Residual deformations after machining

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Deformations in machining process

Several factors can cause deformation of workpieces during and after a machining process.

The condition of the material is a factor that can lead to deformations due to the relief of residual stresses in the bulk material.

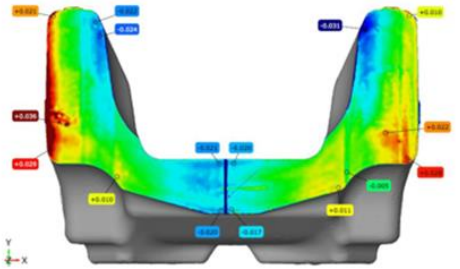
In this presentation, the work and results of a recently completed project on estimation and compensation methods for residual deformation are presented.

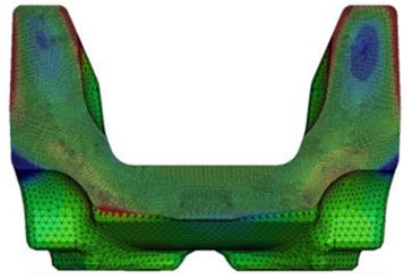
Project leader: Daniel Semere, KTH.

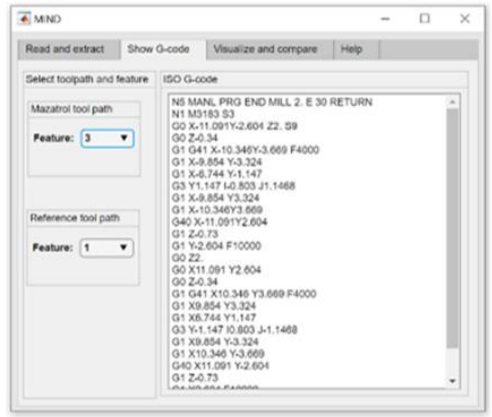
Project time: 2019-11-01 to 2022-10-31

Project partners:

LEAX Falun AB, ETP Transmission AB, Forgex AB
Acoutronic AB, RISE, KTH

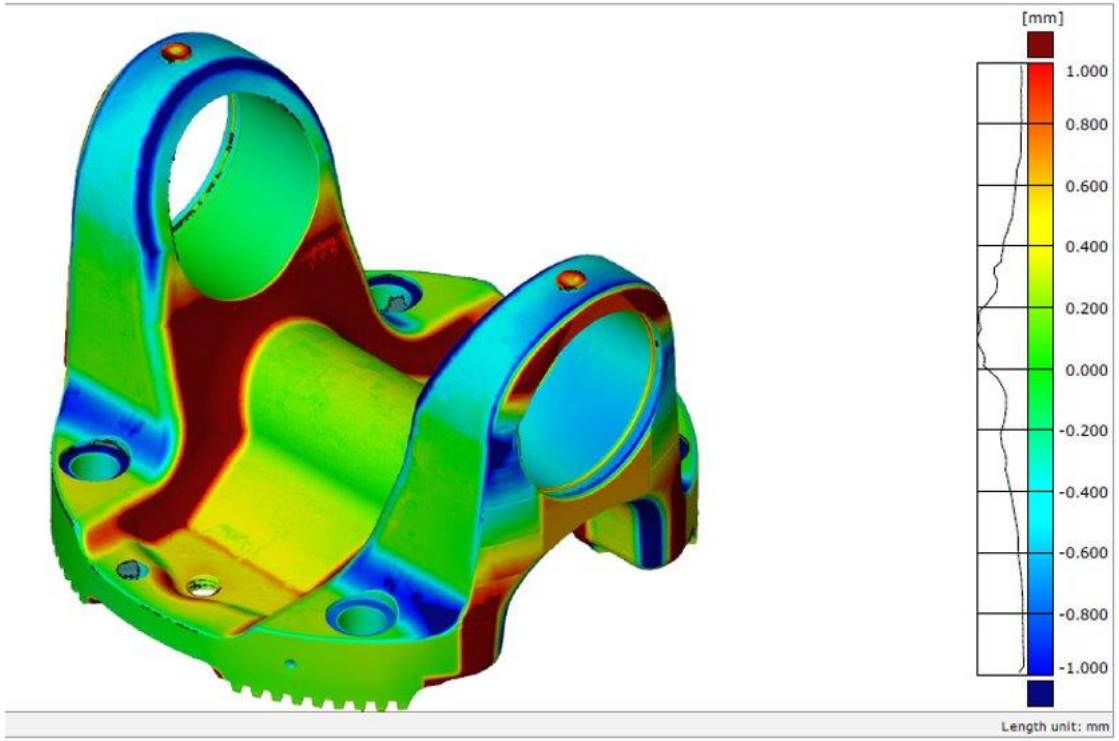






Deformation during/after machining due to residual stresses.

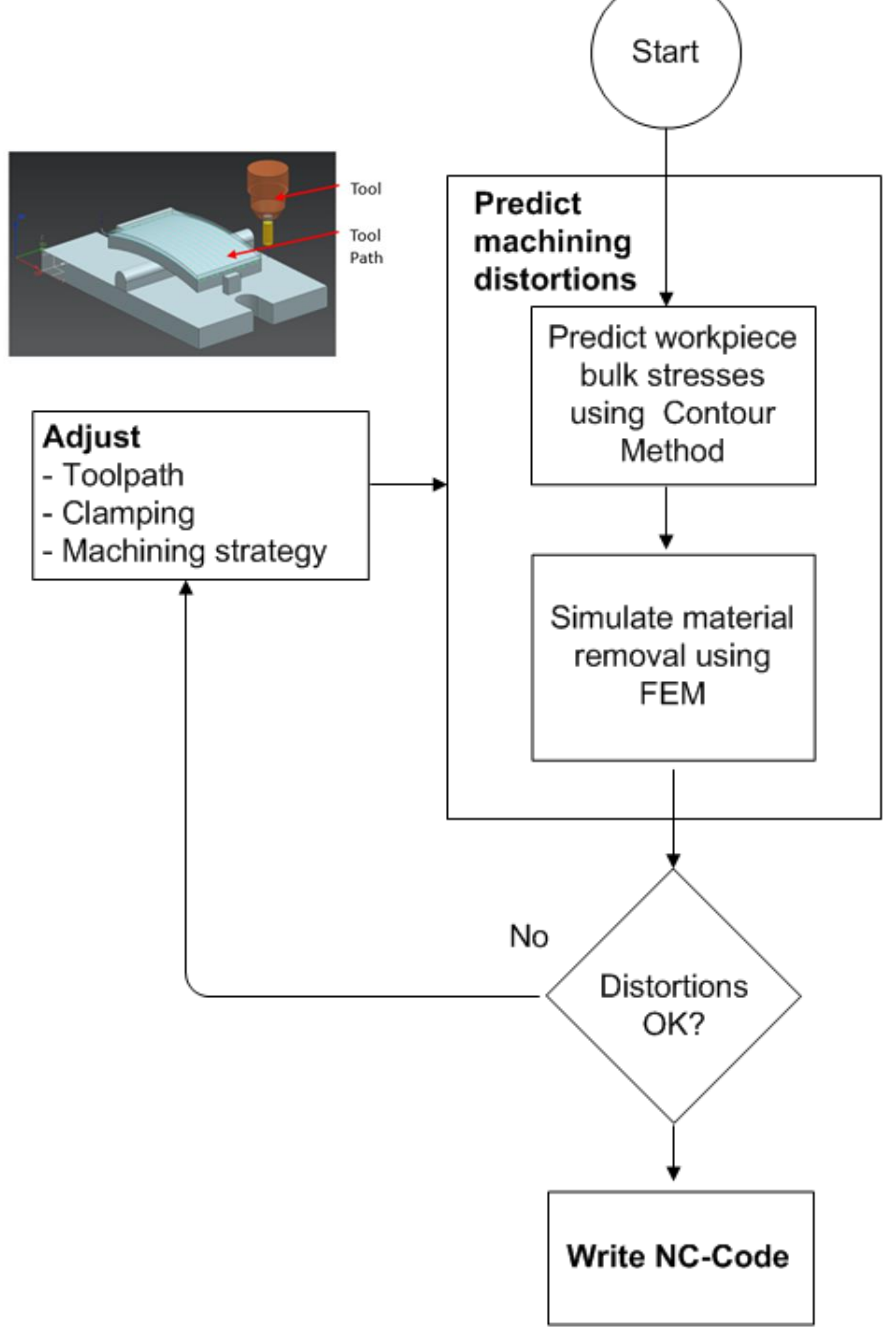
- During machining, the remaining bulk loads caused by previous forming and heat treatment processes will be released.
- This causes unwanted deformations of the final component.
- These deformations are difficult to predict and in practice large tolerances and several machining steps are applied.
- The cost is significant for the manufacturing industry in terms of scrap and readjustments.



Deviation from the CAD- model

Purpose of the project

- Develop tools for minimizing residual deformations
- Improve quality and refine tolerances on components
- Reduce costs related to scrap and readjustments at companies
- Development work focused on
  - Development of the Contour Method
  - Development of NC-Code verification
  - Development of advanced tool holder



METALLISKA MATERIAL

Working methodology

STATE OF THE BLANC MATERIAL

Methods of the analysis

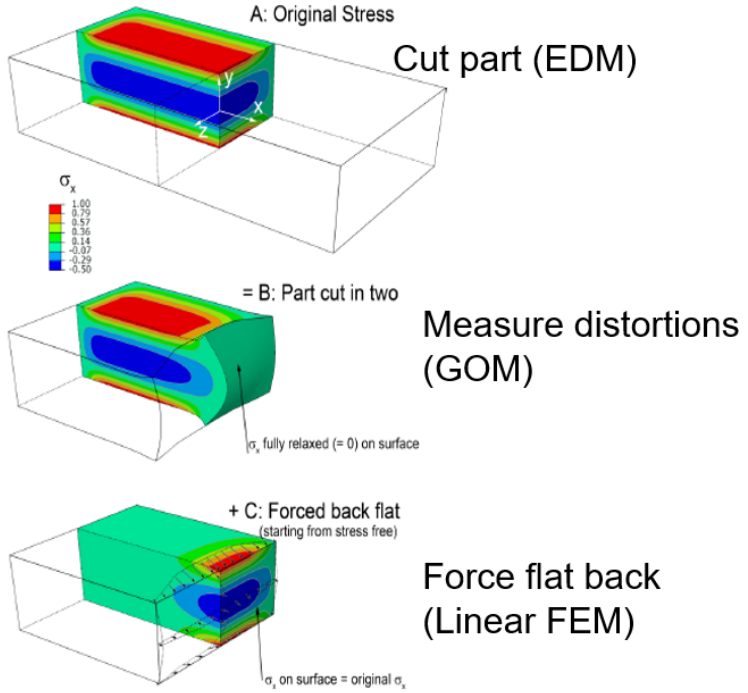
i. Analysis of residual stresses
ii. Prediction of deformation profile due to residual stresses during process development
iii. Physical measurements and analysis of deformation in manufacturing

Actions (Methodology and tools)

i. Optimation of the NC-code
ii. Adaptive solutions in manufacturing (fixture)
iii. Feedback to the forming process

The contour method

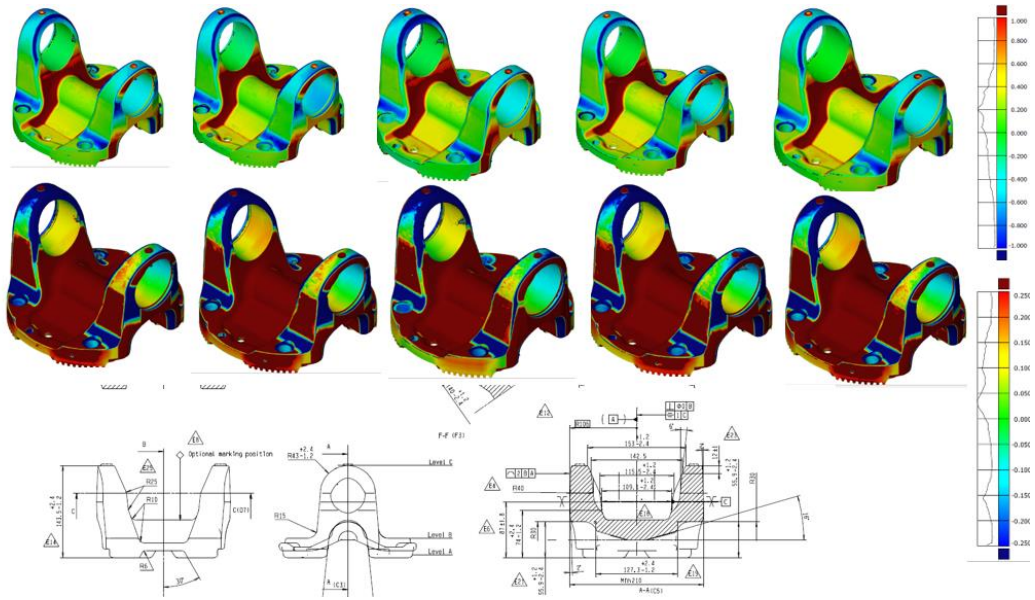
- Developed by Los Alamos Lab, USA
- Combination of measurement and data analysis
- Can replace/supplement process simulation
- Workflow:
  - electrical discharge machining (EDM)
  - measurement of residual deformations with (CMM) and
  - data management (FEM analysis)
- To get good results, the method must be done with high precision.



Ref: Werke, Wretland, Ottosson, Holmberg, Machens, Semere, 2018, ”Geometric distortion analysis using a combination of the contour method and machining simulation”, 51st CIRP conference of Manufacturing Systems, Stockholm

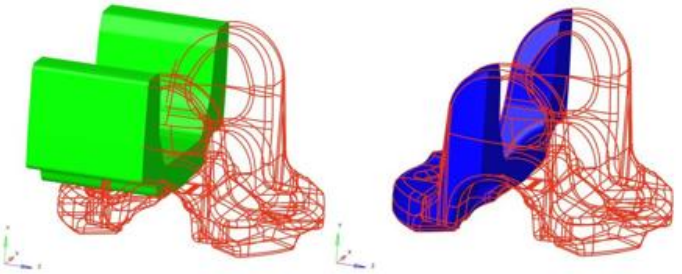
Results - the contour method

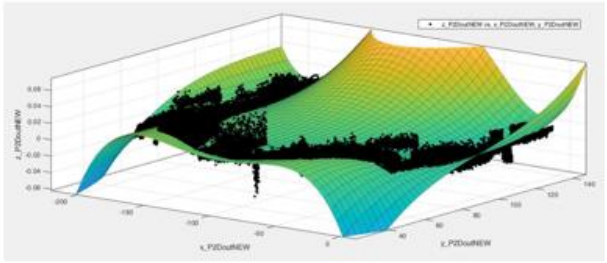
- Estimation of residual stresses is ongoing using the Contour method.
- Preliminary results with show an even RS distribution both in the forged and machined parts.
- Optimization of wire cut parameters to optimize the EDM process and thereby improve the accuracy of the analysis.

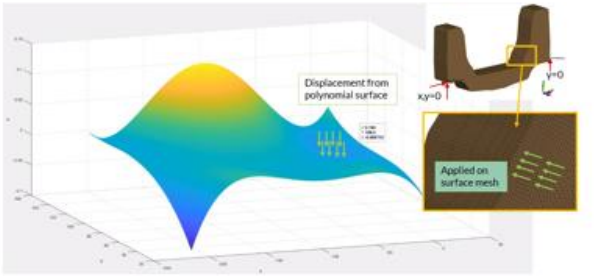


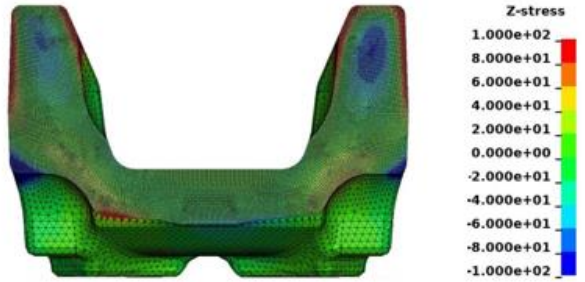
FE modelling – analysis of two strategies

- In the first option, the geometry of the 2D cut was extruded, after which a 3D mesh was created.
- In the second option, the 3D mesh was created based on the CAD model
- Displacements in the nodes of the interface were then applied based on a calculated polynomial surface with measured deformations in the cut
- The calculations did not indicate much difference in the results of the two alternatives.
- The extruded principle of meshing is recommended due to better possibilities for automation.









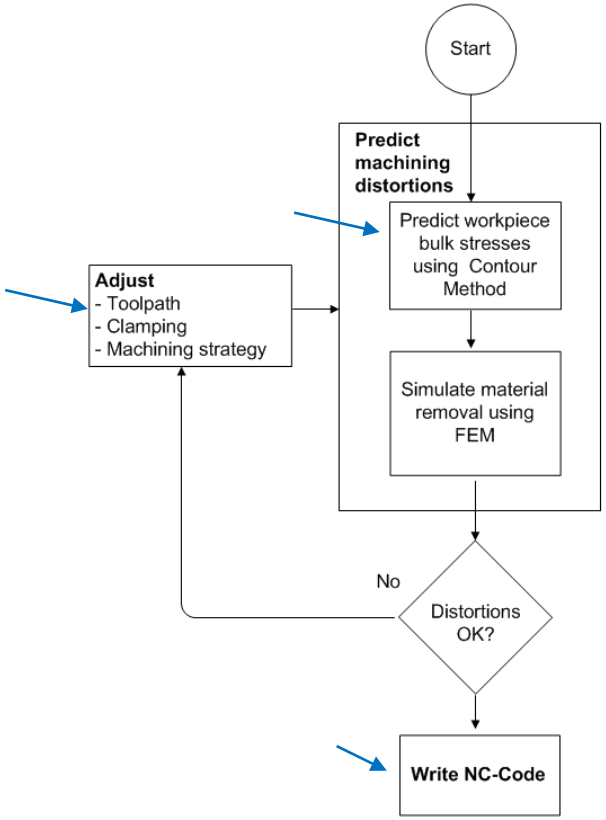
Challenges

The contour method

- Optimize wire EDM
- Modeling and FE meshing
- Data Analytics Automation

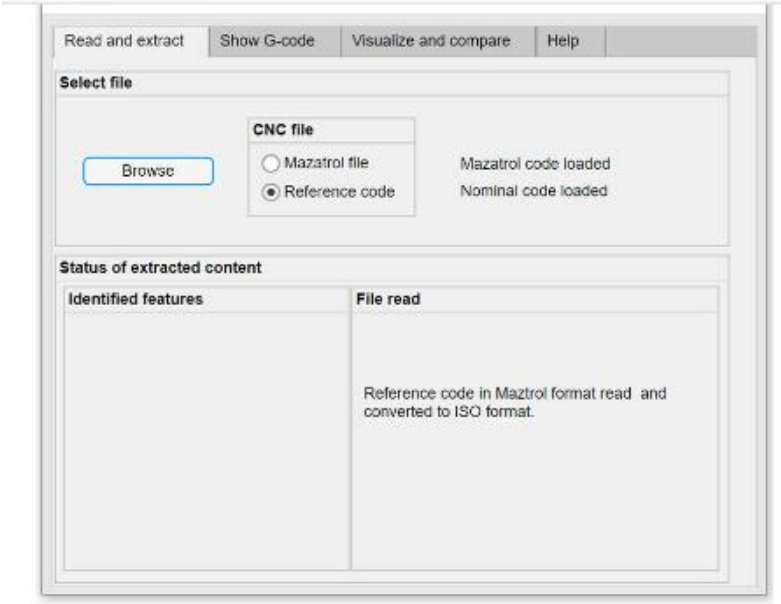
Optimization of NC code (as compensation)

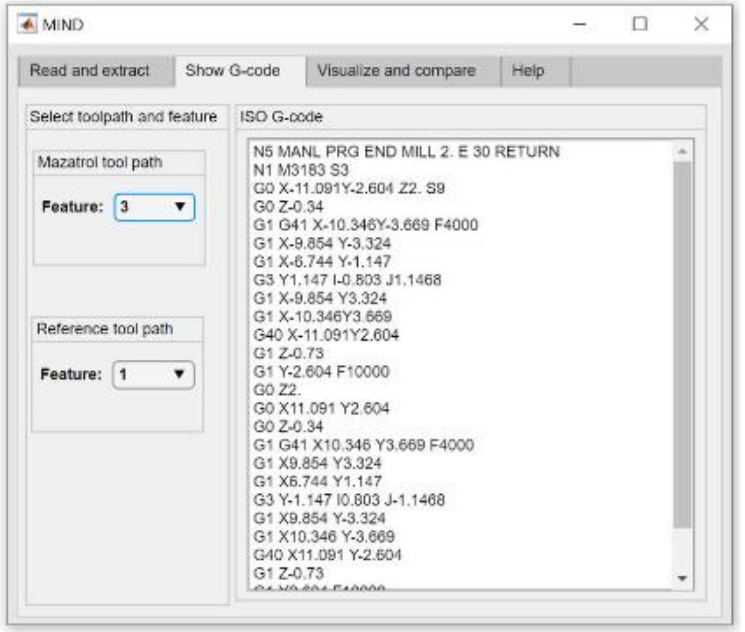
- The development work has been carried out with the support of test cases
  - Forged and machined Cardan joint
  - Casted and machined Hub cover



NC code verification tool

- NC code is one of the compensation methods in which distortion can be detected.
- To make the changes to the code, there is a need for a tool that integrates the estimated distortion into the NC code.
- As a step towards this, an NC code verification and translation tool has been developed.
- The tool translates the machine's own NC format into an ISO format that can be verified, optimized and/or modified as needed.





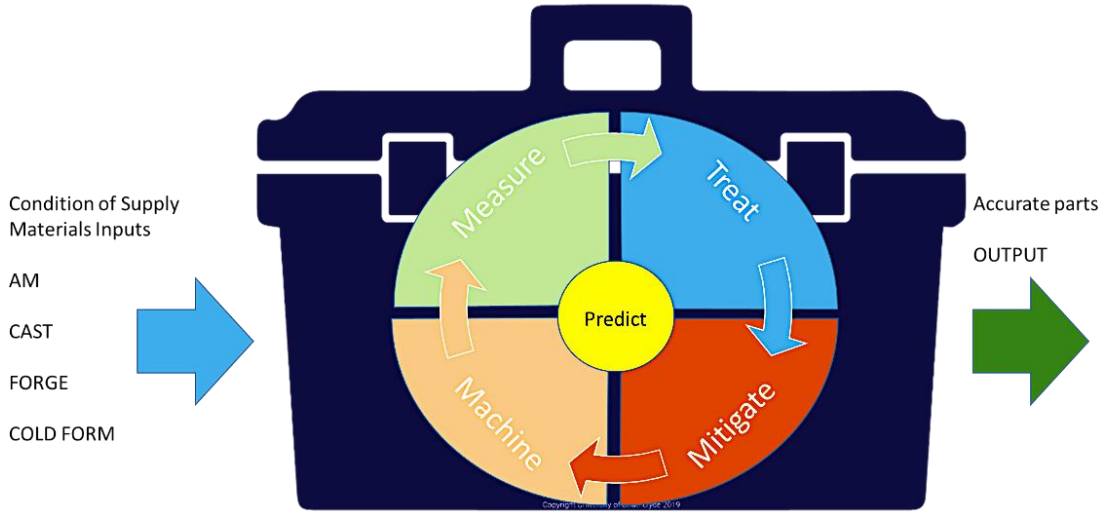
The project's contribution to the field

- The project's contribution to the field is to analyze the effect of the state of the material in order to:
- Minimize scraps from the machining process
- Enable methods for companies to be able to machine forged and heat-treated substances capable where inherent residual stresses are released during processing.

- Develop modules and tools to streamline the way of working around the manufacture of metallic materials.
- The project has resulted in a scientific publication "Prediction of residual stresses in components using the Contour method, SPS2022, Skövde"

Implementation of the results after the project

- The ambition is to implement the contour method in participating companies
- NC-code program installed at LEAX
- Further and ongoing project
  - Eureka MINDESTRESS toolbox for distortion estimation and minimization,
  - Extending the concept to tools for moulds and dies forming,
  - Applications for aerospace components,



MINDESTRESS:
”Toolbox” for minimizing machining distortions

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Questions?