



**FLUOREM**

"to reach « terra incognita » new designs"

# Turb'Opty™

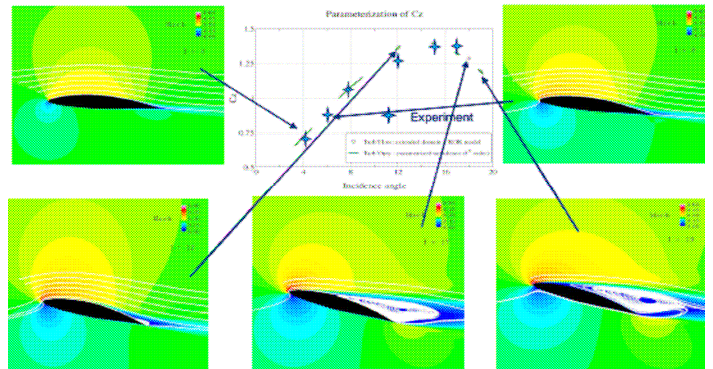
## One single CFD run for thousands of configurations!

Fluorem designed Turb'Opty™ because the role of CFD in engineering predictions has become so strong that it is currently the preferred means of testing alternative designs in many engineering companies before the final, if any, experimental testing takes place.

However, in major companies, the main business focus lies in the designer-users who do not want to think about fluid mechanics, but rather concentrate on consumer requirements and build objects satisfying normalized building codes thanks to an integrated, ready-to-use, tool.

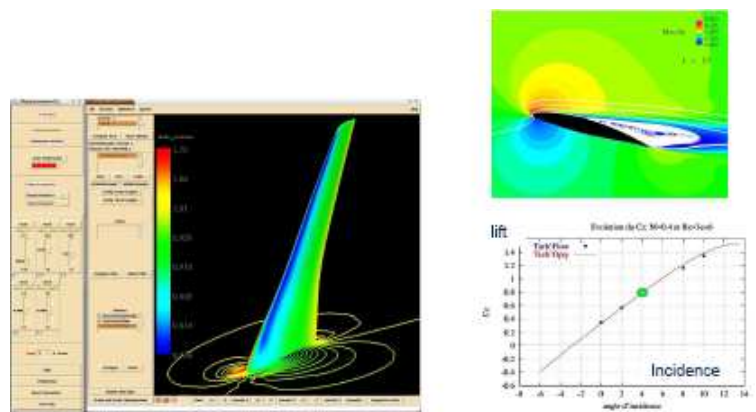
Previous to the development of Turb'Opty™, CFD engineers were compelled to multiply the geometries, boundary conditions and, as a result, the number of meshes and calculations.

Today, with Turb'Opty™, designers can directly view all the solutions of a specific fluid mechanics problem, by setting parameters of the flow field: within a single operation, they gain, in real time, access to thousands of solutions, simply with a click.



### Standard approach

- 1 run = 1 diagnosis for 1 solution
- N solutions = N runs
- No domain of validation



### Parametric approach: just take an easy solution

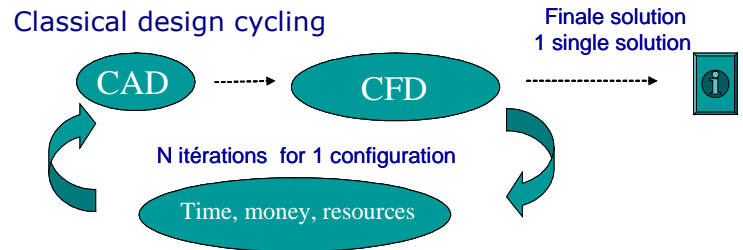
- 1 run only = all the solutions
- The overall solutions = optimal solution according to the geometric and flow-related design parameters.
- Large parameters variation intervals ( $\pm 200$  to  $300$  %) with an assessment of uncertainties



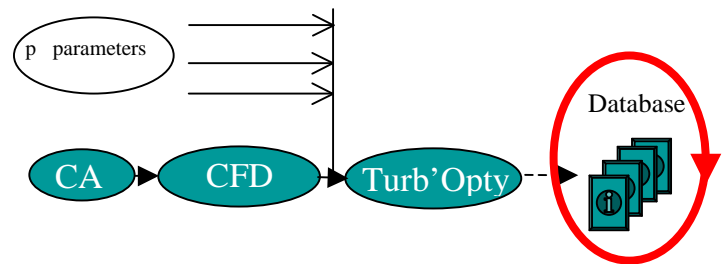
## Turb'Opty™, an aid to analysis

The parametric technology upon which Turb'Opty™ is based on breaks the bottleneck of CFD. Turb'Opty™ disconnects CFD from the conception.

From an initial solution field, Turb'Opty™ determines the relations between any single or several coupled parameters (design variables or flow related conditions like velocity, mass flow, etc.) needed for the conception, and the target function, such as efficiency, power, lift, etc. The solution is an analytical polynomial function of the flow field depending on design parameters. The coefficients of the polynomial, up to the N<sup>th</sup> order, are built by the engineer using Turb'Opty™ and the constructed flow database is provided to the end-user.



Now using Turb'Opty™.....



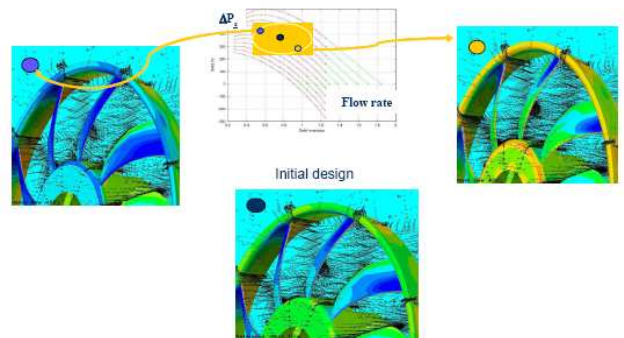
## Turb'Opty™, an aid to design and conception

Exploring the *entire* domain of conception, users gain a precise knowledge of the influence of each parameter of conception under study, considered independently or not, without any *a priori* restriction often imposed by the CPU time and bad convergences.

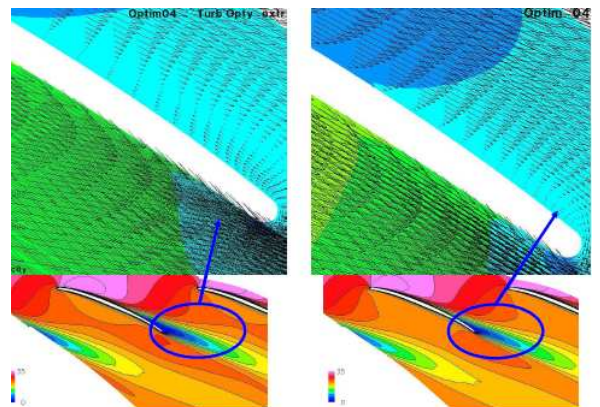
The polynomial of high order generated account for the inherent non-linearities within the NS governing equations, going much further than any gradient method can do.

As the solution of the extrapolation is the entire flow field, the user can see directly in the GUI the response of the pressure, the temperature or the velocity field to the modification of the different parameters.

He can thus design "on the fly" new geometries corresponding to his objectives, based solely on his specific industrial constraints, without any CFD considerations, simply playing with the different cursors controlling each design variable.



Flow map using Turb'Opty™: characteristics of a ventilator to determine the adapted geometry for each specific use



"On the fly" optimization: playing with the different geometrical parameters of the flow database to limit the stall at the trailing edge



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## Turb'Opty™: parameterization for optimization

The flow database can easily be linked to any optimization algorithm and provide the  $N_{pop}$  individuals during the  $N_{gen}$  generations leading to the Pareto-optimal solutions at the end of the optimization process. As the interrogation is immediate, no CPU or convergence constraint is limiting the way to the optimum.

The richness of the information allows determining the relations between different coupled parameters: a sensitivity analysis, even at the 2<sup>nd</sup> order, could lead to the conclusion that one specific parameter has no influence on the flow field. Combined to another one, the result might be totally different!

## Turb'Opty™, features and area of application

The major challenge to developing Turb'Opty™ was its complexity. The derivation of a numerical code in CFD had never functioned in precedent tests. The exception was developed by Fluorem.

The cutting-edge technology under Turb'Opty™ is an analytical derivation of the Navier-Stokes equations. Unlike finite difference methods, each model of the solver has been derivated at high orders, using Fluorem own automatic differentiation.

Classical NS solvers provide, at convergence, the flow field with respect to a specific set of boundary conditions. Turb'Opty™ provides the high order derivatives of the flow field, with respect to a set of specific design variables.

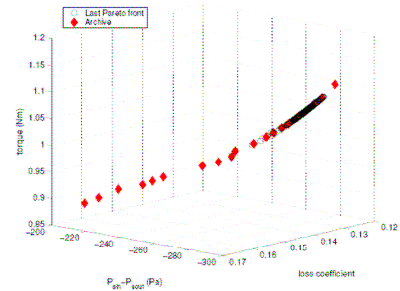
The reference solution can be produced with any other CFD solver, provided that they use similar models as the ones implemented in the NS solver of Fluorem.

Many features are available in Turb'Opty™. We are fully committed to build together the operational version of your specific needs.

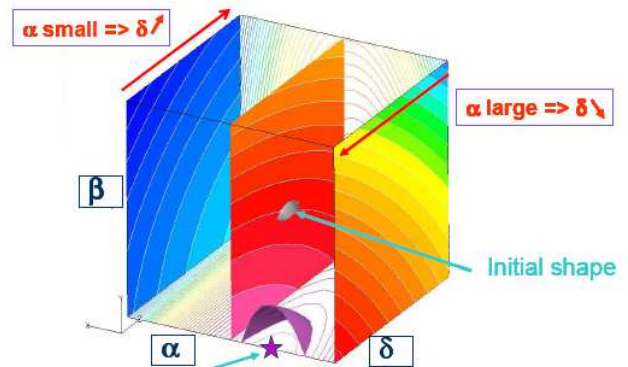
GA parameters	
$N_{pop}$	= 500
$N_{gen}$	= 100
$N_{sch}$	= 20

GA performances	
$N_{sol}$	= 350
CPU time	= 2.600 s.



Pareto front and Archive : 5 coupled design parameters  
3 objectives – 50 000 evaluations – ¾ hour



Importance of the coupling (cross derivatives) : influence of  $\delta$  is different for small values of  $\alpha$  and for large values of  $\alpha$

Quiz	Your need	Additional
<b>Numeric</b>		
Structured	<input type="checkbox"/>	
Non-structured	<input type="checkbox"/>	
Chimera grid	<input type="checkbox"/>	
<b>Branch</b>		
Hydraulics	<input type="checkbox"/>	
Hydrodynamics	<input type="checkbox"/>	
Aerodynamics	<input type="checkbox"/>	
Combustion	<input type="checkbox"/>	
Polyphasic flows	<input type="checkbox"/>	
Biomechanics	<input type="checkbox"/>	
Microfluidic	<input type="checkbox"/>	
.....		
<b>Flows</b>		
Internal	<input type="checkbox"/>	
Turbulent	<input type="checkbox"/>	
Unsteady	<input type="checkbox"/>	
Transonic	<input type="checkbox"/>	
.....		
<b>Application</b>		
Turbomachinery (isolated rotor, multi-stage,...)	<input type="checkbox"/>	
Aircraft (airfoil, fuselage, nacelle,...)	<input type="checkbox"/>	
Fluid/structure interactions	<input type="checkbox"/>	
Acoustic, vibroacoustic	<input type="checkbox"/>	
Objectives: physical analysis, design, optimization, ...	<input type="checkbox"/>	
.....		



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## Parameterization offering

Fluorem offers several licences and services such as full access to a parametric database, as presented in this table:

Parameterization package	Monoparametric derivatives	Multiparametric derivatives	Order of derivation	<i>Turb'Mesh</i> *	<i>Turb'Post</i> *	<i>Turb'View</i> *
<b><i>Turb'Design</i></b> <sup>TM</sup> The package for robust design analyses	✓	✗	≤ 2	✓	✓	✓
<b><i>Turb'Opty</i></b> <sup>TM</sup> The full package for advanced design analyses	✓	✓	≥ 2	✓	✓	✓
<b>A parametric database</b>	-	-	-	✓	✓	✓

These package are delivered in a one year licence, including

- \* *Turb'Mesh*<sup>TM</sup> for the parameterization of the mesh
- \* *Turb'Post*<sup>TM</sup> for the exploitation of the flow and the geometry databases
- \* *Turb'View*<sup>TM</sup> the Graphic User Interface

In the case of consulting or services for specific studies: the delivery is generally, together with our expertise and support, a database generated with the parameters defined by the user and all the necessary tools for its exploitation. The end-user can thus easily make his own parametric study and design his new product with respect to his industrial constraints. This database can be enriched by new parameters in future works.

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