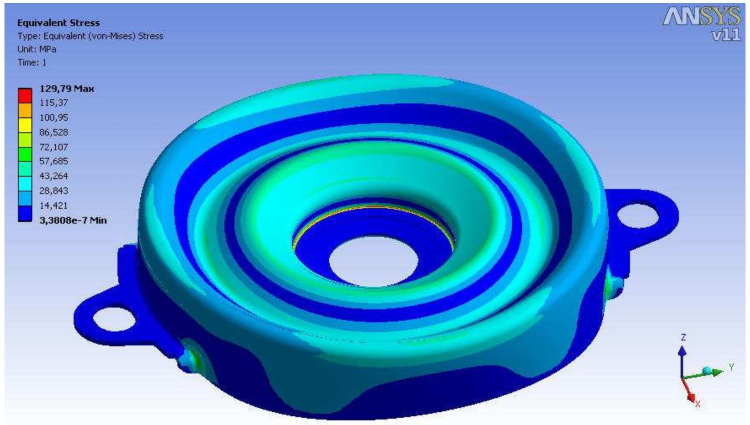
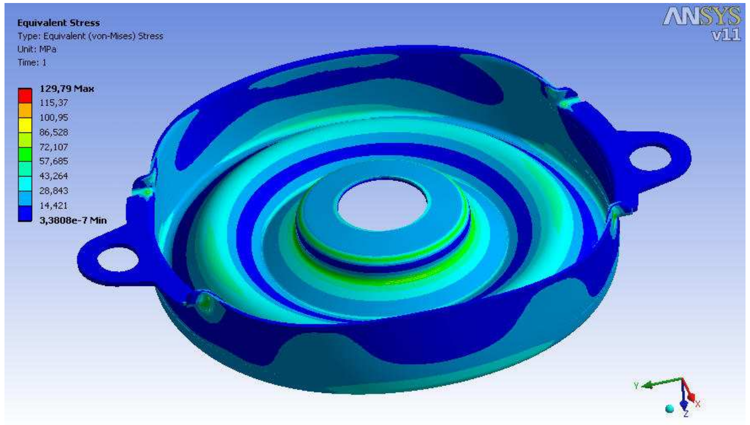
Product improvement optimization output

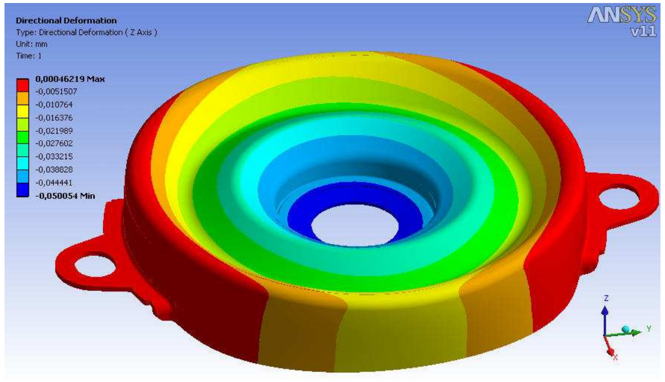
The FEA of the optimized Design 38 shows a consistent stress distribution, the maximum stress is significant lower.



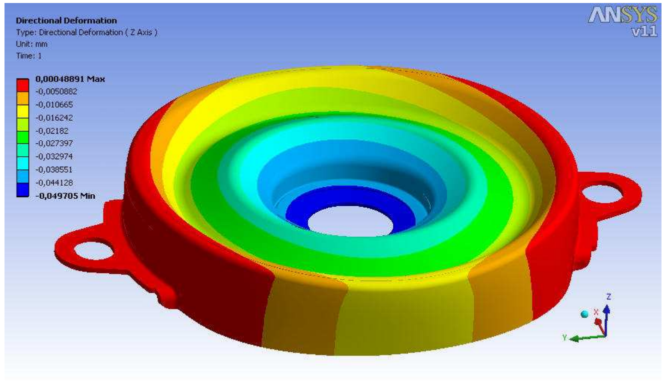


Product improvement

- **For a suitable production the parameters are to adjust slightly:**
- **All parameters are rounded to even numbers. Thereby the sensitivity analysis made earlier points the direction.**
- **The modified Design is calculated again:**
- **The stiffness is even higher!**



Design 38: Deformation 0,05mm



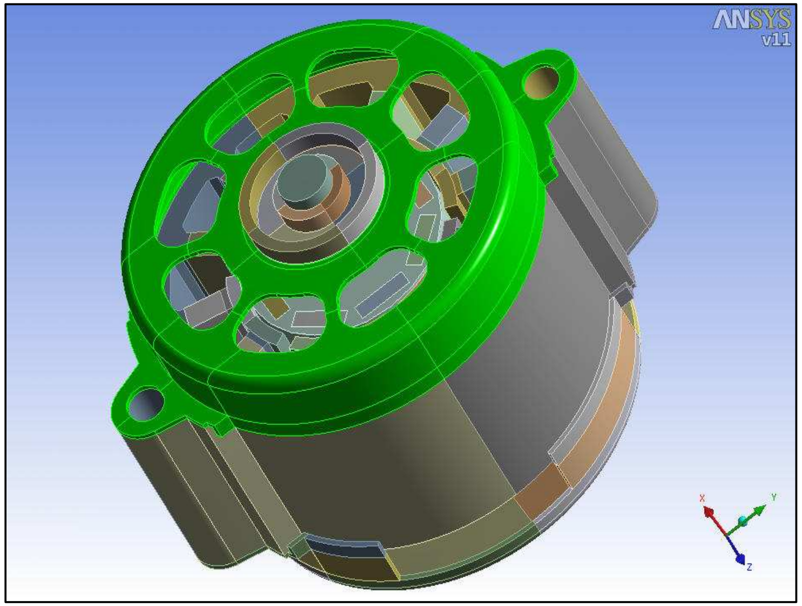
Modified model: Deformation 0,0497mm

Product improvement

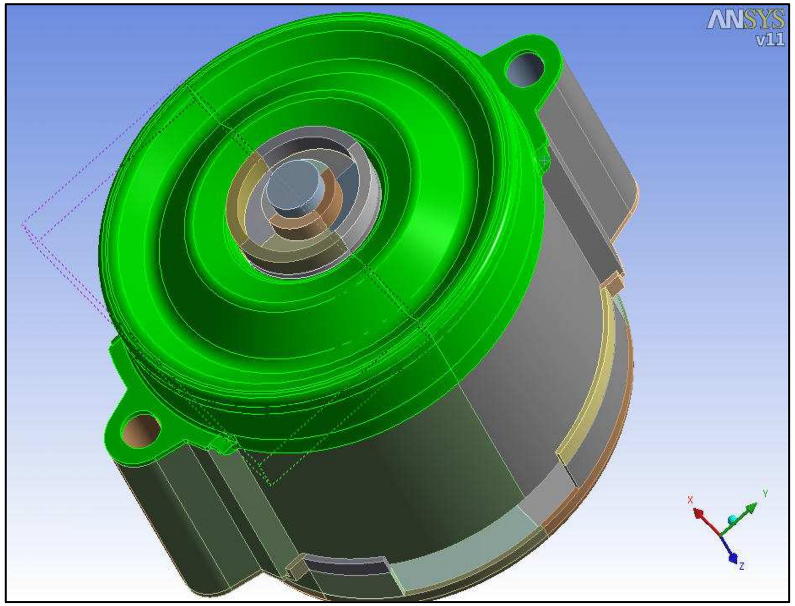
Modal analysis

- **Now the modified bearing shield is used for a dynamic FE-model with respect to the motor masses like at the test bench.**

  Object of comparison is the axial resonance frequency.



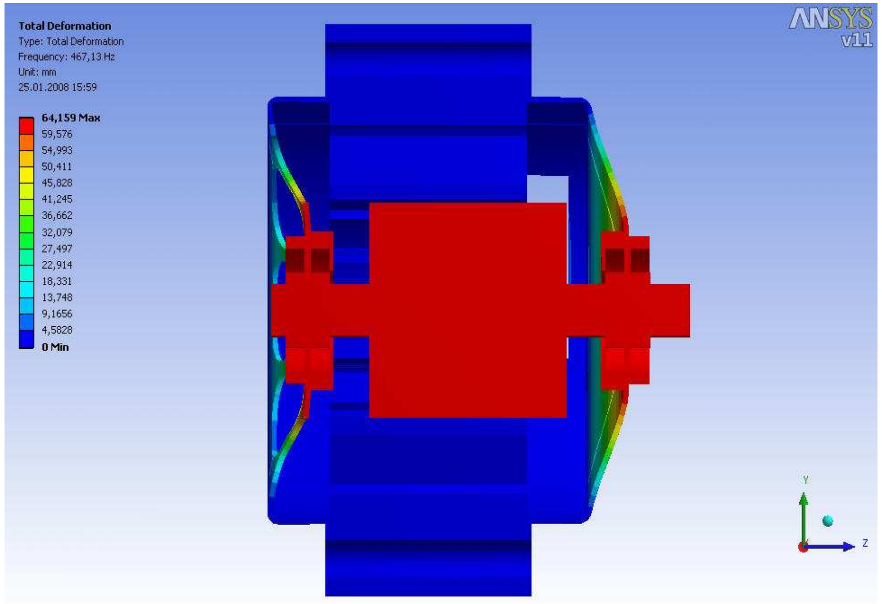
FEM model with original B-bearing shield



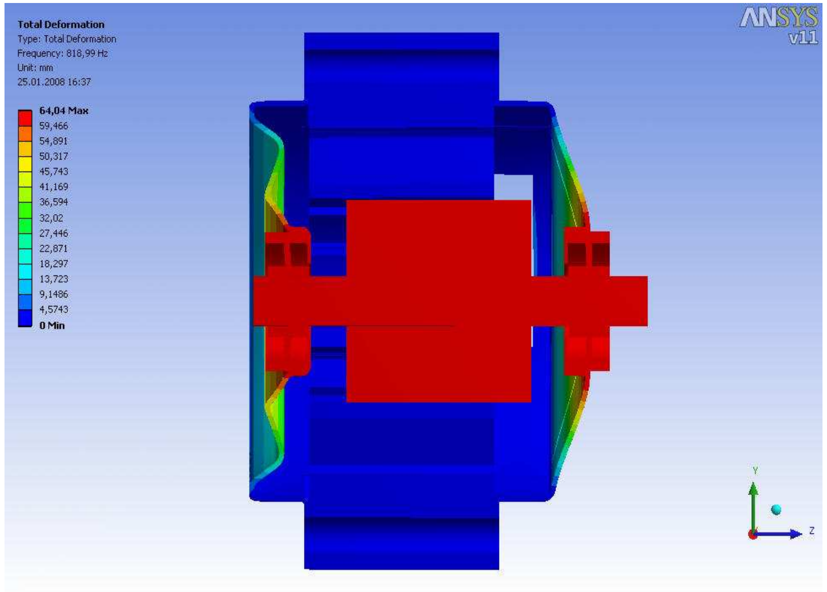
FEM model with B-bearing shield out of optimization

Product improvement

Modal analysis



Axial mode of original: ca. **460 Hz**

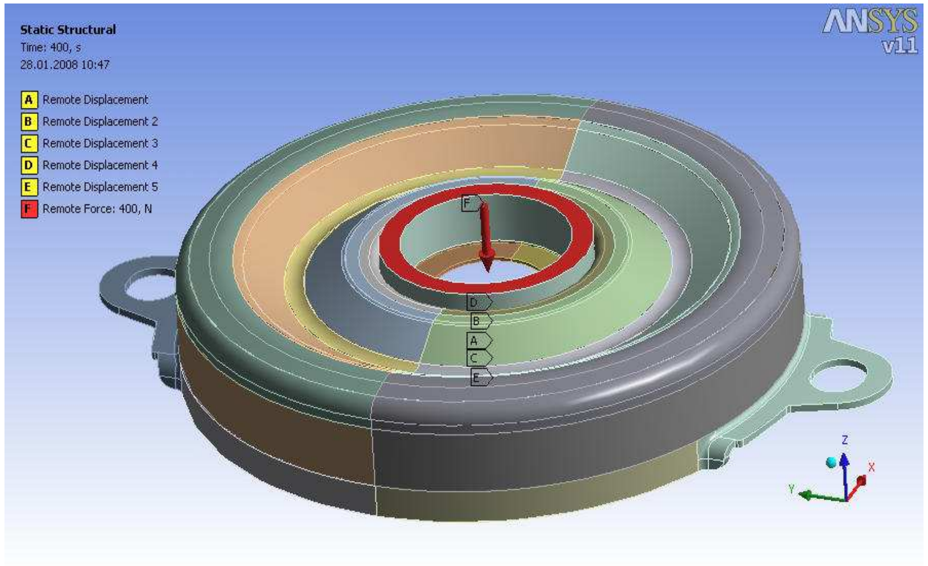


Axial mode of optimized model: ca. **820 Hz**

The frequency is increased about 80%!

Product improvement

- For validation finally a static nonlinear FEA is performed:
- Nonlinear material
- Contact at the bearing seat
- Higher load



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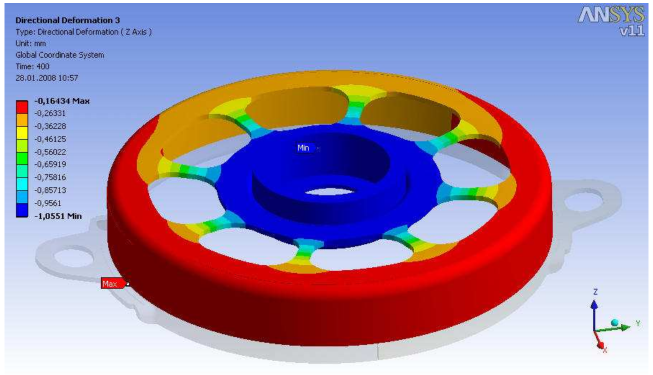
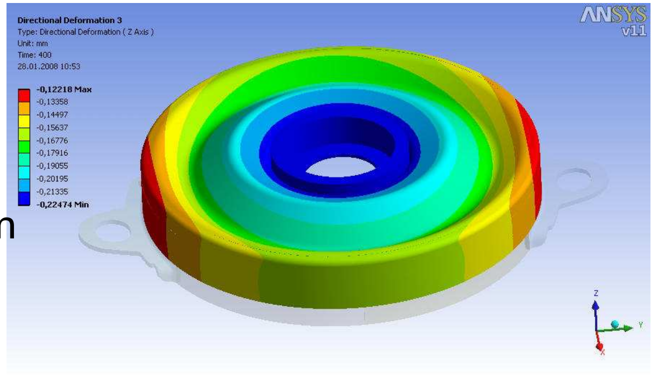
Product improvement

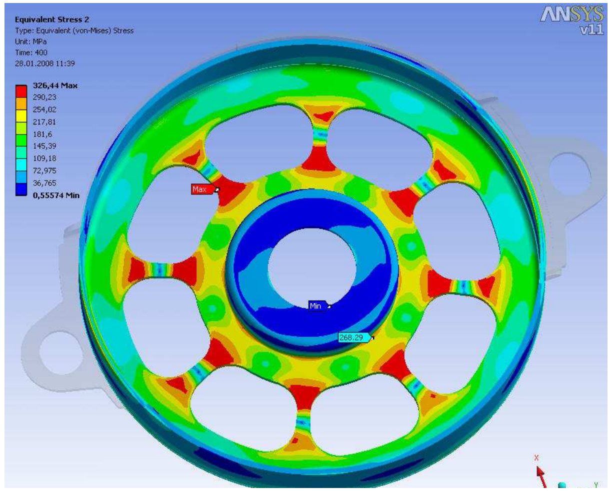


Deformation

Old: 1,05mm

New: 0,22mm

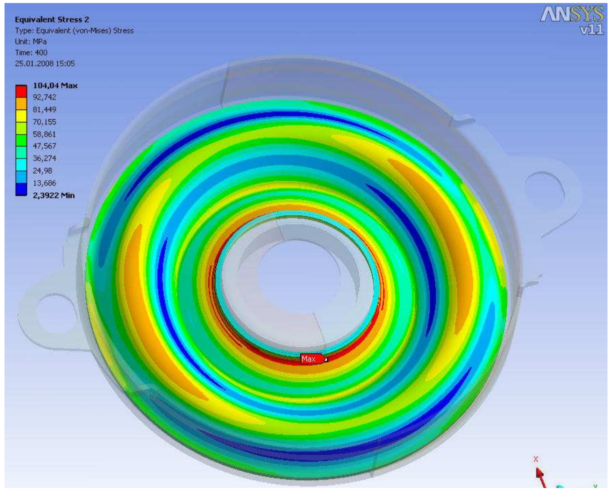




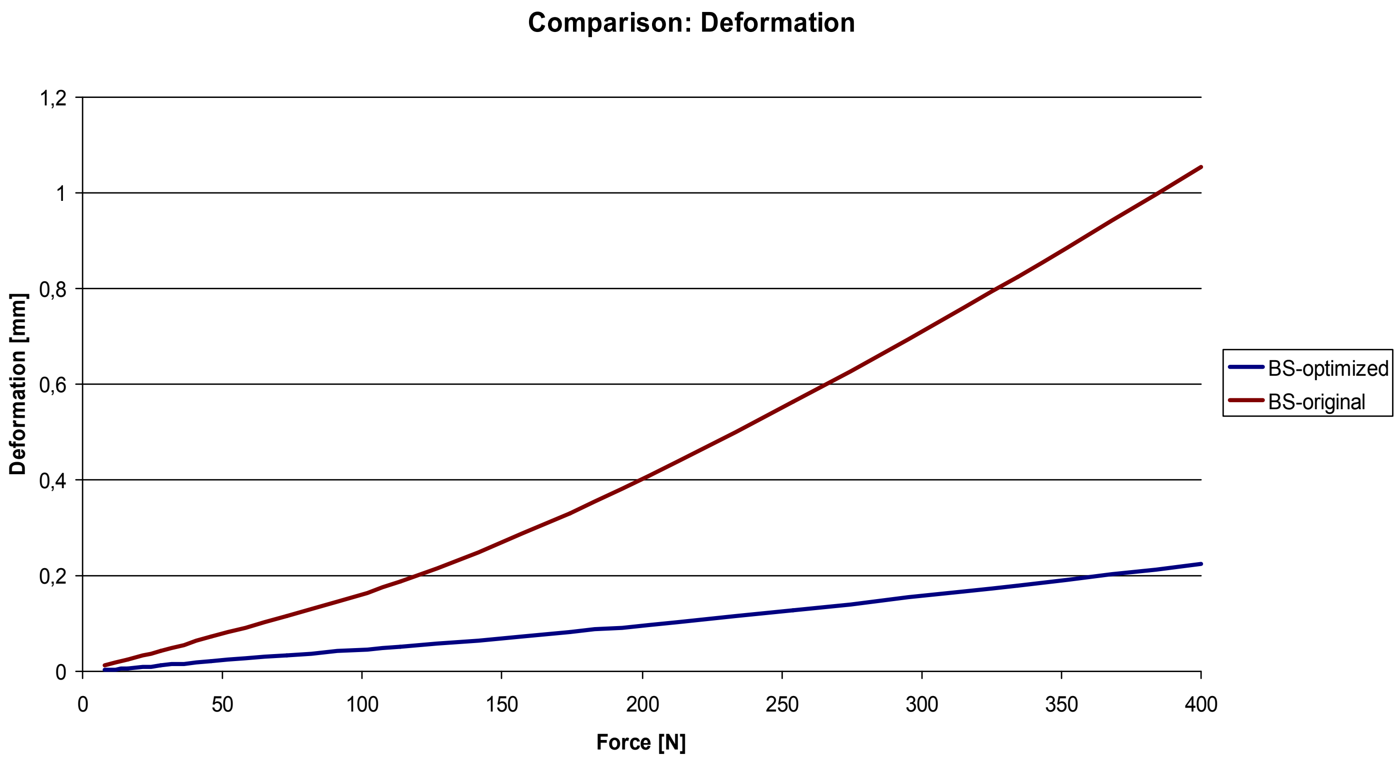
Equiv. stress

Old: 326MPa

New: 104MPa



Product improvement



The behavior is now nearly linear!

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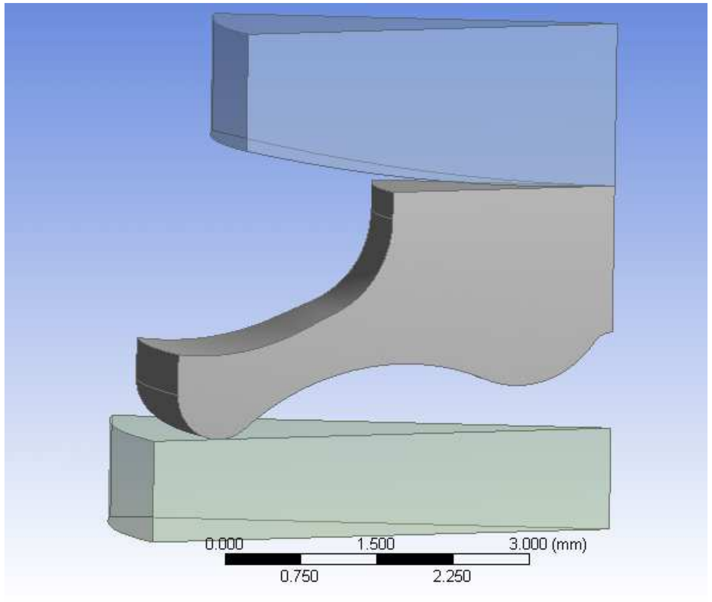
Product development

1. Design and parameterization within the DesignModeler

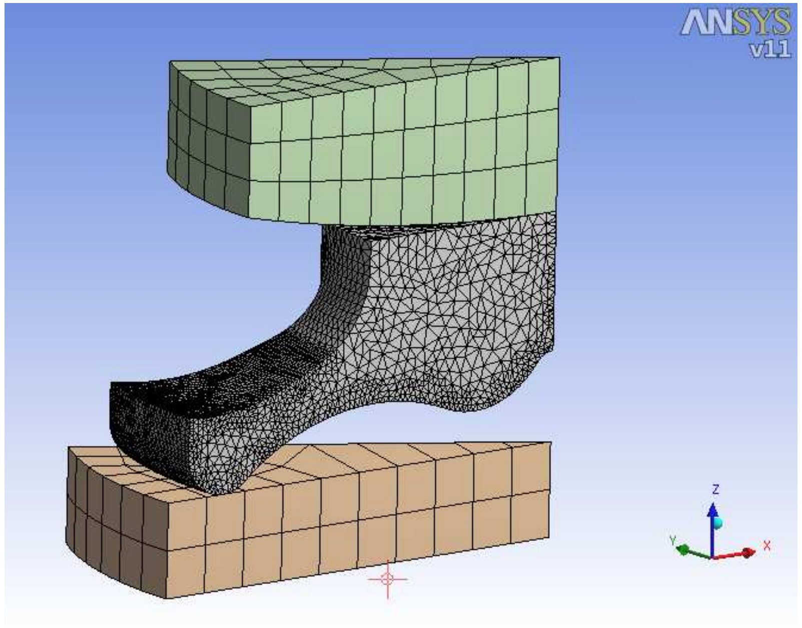
- Complete new idea, no CAD model existing.
- Geometry can be modeled for purpose of FEA from the beginning!



Product development

2. Generate FE-model in ANSYS

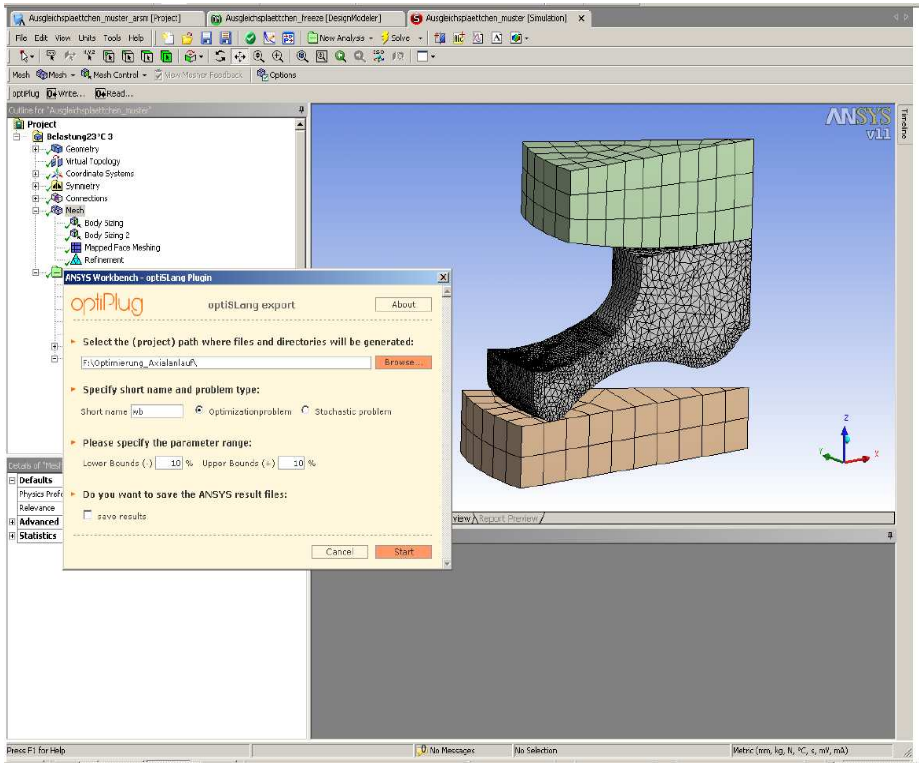
- The mesh is performed accurate for all possible combinations of parameters.
- A extra fine tetrahedron mesh ensures a good input for the optimization.



Product development

3. Problem file with Optiplug

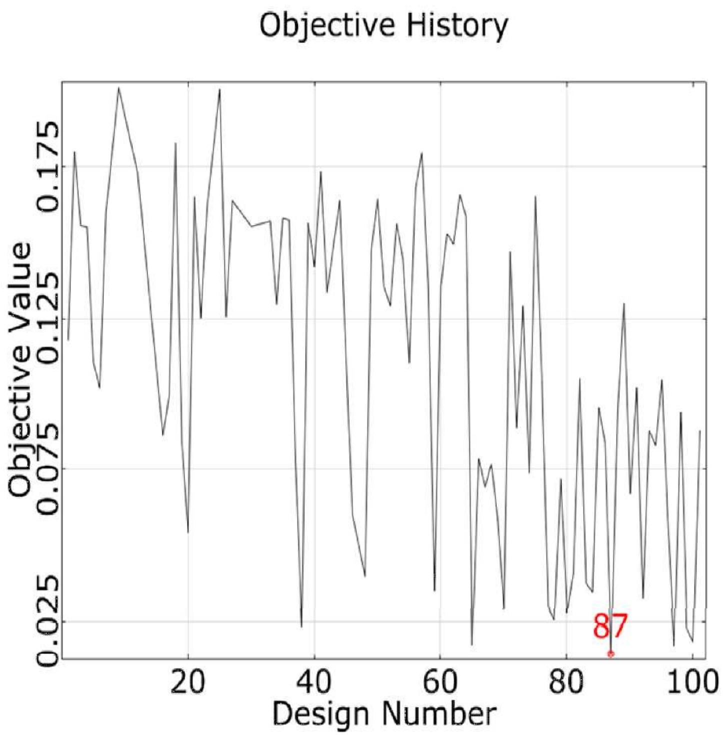
- At the push of a button Optiplug writes the input parameters, output parameters and the problem file for further handling within OptiSLang.
- Example: 12 parameters.



Product development

4. Optimization with OptiSLang

- After sensitivity analysis the optimization is started.
- In this example (<15 parameter) the ARSM is chosen for optimization.



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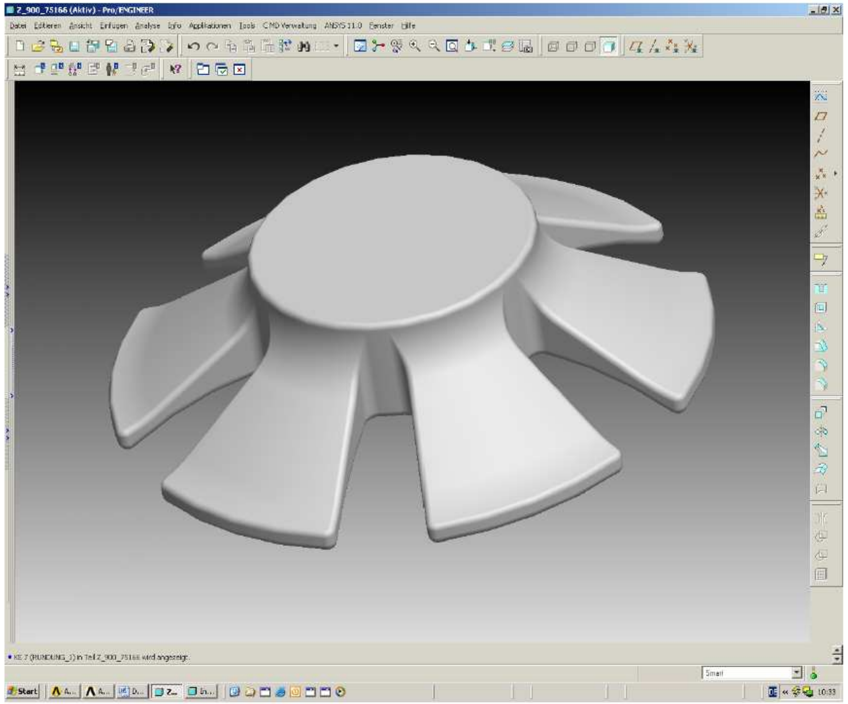
Product development

5. Generation of the CAD model

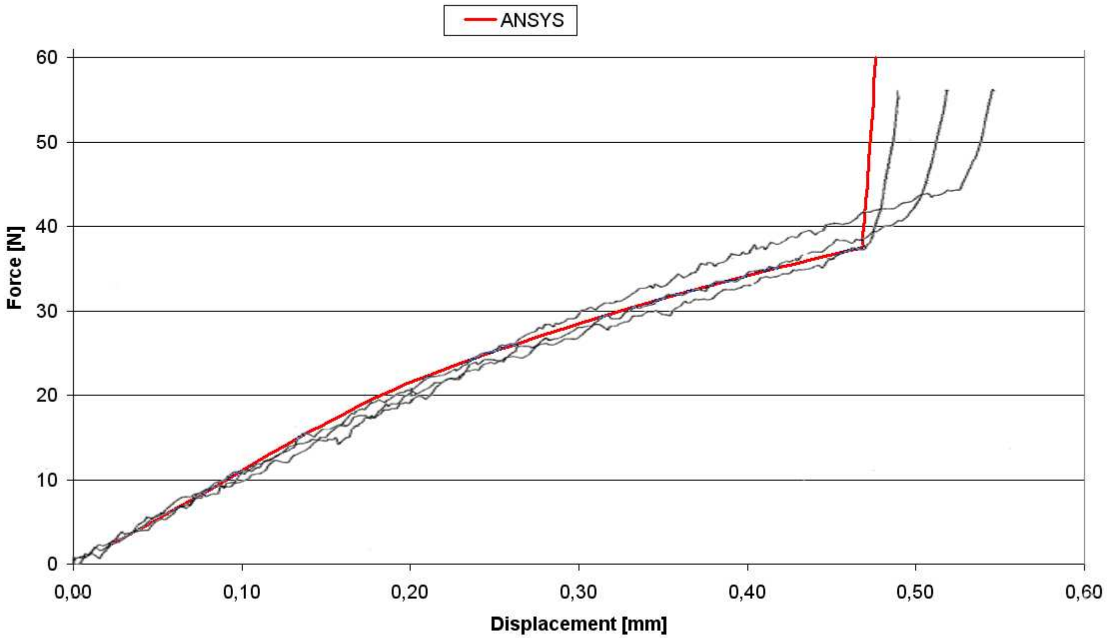
- Parameters are rounded to suitable dimensions.
- The modified geometry is calculated again.
- A CAD file is generated.
- A possible supplier gets a step file for an expert opinion in view to producibility.



Product development

Calculation and validation.

As soon as a sample exists, the FE calculation is compared to a simple measurement and in doing so the model is validated.



Conclusions

- Several areas of applications exists.
- OptiSLang can be used for complex geometries as well as for simple problems
- With accurate FE-models a nearly virtual development is possible.
- In the case of virtual development tolerances and variability for robustness must be determined with samples.