Conservative approach for rotor-stator coupling in turbomachinery computations

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Rotor-stator interactions modelling

Frozen rotor

- frozen geometry for rotor and stator
- flow resolved in the relative frame of reference attached to the blades (Coriolis and centrifugal pseudo-forces in the rotor)

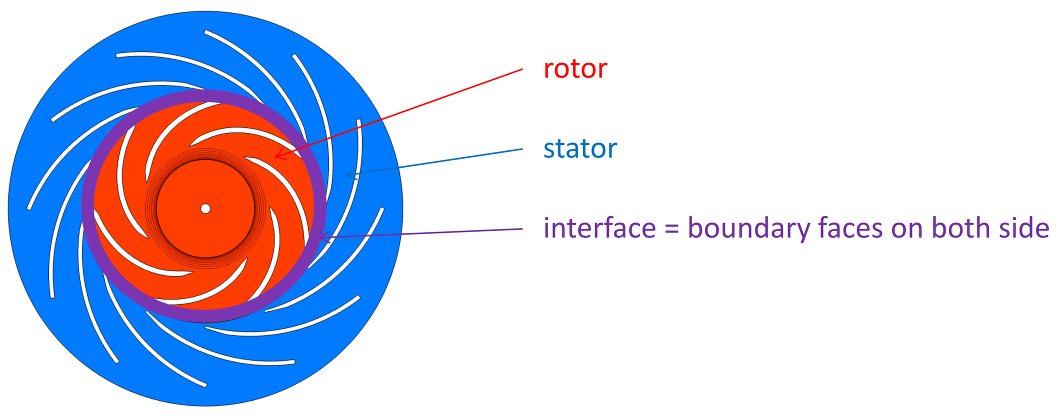
Unsteady rotor-stator

- rotor mesh actually rotating
- flow resolved in a galilean frame of reference (ALE formulation in the rotor)

A new treatment in *Code_Saturne*

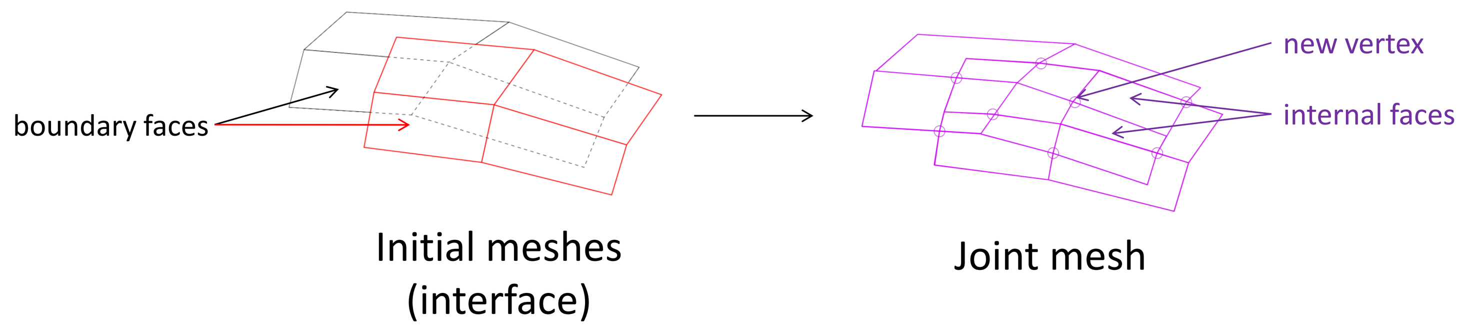
Previous approach: **code-code coupling**

- one calculation for the rotor and one calculation for the stator
- boundary conditions at rotor-stator interface: coupling scheme based on the closest cells on both side of the interface



New approach: **interface joining**

- Single *Code_Saturne* calculation on joint mesh



- ✓ conservative (mass and momentum)
- ✓ extensible: intrinsic compatibility with other modules (Lagrangian in particular)
- ✓ user friendly: single data management

Frozen Rotor:

- mesh joining at the begining of the computation
- incompressible momentum equation in the rotor inverted in the form:

$$\frac{\partial u_A}{\partial t} + \nabla\cdot(u_A \otimes u_R) + \Omega \wedge u_A = -\frac{1}{\rho}\nabla p + \nabla\cdot(\nu\nabla u_A)$$

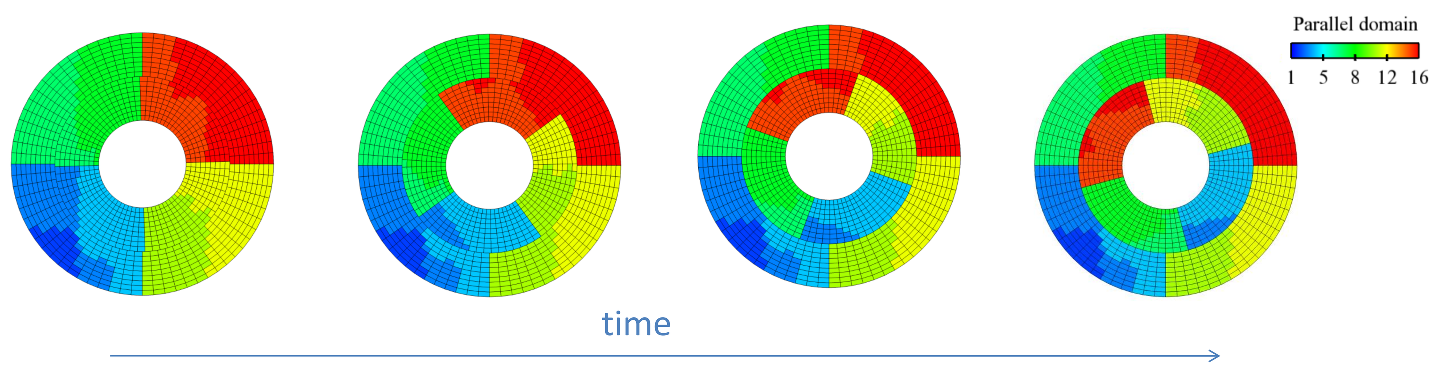
with:

u_A : absolute velocity (**primary variable**)

$u_R = u_A - \Omega \wedge x$: relative velocity

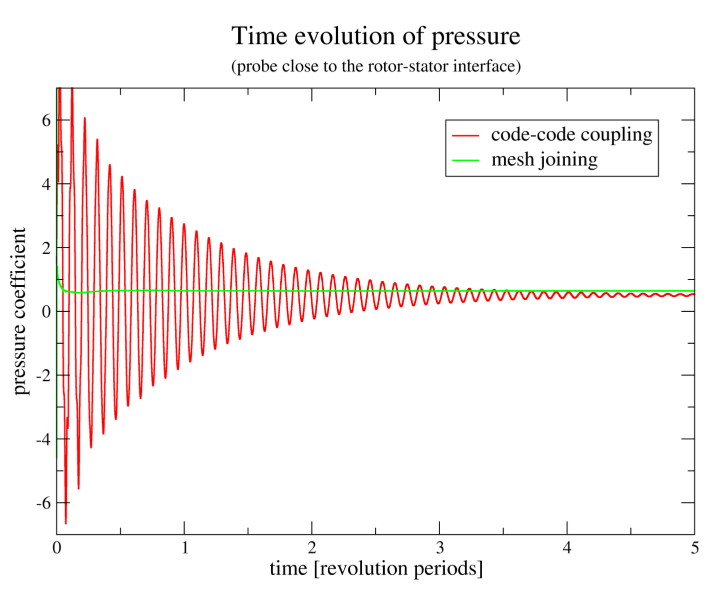
Unsteady rotor-stator:

- update geometry and join meshes at each time step
- partition mesh at the beginning of the computation (parallelism)

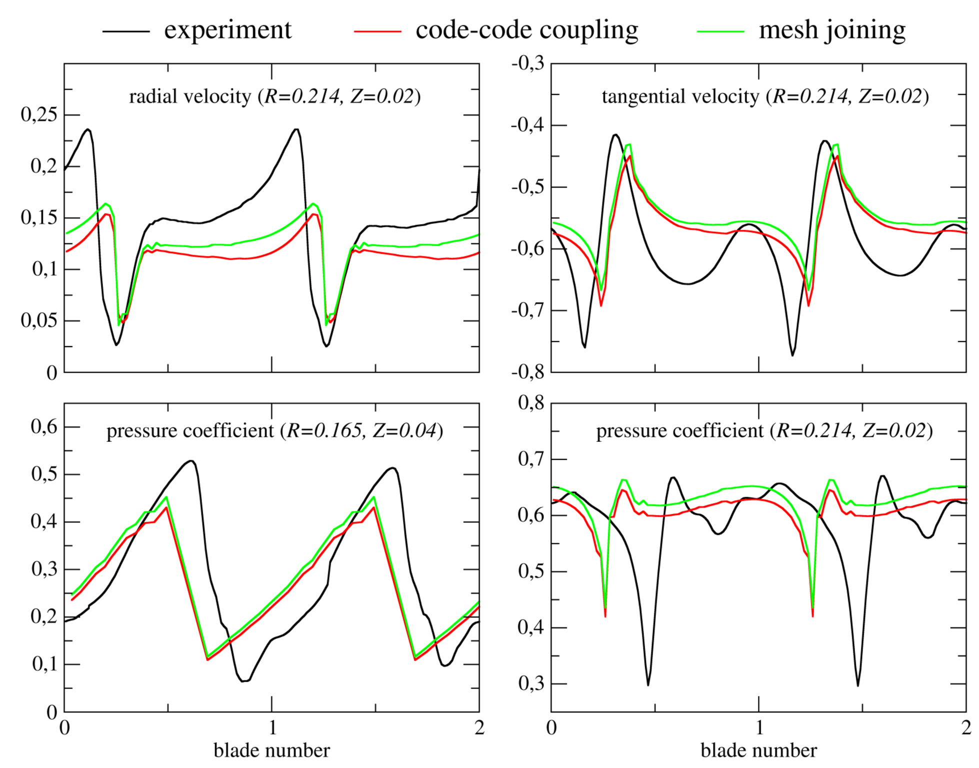


Validation case

- **Genova's pump**: centrifugal pump with vaned diffuser, quite simple geometry



Convergence of frozen rotor computations



Mean profiles in unsteady rotor-stator computations

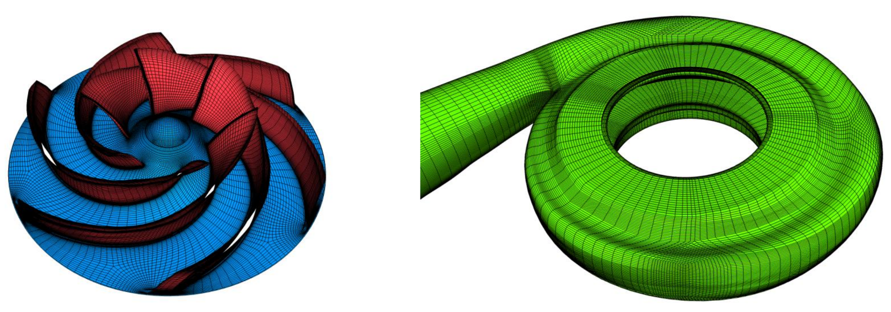
CPU time of joining operations / total CPU with mesh joining algorithm	15 %
total CPU with mesh joining algorithm / total CPU with code-code coupling algorithm	80 %

Performances of unsteady rotor-stator computations

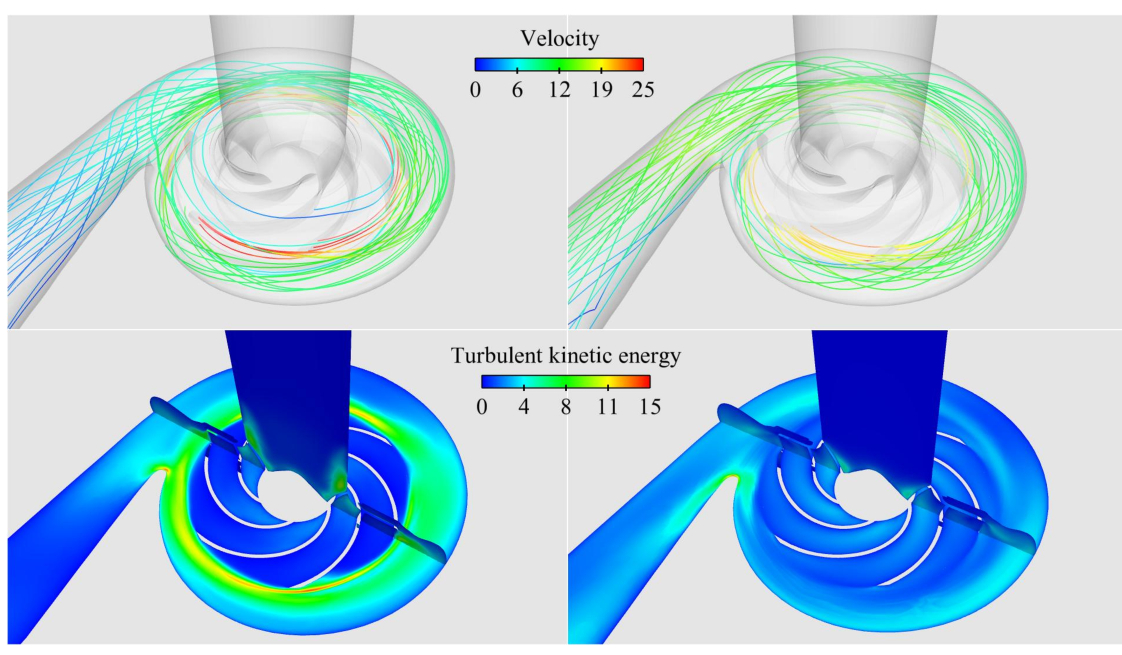
- ✓ Similar results compared with previous algorithm
- ✓ Better convergence in frozen rotor
- ✓ Computation savings in unsteady rotor-stator

Industrial case

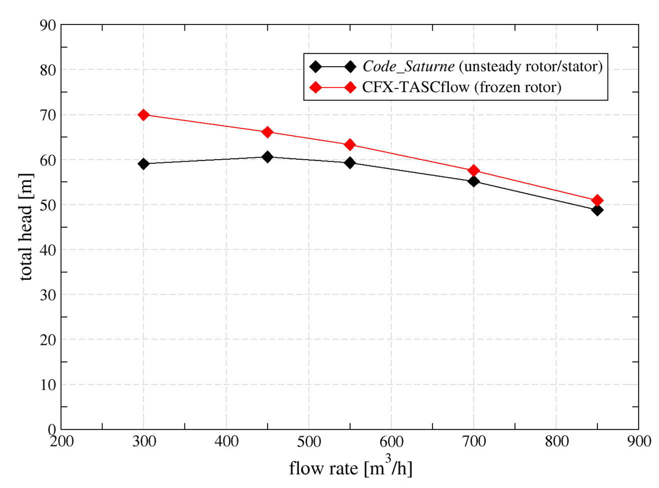
- **Gourdain's pump**: centrifugal impeller + casing



Visualisation of the mesh (1.2 M cells)



Visualisation of the flow in subrate (left) and nominal (right) conditions



Specification of the pump: total head