

Flow Optimization of CC Manifold: Coupling HyperWorks and Cradle Solutions

bosal

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 **Altair**

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 **CRADLE**

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BOSAL COMPANY PROFILE

- AUTOMOTIVE SUPPLIER
- PRIVATELY OWNED & SELF FINANCED
- R&D CENTER IN BELGIUM
- TURNOVER ~800M€
- ANNUAL INVESTMENTS ~43M€
- HEADCOUNT ~6000
- WORLDWIDE FACTORIES ~43



CAE CAPABILITIES

- **SOFTWARE**

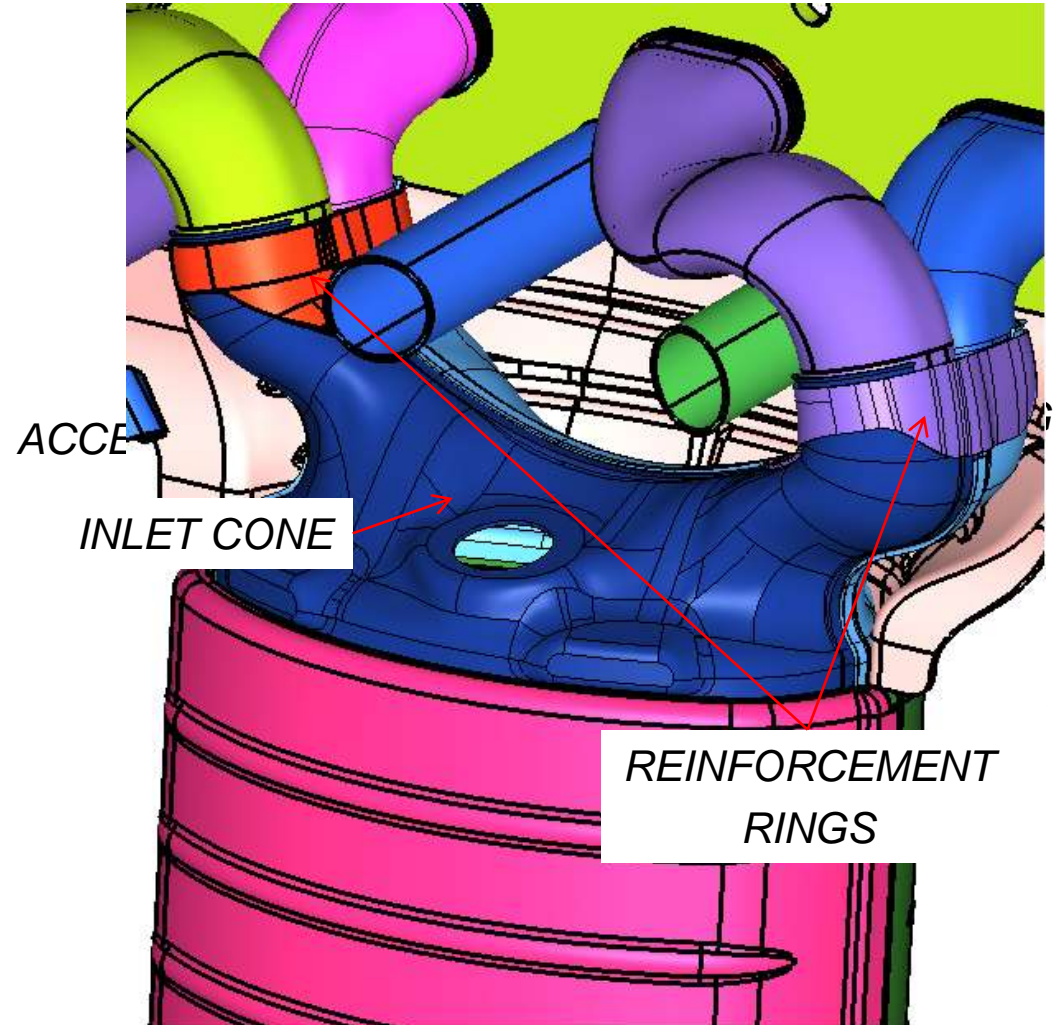
- ABAQUS (SIMULIA)
 - STANDARD & EXPLICIT
- GLYPHWORKS (NCODE)
- HYPERWORKS (ALTAIR)
 - HYPERMESH
 - HYPERSTUDY
 - HYPERFORM
 - DESGIN LIFE (PARTNER P.)
 - SC TETRA (PARTNER P.)

- **CAE COMPETENCES**



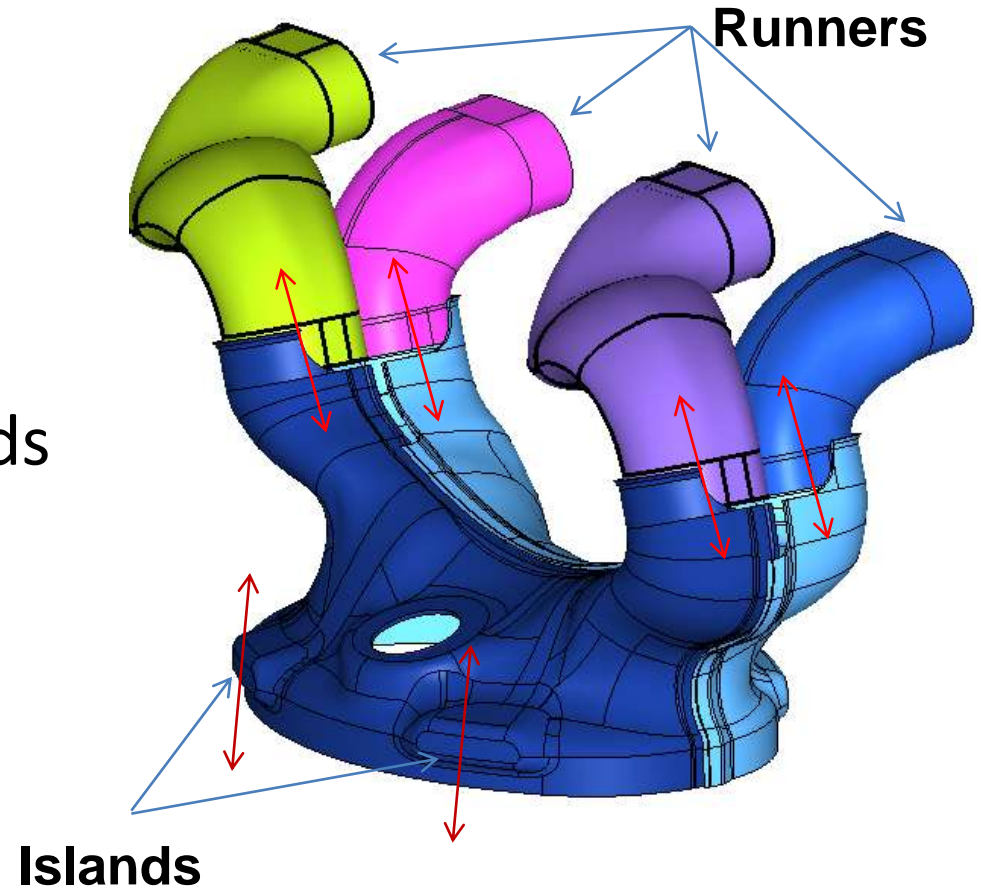
ORIGINAL CONCEPT

- Compact
- Insulated
- Minimized welding
- Locally reinforced



ORIGINAL CONCEPT

- Sliding runners
- 2x2 maintaining Islands



GLOBAL OBJECTIVES

- Flow Uniformity > 90-95%
- Backpres. < reference

• Scope of this project

- Limited skin T°
- No vibration mode in engine operating range
- Durability
 - Thermo-mechanical
 - Road events
- ...

• Out of scope for this project

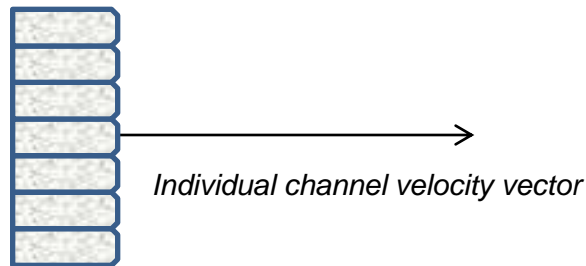
Uniformity Index (UI)

- UI measures how uniform the flow is through a given section

$$\gamma = 1 - \frac{\sum_{i=1}^N |w_i - \bar{w}| \cdot A_i}{2 \cdot A \cdot \bar{w}}$$

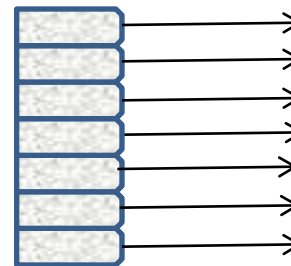
UI~0%

Whole flow going through a single channel

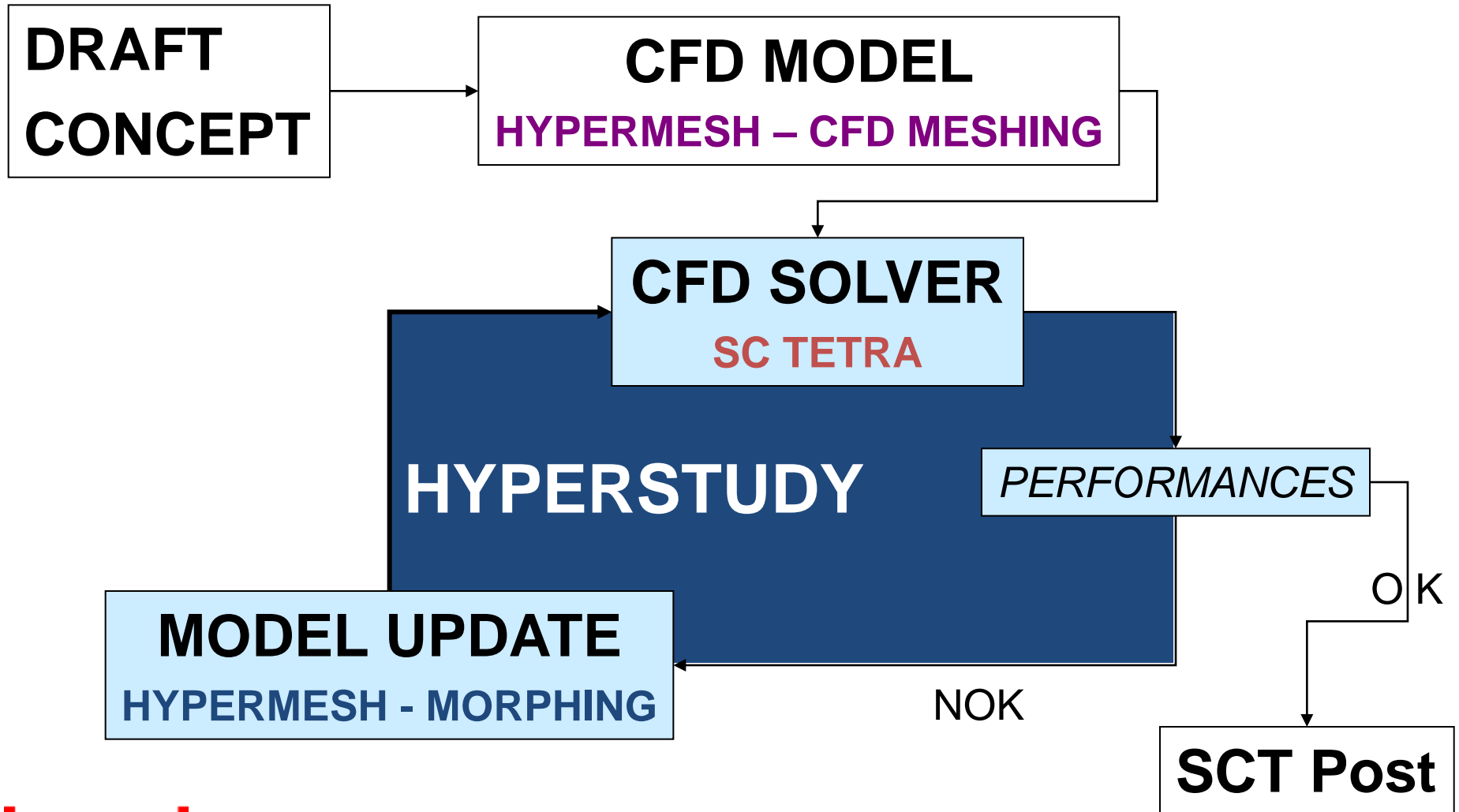


UI=100%

Flow equally spread over all channels



Process Description

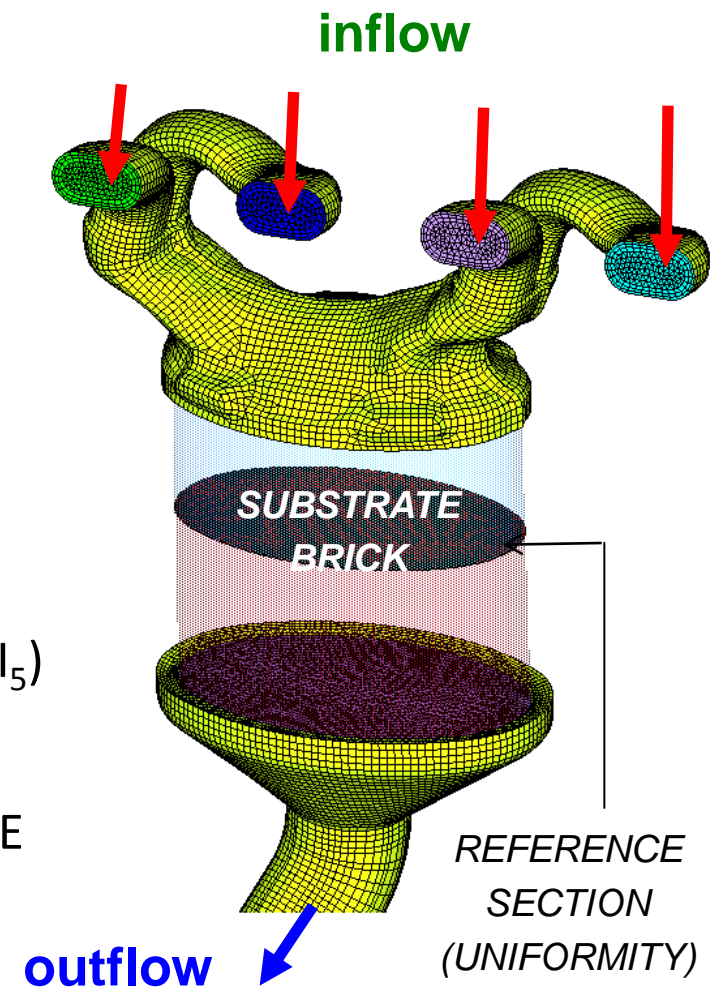


OPTIMIZATION SET UP

- **General process:** Five loadcases

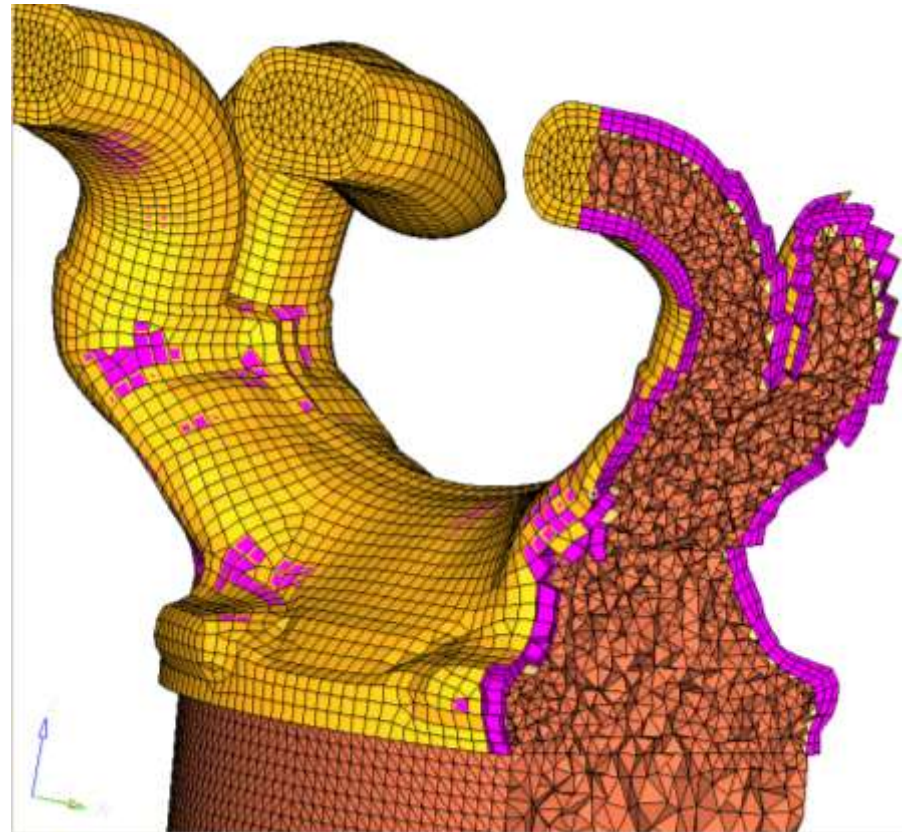
Case	Runner 1	Runner 2	Runner 3	Runner 4
1	wall	wall	wall	inflow
2	wall	wall	inflow	wall
3	wall	inflow	wall	wall
4	inflow	wall	wall	wall
5	inflow	inflow	inflow	Inflow

- **Objective:** $\max. \text{AVERAGE}(UI_1, UI_2, UI_3, UI_4, UI_5)$
- **Constraints:**
 - $\text{MAX}(BP_1, BP_2, BP_3, BP_4, BP_5) < \text{REFERENCE}$
 - $\text{MIN}(UI_1, UI_2, UI_3, UI_4, UI_5) > 0.85$



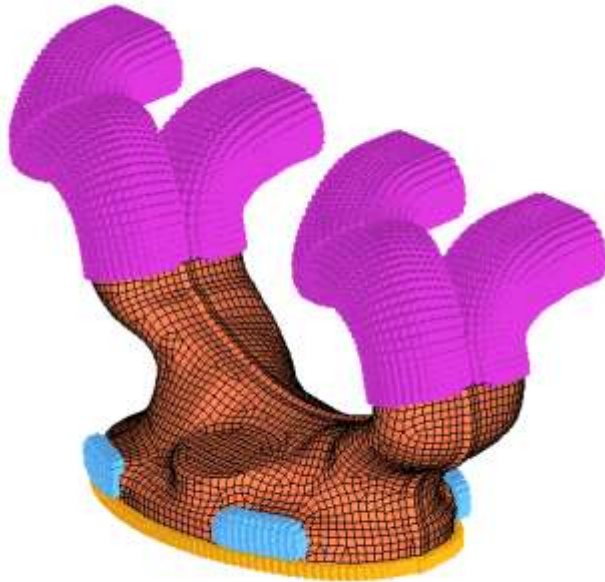
CFD MESHING (HYPERMESH)

- **Clean up**
 - Close gaps
 - Suppress features
 - Close holes
 - Extract wetted surface
- **Meshing**
 - 1st layer thickness estimation
(important for turbulence model)
 - tetra + BL generation
(400.000 cells)

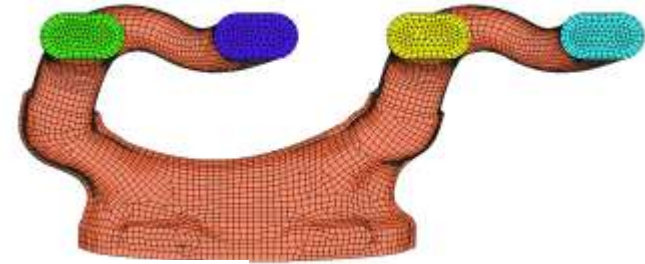


MORPHING (HYPERMORPH)

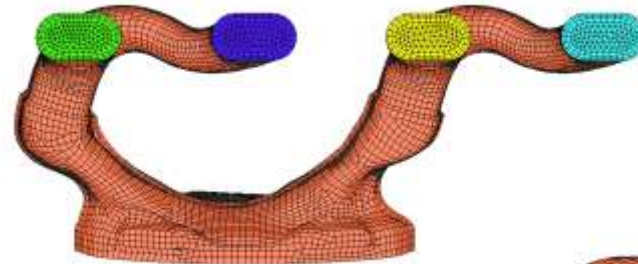
Morphing constraints \longrightarrow Shapes



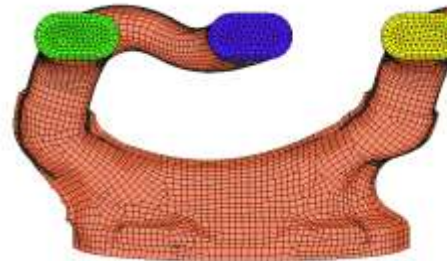
Bottom face frozen
Islands frozen
Runners not included



S3



S1



S2



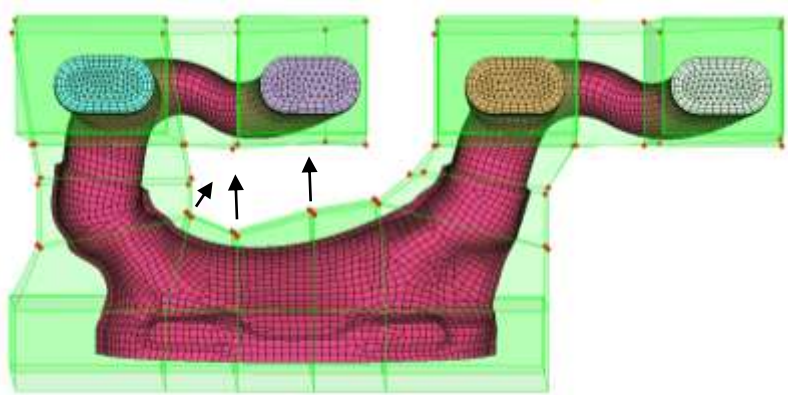
S4



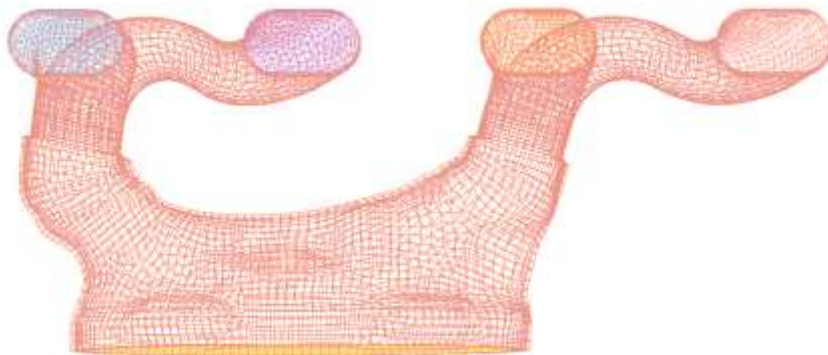
S5

Five shapes & combinations
Shape scale factors [-1, +1]

MORPHING (HYPERMORPH)

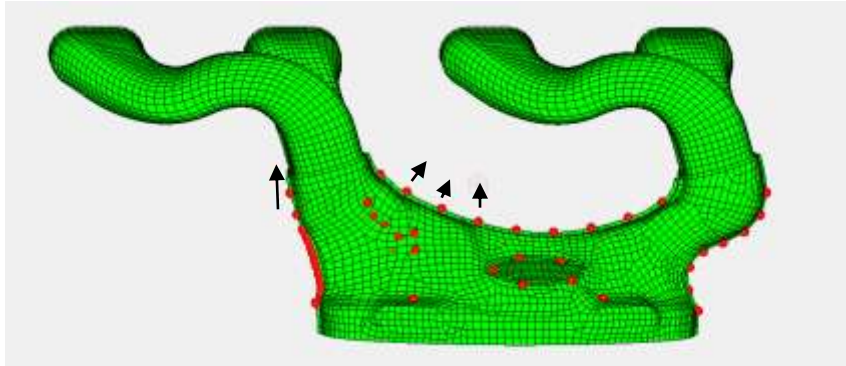


- Several morphing options:
 - Global domains
 - For global structure morphing
 - Commonly used in a first step
 - Surrounding blocks corners moved

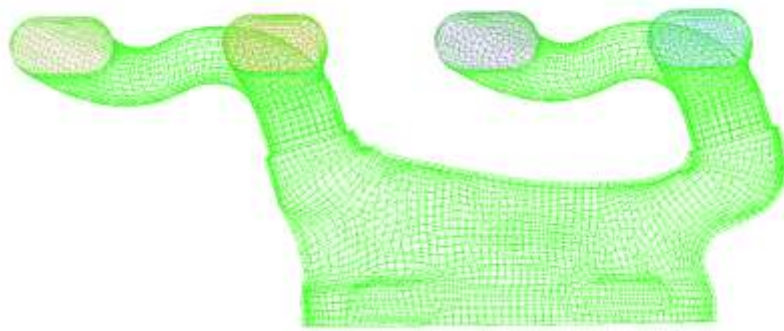


- Local domains
 - For fine structure morphing
 - Commonly used in final step
 - Local projections, local smoothing operations, etc.
 - Working directly on mesh

MORPHING (HYPERMORPH)

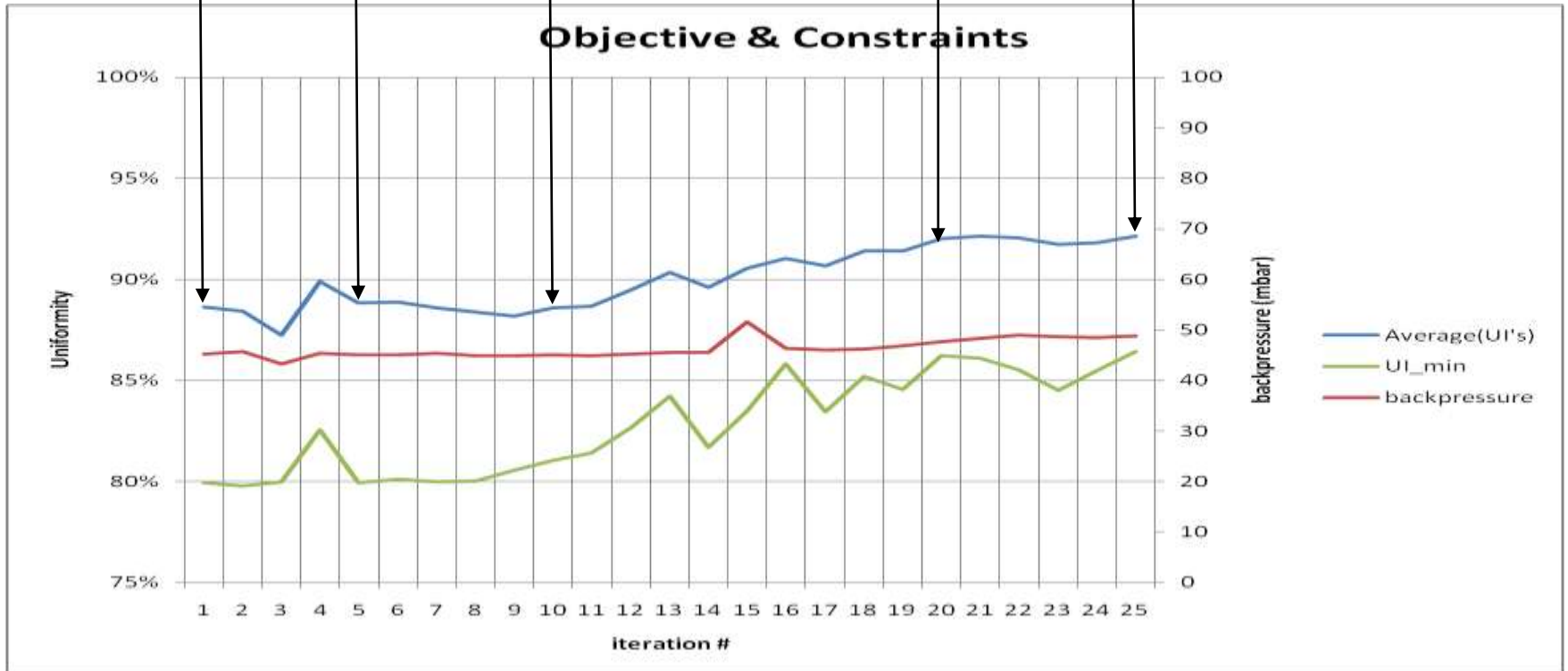
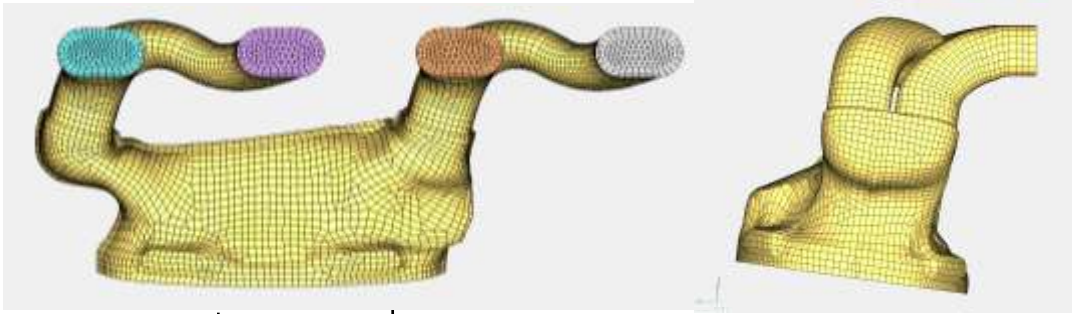


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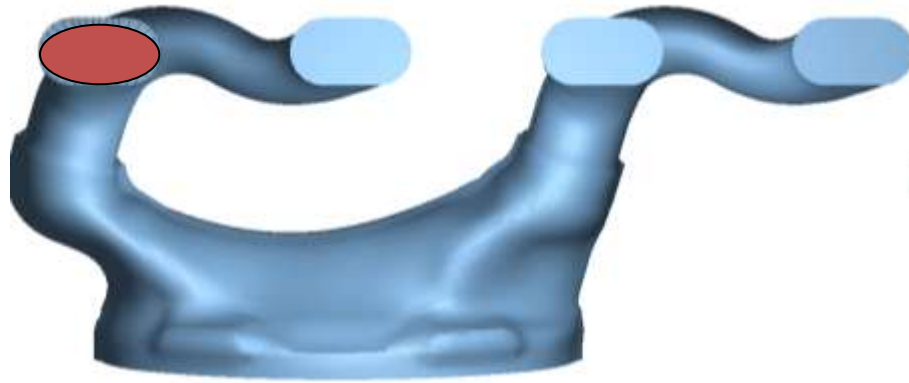


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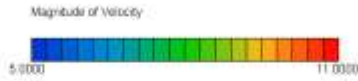
OPTIMIZATION



Initial design



File : runner01_200.fld
Cycle: 200
Time : 0.000000

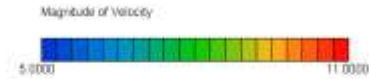


CRADLE

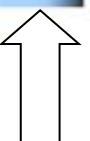
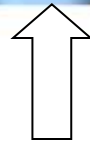
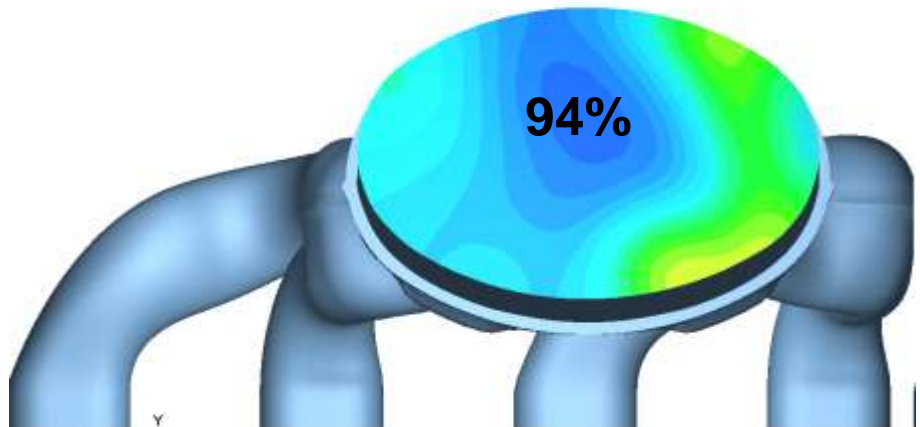
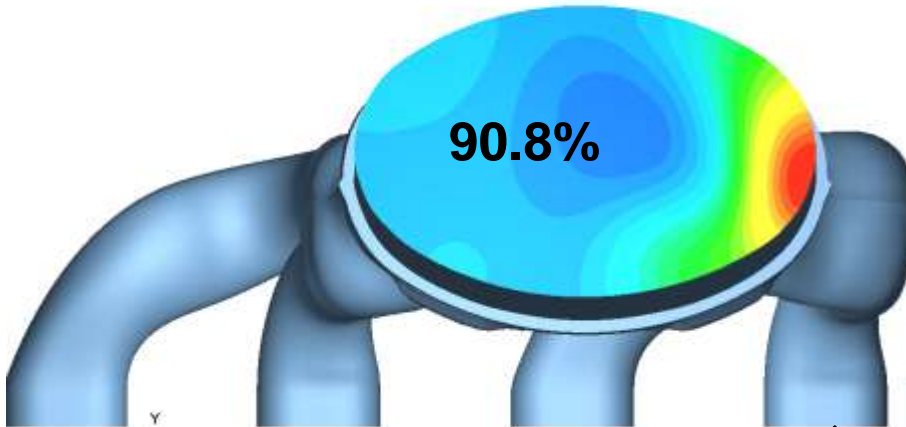
Optimized design



File : runner01_100.fld
Cycle: 100
Time : 0.000000

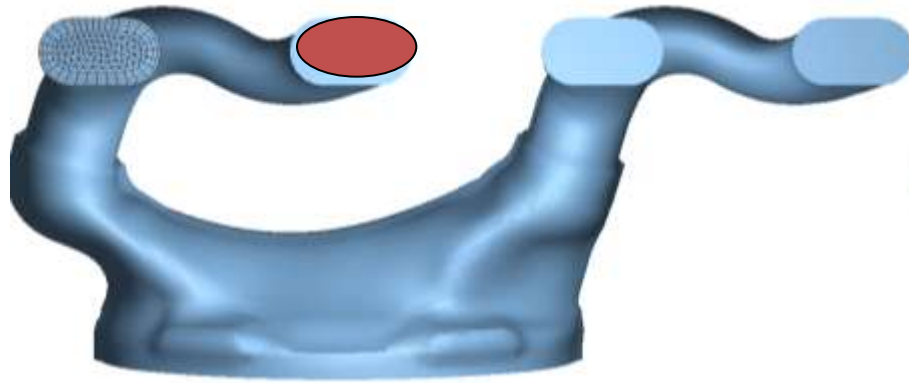


CRADLE

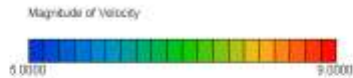


Flow through runner 1

Initial design

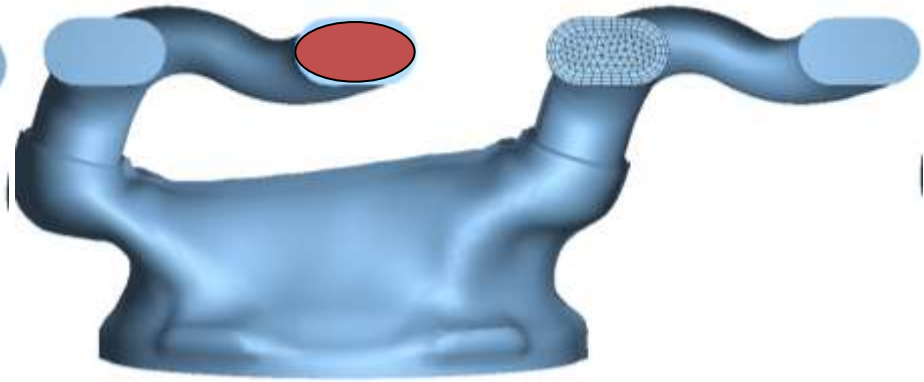


File : runner02_200.fld
Cycle: 200
Time : 0.000000

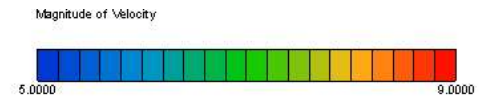


CRADLE

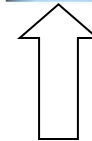
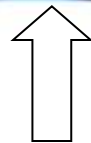
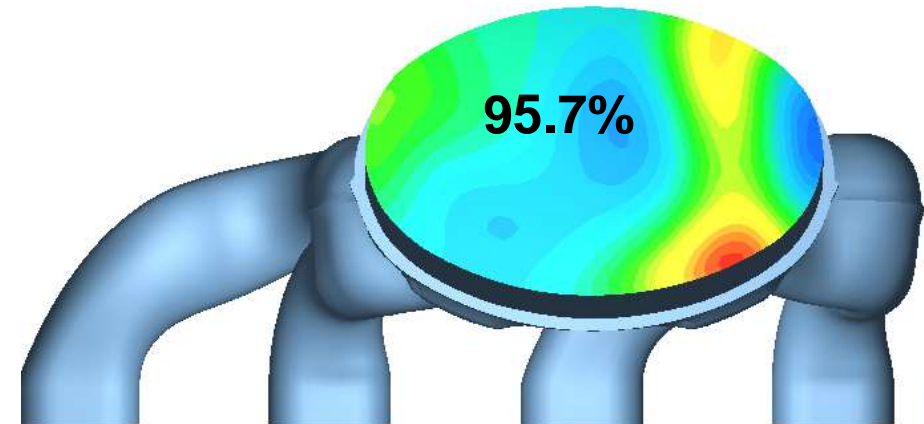
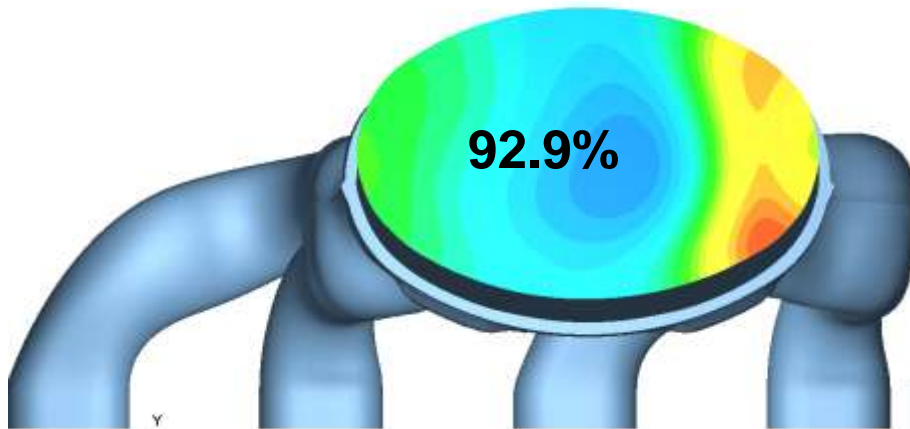
Optimized design



File : runner02_100.fld
Cycle: 100
Time : 0.000000

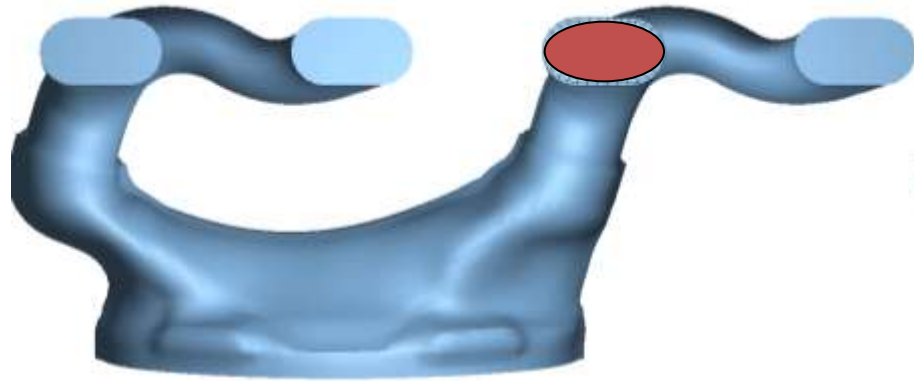


CRADLE

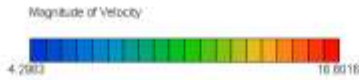


Flow through runner 2

Initial design

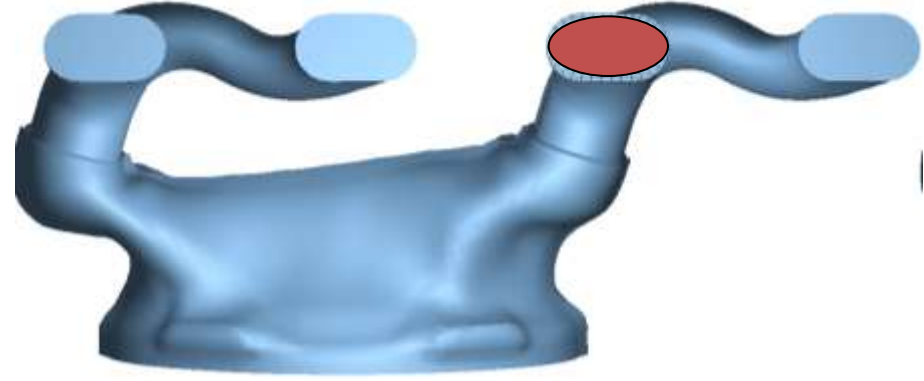


File : runner03_200.fld
Cycle: 200
Time : 0.000000



CRADLE

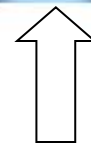
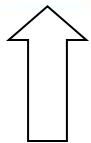
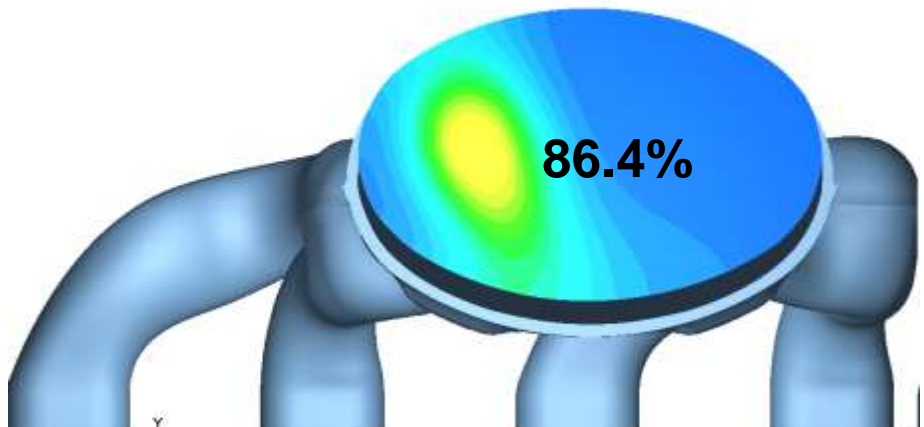
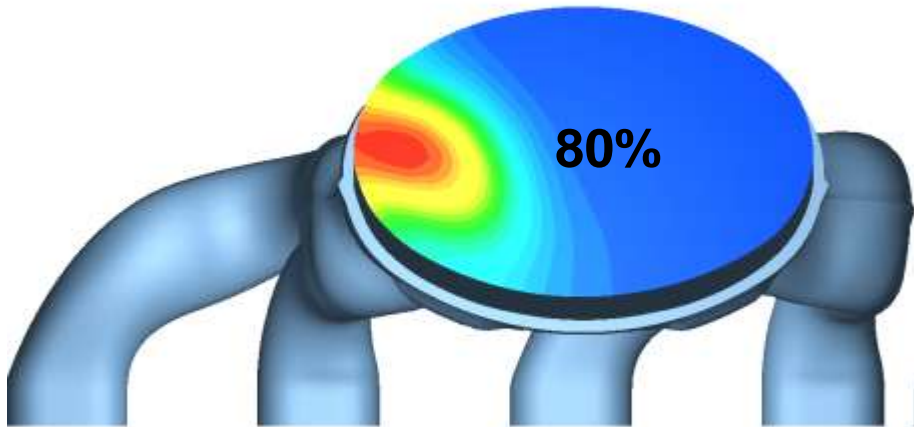
Optimized design



File : runner03_100.fld
Cycle: 100
Time : 0.000000

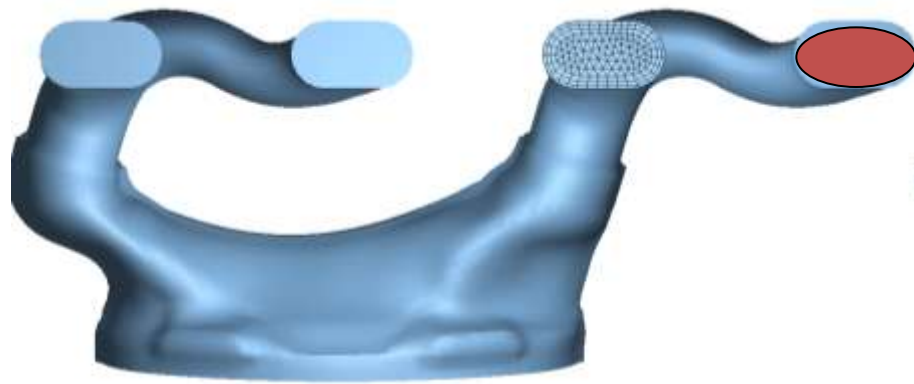


CRADLE



Flow through runner 3

Initial design



File : runner04_200.fld
Cycle: 200
Time : 0.000000

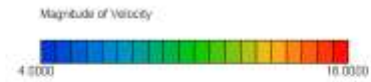


CRADLE

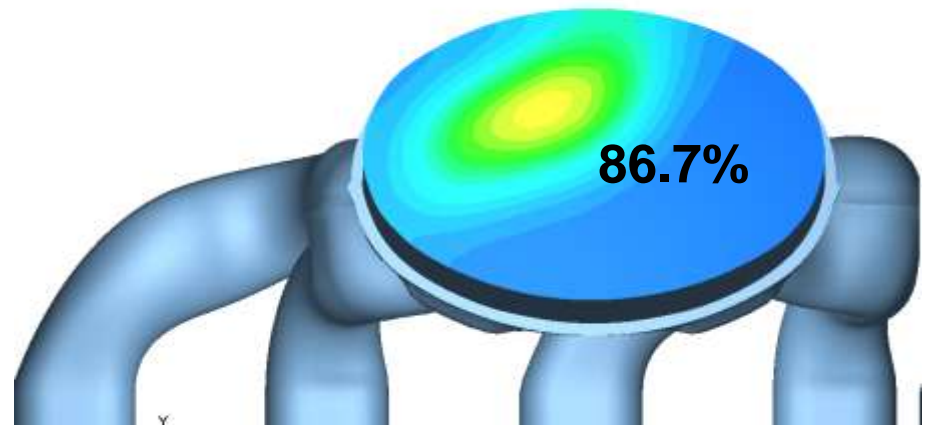
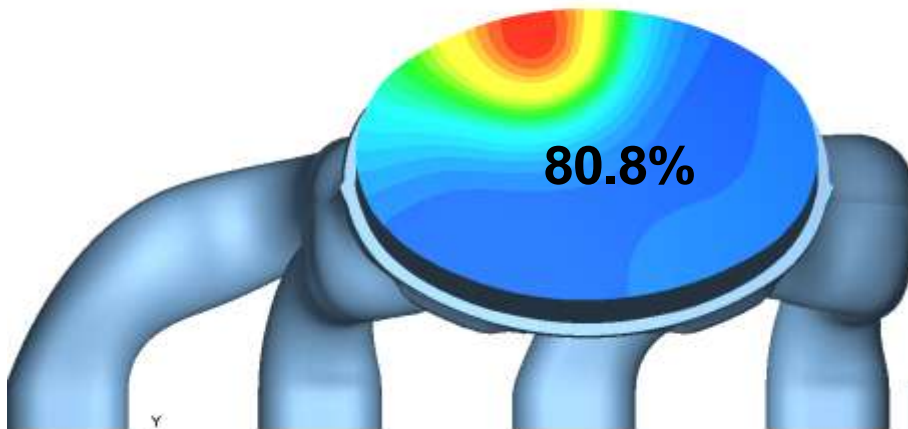
Optimized design



File : runner04_100.fld
Cycle: 100
Time : 0.000000

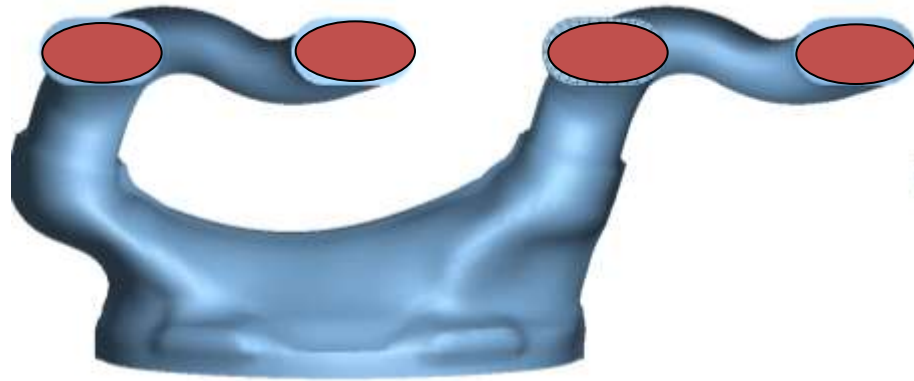


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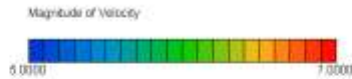


Flow through runner 4

Initial design

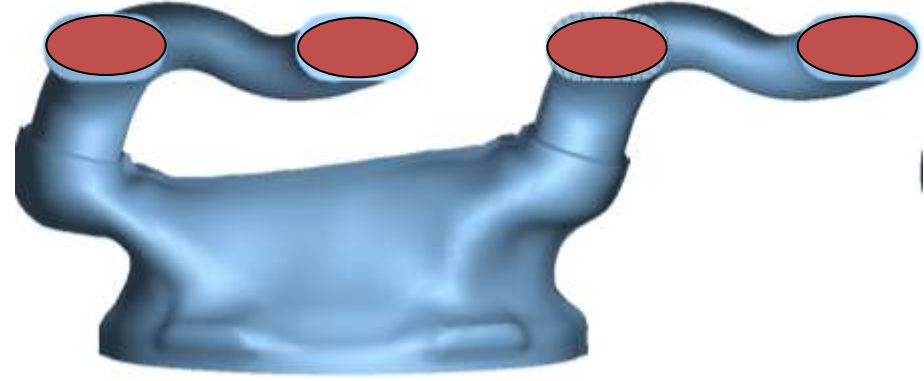


File : runnerAll_200.fld
Cycle: 200
Time : 0.000000

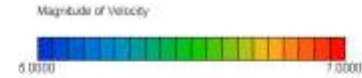


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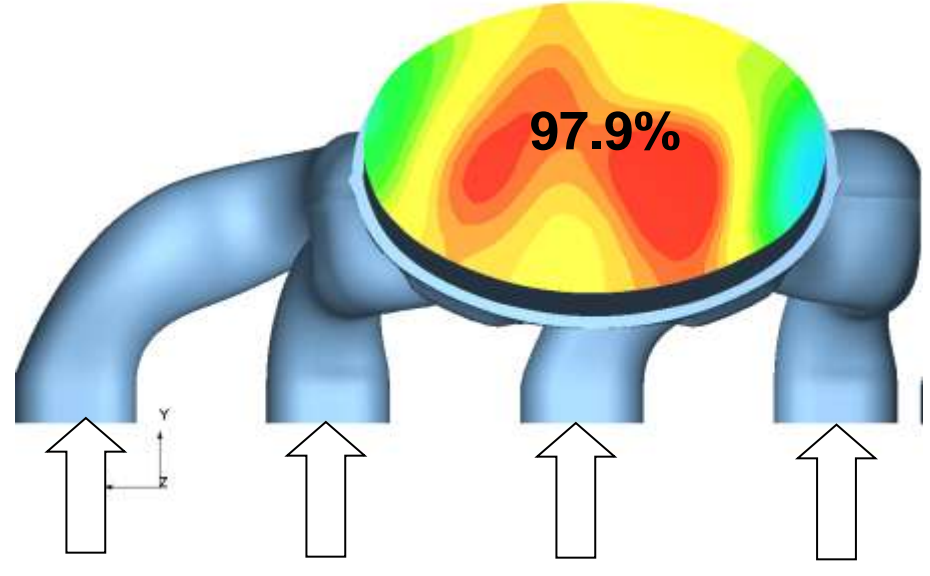
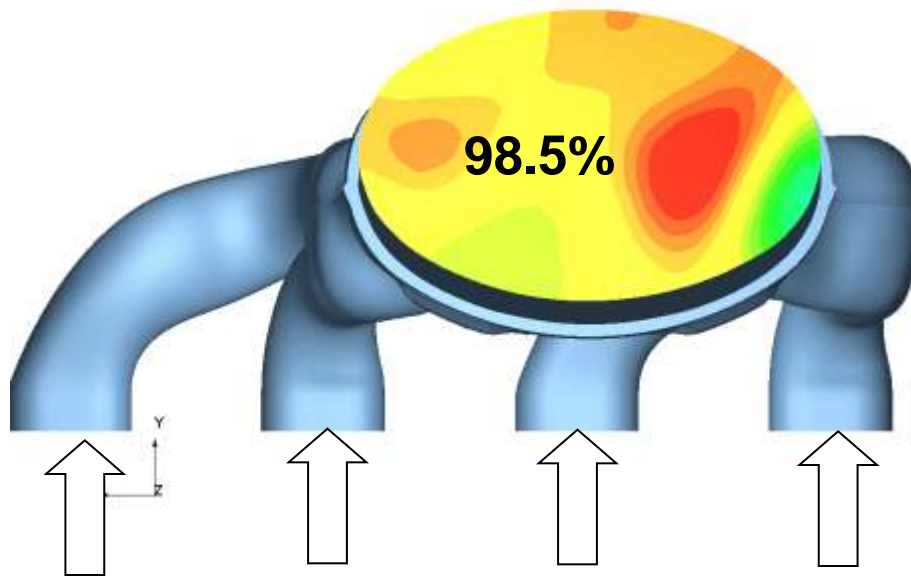
Optimized design



File : runnerAll_100.fld
Cycle: 100
Time : 0.000000

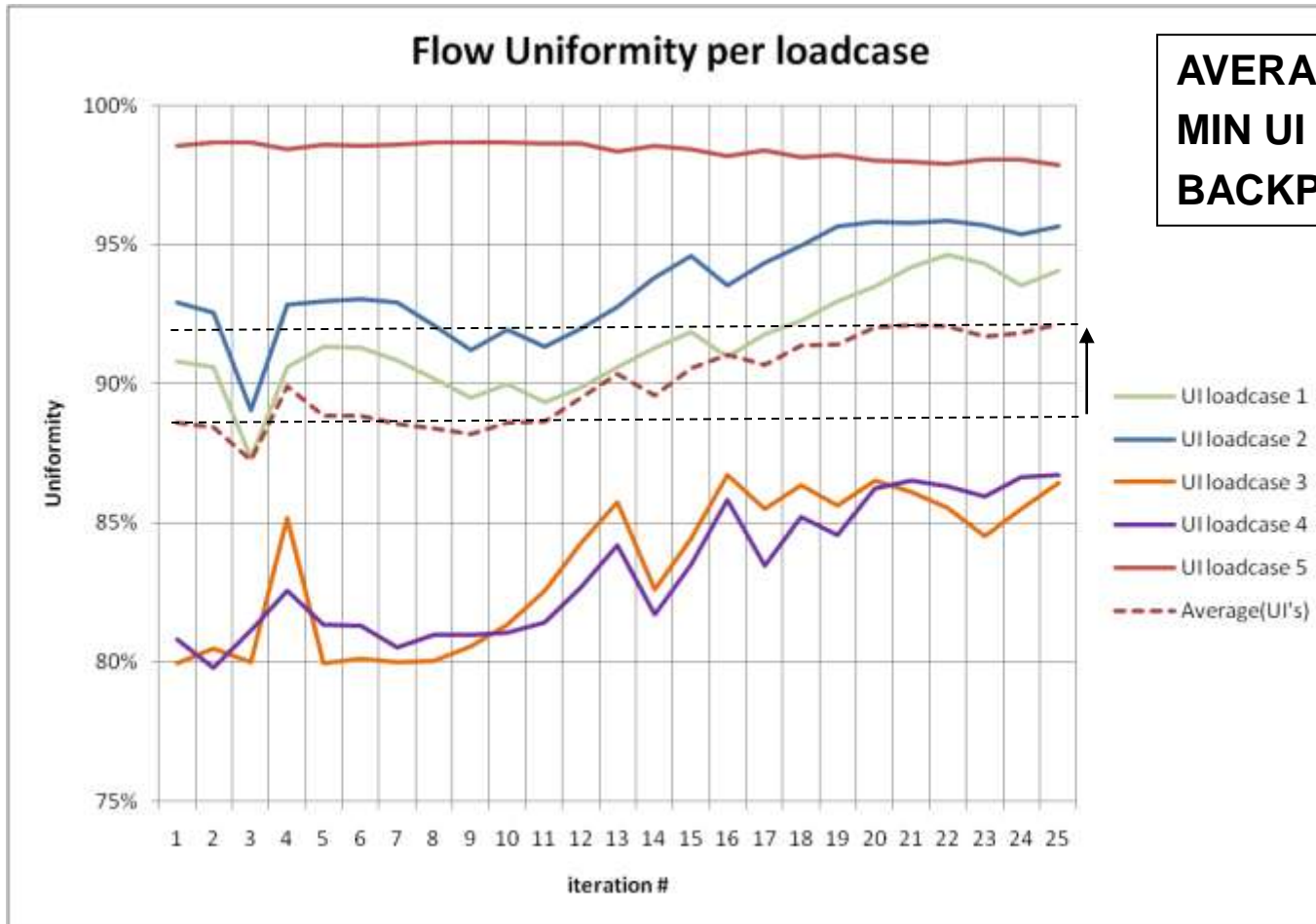


CRADLE



Flow through all runners

RESULTS SUMMARY

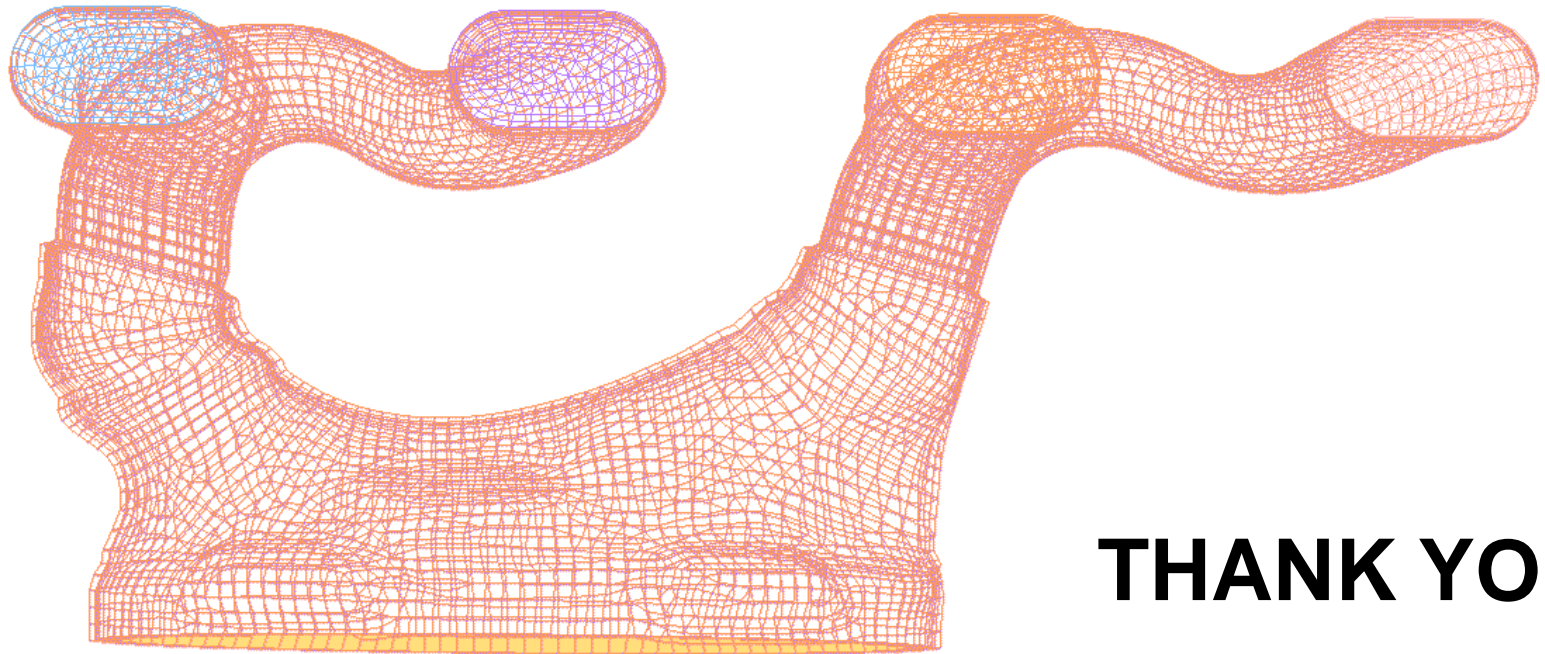


AVERAGE UI	+4%
MIN UI	+7%
BACKP.	< REFERENCE

CONCLUSIONS

- **Integrated early stage optimization**
 - Coupling HyperStudy, SC/Tetra, Morphing
 - Increase of minimum uniformity by **7%**
 - Meshing (1d) + morphing (2d) + HyperStudy (1d)= **4days**
- **No extra budget needed**
 - Altair Partner Program, **CFD solver on demand**
- **Clear added value in development**
- **Multiphysics procedure achievable**
 - Include manufacturing, fatigue,... in optimization
- **Next step: add runners in design space**

Quick global morphing incl. runners



THANK YOU