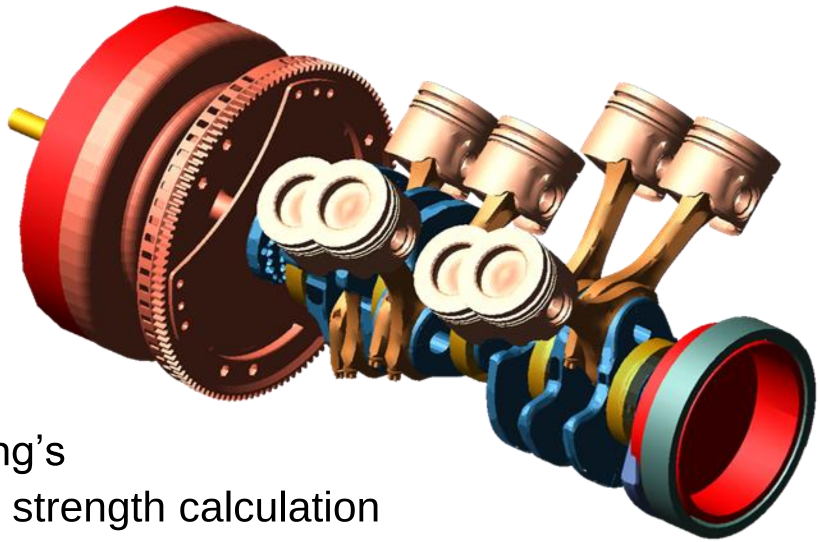
Audi
Vorsprung durch Technik

Mapping of Pressure Distributions & Displacements using ANSA & μETA

Reinhard Wersching, Audi AG Neckarsulm

Overview



- Mapping of pressure distributions by **ANSA**
  - Transfer the pressure distributions of the bearing's Elasto-Hydro-Dynamic (EHD) calculation in the strength calculation using Abaqus or Nastran

- Mapping of displacements using **μETA**
  - Automated transfer of displacements from an ADAMS calculation in NASTRAN format to a stress recalculation

Mapping of Pressure Distributions using ANSA

One of the results of an EHD calculation for a connecting rod bearing
is the oil film pressure distribution during a single rotation, at any time and any position.

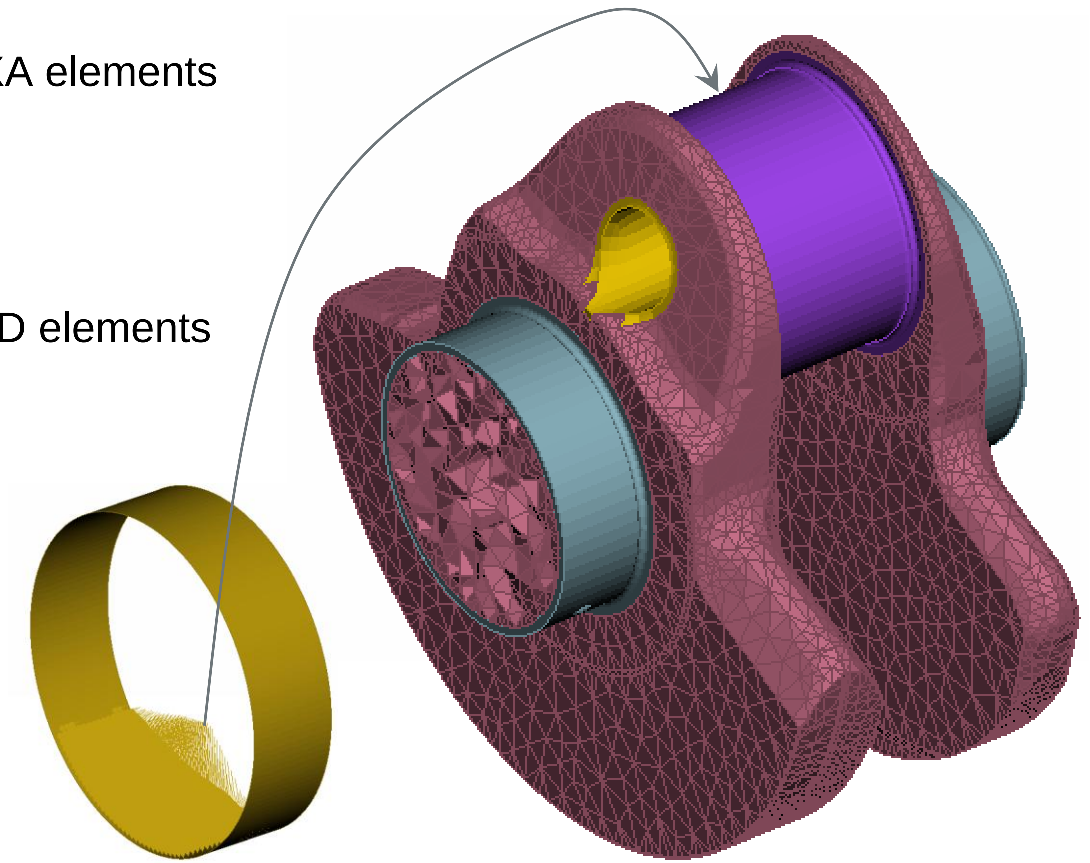
For a FE analysis of the crankshaft, the load pressure distribution should be mapped from the EHD-mesh to the FE model mesh with the help of ANSA.

Task:

- Step 1: Import in ANSA the Nastran finite element model
- Step 2 : Read the EHD pressures in Abaqus format
- Step 3: Map the results

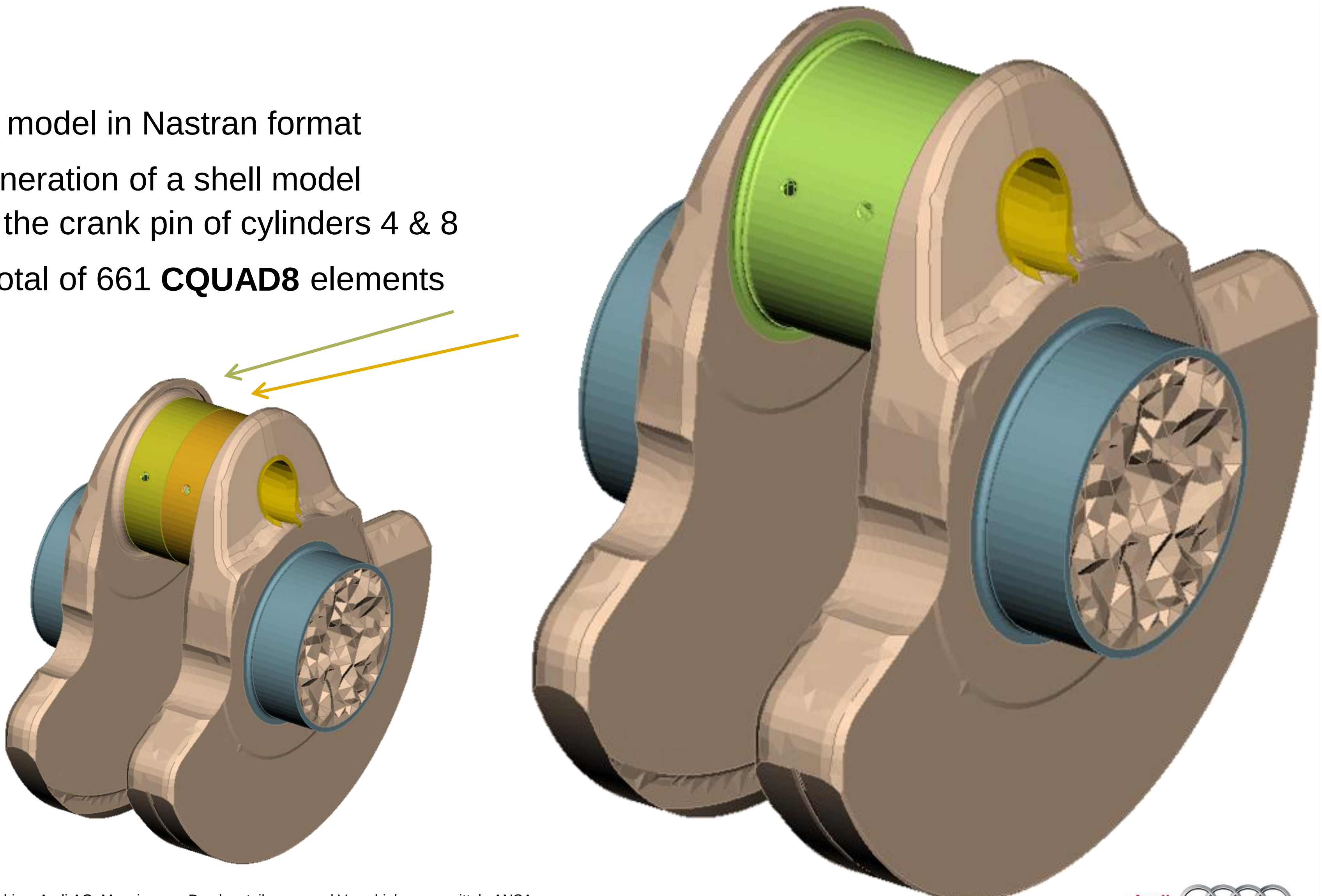
Mapping of Pressure Distributions using ANSA

- Initial modeling conditions
  - V8 crankshaft:
    Nastran model of 2nd order HEXA elements
  - Bearing:
    Abaqus model of 1st order QUAD elements
    with pressure distribution
    from a EHD calculation

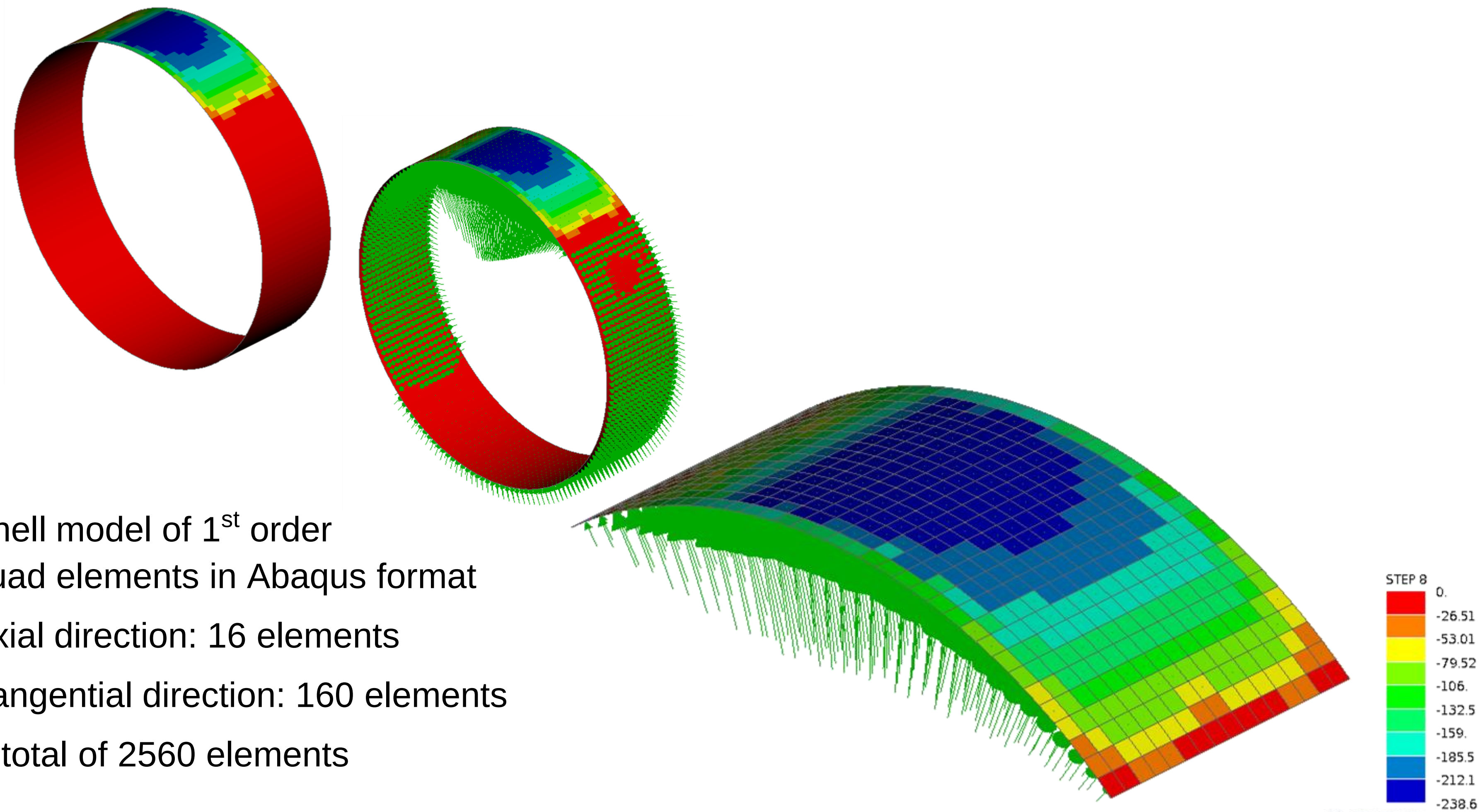


Mapping of Pressure Distributions using ANSA
Step 1: Import the FE model

- FE model in Nastran format
- Generation of a shell model
  for the crank pin of cylinders 4 & 8
- A total of 661 **CQUAD8** elements



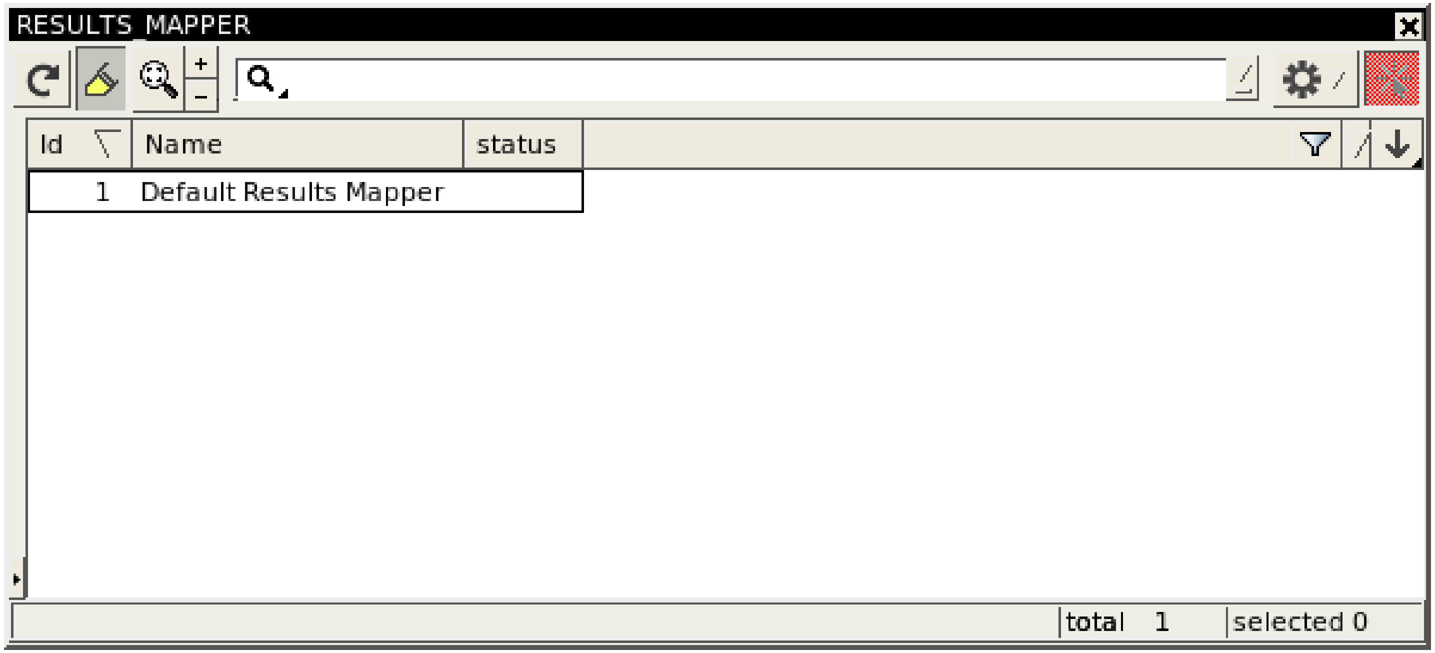
Mapping of Pressure Distributions using ANSA
Step 2 : Read the EHD FE-model with the pressures



- Shell model of 1st order quad elements in Abaqus format
- Axial direction: 16 elements
- Tangential direction: 160 elements
- A total of 2560 elements

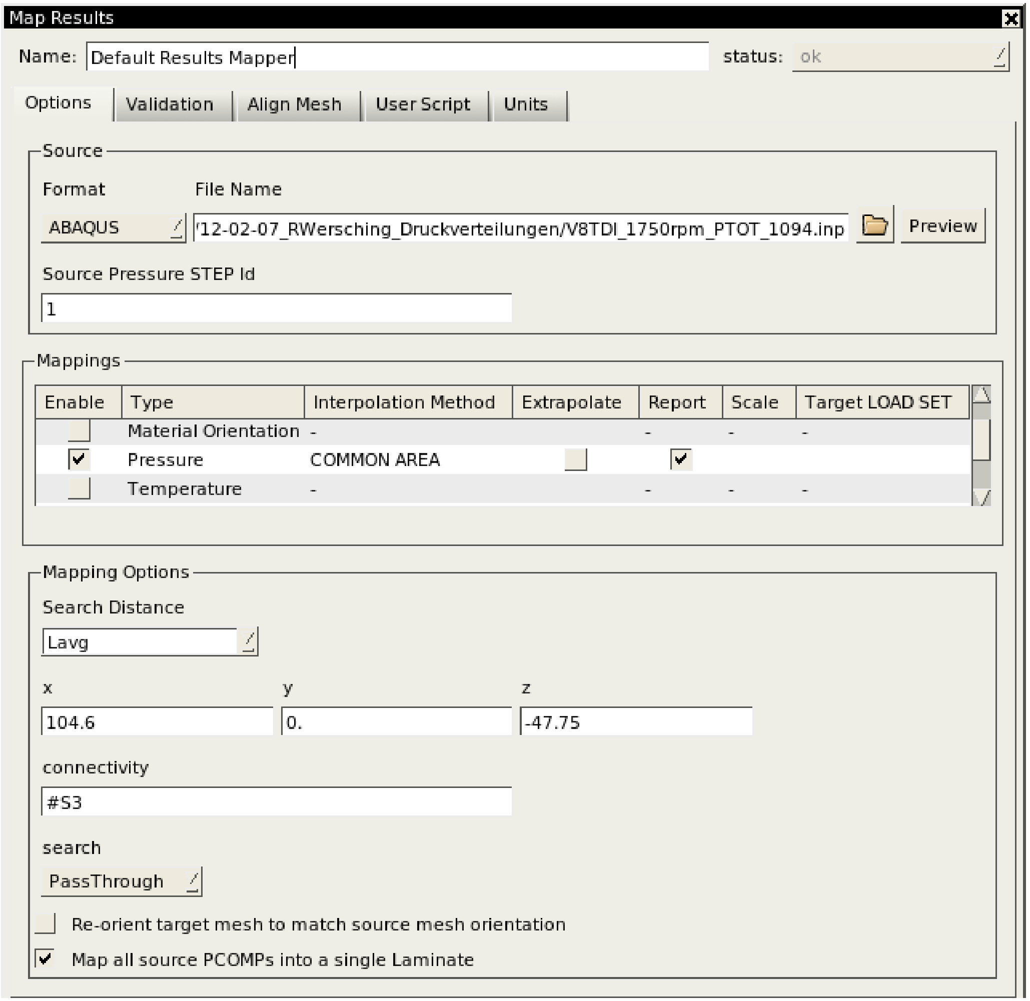
Mapping of Pressure Distributions using ANSA
Step 3: Results mapping

- Results Mapping in ANSA
  - Deck: NASTRAN>AUXILIARIES>RES.MAP
    This function maps data regarding nodal thickness, pressure, initial stress etc. from an existing solver file to a different mesh
  - Right Mouse select "NEW" button to define a new Map Result.
  - Double Click / Open "Default Results Mapper"



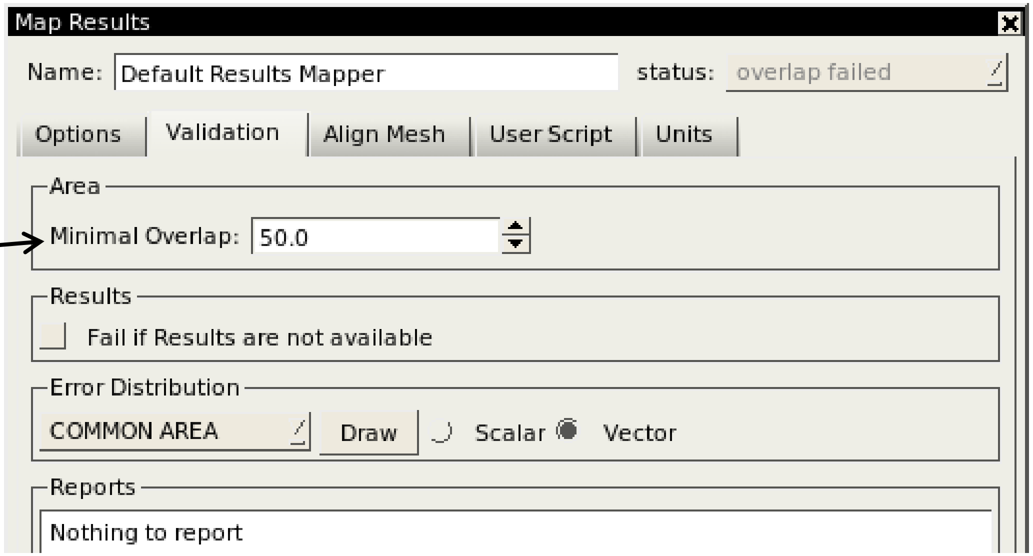
Mapping of Pressure Distributions using ANSA
Step 3: Results mapping

- *Map Results* window: *Options* tab
- *Source* information
- *STEP Id*
- Result mapping information: Pressure, COMMON AREA
- Position of center point
- *connectivity*: current (target) mesh, where mapping will be applied ⇨ Shell Elements of SET 3 (crank-pin 8)
- Orientation of Pressure Load

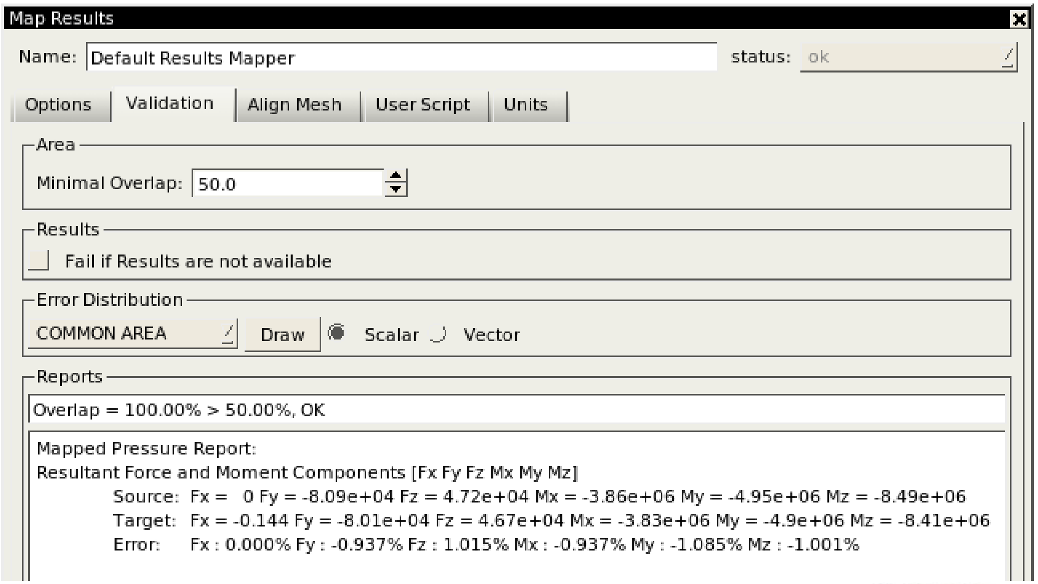


Mapping of Pressure Distributions using ANSA

- *Map Results* window: *Validation* tab
- Important: *Minimal Overlap* to aid the mapping of the optimal Area / Region

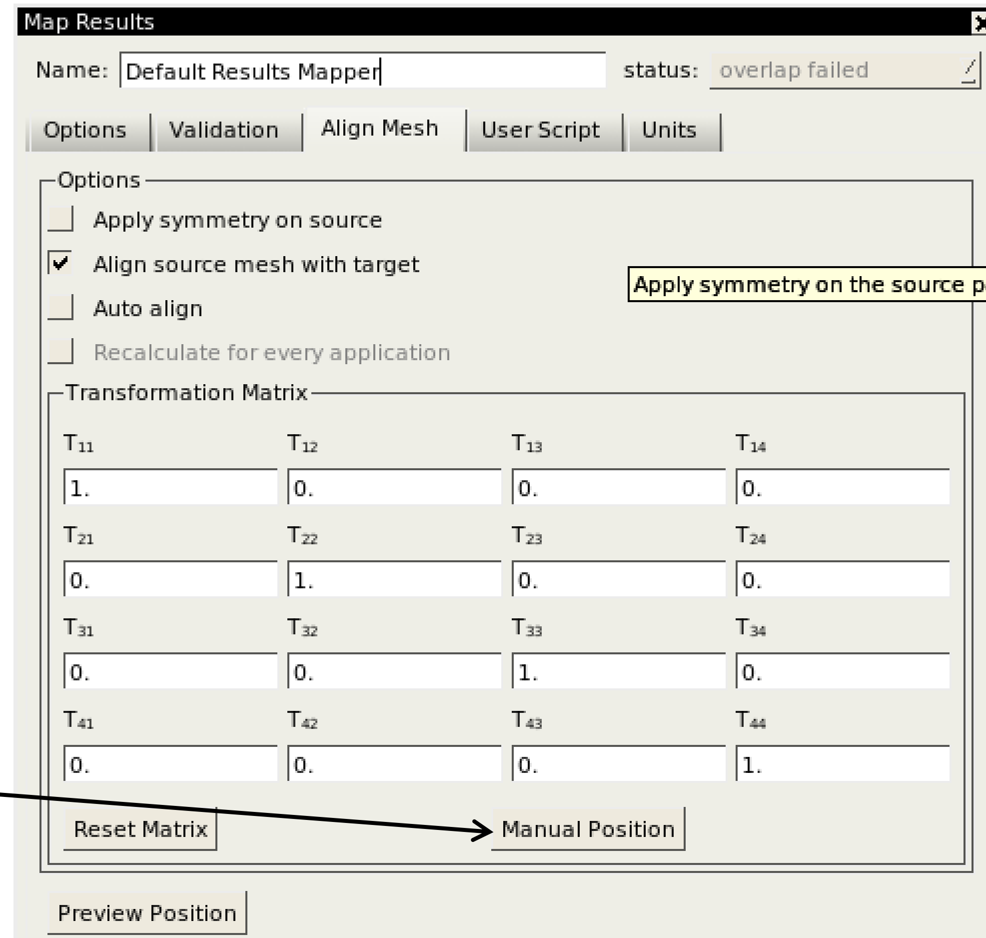


- *Reports*: Feedback about Transformation of Results
- ... before Mapping
- ... after Mapping



Mapping of Pressure Distributions using ANSA

- *Map Results* window: *Align Mesh* tab
- *Align the source with the target mesh*
- *Transformation Matrix*:
  Table for units' and position transformation
- Coordinates can be derived interactively:
  Select *Manual Position*



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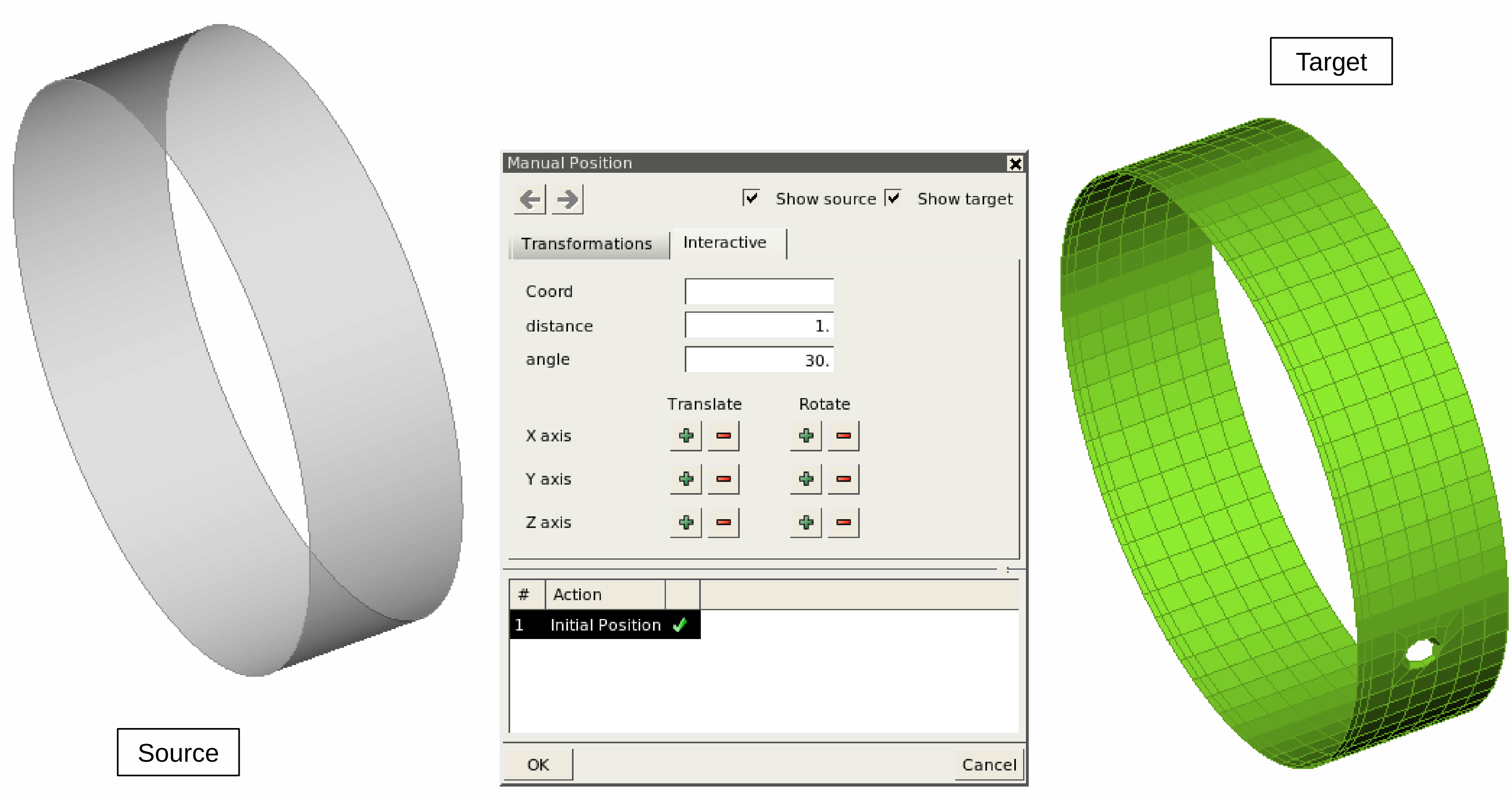
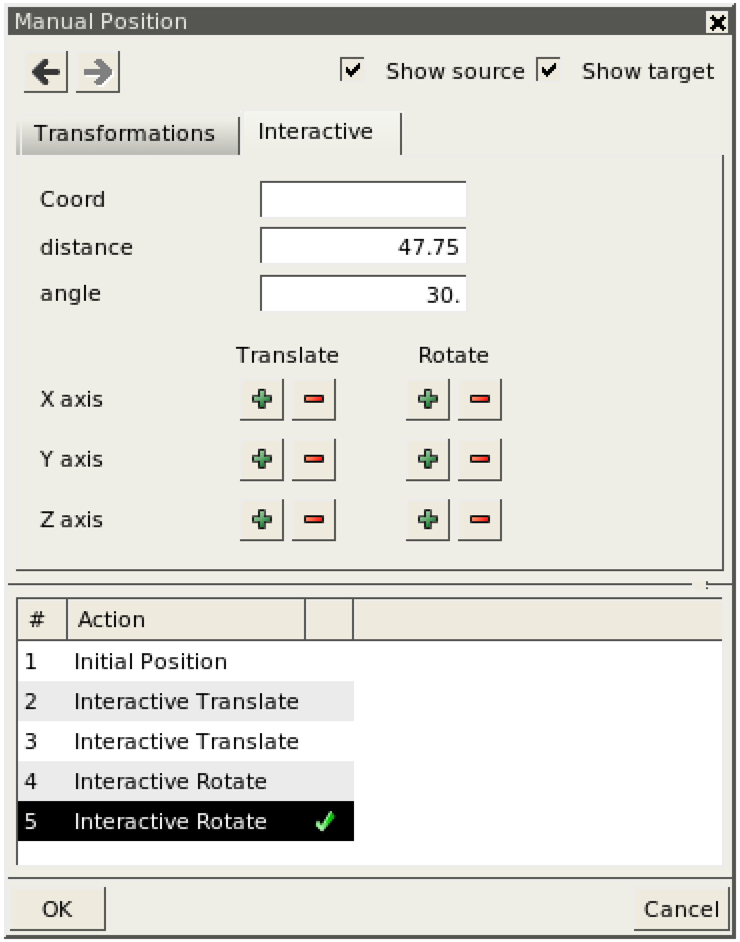
Mapping of Pressure Distributions using ANSA

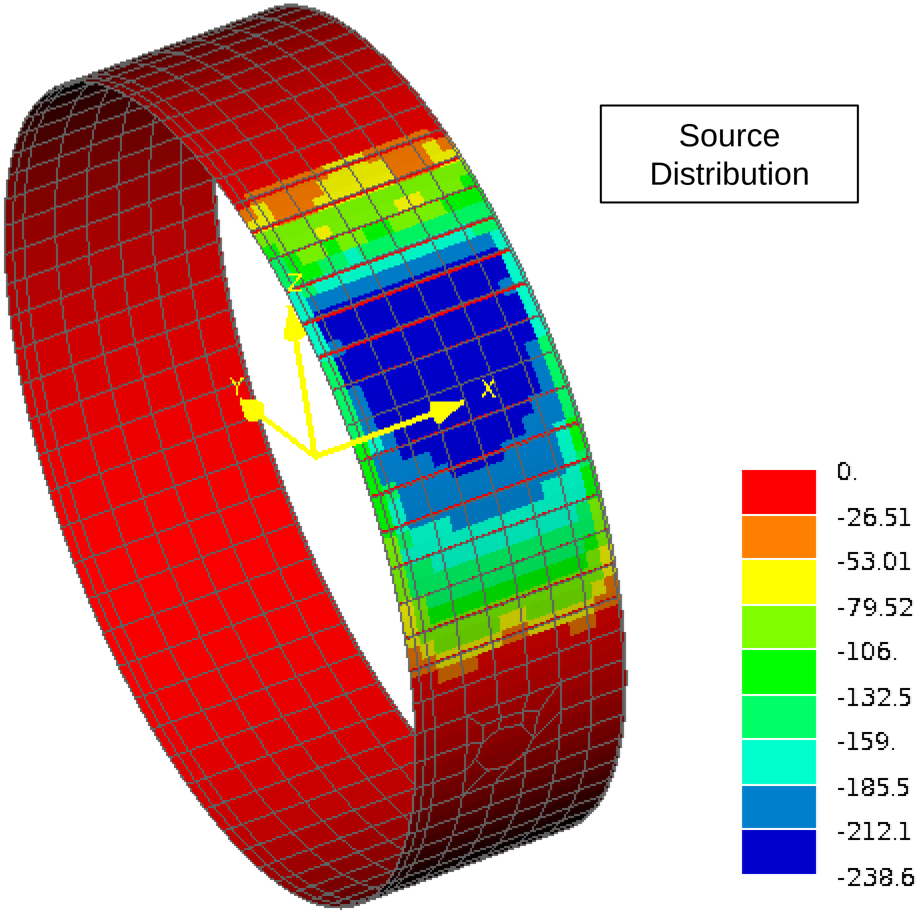
- *Manual Position*: *Interactive* tab



Mapping of Pressure Distributions using ANSA

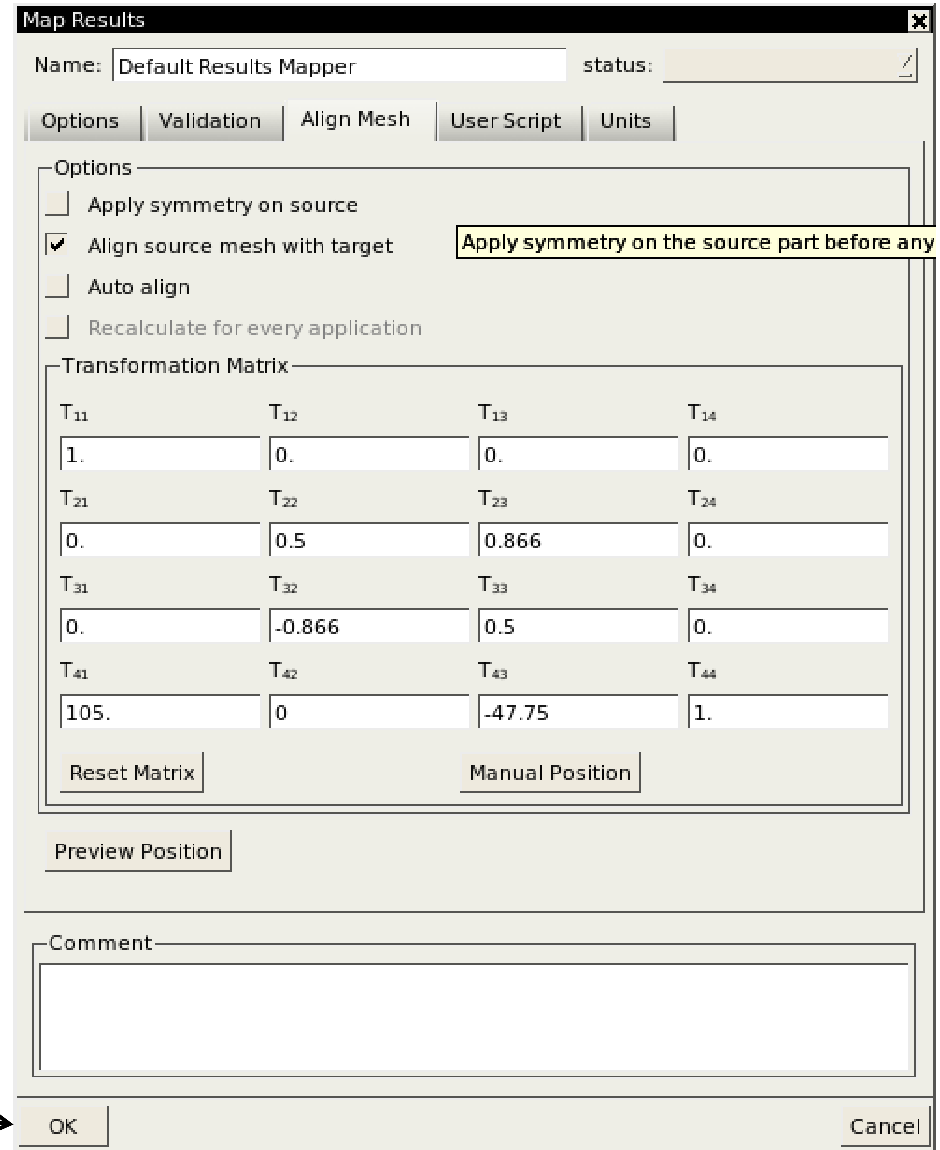
- *Manual Position*: *Interactive* tab
  Source mesh aligned with the target mesh





Mapping of Pressure Distributions using ANSA

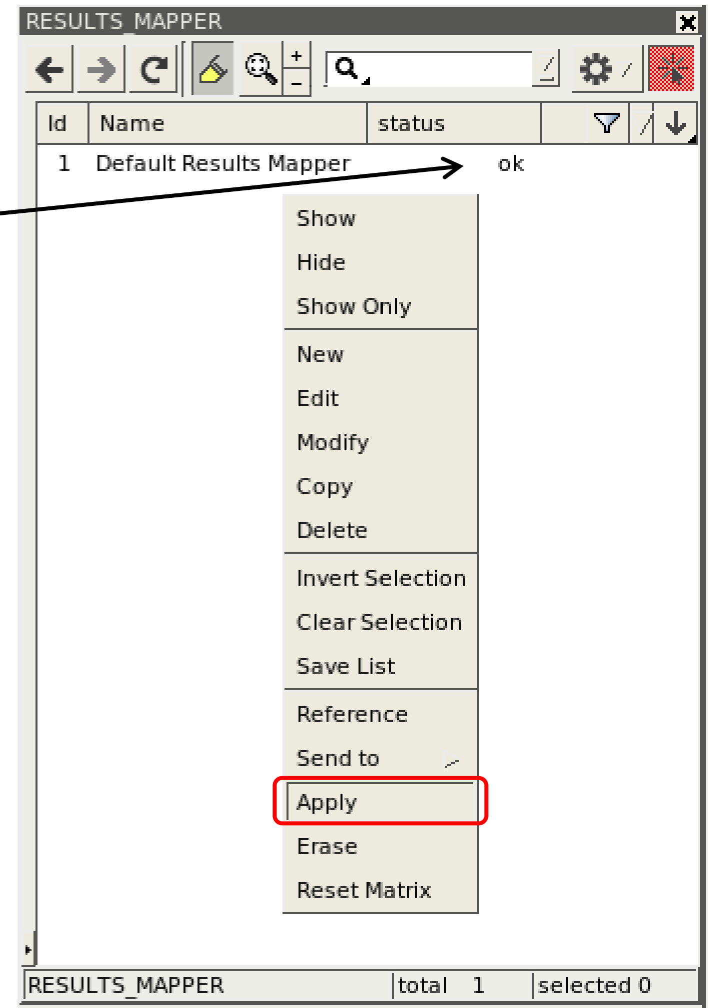
- Back from Manual Position
  The transformation table is updated

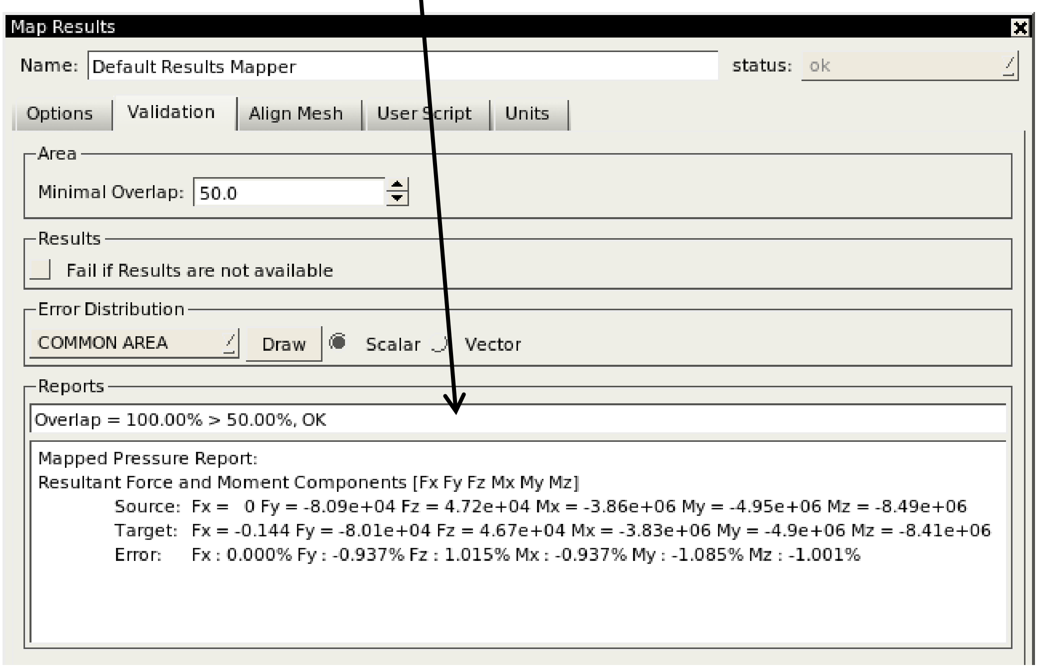


- Press OK to conclude
  the RES.MAP Setup

Mapping of Pressure Distributions using ANSA

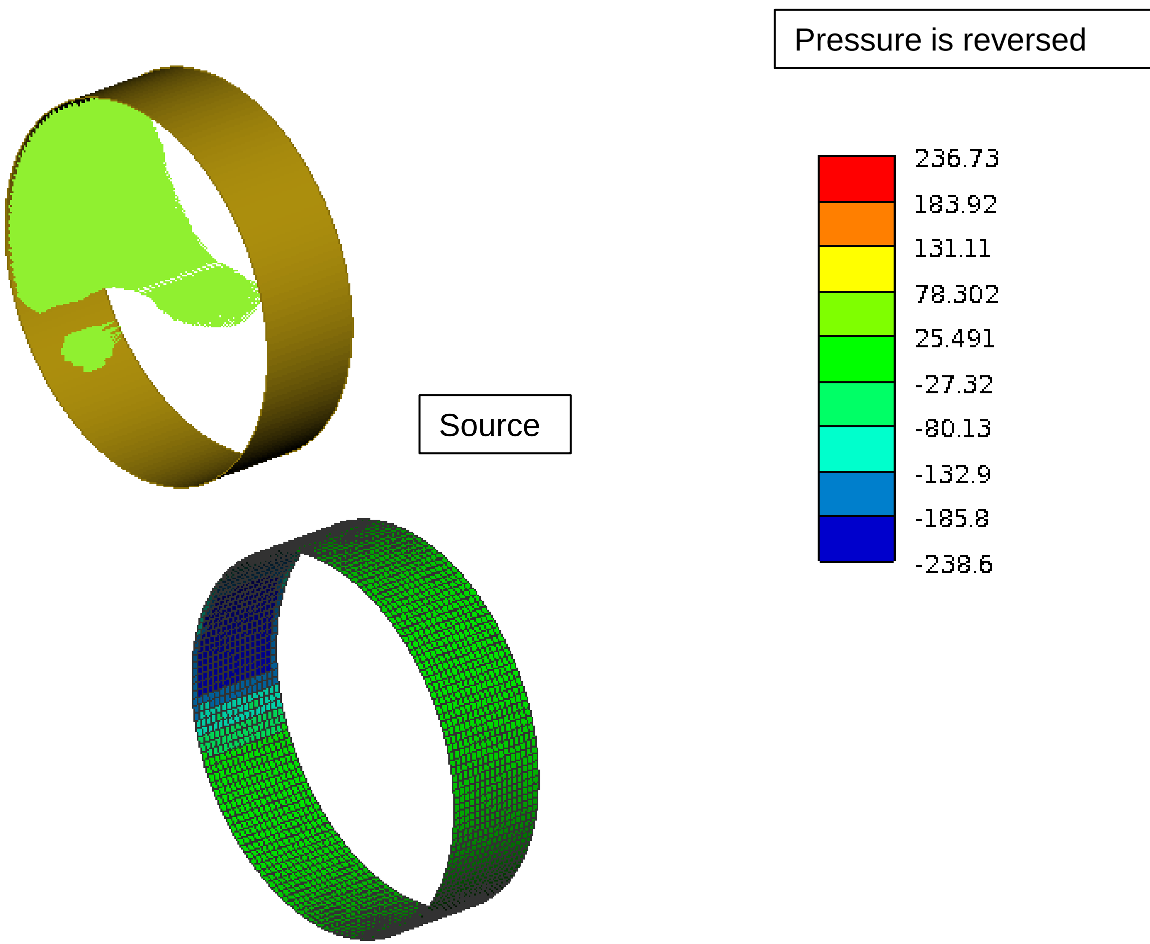
- Very Important: activate Results Mapping by Right Mouse Click on "Results Mapper" and select to "Apply"!
- Check the Status and the *Reports*

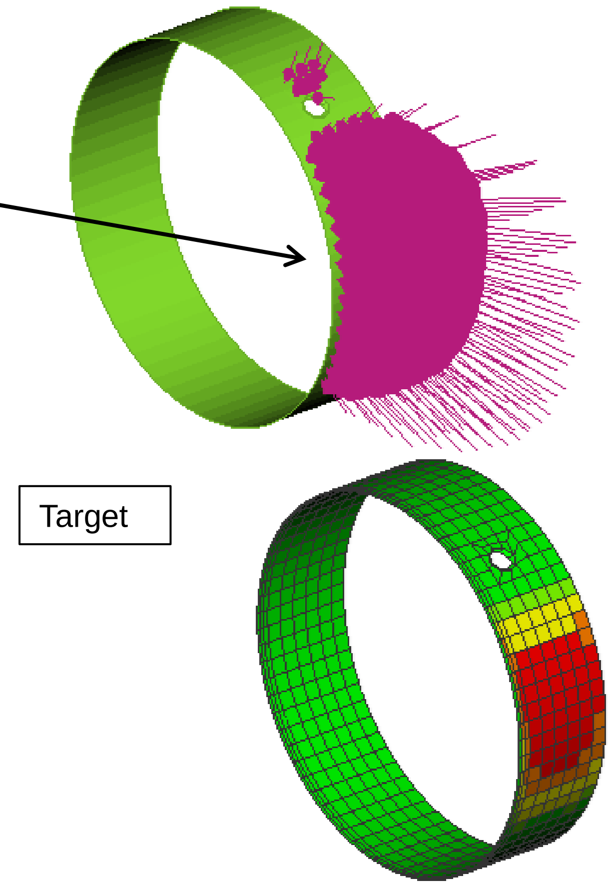




Mapping of Pressure Distributions using ANSA

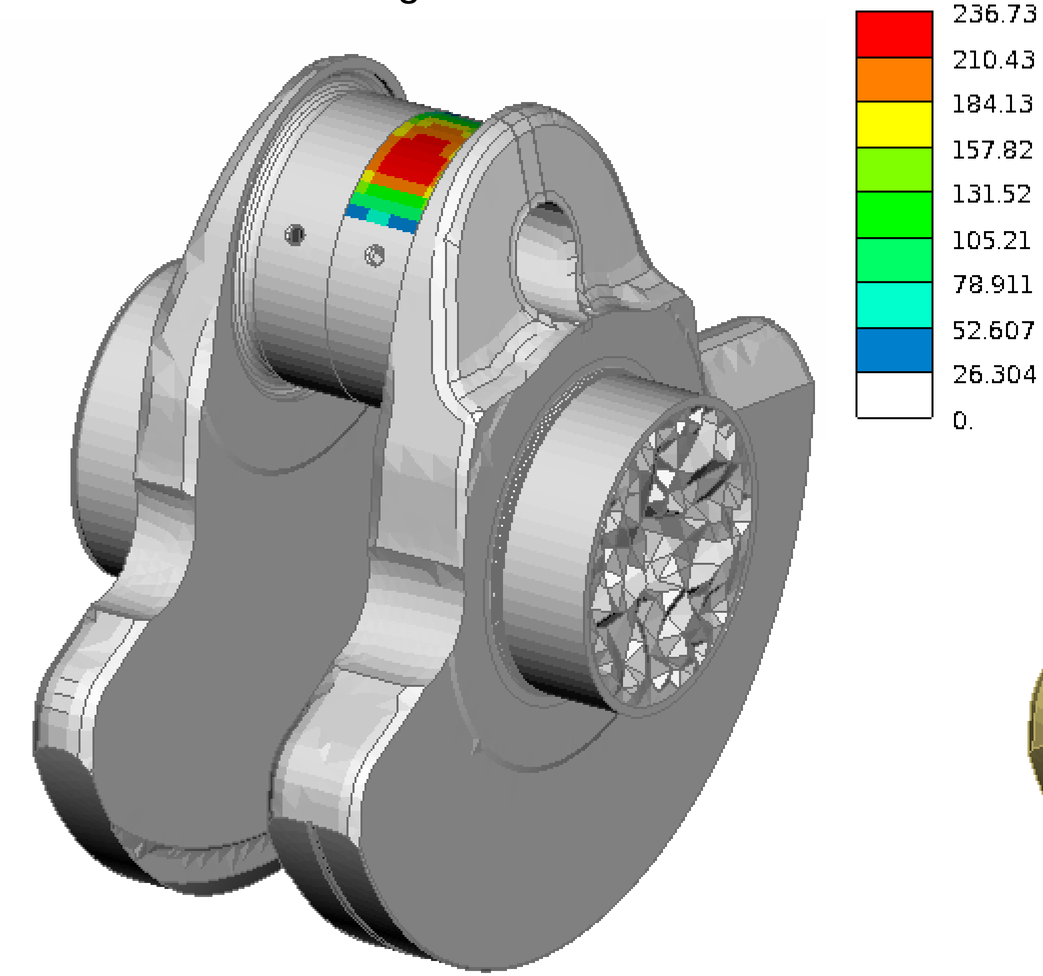
- Result for bearing #8

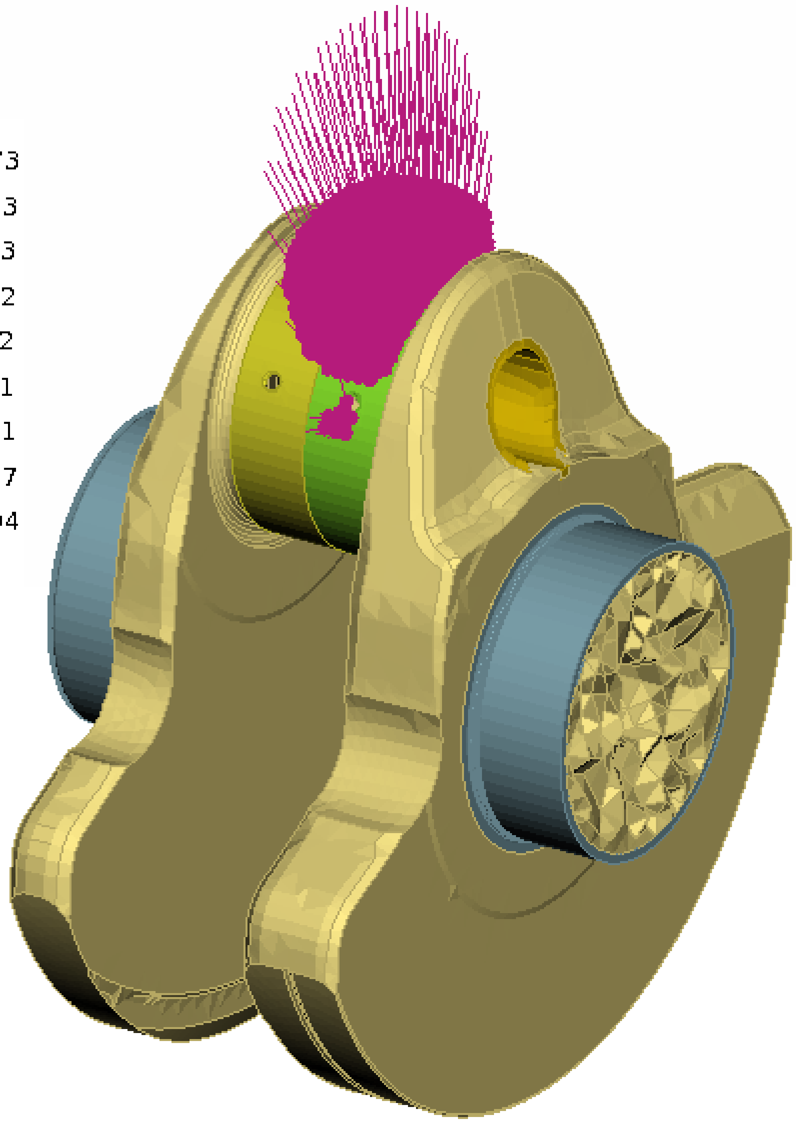




Mapping of Pressure Distributions using ANSA

- Result for bearing #8

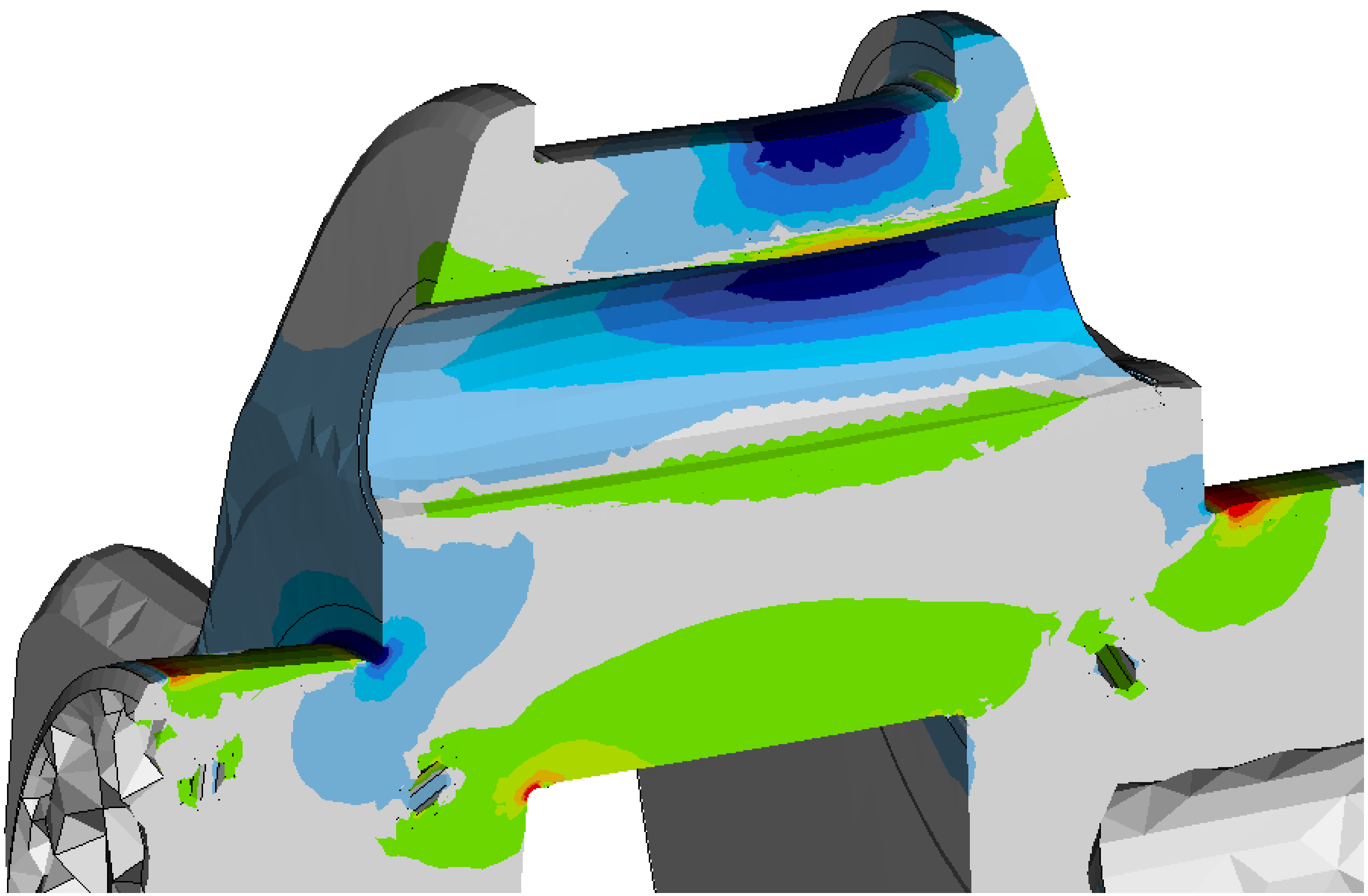




Mapping of Pressure Distributions using ANSA
Example: Stiffness calculation of a crankshaft

- Deflection is the result of the lateral force on the crankshaft pin from the EHD calculation

Stresses,Signed Max Principal,Max of Top Bottom,Corner : Zapfen 8: EHD-Druck 92kN, Scale 50



Mapping of Pressure Distributions using ANSA
Summary

- The RES.MAP tool of ANSA is relatively easy to use

- After making the calculations for bearing #8, it was possible
to use the same result by easily repositioning for bearing #4

- Different FE models are not a problem:
neither the solver (Nastran or Abaqus, etc)
nor the element length or the position in space

- The tool can be used for mapping EHD-results on plain bearings,
e.g. in the crankshaft pin bearing area calculation or
in examining the crankshaft strength in detail

Mapping of Displacements using μETA
Overview

- Mapping of pressure distributions by ANSA
  - Transfer of the pressure distributions of the bearing's Elasto-Hydro-Dynamic (EHD) calculation in the strength calculation using Abaqus or Nastran
- Mapping of displacements using μETA
  - Automated transfer of displacements from an ADAMS calculation in NASTRAN format to a stress recalculation

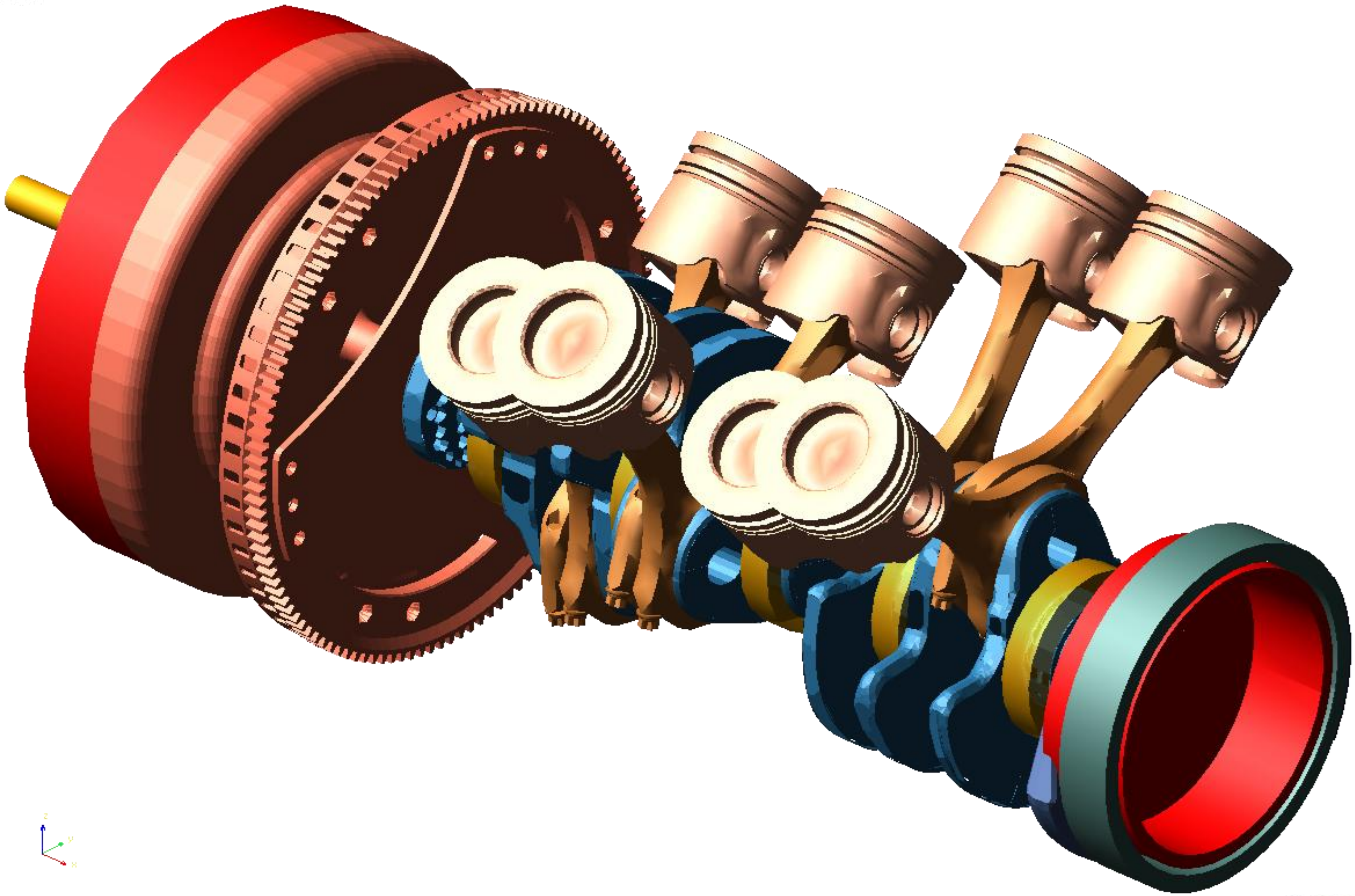
Mapping of Displacements using µETA

Task:

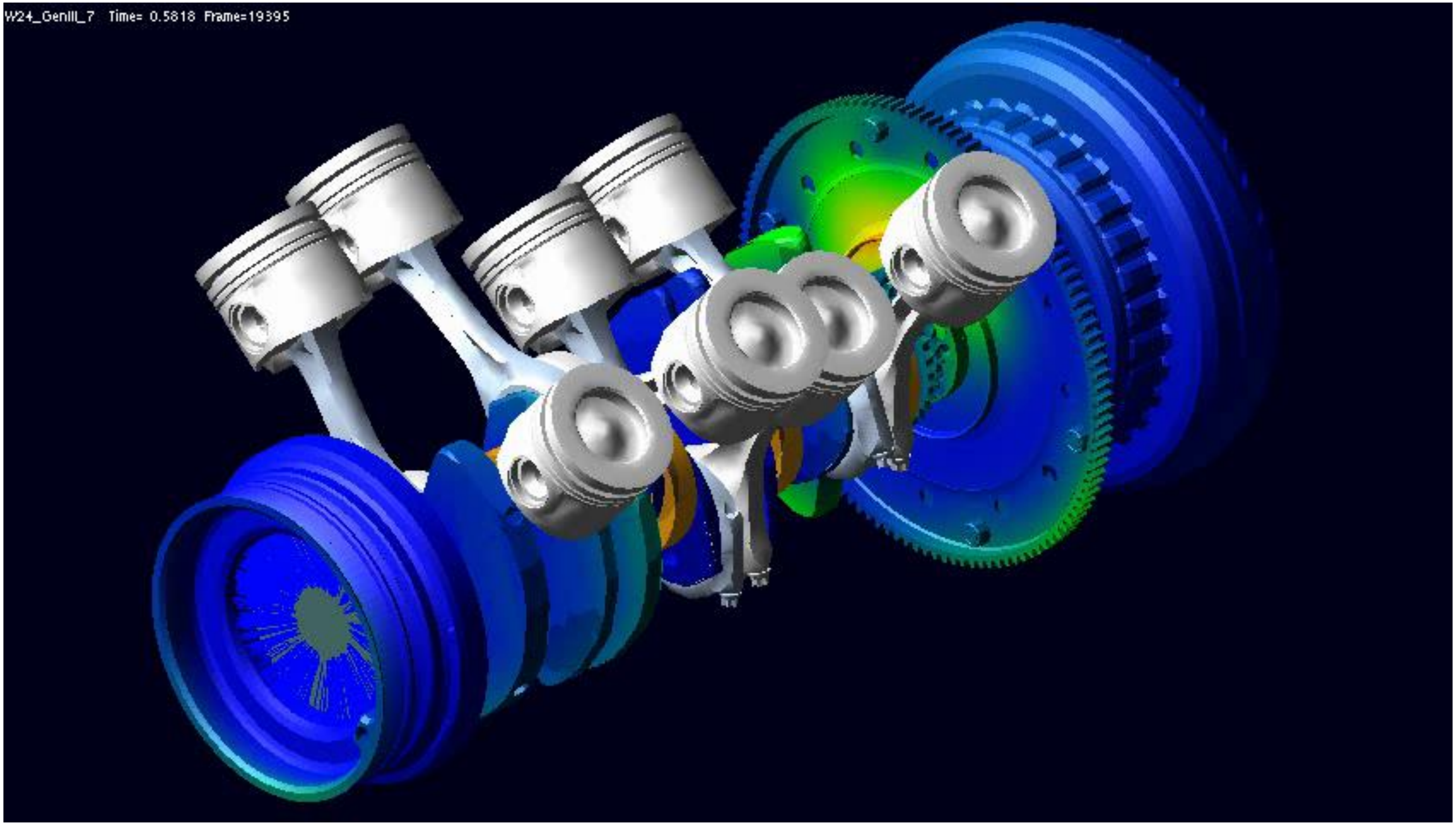
- The process of examining the strength of a crankshaft is based on an ADAMS calculation
- The results of the engine run are, among others, the modal coordinates of all modes in the time domain of the calculation
- These Modal coordinates form the input for the calculation of safety: the most important calculation
- Perform a stress [reverse-]calculation based on the displacements of two crankshaft revolutions (i.e. 4 cycles of a 4 stroke engine) at a specific rotation speed

This presentation describes the process used in Audi

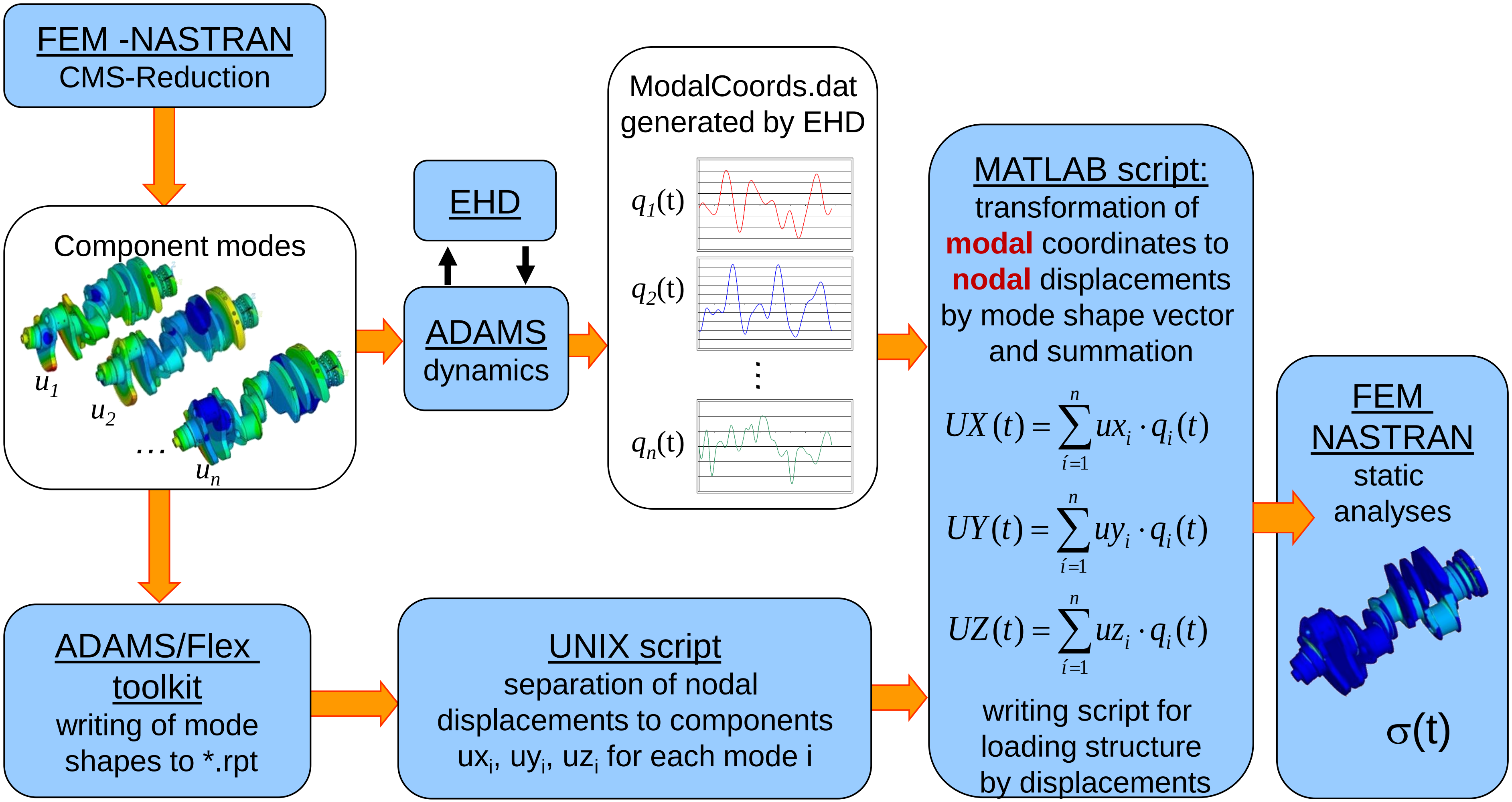
Mapping of Displacements using μETA
V8 TDI Crankshaft



Mapping of Displacements using μETA
V8 TDI Crankshaft



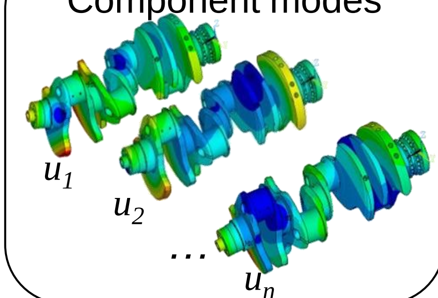
Mapping of Displacements using μETA
Old Workflow: Stress reverse-calculation of a linear model



Mapping of Displacements using µETA
New Workflow: Stress reverse-calculation of a 2nd order model

FEM -NASTRAN
Reduction

Component modes

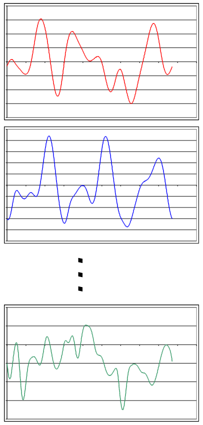


ADAMS/Flex toolkit
writing of mode shapes to *.rpt

EHD

ADAMS
dynamics

ModalCoords.dat generated by EHD



UNIX script
separation of nodal displacements to components
ux_i, uy_i, uz_i for each mode i

MATLAB script:
transformation of **modal** coordinates to **nodal** displacements by mode shape vector and summation

$$UX(t) = \sum_{i=1}^{n} ux_i \cdot q_i(t)$$

$$UY(t) = \sum_{i=1}^{n} uy_i \cdot q_i(t)$$

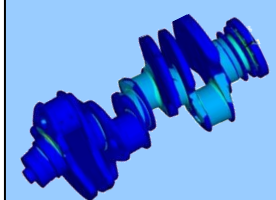
$$UZ(t) = \sum_{i=1}^{n} uz_i \cdot q_i(t)$$

writing script for loading structure by displacements

µETA script
Displ. Mapping from 1st to 2nd order model

Unix Script
SPCD-Load-Files for NASTRAN

FEM NASTRAN
static analyses

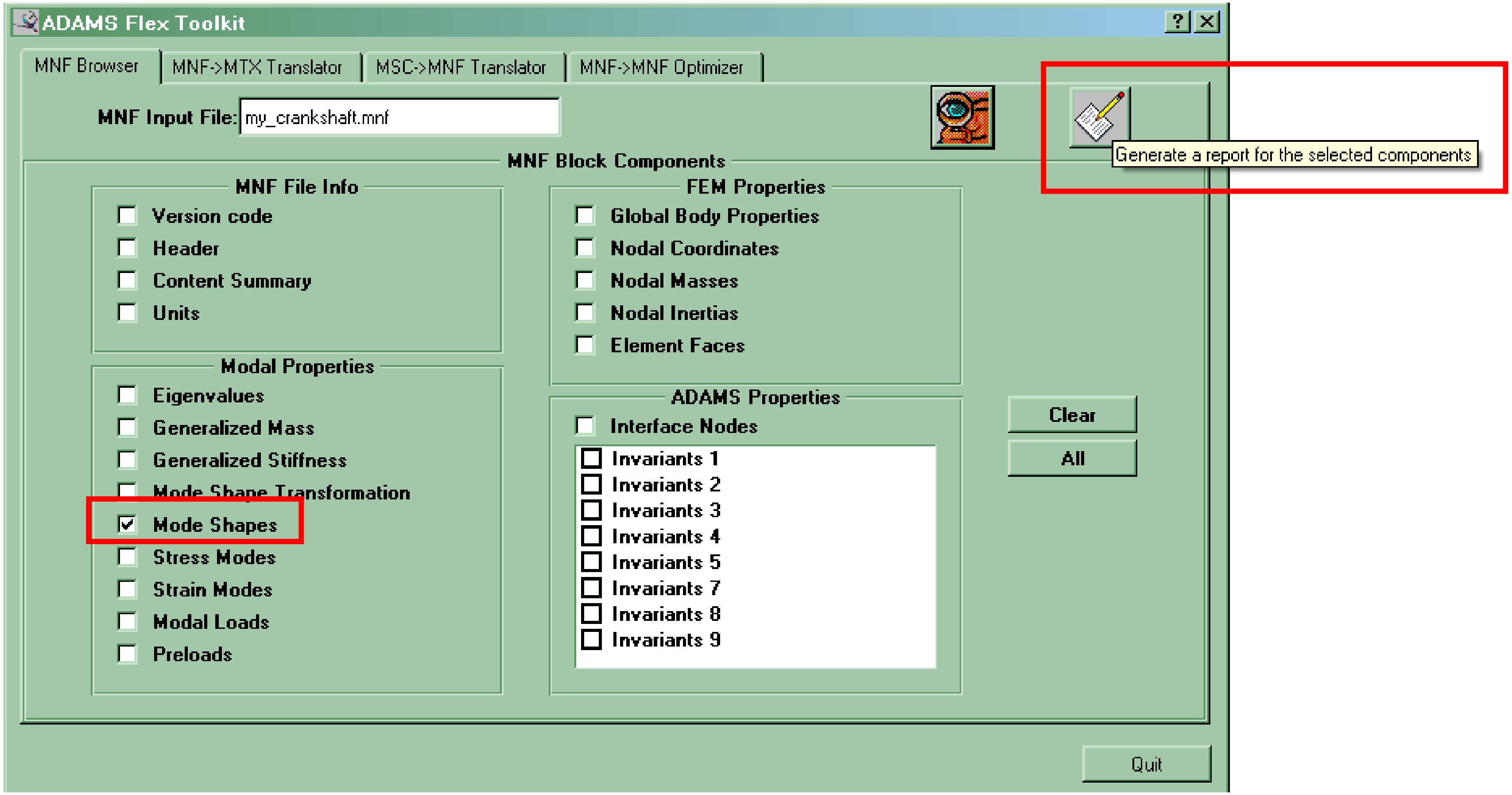


$\sigma(t)$

Mapping of Displacements using μETA
New Workflow: Stress reverse-calculation of a 2nd order model

- Generating a linear and a non-linear (2nd order) surface model in ANSA
- Generating a ". * rpt" Ascii file containing the mode shapes,
  using the ADAMS / Flex Toolkit – program
- Execution of the Unix script "transform_macro.sh"
- Execution of the Matlab script "recovery_solid.m"
- Execution of the script μETA "Map.ses"
- Execution of the Unix scripts "meta_spcd.sh"
- Running the Static analysis with Nastran

Mapping of Displacements using µETA
Creating the RPT-Files with the Mode Shapes



The "*. Rpt" Ascii file contains the mode shapes of the crankshaft, but only the positions of the surface nodes and only the corner nodes, when 2nd order elements have been used.

Mapping of Displacements using μETA
Unix script *"transform_macro.sh"*

- Unix script to generate modal components for the Matlab script "Recovery_solid.m".

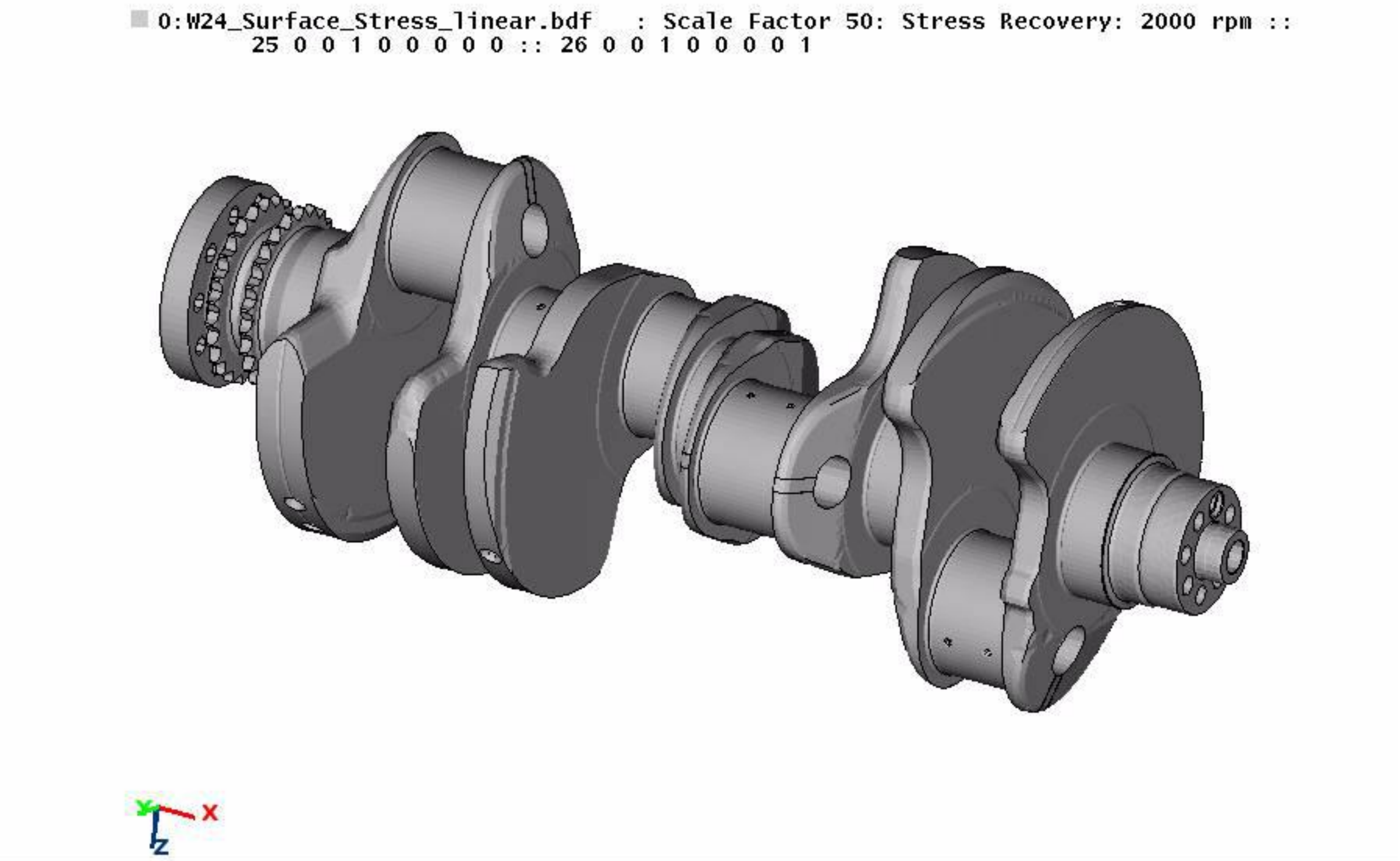
- Input
  - From ADAMS / Flex Toolkit

- Output
  - A *.txt file for each mode and each component: x, y, & z

Mapping of Displacements using µETA
MatLab script *"recovery_solid.m"*

- Macro for the transformation of modal coordinates to nodal displacements and generation of the Nastran deck
- Input
  - Engine revs-per-min (rpm) and definition of the angle step
  - File with modal coordinates (directly from ADAMS)
  - Files of mode shapes for the three components x, y and z (from unix scripts)
  - Output file type (NASTRAN, ABAQUS, PATRAN)
- Output - PATRAN
  - A directory with the surface node displacements in PATRAN format for every loadcase of the engine cycle(2 revs equals to 720° crank angles): for a time step of 3° of crank rotation 240 text files are output
- These displacements can directly be read and animated in µETA for the linear model

Mapping of Displacements using μETA
Animation of Displacements



Mapping of Displacements using μETA
μETA script *"Map.ses"*

- The stress calculation is necessary for the 2nd order FE model because the safety calculation of this model will follow and is based on the same 2nd order elements
- The META Map.ses script was developed which includes the following steps:
  - Reading the 1st order (linear) surface model (Model 0)
  - Reading the 2nd order surface model (Model 1)
  - A group "Group_Surface" is defined for both models with the same name
  - Loop over all load cases
    - Reading the displacements for model 0
    - Mapping the displacements to model 1
      groups modelmapresults nocheckprojnodal 1 0 current ***Group_Surface Group_Surface*** 10
    - Save the displacements for each timestep for both models in a CSV format file: for a 3° angle step, 240 files are the output.
      File Contents: Model, Node ID, x-dis, y-dis, z-dis
  - Ready!

Mapping of Displacements using μETA
Unix script *"meta_spcd.sh"*

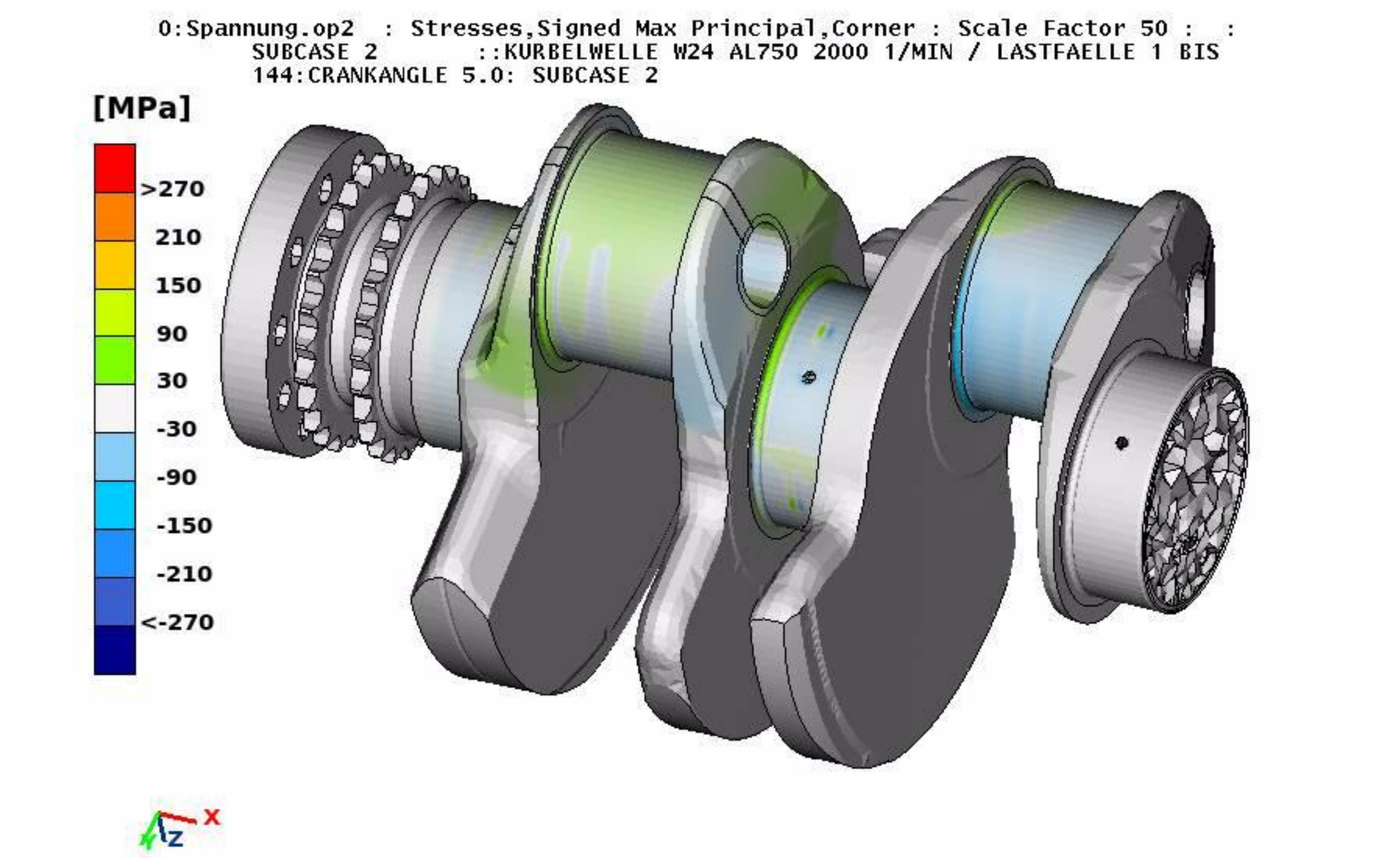
- The Unix script reads each displacement file written by the META session Map.ses in CSV format file and outputs them in NASTRAN SPCD format for each time step in a single file

- Stresses are calculated for the 2nd order model for one crankshaft cycle and for the selected engine rpm

- This calculation is based on the forced displacement of the surface nodes

- The size of the .op2 file output by NASTRAN for a V8 crankshaft with 240 loadcases is approximately 150 GB

Mapping of Displacements using μETA
Animation of stresses



Mapping of Displacements using μETA
Summary

- We were able to generate a workflow that makes it possible to calculate the stresses at any point in the crankshaft at any time, based on the ADAMS results

- Using the Results Mapping capabilities of META, the stresses of 2nd order models can now be calculated and thus improve the accuracy of the results

- Many hanks for the support from Thessaloniki and, here specifically, to Emmanouil Kastrinakis