DRIMI - DOTTORATO DI RICERCA IN INGEGNERIA MECCANICA ED INDUSTRIALE

TURBOPUMP IMPELLER DESIGN BY OPEN-SOURCE CFD AND SHAPE OPTIMIZATION SOFTWARE

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2nd year presentation - Brescia, 18/10/2016

Contents

Introduction

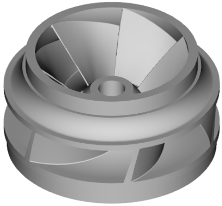
- Turbopumps are very used in industry
- Design techniques to achieve the optimal geometry for the given working point are too expensive
- The efficiency and the pressure ratio of a centrifugal pump greatly depend on the shape of the impeller and the flow passage between the hub and shroud
- Other components of the pump play a role in the performance definition, however only the impeller is considered in this study

Introduction

- An existing and well known impeller geometry is chosen as starting design
- The starting design has been re-expressed in terms of Bezier polynomials
- The efficiency and pressure ratio of the turbopump impeller are evaluated through computational fluid dynamics
- Direct single objective genetic algorithm optimization is compared to a surrogate based optimization techinque
- Open-source software are used in order to fully exploit the available hardware without requiring software licenses
- The objective of the optimization methods proposed is to make the turbopump impeller design automatic, robust and optimal

Methodology: impeller shape definition (1/3)

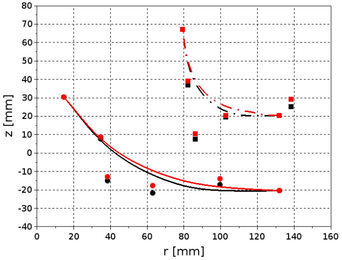
- mixed flow pump
- experiments by Boccazzi *
- geometry through data points for hub, shroud and blade

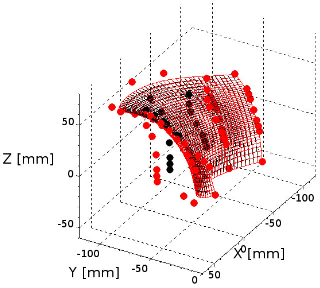


Original impeller.
Geometry and results of the experiments:
$D_{out} = 0.224$ m
$\omega = 55.4$ rad/s
$\omega_s = 1.08$
$\phi = 0.31$
$\psi = 0.44$
$\eta = 0.75$

** Boccazzi, A., Miorini, R., Sala, R., Marinoni, F. (2009), Unsteady Flow Field in a Radial Pump Vaned Diffuser, 8th European Conference on Turbo-machinery, Graz, Austria, Mar. 23-27, pp. 1103-1112*

Methodology: impeller shape definition (2/3)

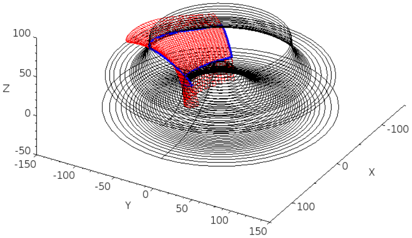


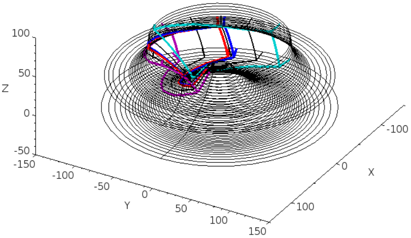


Hub and shroud definition through Bezier curves

Blade definition through Bezier surface

Methodology: impeller shape definition (3/3)



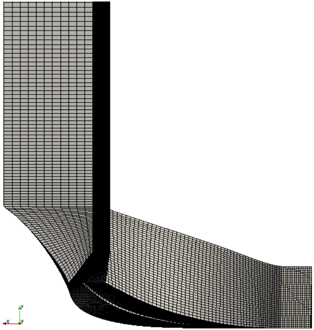


detail of blade intersection with hub and shroud

detail of fluid domain preparation

Methodology: computational setup

- fully hexa grid through blockMesh
- incompressible flow
- steady-state condition
- 3D RANS equations
- SST k-omega turbulence model
- ϕ=0.31 prescribed
- ψ=0.45 and η=0.90 through OpenFOAM

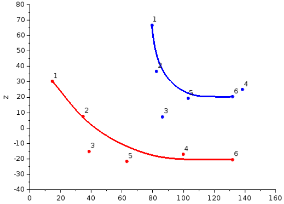


Grid for the CFD calculation

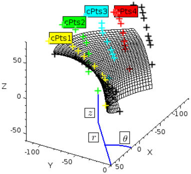
Methodology: optimization setup (1/2)

variables [mm]	zH1	zH2	zH3	zH4
IP	0.0	0.0	0.0	0.0
LB	-5.0	-5.0	-5.0	-5.0
UB	5.0	5.0	5.0	5.0

variables [mm]	zS1	zS2	zS3	zS4
IP	0.0	0.0	0.0	0.0
LB	-5.0	-5.0	-5.0	-5.0
UB	5.0	5.0	5.0	5.0

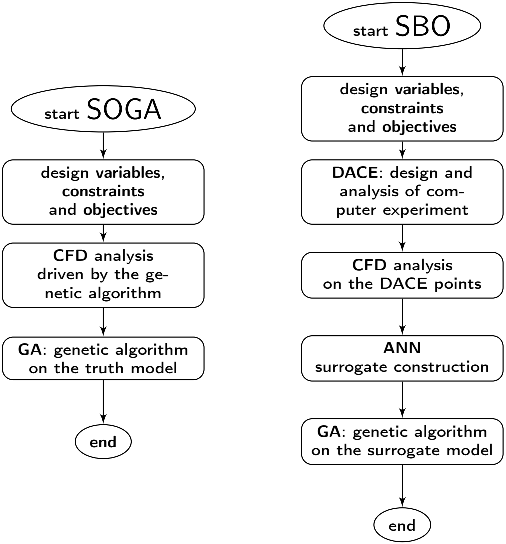


variables [rad]	θB1	θB2	θB3	θB4
IP	0.0	0.0	0.0	0.0
LB	-0.2	-0.2	-0.2	-0.2
UB	0.5	0.5	0.5	0.5



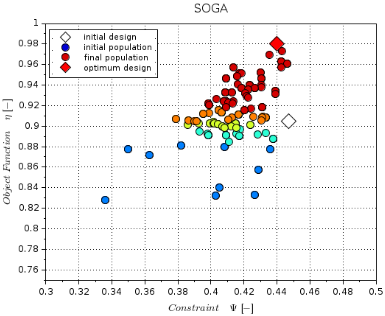
responses	type	sense	LB	UB
η	objective	max	-	-
ψ	NL-IC	-	0.38	0.52

Methodology: optimization setup (2/2)

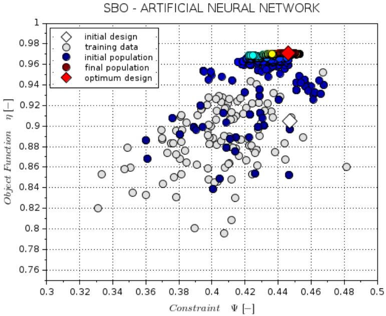


Results

Optimization methods behaviour



SOGA

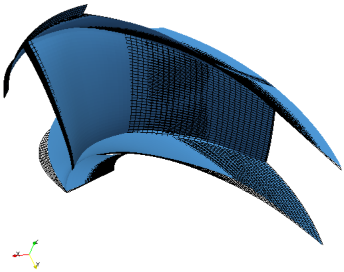


SBO

Results

Detail of blade suction side: comparison between original impeller (black wireframe) and best solution after optimization

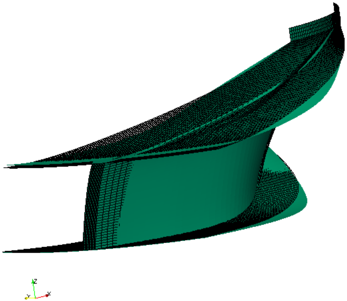
SOGA



SBO

Results

Detail of blade pressure side: comparison between original impeller (black wireframe) and best solution after optimization



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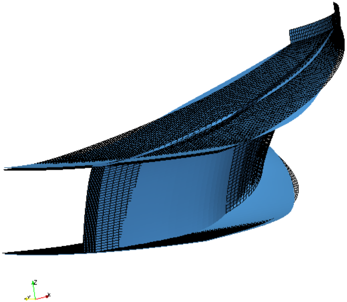

SBO

Conclusion and future work

- Two fully automated optimization methods have been presented for improving the turbopump impeller efficiency, both are entirely based on open-source software
- The impeller shape has been converted in Bezier polynomials from data points. Twelve control points have been used as input variables for the optimization. The impeller efficiency η has been chosen as objective function and the head coefficient ψ has been used as constraint
- A single objective genetic algorithm optimization has been compared with a surrogate based optimization with ANN response surface

Conclusion and future work

- The surrogate based optimization method has shown almost the same optimum value provided by the standard optimization method, with saving the 37.5% of CFD simulations and therefore decreasing significantly the calculation time
- Although the high efficiency values predicted by the CFD simulations probably indicate the need of a more accurate CFD model, it seems reasonable to expect considerable room for efficiency improvement
- Different numerical methods for considering the rotor-stator interaction as well as new optimization strategies are planned for the next future, in order to further investigate the possibility of design improvement

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Thank You For Your Attention

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