CFD Centre
Faculty of Engineering

UNIVERSITY OF LEEDS

An optimization study of a ship hull

A. Pranzitelli[a] & D. Caridi[b]
[a]University of Leeds, Leeds, UK
[b]ANSYS UK, Sheffield

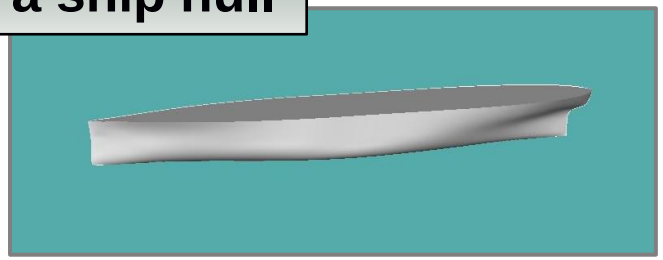
ANSYS Webinar 7,9 June 2011

ANSYS

Optimization of a ship hull

UNIVERSITY OF LEEDS

Improving the performance of a ship hull



HOW?
Several configurations have to be tested

Classical approach: towing tank tests → money and time demanding

CFD optimization
Requisites:
- reliable
- cheap
- fast

ANSYS Workbench
+
ANSYS FLUENT
+
RBF-Morph

CAD & mesh generation
require many man-hours

RBF-Morph

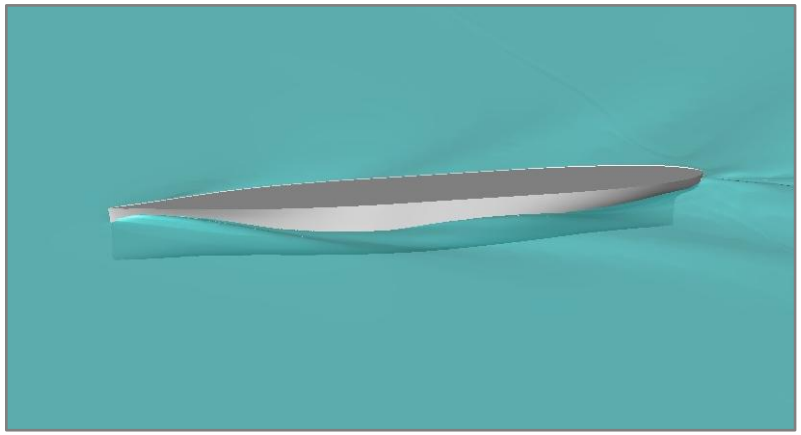
ANSYS

Test case description

UNIVERSITY OF LEEDS

Ship hull: Series 60, C_B=0.6

- external hydrodynamics
- multiphase flow (air & water)
- ship advancing steadly in calm water
- trim and sinkage fixed
- displaced volume as constraint
- resistance prediction



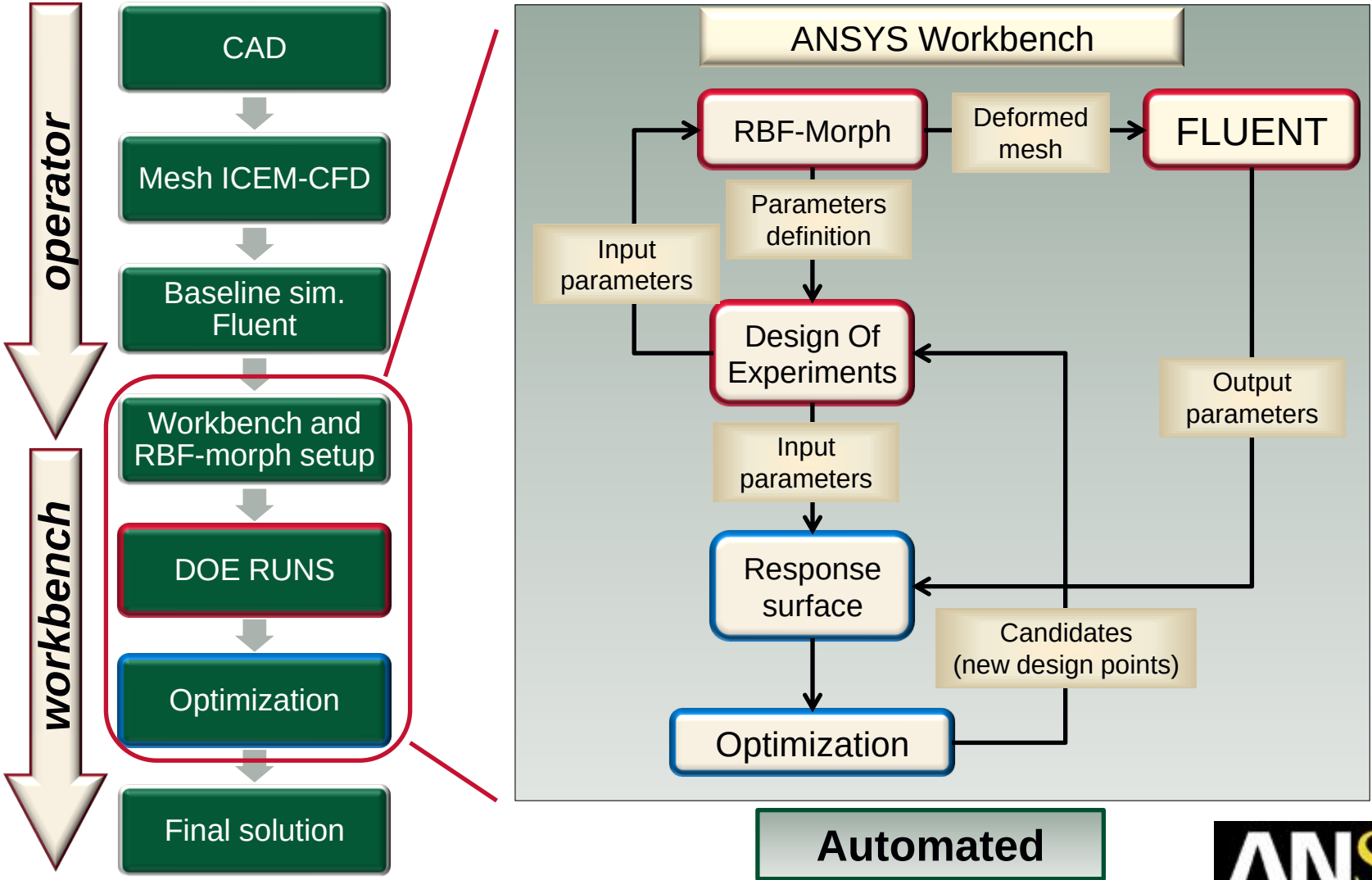
TARGET:
Optimization of the hull shape
with no displacement reduction

→ **Reduction of the resistance**

ANSYS

Workflow

UNIVERSITY OF LEEDS



ANSYS

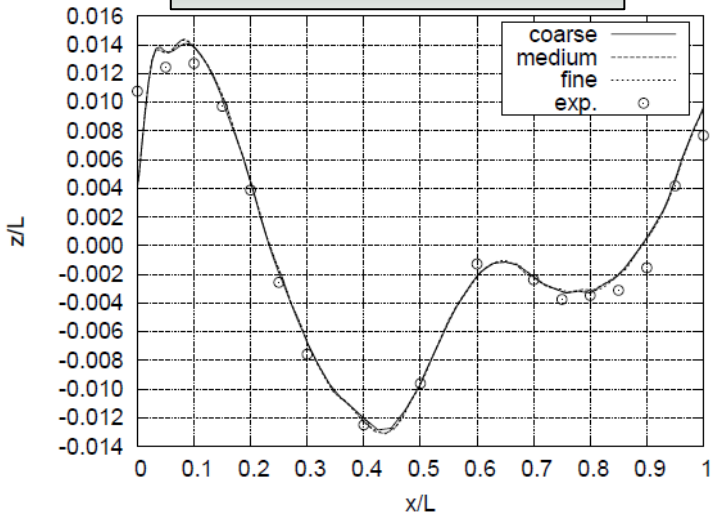
Baseline simulation, results

UNIVERSITY OF LEEDS

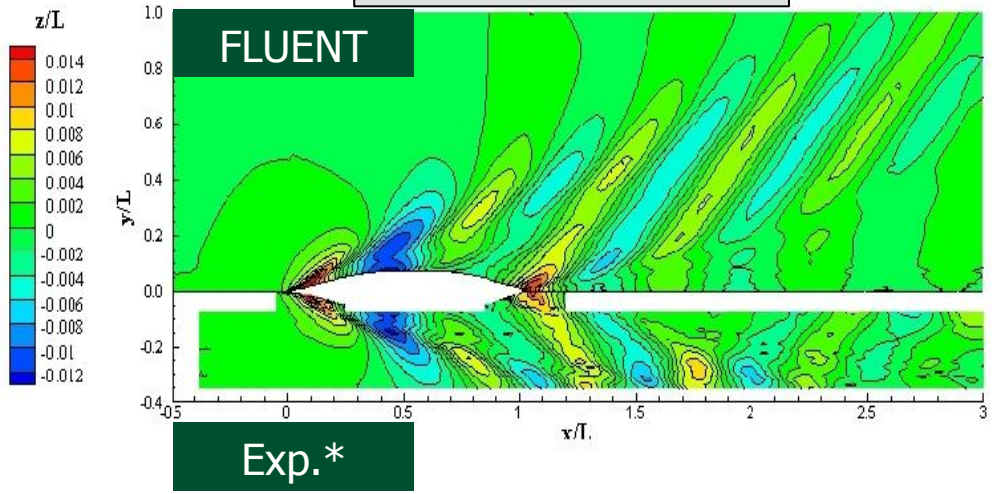
- **Steady-state simulations; VOF**
- **Structured grids (ICEM-CFD)**

- **Model length (L_{pp})=3.048m;**
- **F_r=0.316**

Wave profile on the hull



Wave pattern



Exp.*

Selected for optimization

	cells	C_T	ΔC_T
Coarse	**331'652**	**5.81×10^{-3}**	**-2.52%**
Medium	692'984	5.94×10^{-3}	-0.34%
Fine	1'274'742	5.96×10^{-3}	0%
Exp.*	-	5.96×10^{-3}	-

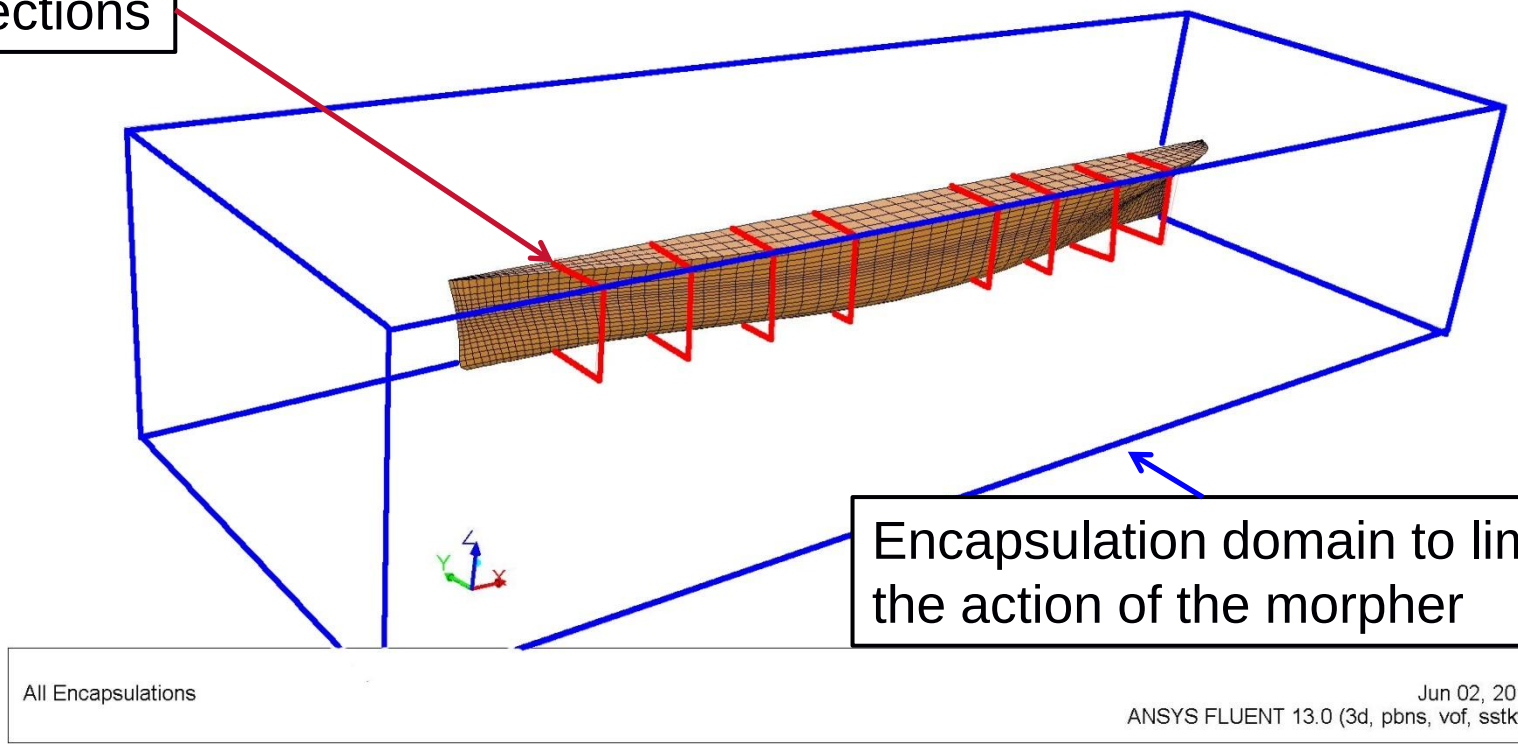
*IIHR, University of Iowa

ANSYS

RBF-Morph setup

UNIVERSITY OF LEEDS

Cross sections

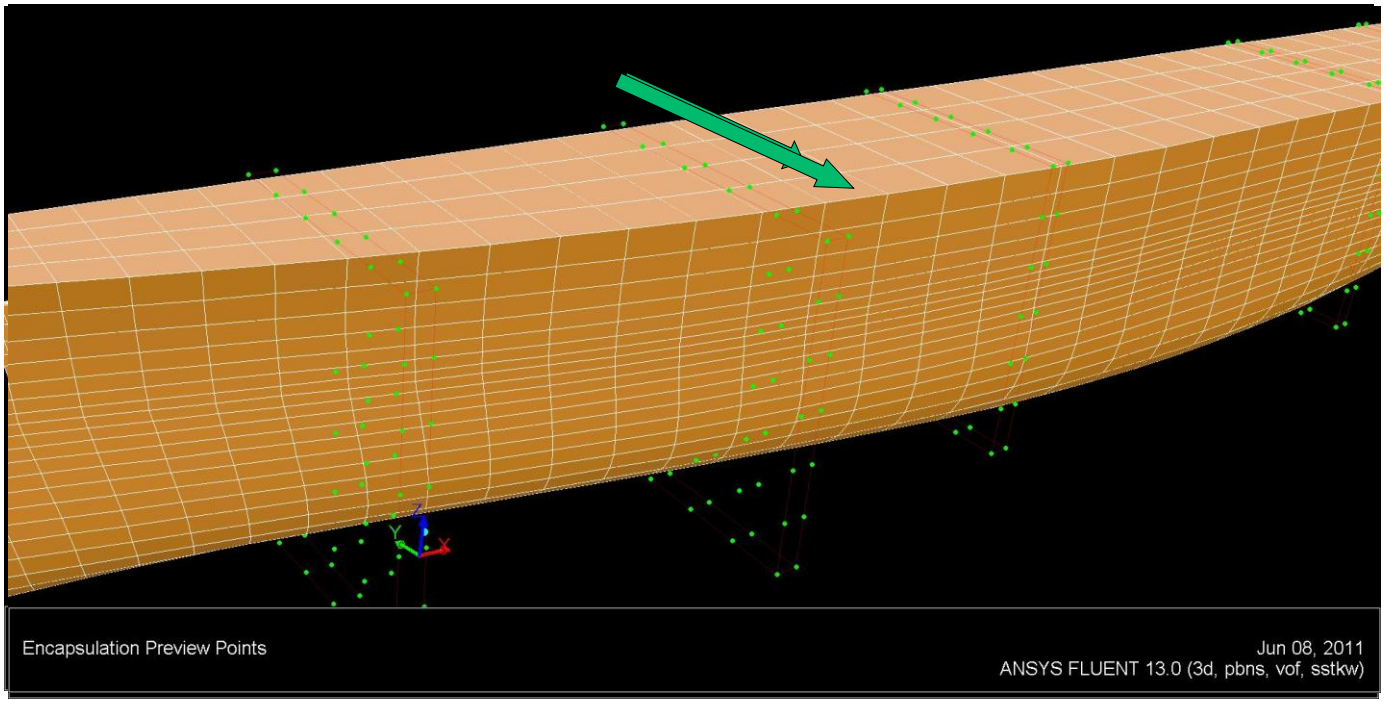


ANSYS

RBF-Morph setup

UNIVERSITY OF LEEDS

- Symmetry plane fixed
- Morphing domain
- Eight cross sections
- Sections deformation

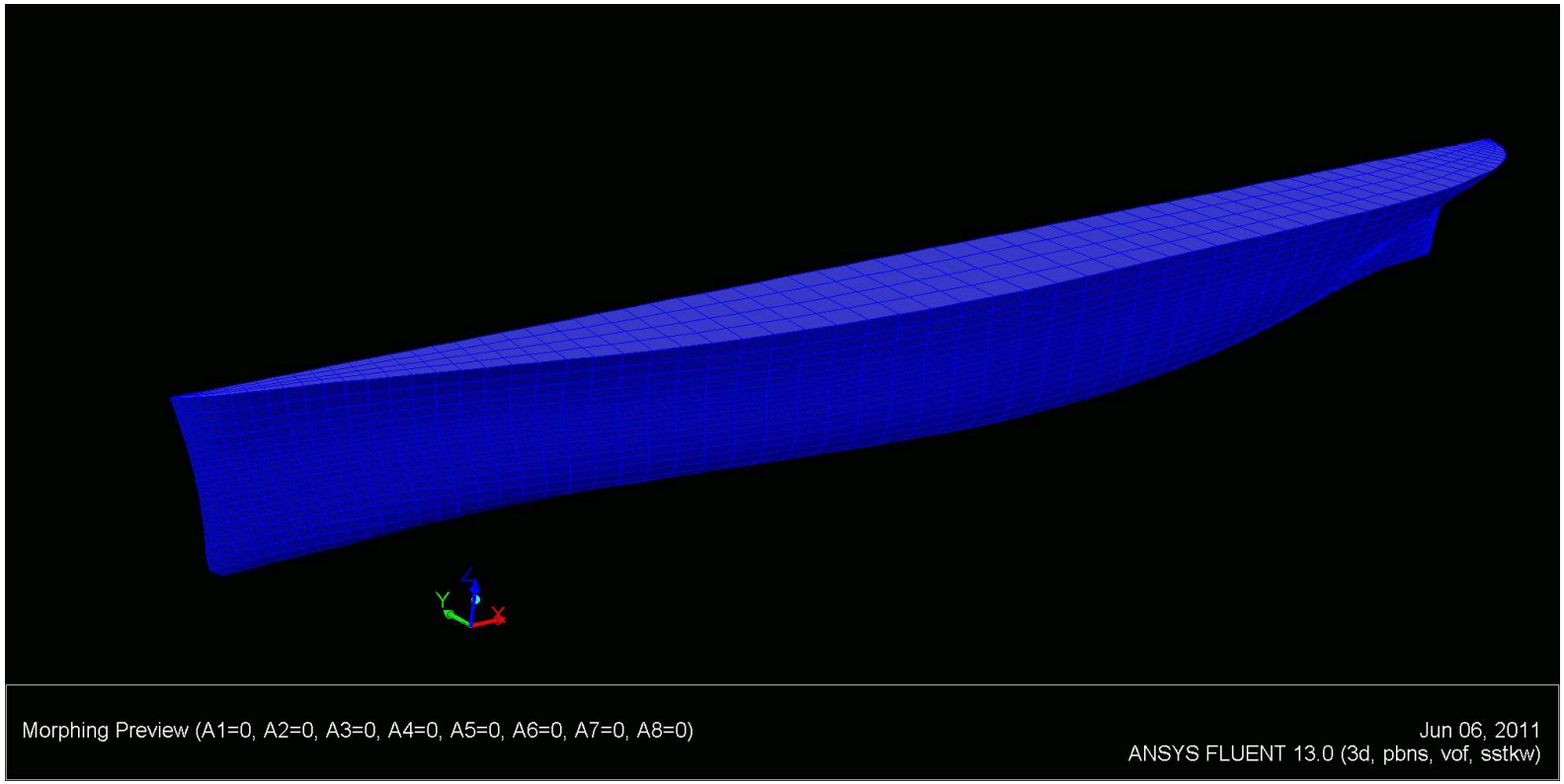


Base scale factor for each section: 1.1
Multiplied by the amplification factor

ANSYS

Morphing, sections

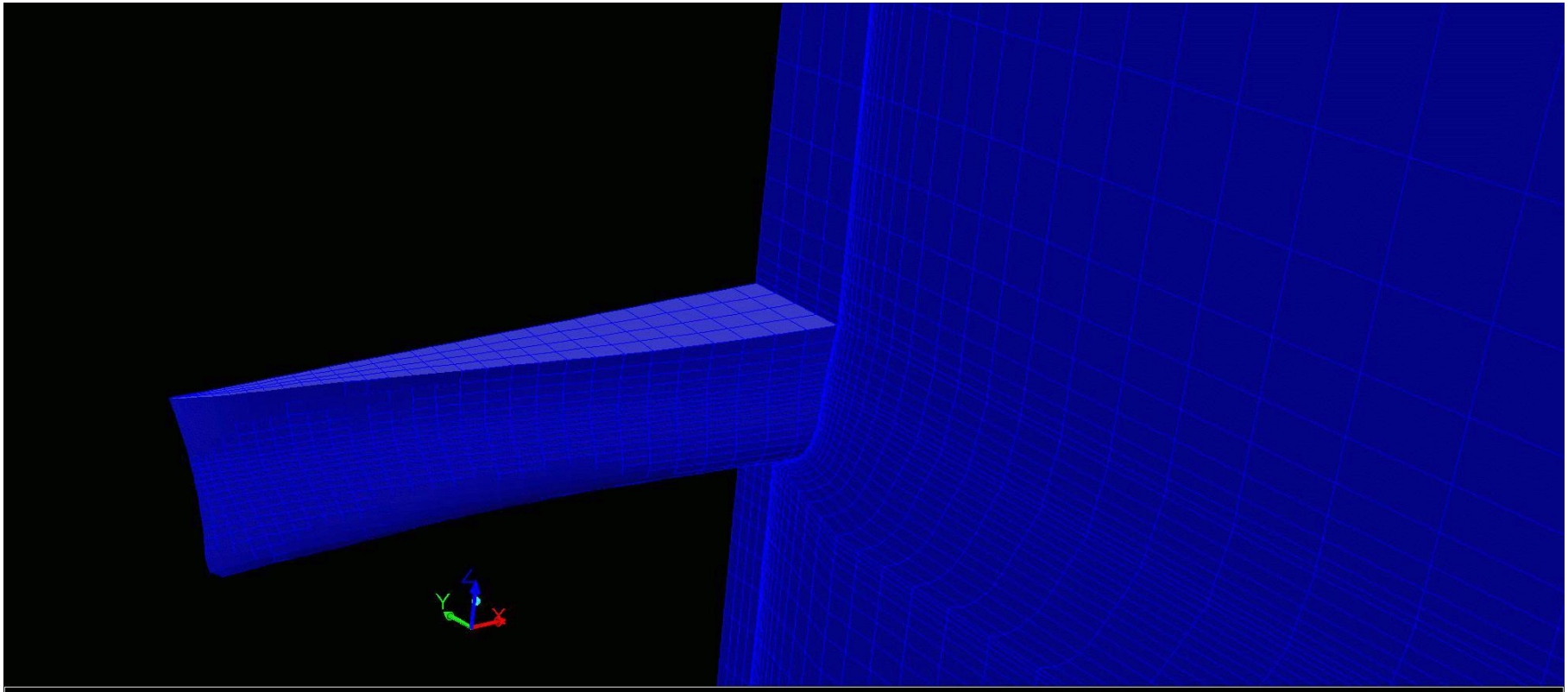
UNIVERSITY OF LEEDS



ANSYS

Morphing, effect on the mesh

UNIVERSITY OF LEEDS



Morphing Preview (A1=0, A2=0, A3=0, A4=0, A5=0, A6=0, A7=0, A8=0)

Jun 06, 2011
ANSYS FLUENT 13.0 (3d, pbns, vof, sstkw)

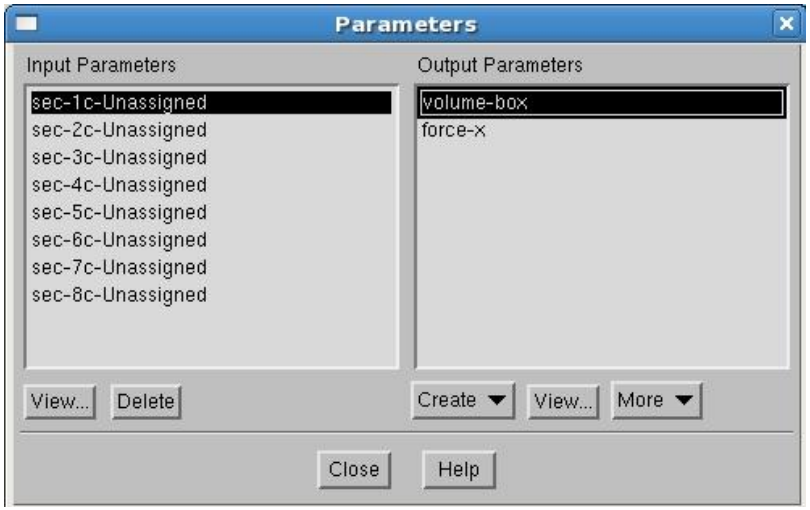
ANSYS

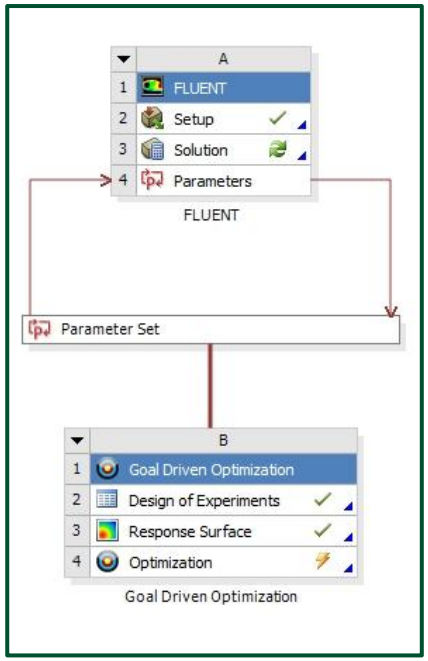
RBF-Morph set-up, integration in the workbench

UNIVERSITY OF LEEDS

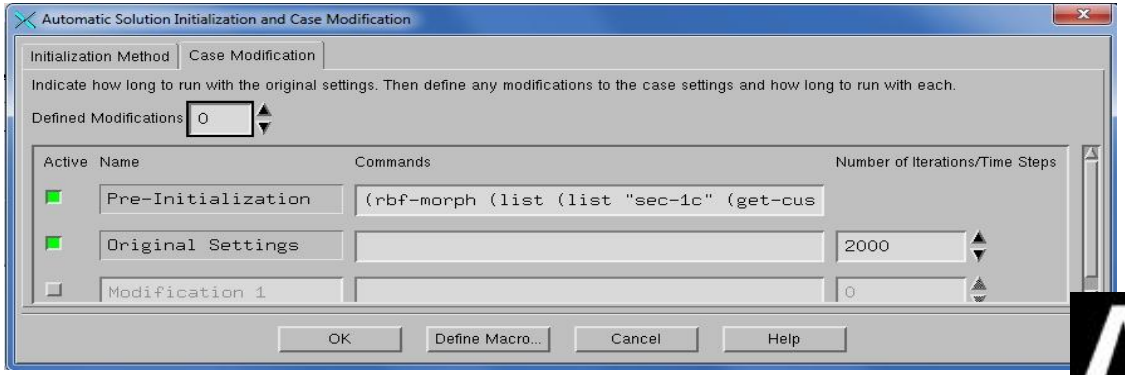
Parameters definition (Fluent + RBF Morph)

- 8 input parameters: amplification factors
- 2 output parameters: resistance and volume





- Amplification factors exported as parameters to the workbench
- Initial solution: baseline solution
- Automatic modification of the case file: morphing

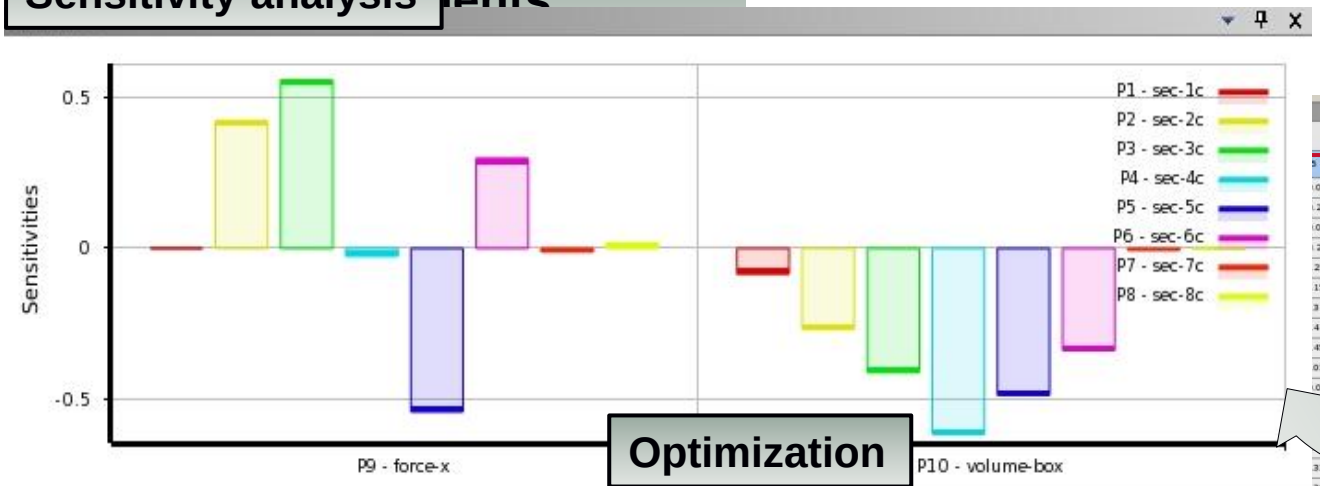


ANSYS

Workbench set-up, Goal driven optimization

UNIVERSITY OF LEEDS

Sensitivity analysis

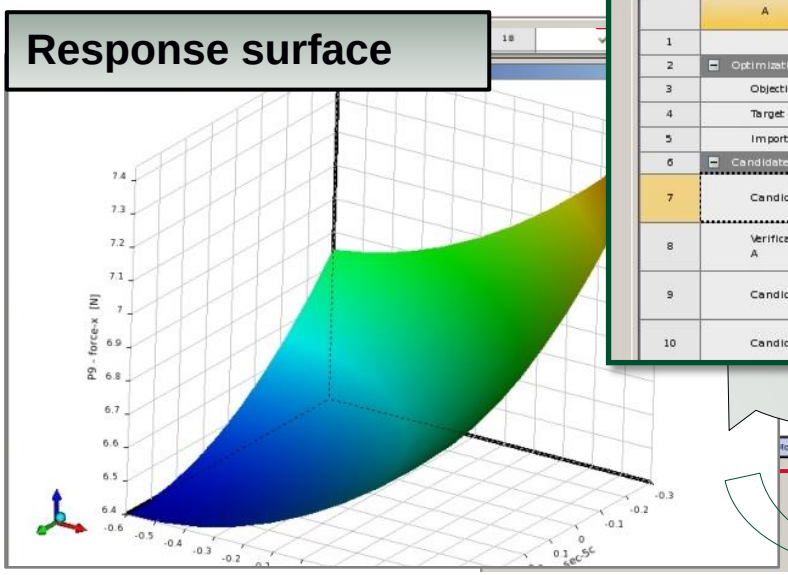


Optimization

Table of Schematic B4: Optimization

	A	B	C	D	E	F	G	H	I	J	K
1		P1 - sec-1c	P2 - sec-2c	P3 - sec-3c	P4 - sec-4c	P5 - sec-5c	P6 - sec-6c	P7 - sec-7c	P8 - sec-8c	P9 - force-x (N)	P10 - volume-box (m^3
2	Optimization Study										
3	Objective	No Objective	No Objective	No Objective	No Objective	No Objective	No Objective	No Objective	No Objective	Minimize	Values <= Target
4	Target Value										3.1779
5	Importance	Default	Default	Default	Default	Default	Default	Default	Default	Default	Default
6	Candidate Points										
7	Candidate A	0.2835	-0.37709	-0.59744	0.08802	0.48008	-0.0038825	0.26021	-0.24133	6.3275	3.1778
8	Verification A									6.2882	3.1778
9	Candidate B	-0.2709	-0.54789	-0.38217	0.2685	0.48407	0.017755	0.16845	0.26476	6.3395	3.1774
10	Candidate C	-0.1449	-0.3223	-0.31276	0.1437	0.4141	0.07185	0.30609	-0.2169	6.3697	3.1774

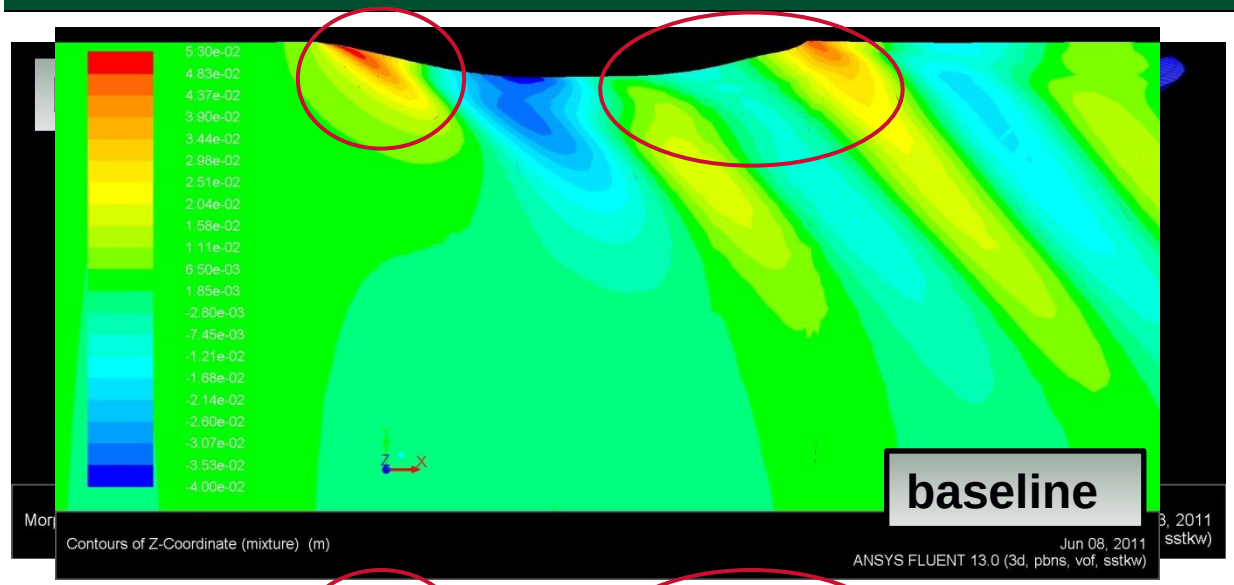
Response surface

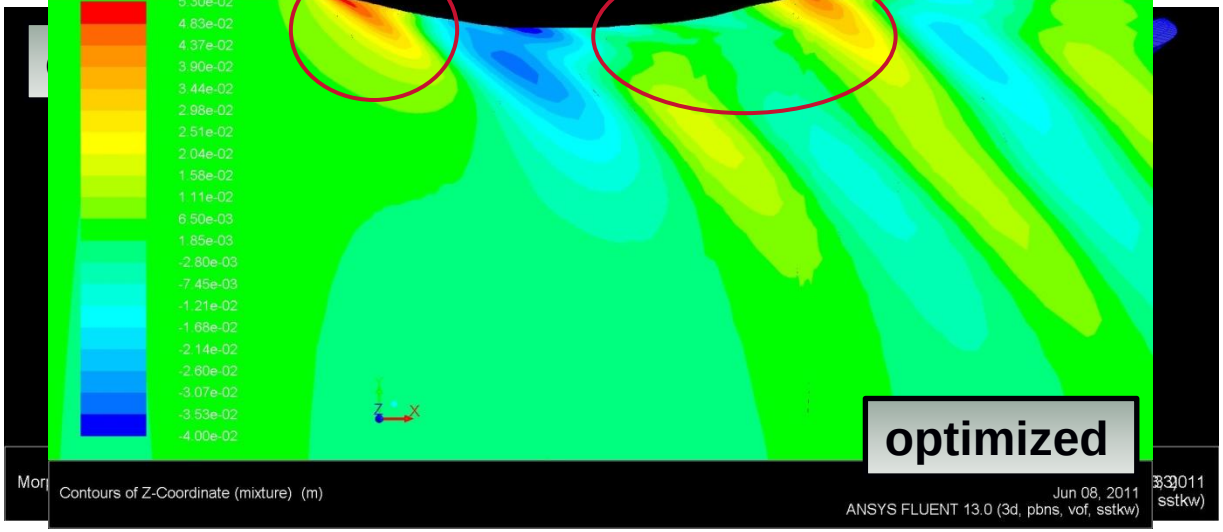


ANSYS

Results

UNIVERSITY OF LEEDS





	Baseline	Optimized
F_x	6.83N	6.29N

-7.9%
resistance reduction
No volume reduction

ANSYS

Conclusions

UNIVERSITY OF LEEDS

Performance:

- Mesh generation: 6 man-hours
- Fluent case setup: 1 man-hours
- Baseline simulation (coarse grid): 4 CPU*-hours
- Workbench and RBF-Morph setup:1 man-hours
- DOE (45 simulations): 45 CPU*-hours

=

✓ 1 day man-time
✓ 2 days CPU-time

Benefits:

✓ integrated in the ANSYS software, automated
✓ no need to go back to CAD
✓ no need to remesh the model
✓ no loss of grid quality for small deformations
✓ few human hours necessary

What without Workbench & RBF-Morph....

- Mesh generation (first mesh): 6 man-hours
- Geometry (CAD) and mesh modification for each case (considering mesh automation in ICEM-CFD): 1x45 = 45 man-hours
- Cases management (Fluent): 1x46 = 46 man-hours
- Cases execution: 4+45 = 49 CPU*-hours
- use of other optimization tools: ??

➢ ≈100 man-hours
➢ 2 days CPU-time (optimistically...)

***one Intel® i7 quad-core processor, 2.8GHz**

ANSYS®

Next Steps

UNIVERSITY OF LEEDS

- **more cross sections**
  - **higher resolution**
- **trim and sinkage corrections**
  - **2 Degrees of Freedom**
  - **Moving mesh**

Thank you for your attention

ANSYS