VIRTUAL ENGINEERING FOR ROBUST MANUFACTURING WITH DESIGN INTEGRATION

VERDI

AST4-CT-2005516046
Specific Targeted REsearch Project
Aeronautics and Space

SUMMARY OF VERDI

(DELIVERABLE 6.7.1.1)
PUBLISHABLE SUMMARY

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Volvo Aero Corporation (*Coordinator*[1]) (VAC)	SE
Luleå University of Technology (LTU)	SE
University West[2] (HTU)	SE
Rolls-Royce Group (RR)	UK
The University of Nottingham (NOT)	UK
MTU Aeroengines (MTU)	DE
WZL, Aachen University of Technology (WZL)	DE
Karlsruhe Institute of Technology[3] (TUK)	DE
Industria de Turbo Propulsores (ITP)	ES
Asociación de Investigación y Cooperación Industrial de Andalucía (AIC)	ES
International Center for Numerical Methods in Engineering, CIMNE (CIM)	ES
Techspace Aero (TA)	BE
Centre of Excellence in Aeronautical Research, CENAERO (CEN)	BE
Avio (AVI)	IT
Politecnico di Torino (PT)	IT
EnginSoft (ES)	IT

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INTRODUCTION

VERDI focus on numerical framework for manufacturing process simulation enabling fabrication of structural components, such as fan/compressor structures and turbine structures, which are typically large castings in today's engines. A long term vision for the use of numerical process simulation tools in aero engine development and support is that the information technology and engineering models will be used in product development and production planning, from the early design phase to the final design. This enables combined design of the component itself and the way it is manufactured in order to achieve wanted properties of the component.

To validate the manufacturing process simulation models and the tools for manufacturing process chain simulations developed within VERDI, two components (further called sub-components) have been manufactured within VERDI. One component represents a rear-engine structure in the nickel based superalloy Alloy 718; the other component represents a front-engine structure in the titanium alloy Ti-6V-4Al. These are not full-scale components, rather parts of full components.

The project includes manufacturing process modelling development and validation, for eight processes. The process modelling development is made in conjunction with material modelling to handle the temperature ranges, temperature rates, strain and strain rates that the processes put onto the material models. Moreover, the project also includes activities for the capability to run process models in virtual manufacturing chains, where different software and space discretisations are not an obstacle.

This report illustrates the main achievements of the 52 month long VERDI project.

PROJECT OBJECTIVES

- Development of multi scale process simulation tools for metal deposition, welding, heat treatment, surface strain hardening and machining.
- Integration of process simulation tools.
- Integration of process simulation and design.
- Integration of process simulation and manufacturing.
- Implementation of manufacturing simulation in Europe's aero engine industry.

THE MAJOR ACHIEVEMENTS

- Demonstrated the capability to carry out virtual manufacturing chains with eight manufacturing processes on two aerospace materials and overcoming problems such as different space discretisations, different locations of the engineers, and different software.
- Validated simulations tools for eight manufacturing processes.
- The capability to carry out virtual evaluations on stability and robustness for all of the manufacturing processes within the project.
- The capability to carry out component life predictions which includes residual states from virtual manufacturing.

WORK PERFORMED

VERDI is a research project with strong focus on development and validation of the numerical framework that is the foundation of virtual fabrication. The process modelling tools are built-up from fundamental material modelling, manufacturing process modelling and integration of the individual models to enable complete virtual fabrication of a component. Two sub-components are manufactured, which are intended to cover all the needs for validation of the process simulation models and tools for simulation of process chains. Figure 1 and Figure 2 illustrate the two components, possible manufacturing sequences and partners involved.

Overview of the manufacturing chains

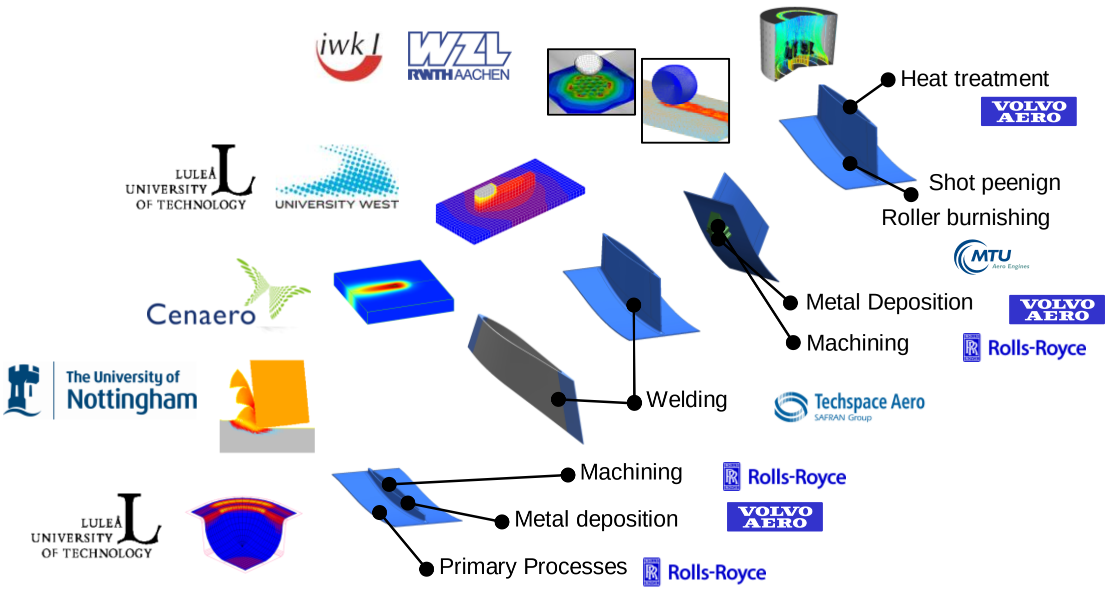

Figure 1: Manufacturing and simulation of the titanium sub-component.

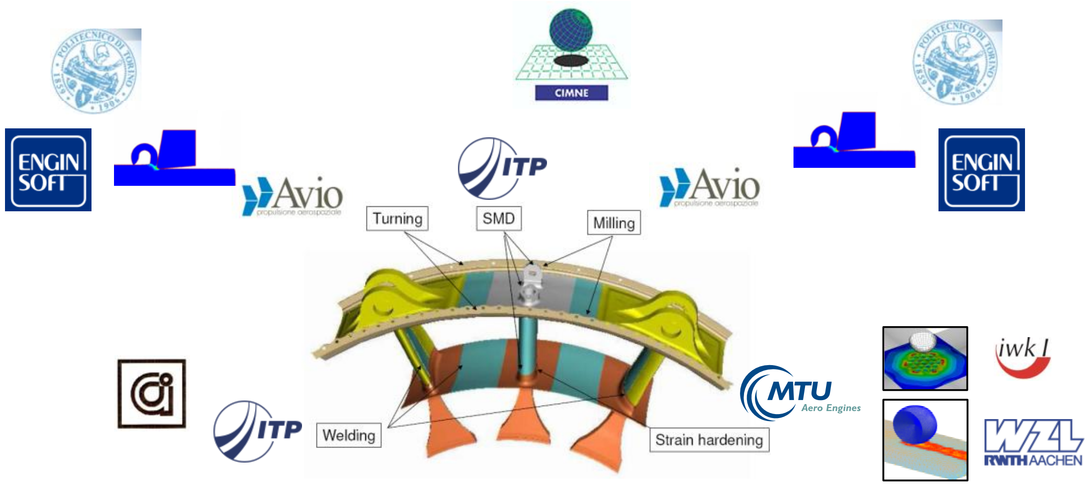

Figure 2: Manufacturing and simulation of the nickel sub-component.

The individual process models are developed and validated, some examples are shown in Figures 3-9.

THE INDIVIDUAL PROCESSES

Shot peening and roller burnishing

Shot peening, ultrasonic peening and roller burnishing have a high potential to improve component lifetime. In order to save high experimental efforts and time within the design process, the process parameters have to be defined based on process simulations. The results and the developed simulation-software have to be usable for both design and process engineers. The results should allow defining robust process parameters for maximal component lifetime.

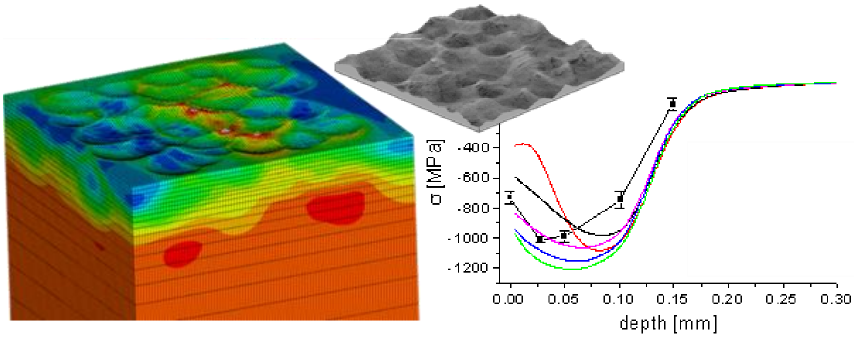

Figure 3: Shot-peening modelling results (TUK and MTU) compared to x-ray and hole drilling measurements of the residual stress distribution in the surface. Also showing experimentally measured surface topographies.

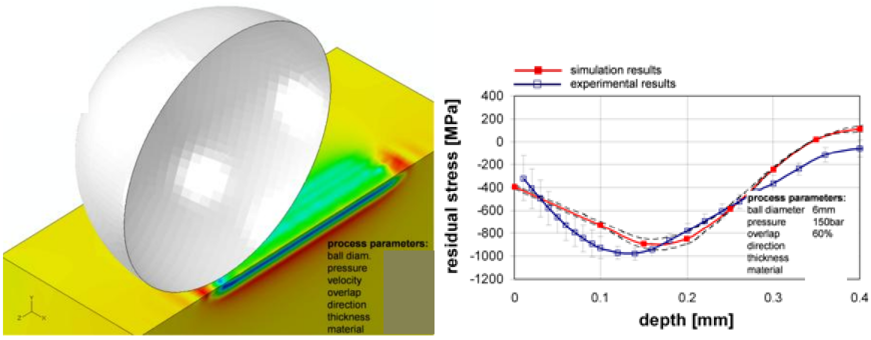

Figure 4: Roller burnishing modelling results (WZL and MTU), showing contour plots of the residual stresses and validation of residual stresses.

Heat treatment

Heat treatment is an important step in the manufacturing chain for fabrication of structural components and are applied on titanium application

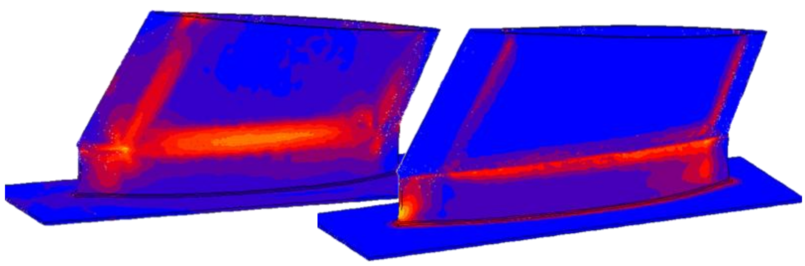

Figure 5: Heat treatment modelling results (VAC), showing residual stress on the titanium sub-component before (left) and after (right) heat treatment.

Metal Deposition

Metal deposition is a process similar to welding for building features such as bosses and flanges on fabricated components. Thermo-mechanical models for welding have been developed in earlier projects, i.e.EU-FP5-MMFSC. The work started on this level with objectives to develop simulation tools for the process to predict properties of the material, and predict residual stress and deformation.

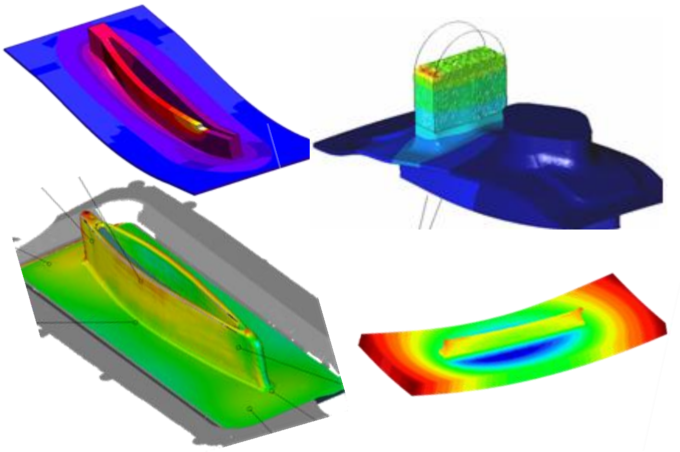

Figure 6: Upper left: Temperature field during Metal Deposition simulation of the titanium sub-component (LTU and VAC). Upper right: Temperature field during Metal Deposition simulation of the nickel sub-component (CIMNE and ITP). Lower left: Validation of deformation on titanium sub-component. Lower right: Contour fills of Z-displacement for validation (CIMNE).

Welding

For welding the project focused on the development of faster welding simulation in order to obtain an agile tool to interact in the design and manufacturing stage and the development of the multi-physics simulation approach for fusion welding, including where the main physical phenomena.

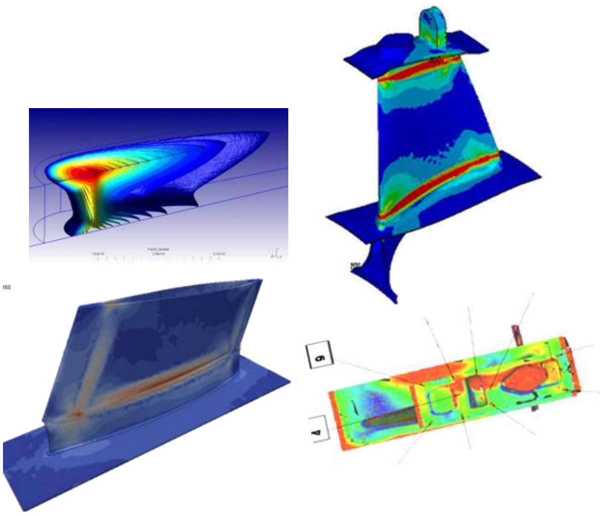

Figure 7: Upper left: Multi-physics welding simulation, temperature field from CFD simulation of weld pool fluid flow. (CEN) Lower left: Residual stresses after welding of the titanium sub-component. (CEN). Upper right: Residual stresses after welding of the nickel sub-component. (AICIA and ITP). Lower right: Validation of deformation on nickel sub-component. (ITP)

Machining

The project has focused to significantly improve the quality of machining using a multi-scale modelling approach. More accurate process simulation models will be developed to facilitate the process time and cost reduction. Particular emphasis will be placed on sequence optimisation, and definition of relevant process parameters to produce the specified tolerances and surface finish. The work will also aim to provide a tool to estimate the induced stresses in the machined components.

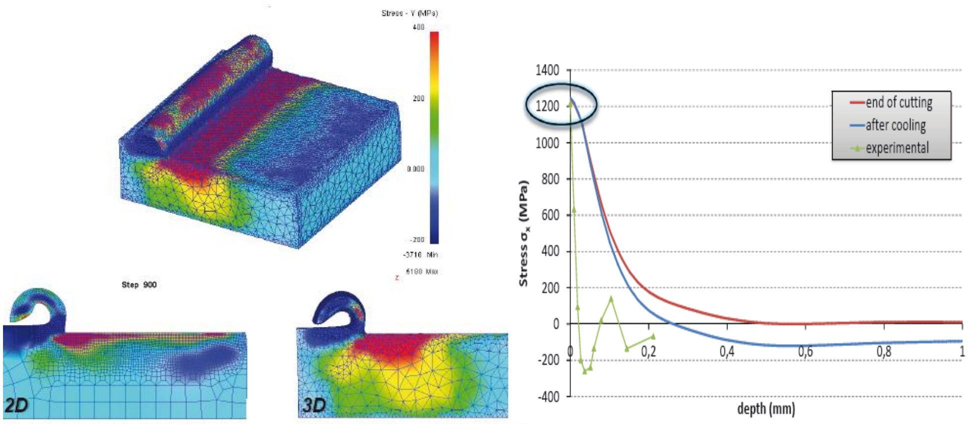

Figure 8: Micro-scale machining simulation for prediction of near-surface residual stresses and comparison to measurements (NOT, PT, RR and AVI).

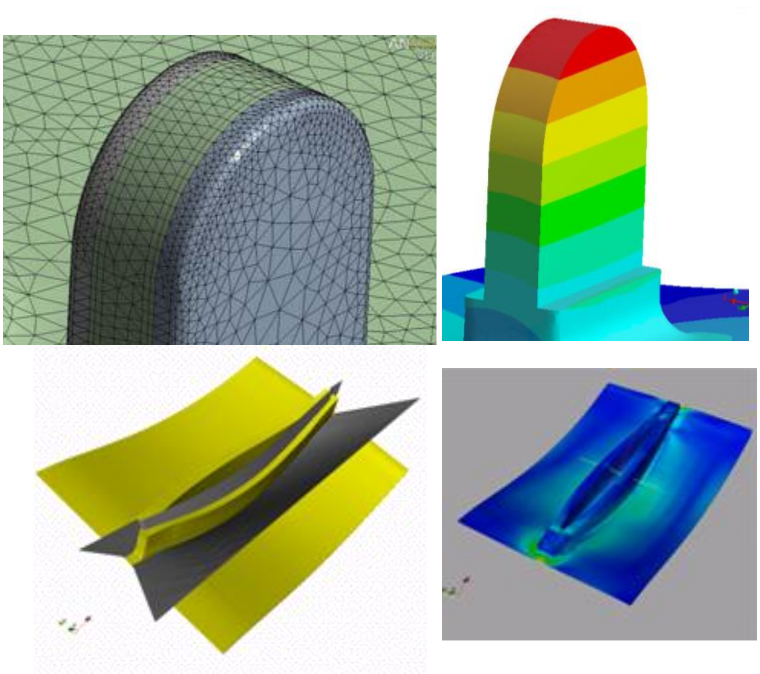

Figure 9: Distortion of a handling lug (ES) and a stand-up (CEN) during macro-scale machining simulation.

DATA TRANSFER AND MAPPING TOOLS

One of the objectives of VERDI is the simulation of generic manufacturing chains, where simulation results can propagate between different process models. This is illustrated in Figure 10, showing the Finite Element results transferred between different Finite Element Meshes (element size and element type) and different Finite Element Solvers via a neutral file format.

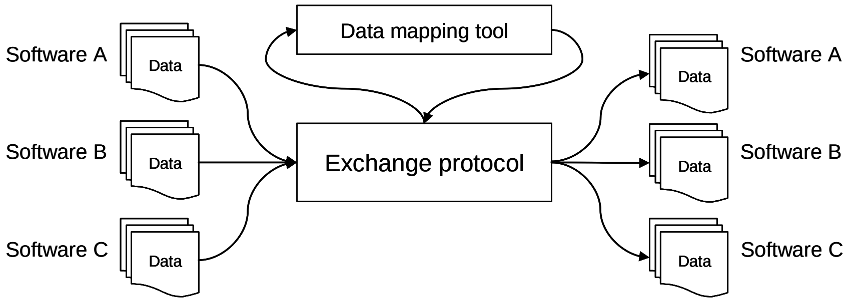

Figure 10: Illustration of the result transfer problem where data is mapped between different Finite Element Meshes and transferred between solvers used in the project. (NOT)

This chaining task is solved by two software, developed within the project. The software, FEDES (Finite Element Data Exchange System) developed by Nottingham University, take care of the data transfer between the different solvers used in VERDI. The other software, developed by Luleå University of Technology, takes care of the mapping between different Finite Element Meshes with different mesh density and different element formulations. The front-end GUI's of the two software are shown in Figure 11.

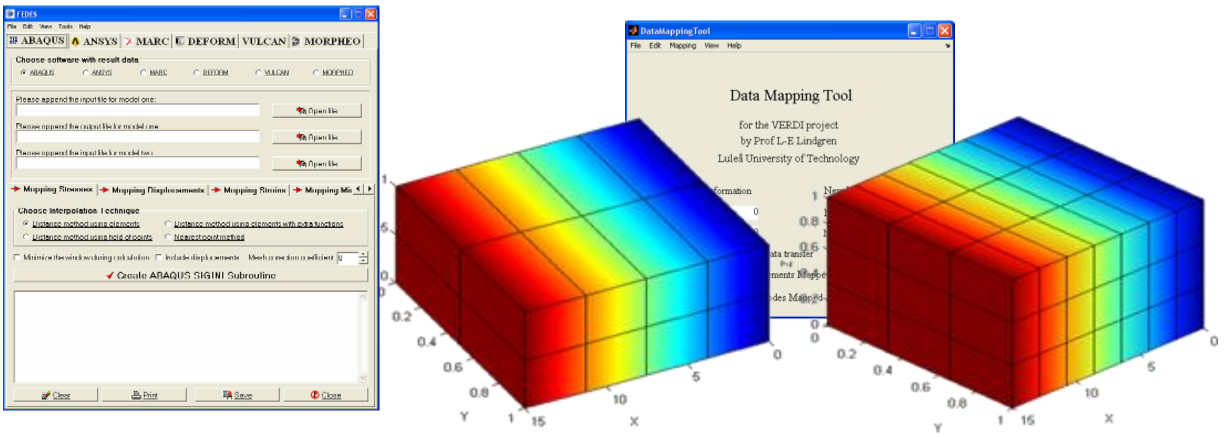

Figure 11: The two software developed within VERDI for simulation of process chains and demonstration of the mapping technology. (NOT and LTU)

MANUFACTURING CHAINS AND SUB-COMPONENTS

The tools for manufacturing chain simulation have been used in both sub-component manufacturing chains. Figure 12 and Figure 13 show the evolution of the residual stress field in the titanium and nickel sub-component, respectively, as it propagates through the manufacturing chain. The manufactured sub-components used for the validation of the manufacturing chains are found in Figure 14.

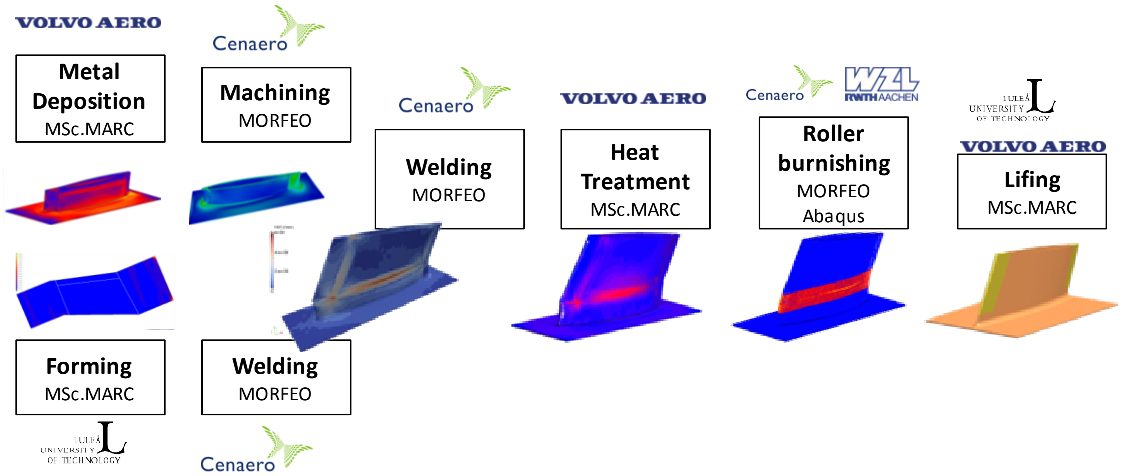

Figure 12: Evolution of the residual stress field in the titanium sub-component. (VAC, CEN, LTU and WZL).

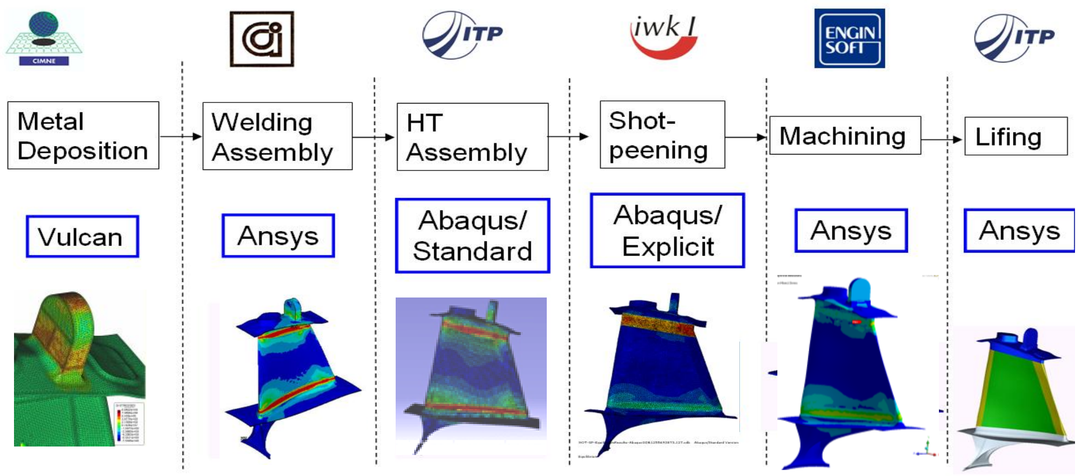

Figure 13: Evolution of the residual stress field in the nickel sub-component. (ITP, CIMNE, AICIA, TUK, and ES).

Figure 14: Left: The titanium sub-component. Right: The nickel sub-component. (VAC and ITP)