17h - 18th
OCTOBER
2016

PARMA
PAGANINI CONGRESSI
ITALY

INTERNATIONAL CAE CONFERENCE

STRUCTURAL OPTIMIZATION OF HEAVY SECTION DUCTILE IRON COMPONENTS: HOW THE INTEGRATION AND OPTIMIZATION OF CASTING PROCESS CAN IMPROVE THEIR DESIGN.

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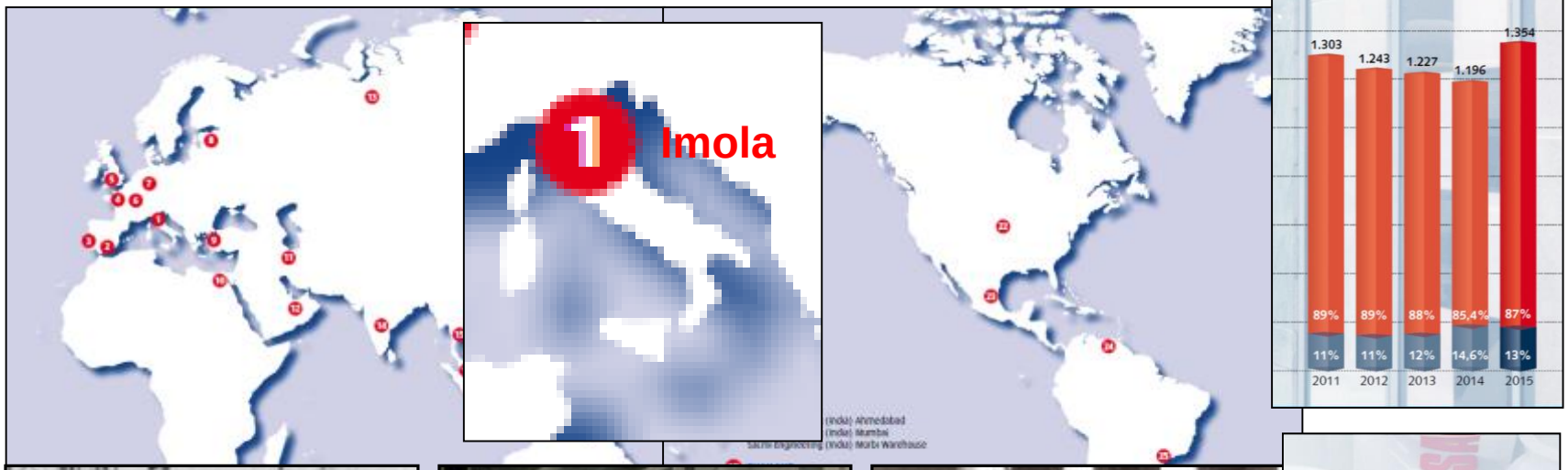
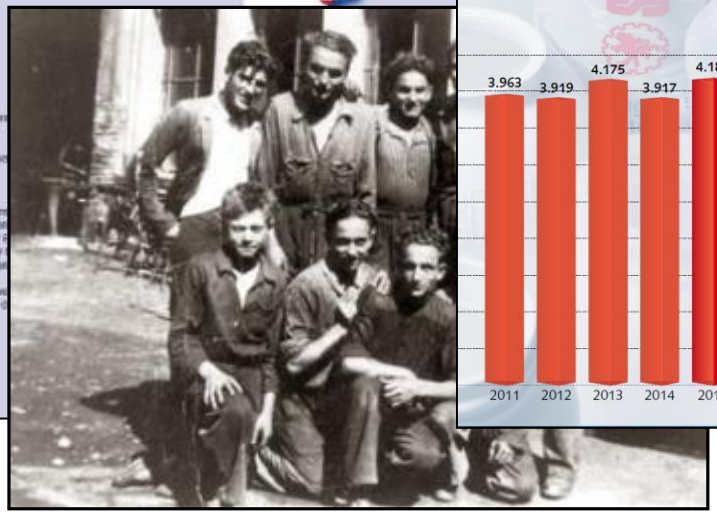
- G. Scarpa, F. Lago – EnginSoft SpA

SACMI: since 1919



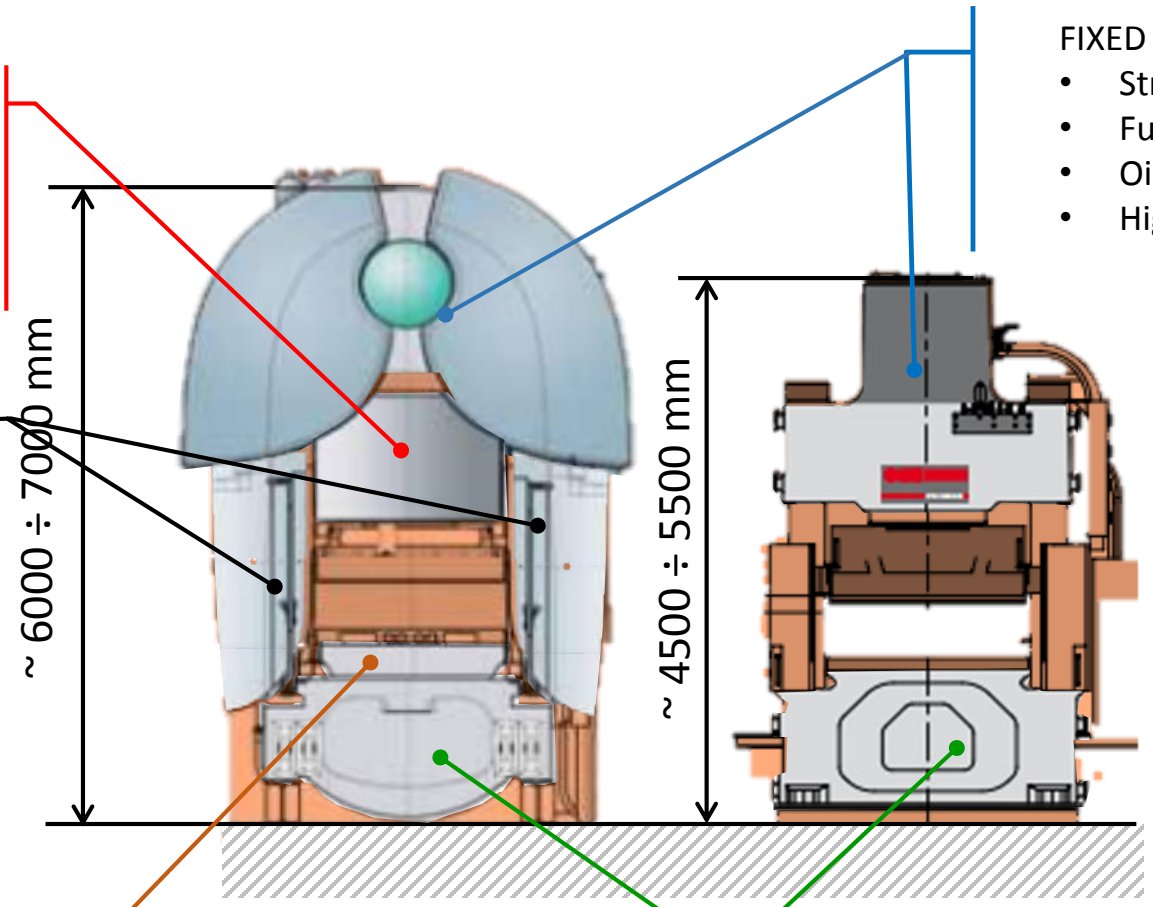


Ductile iron components in hydraulic presses

CYLINDER:
- Structural
- Functional
- High Pressure Oil

SPACER:
- Structural

MOULD SUPPORT:
- Structural



FIXED CROSSBEAM:
- Structural
- Functional
- Oil Tank
- High Pressure Hydraulic Holes

BASEMENT:
- Structural

Why are the castings so important ?

- They represent one of the main cost of the machine;
- Since they are structural parts, a failure could be critical due to safety reasons;
- A failure represents a dramatic issue both from the economical and reputation side.

Ductile iron component design process

DESIGN

Tasks:

Functional & Structural Design
Project/Component reliability

Activities:

Geometry definition (CAD)
Stress analysis (FEA)

ANSYS
SolidWorks
(rbf-morph)™
MAGMA5

CODESIGN

In 2016 SACMI bought MAGMA5 to introduce a first co-design step directly in the technical department

Influence the overall distribution of mechanical properties

Influence the component quality acceptability

TECHNOLOGY

Tasks:

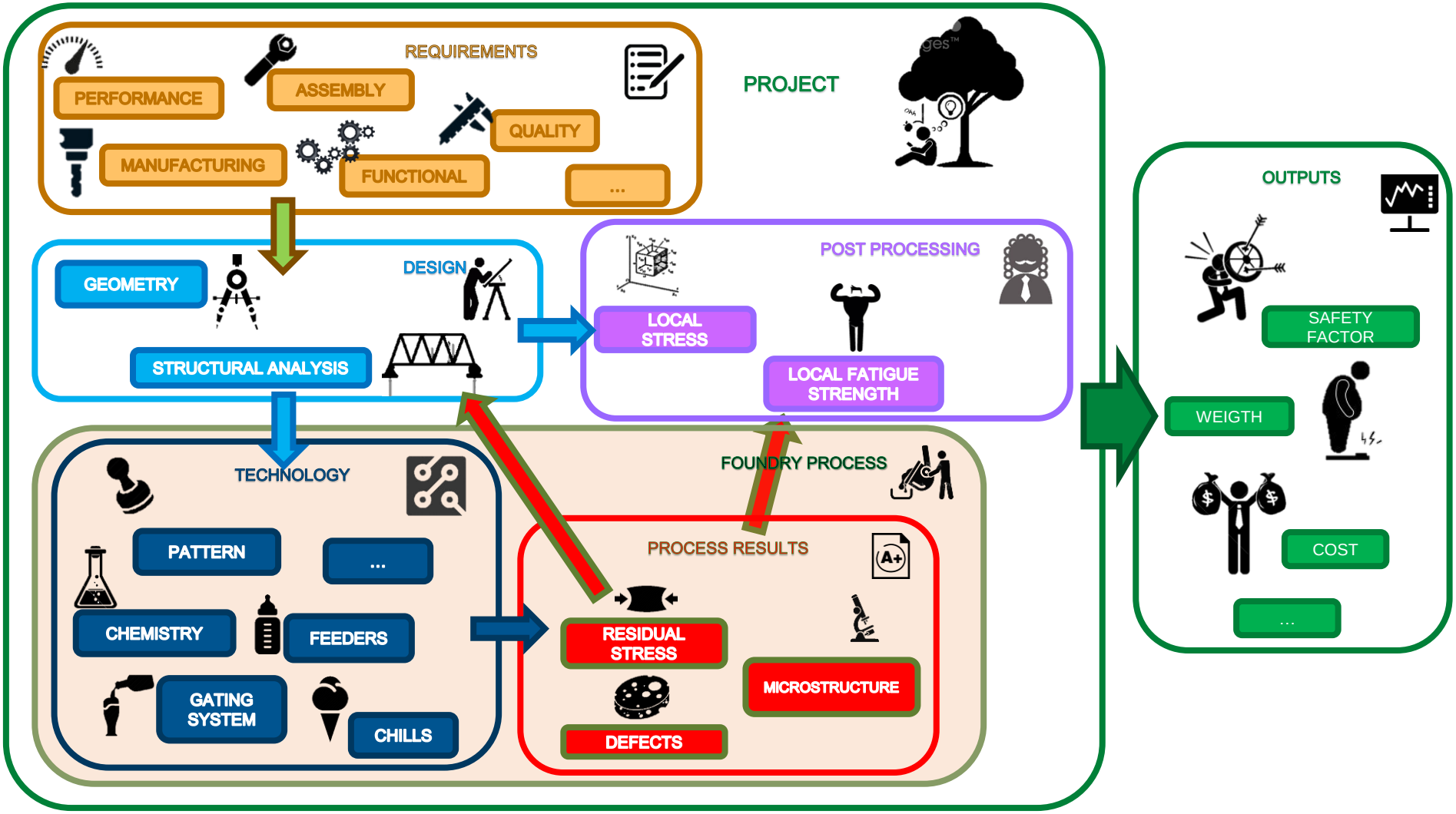
Component Soundness
Local quality improvements
Controlled and Robust Process

Activities:

Pattern definition (CAD)
Casting Process Layout
Casting Process simulation (CAE)

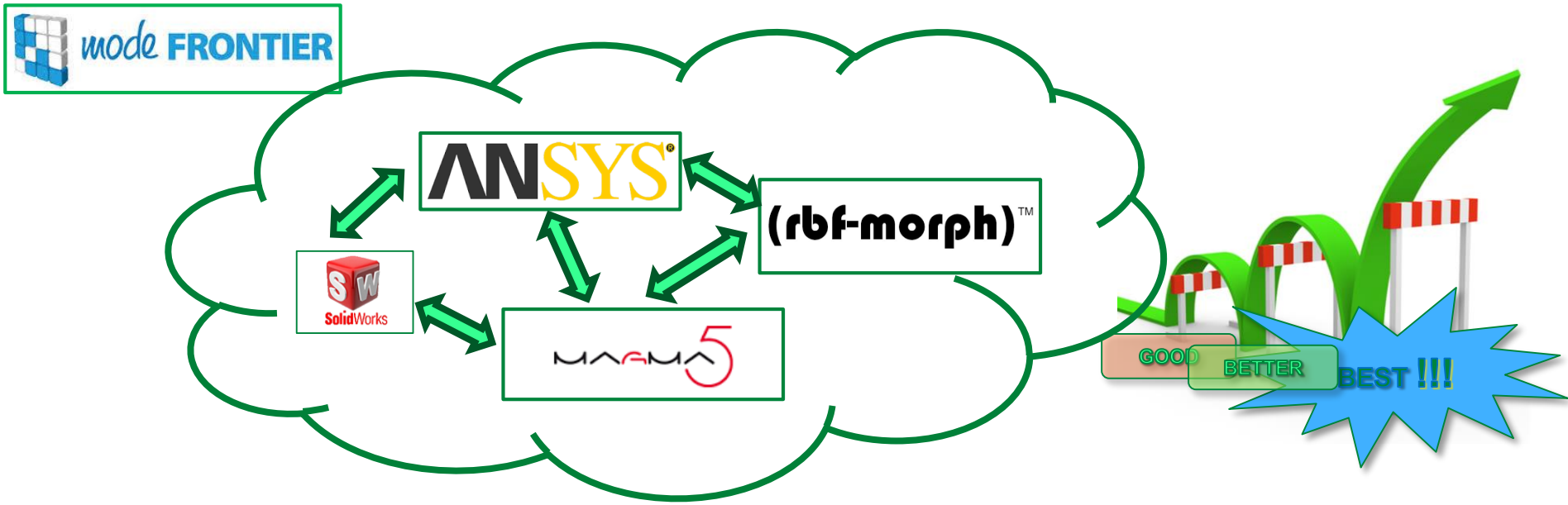
MAGMA5

Ductile iron component design process

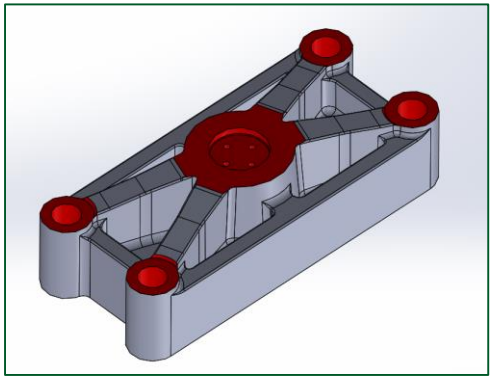


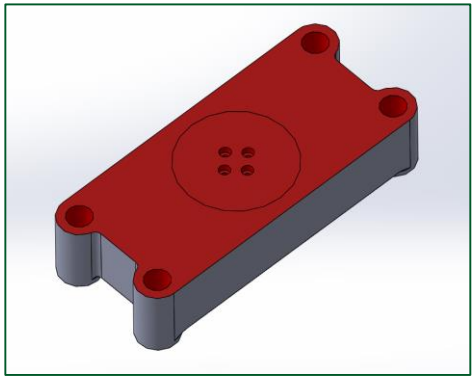
The “Fully Integrated Optimization”

Optimize at the same time the geometry and the process with the same supervisor that manage them with the objective to get the best results coupling and mutually orienting structural design and casting process.



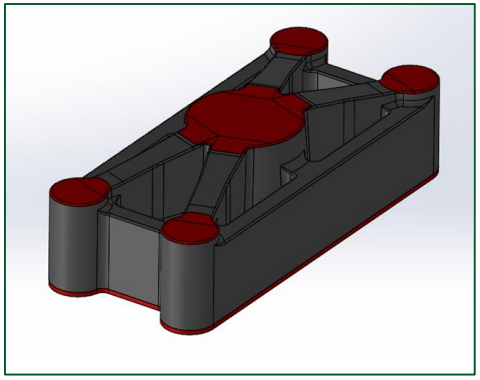
Example: the geometry

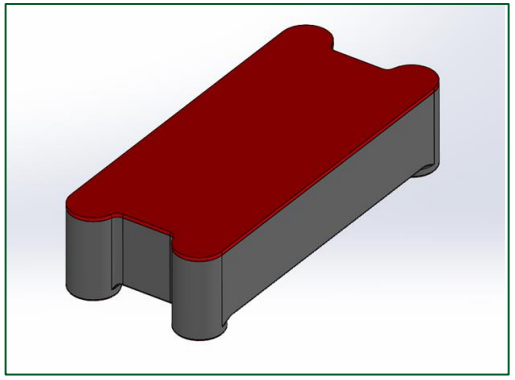




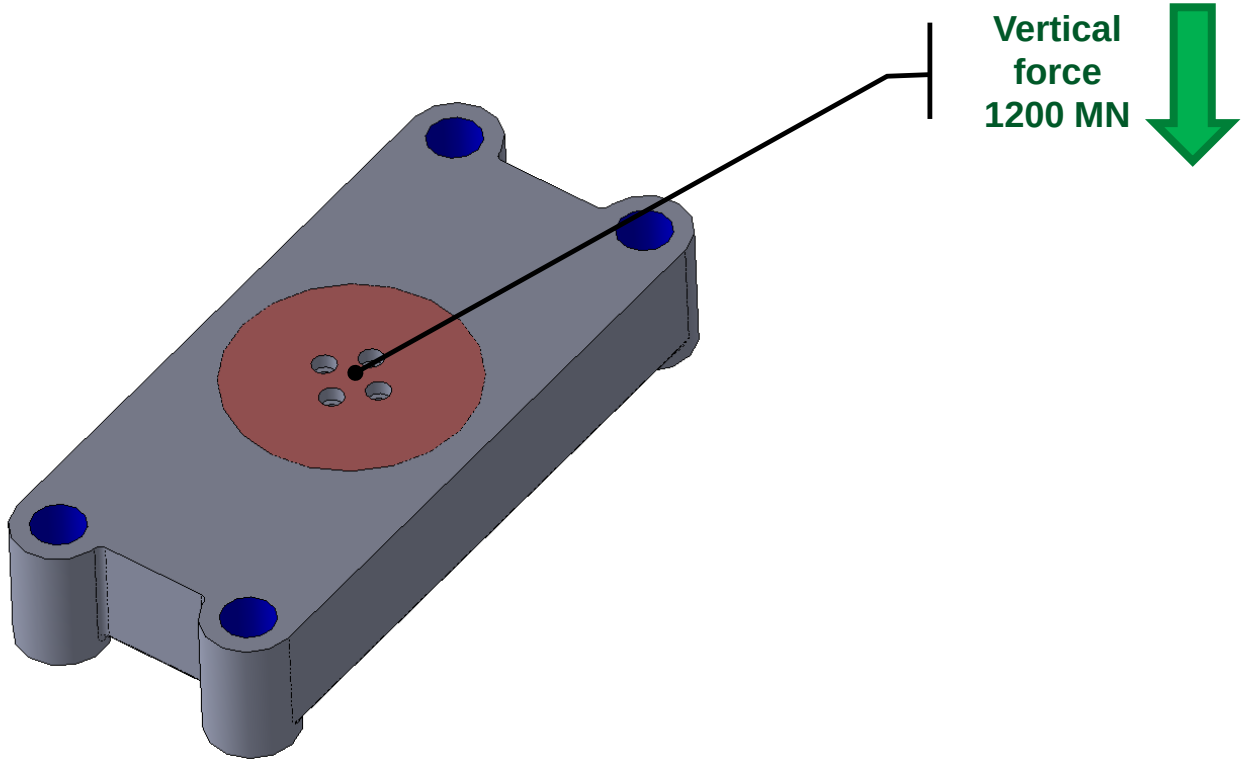
Machined component
(in **red** the machined surfaces, **light grey** as cast)

As Cast component
(in **red** the allowances, **light grey** as cast)

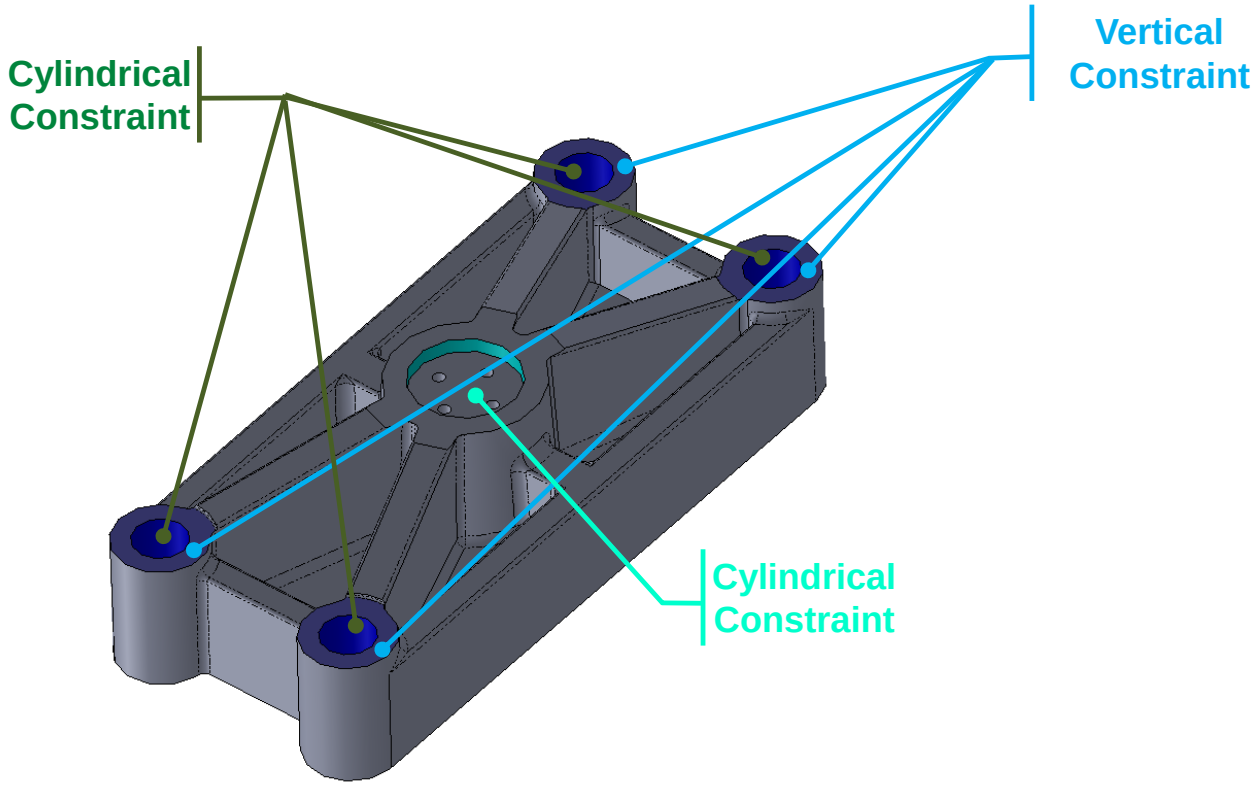




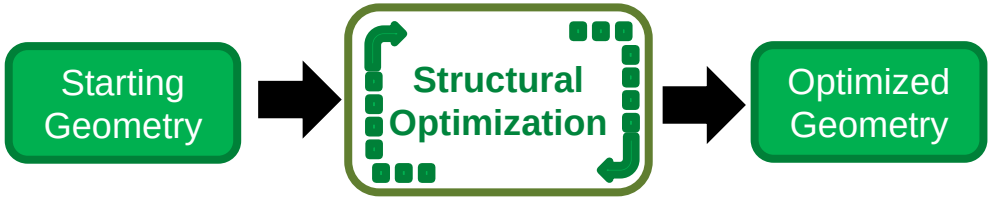
Stress analysis: Loads



Stress analysis: Constraints



OPTI0: Structural Optimization



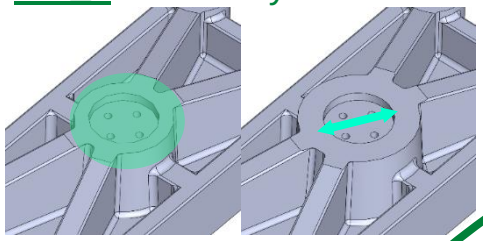
Material is considered homogeneous: same mechanical properties and same microstructure in the whole item.
The microstructure is considered as it is in the cast-on sample (Ferritic matrix, 100 nodules/mm^2).
*

Optimization:

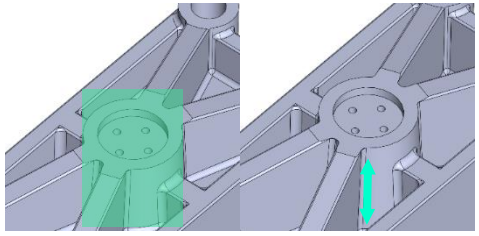
- Constraint: Safety Factor minimum 1.3
- Objective: Minimize the weight

Structural Optimization Variables

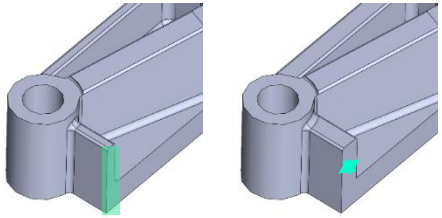
Var_1: central cylinder diameter

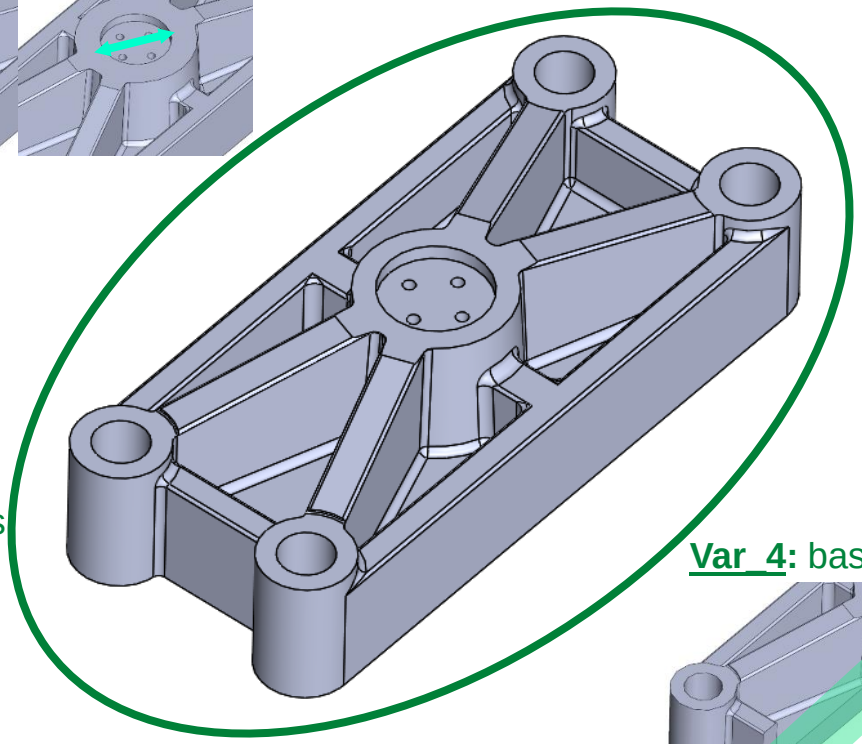


Var_2: central cylinder height

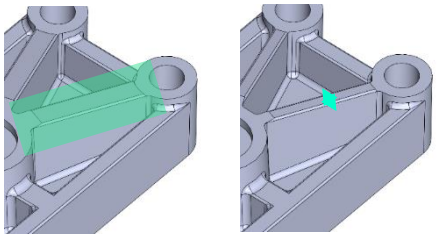


Var_3: external ribs thickness

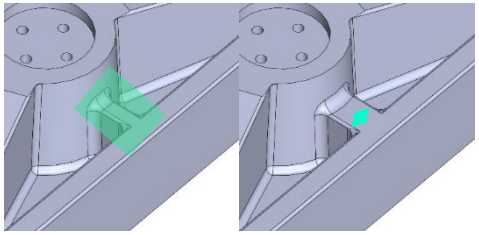




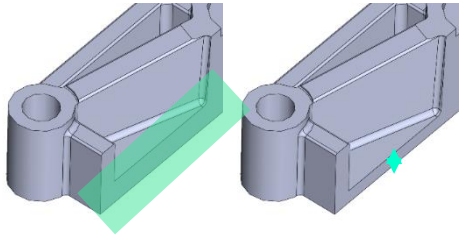
Var_6: lateral ribs thickness



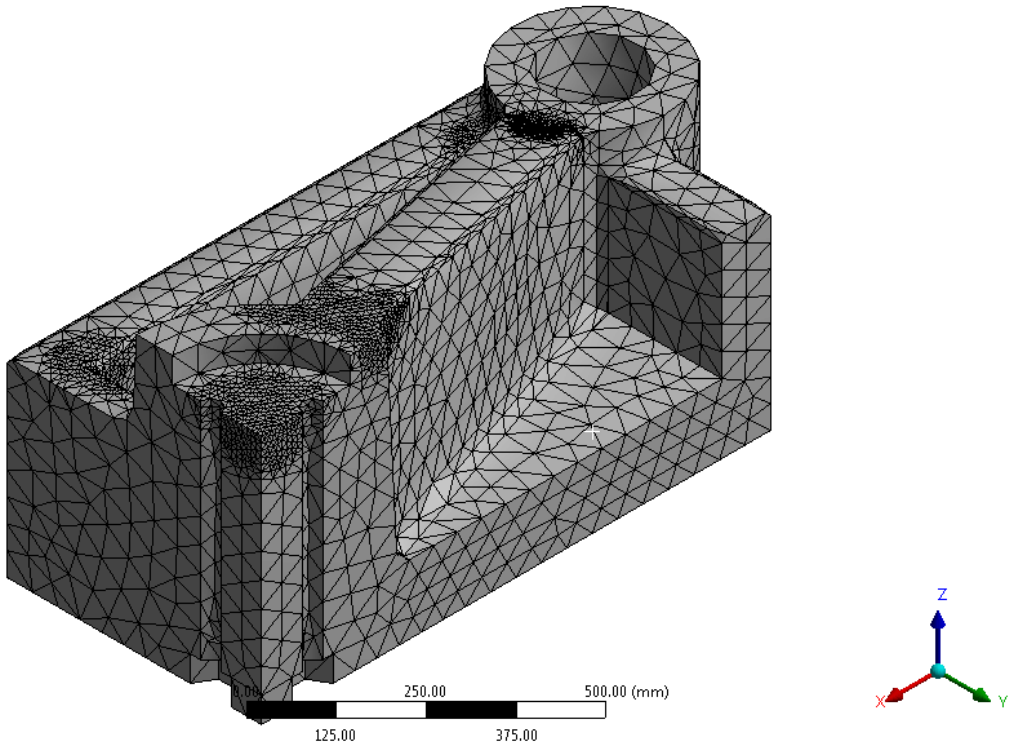
Var_5: central ribs thickness



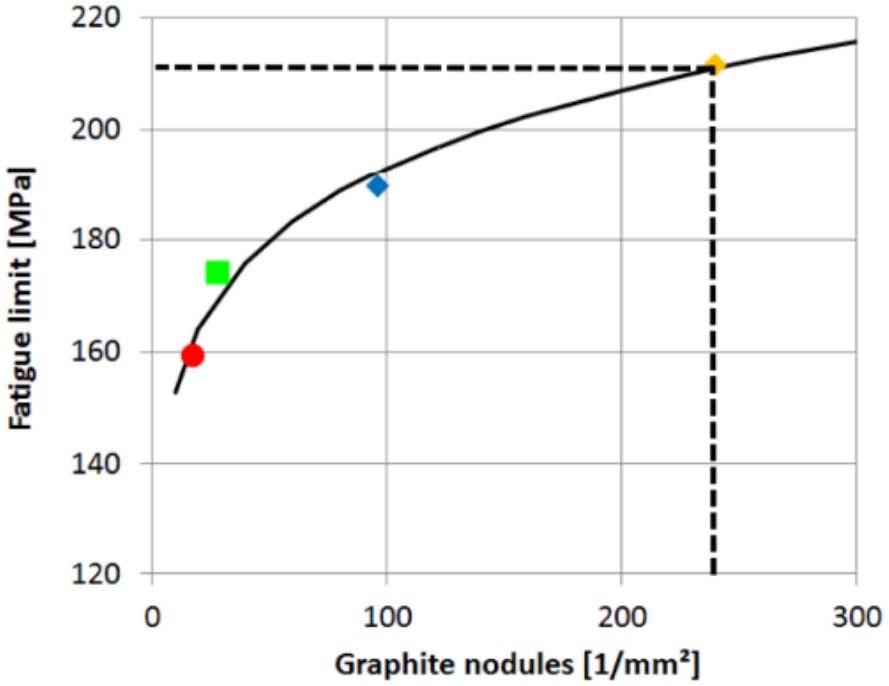
Var_4: base plate thickness



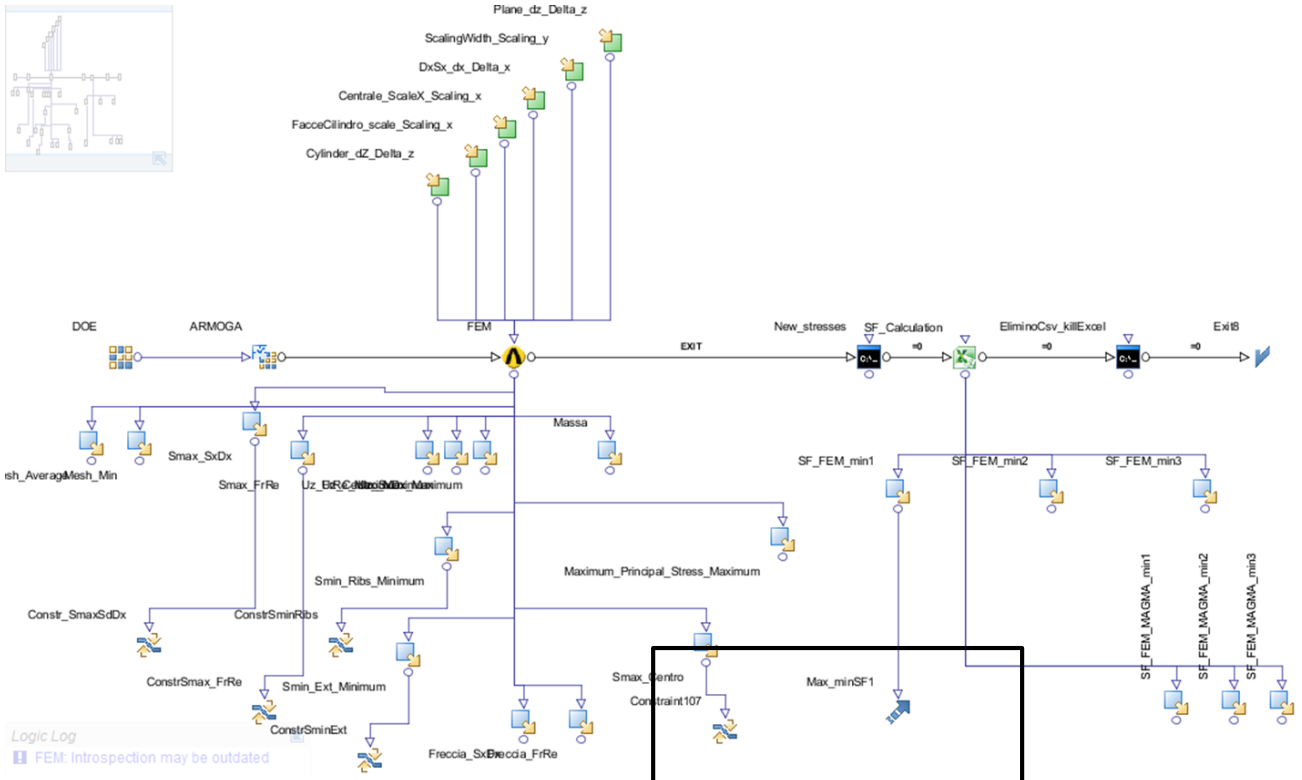
Structural Optimization: Geometry Deformations



* Correlation Microstructure-Fatigue Strength

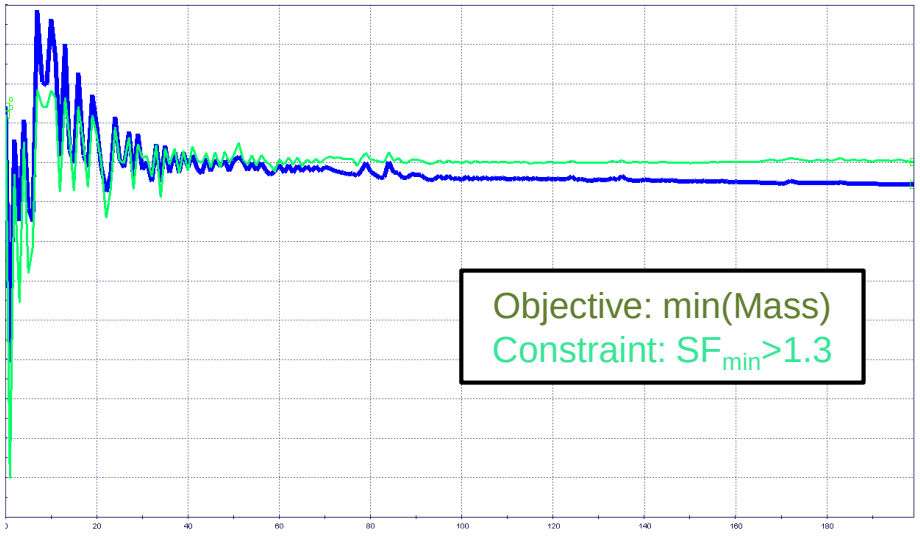


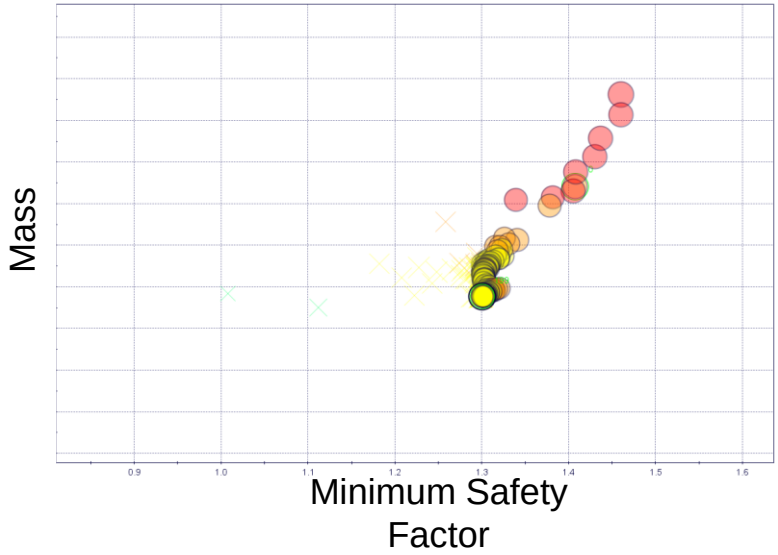
Optimization: the Layout



Objective:
min(Mass)
Constraint:
SF_{min}>1.3

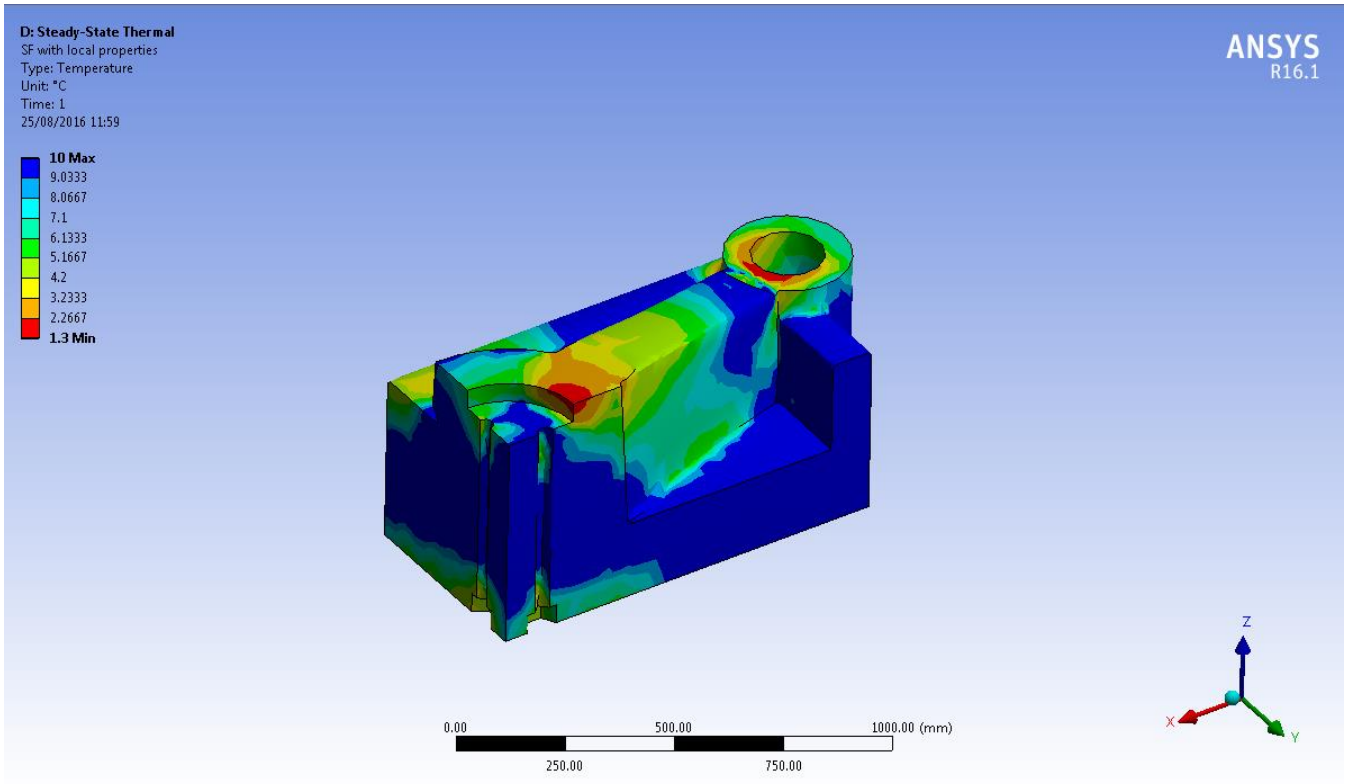
Optimization: the Results



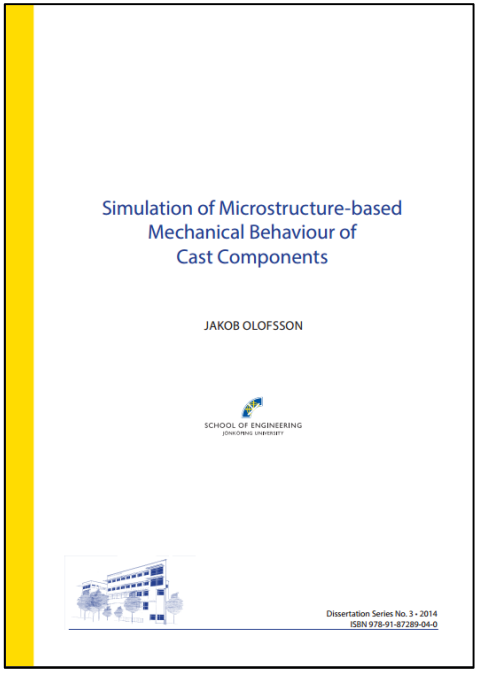


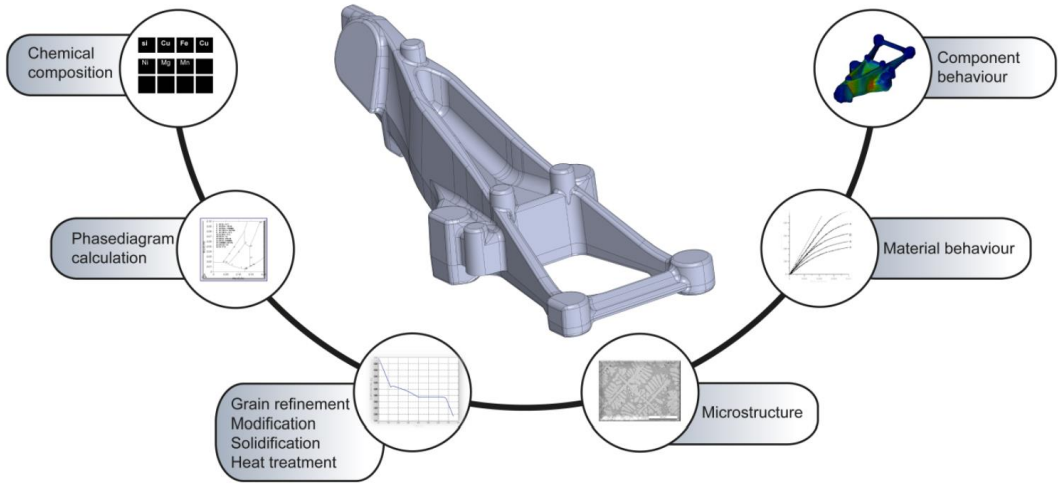
DP_OPTI0
5000 kg
Sf$_{min}$ = 1.3

Optimization: the Results



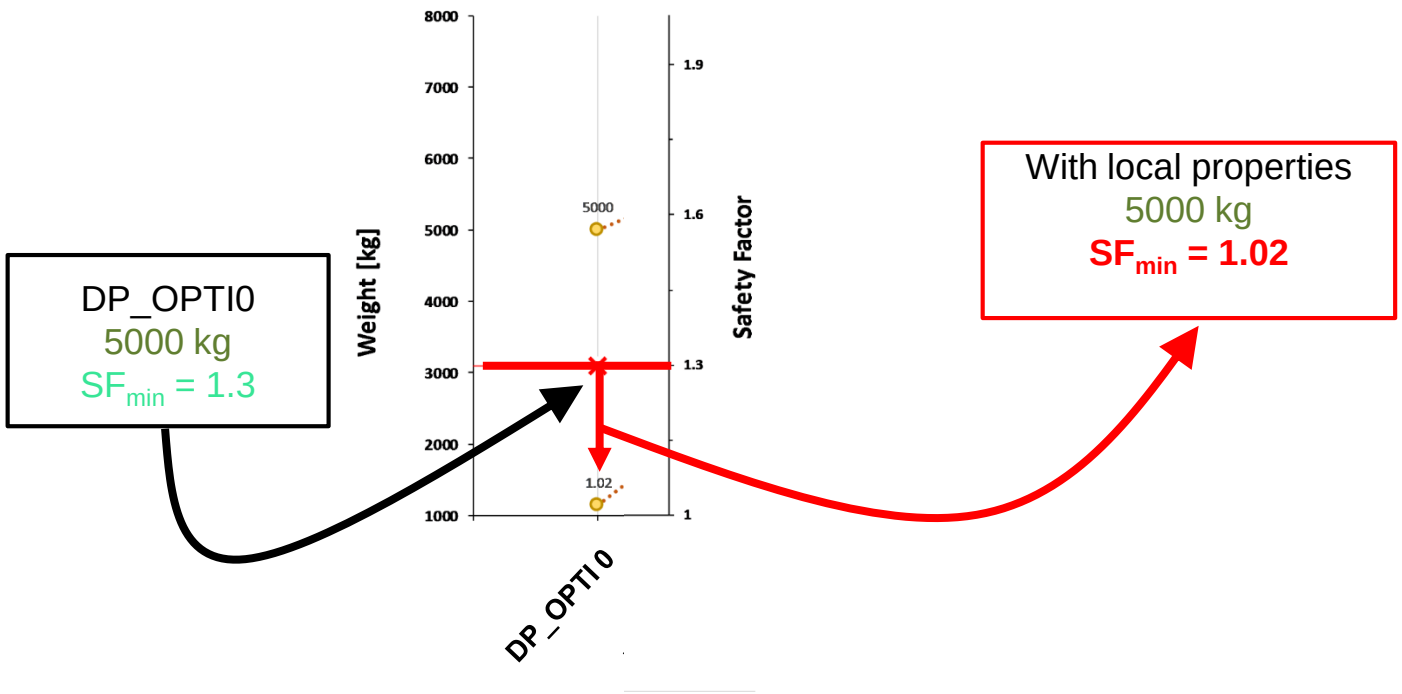
The closed chain of simulations for cast components



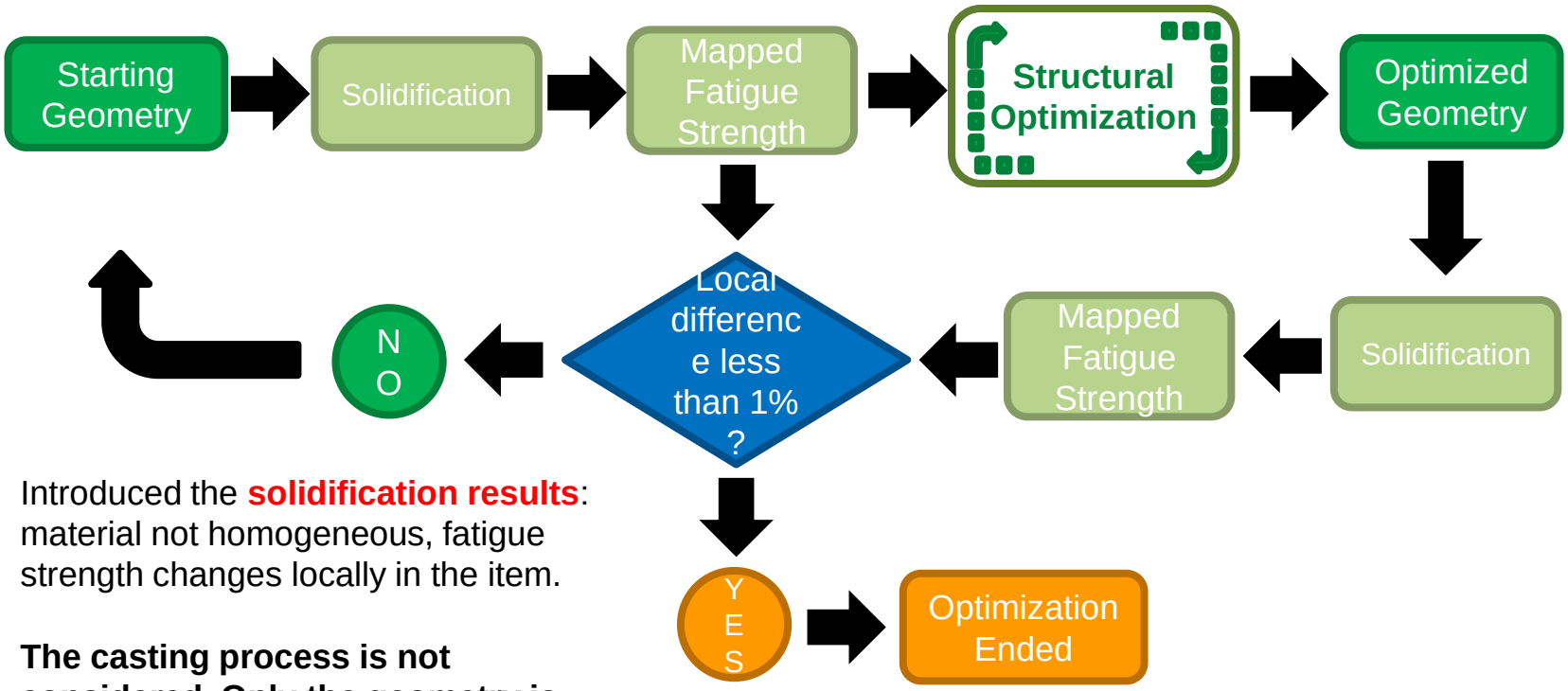


The closed chain of simulations for cast components
from Jakob Olofsson, «Simulation of Microstructure-based Mechanical Behaviour of Cast Components», Ph.D. Thesis, 2014

Are we sure about the Safety Factor ?



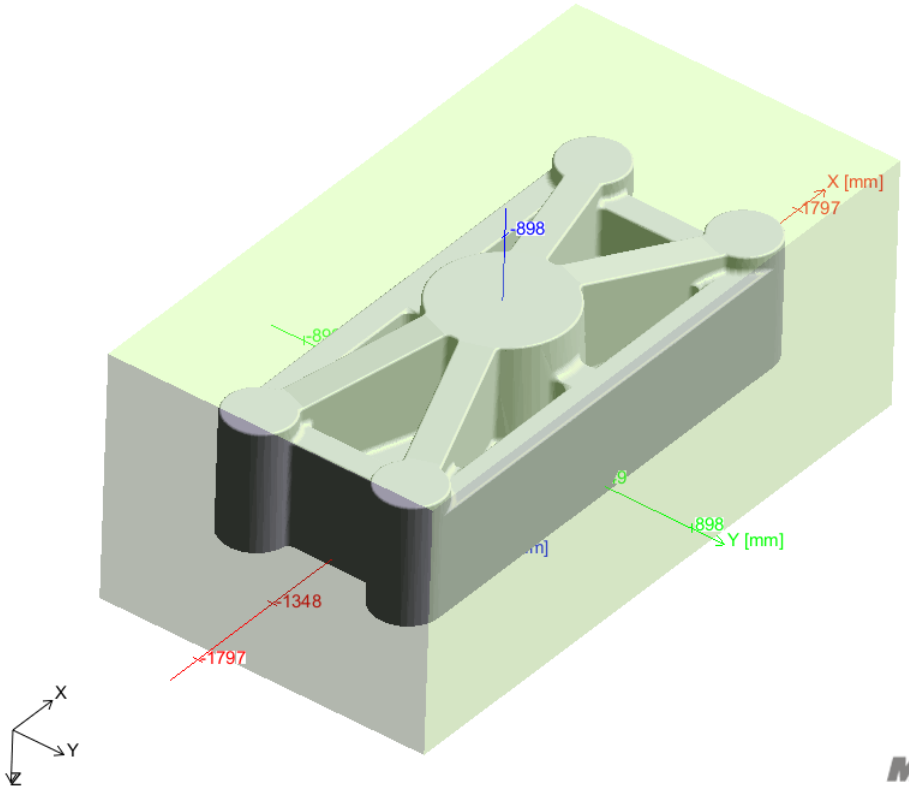
OPTI1,2,3: a Designer Perspective



Introduced the **solidification results**: material not homogeneous, fatigue strength changes locally in the item.

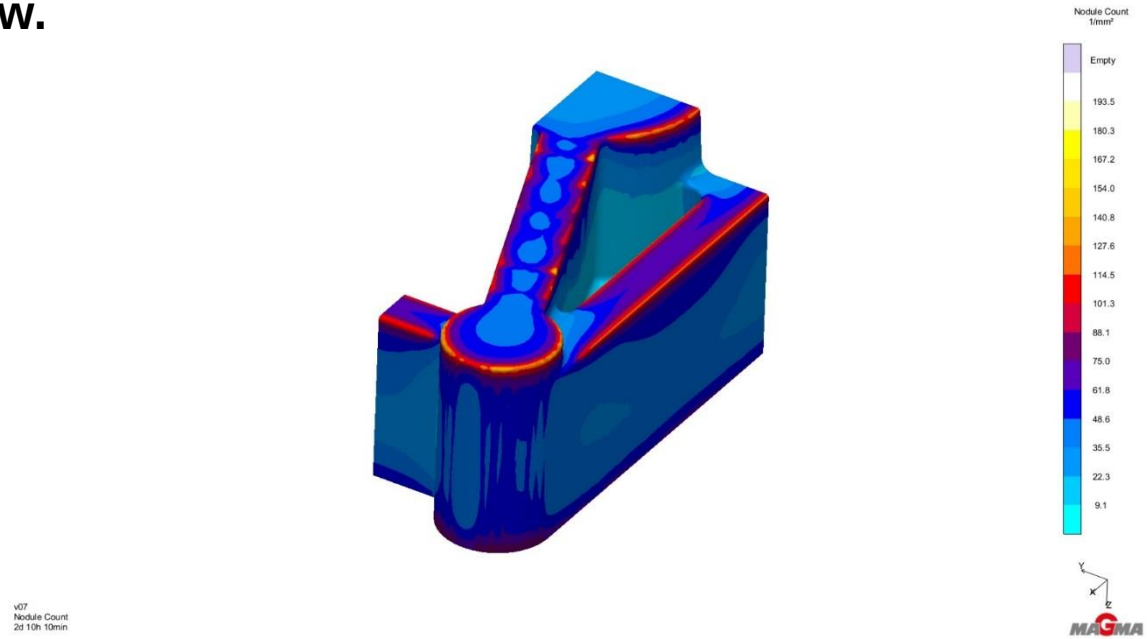
The casting process is not considered. Only the geometry is modified.

Solidification step: the geometry



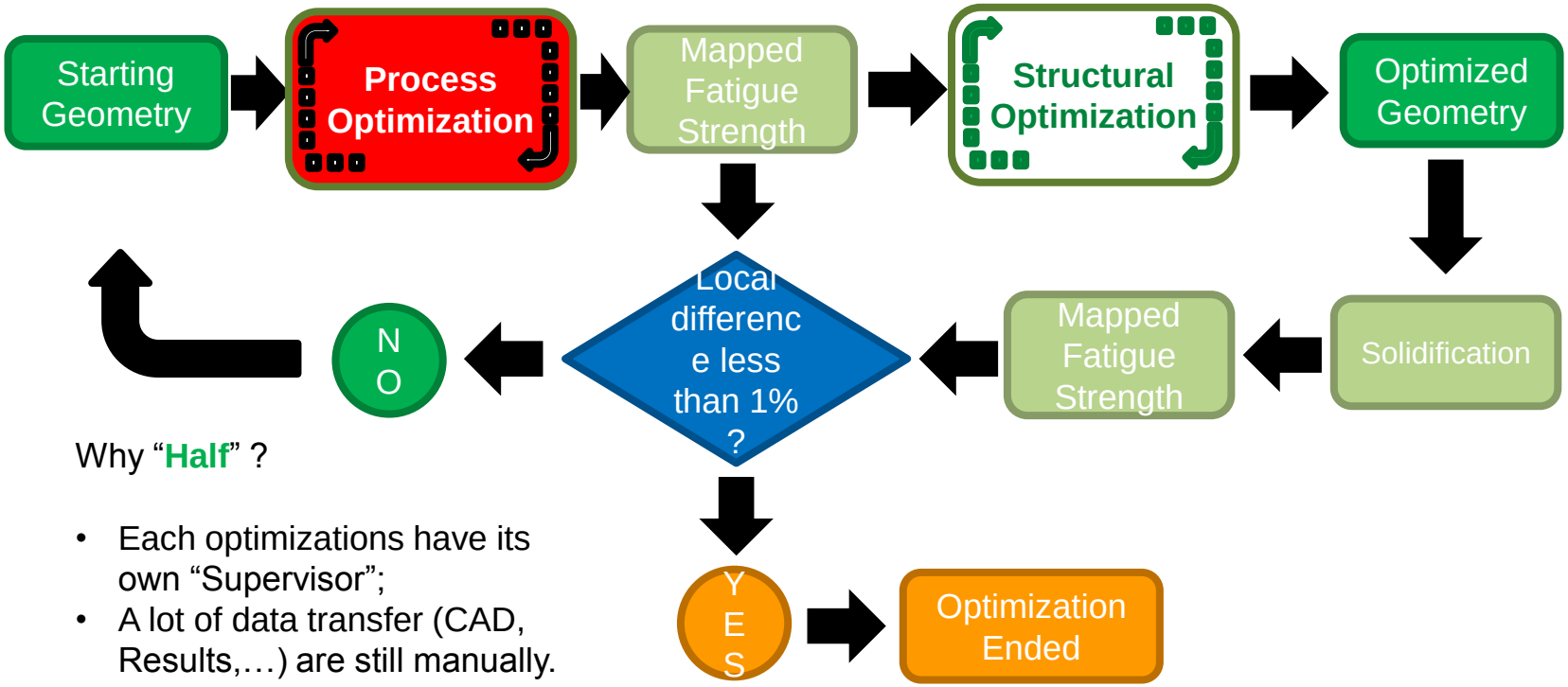
Solidification: Nodule Count

Nodule Count evaluated using *MAGMAIron* and exported using *MAGMALink*. The nodule count is transformed in Local Fatigue Strength using the *Gruen* – *Kainzinger* law.



OPTI4,5,6: the “Half Coupled Optimization”

“Virtual Foundry”: process optimized based on designer’s specific requests.

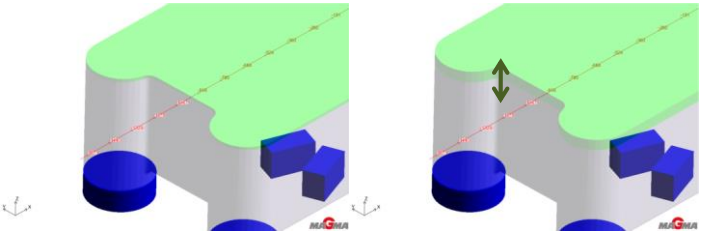


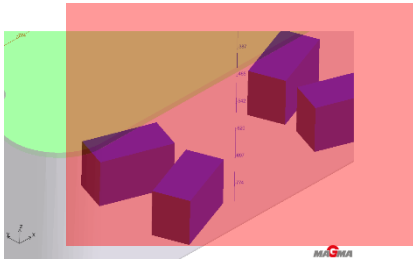
Why “**Half**” ?

- Each optimizations have its own “Supervisor”;
- A lot of data transfer (CAD, Results,…) are still manually.

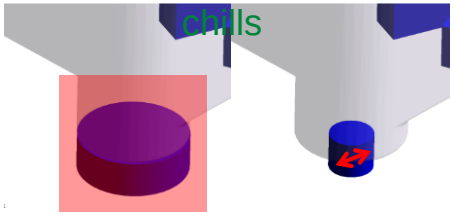
Process Optimization Variables

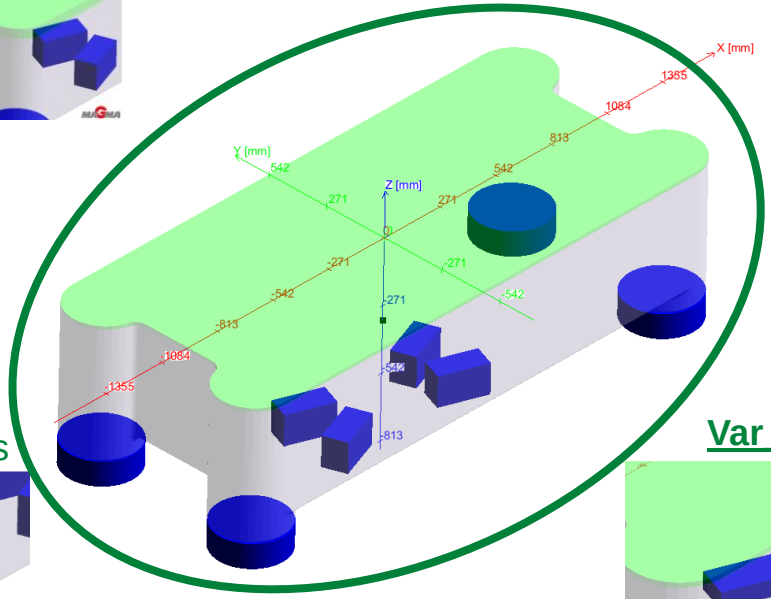
Var_1: allowance main plane



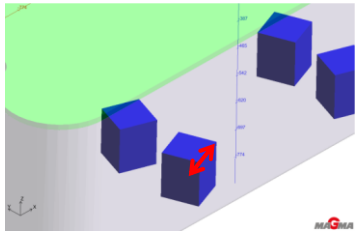


Var_2: diameter cylindrical chills

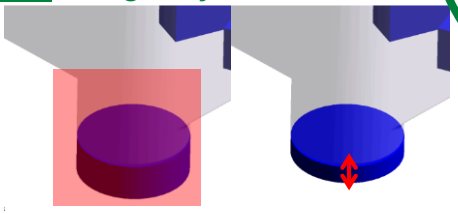




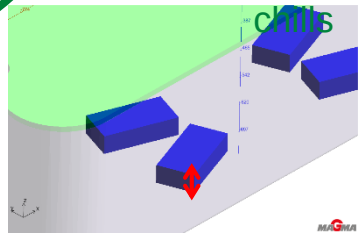
Var_5: length rectangular chills



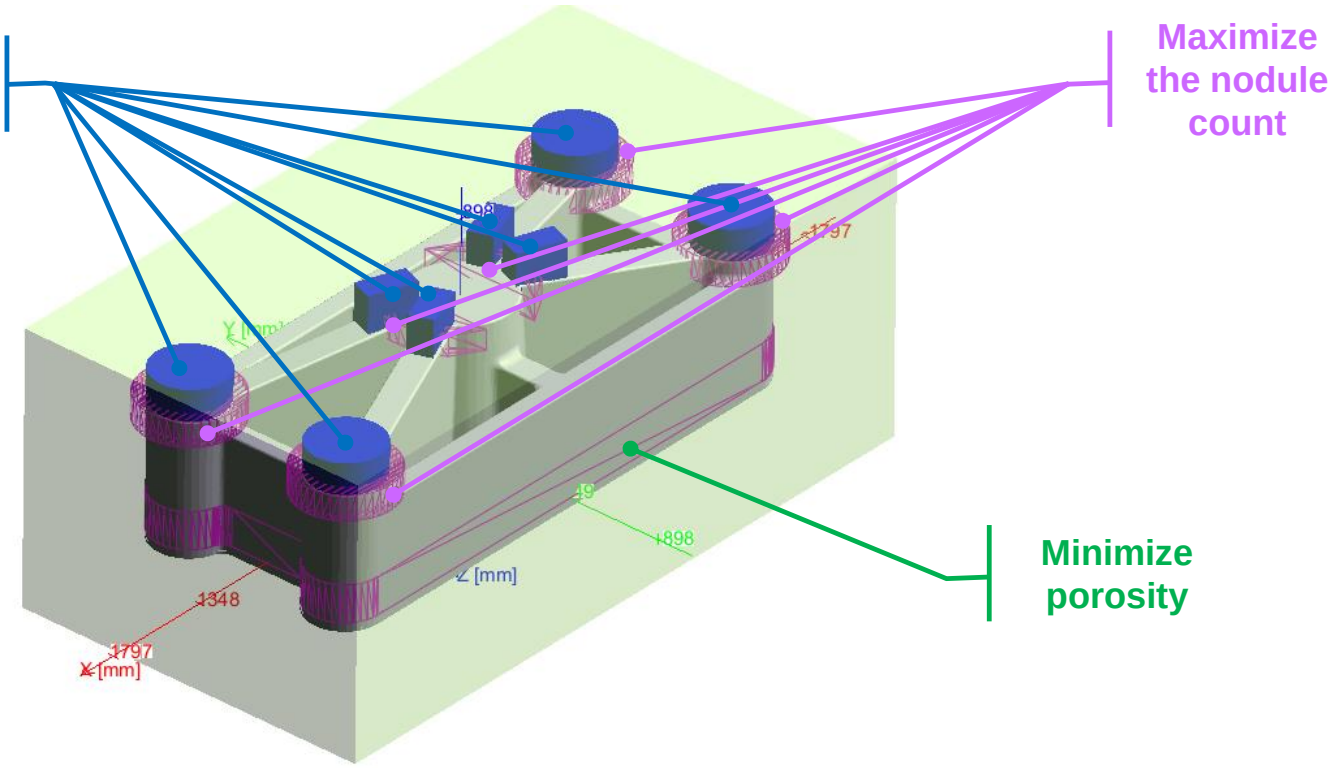
Var_3: height cylindrical chills



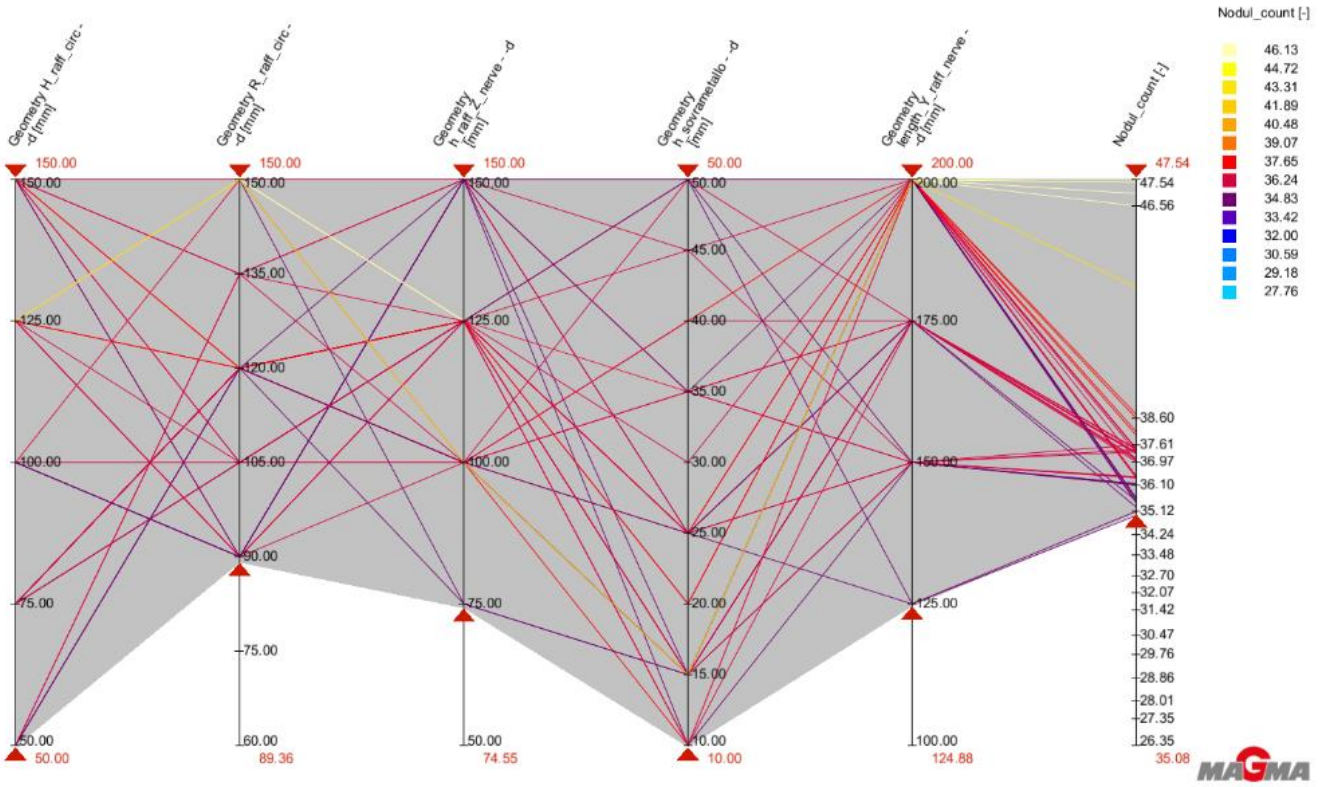
Var_4: height rectangular chills



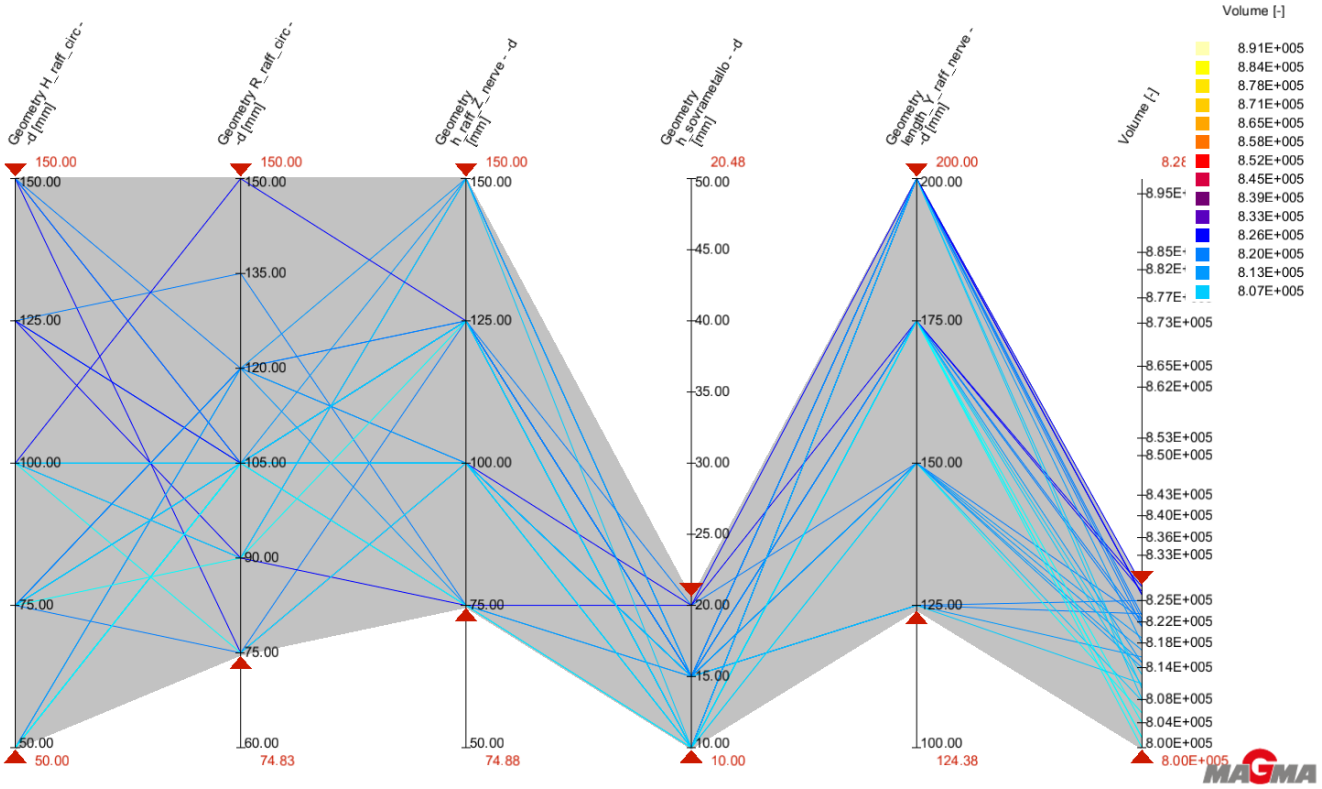
Process Optimization Objectives



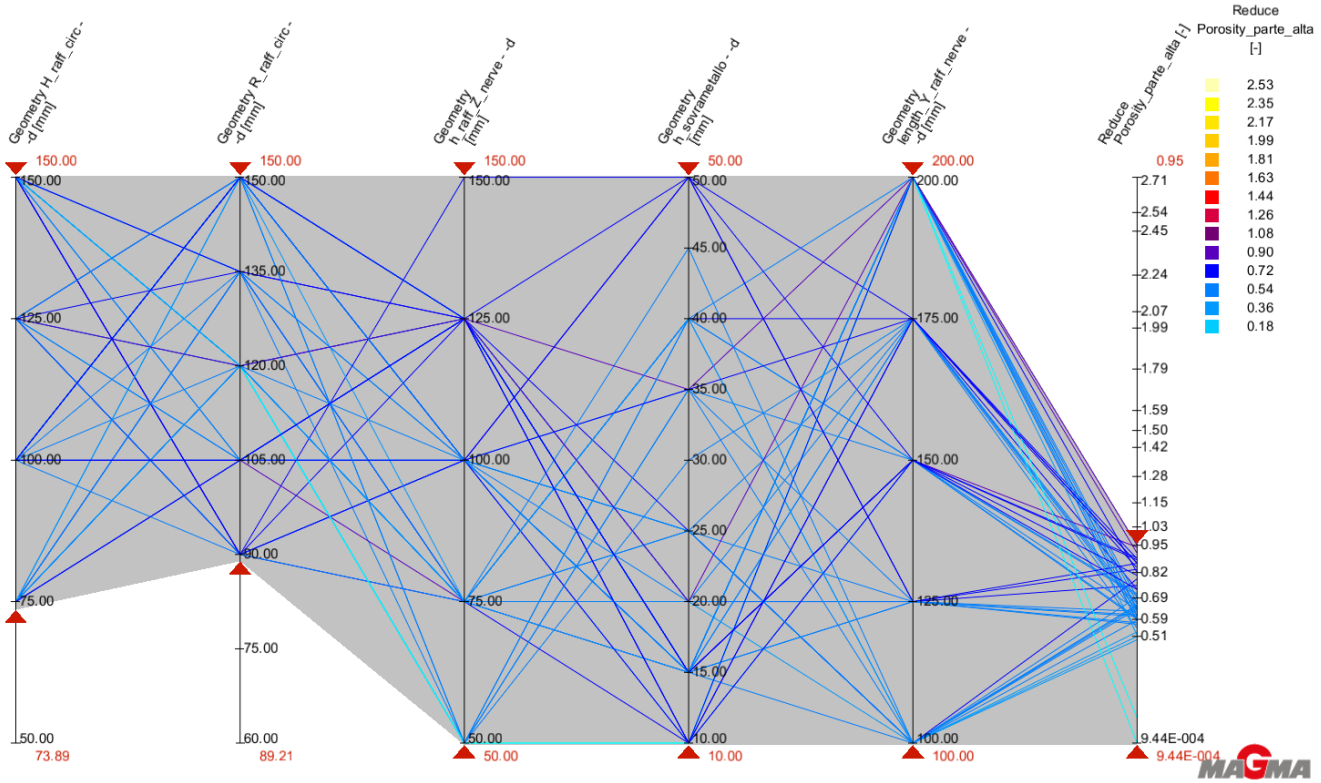
Process Optimization: Overview



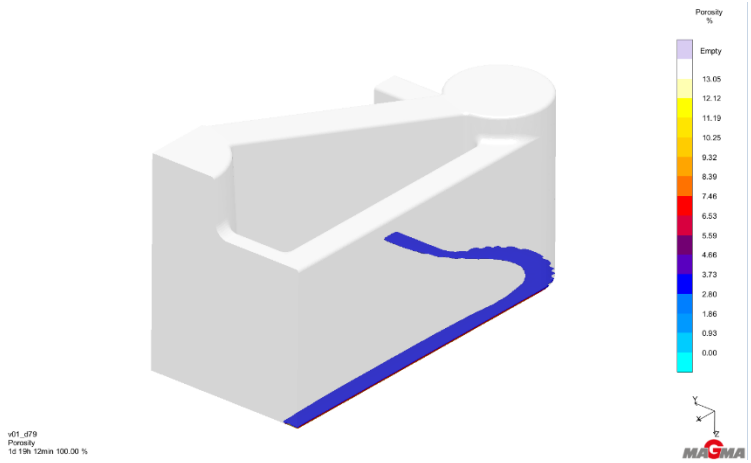
Process Optimization: Overview



Process Optimization: Overview

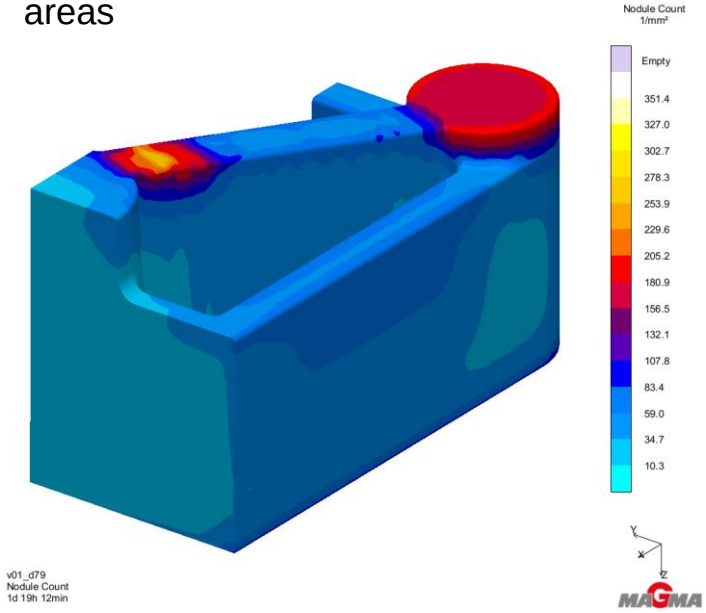


Process Optimization: Results

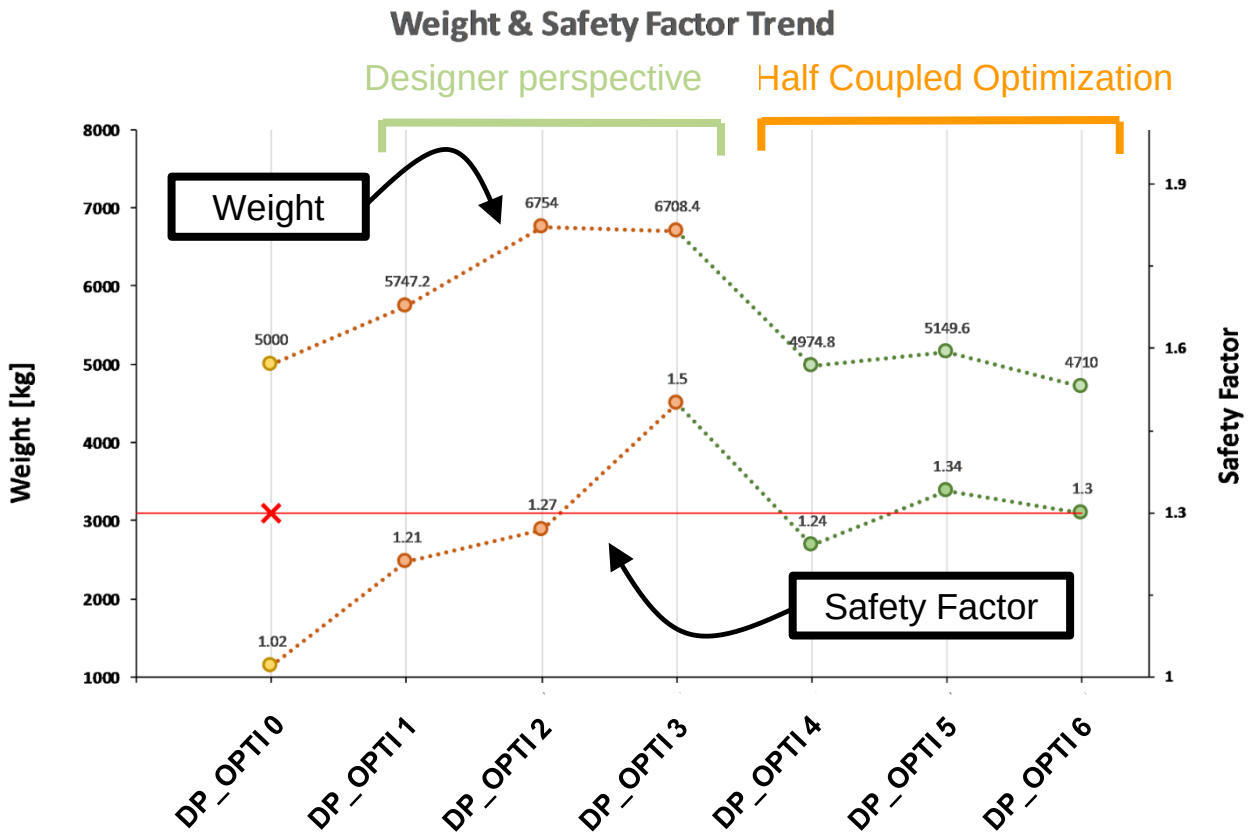


Porosity less than 5% and all in the allowance

Nodule count maximized in the critical areas



Process Optimization: Results



Conclusions:

- An example of coupled structural and process optimization has been presented;
- We demonstrated if the process results are not properly introduced in the design it can bring to un-safety;
- The best results can be got only if both the structural and process optimization are coupled.

CAE Conference 2017 for “Fully Integrated Optimization” ?

THE END

Thanks you all!

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