Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 82 (2015) 209 – 214

Energy Procedia

ATI 2015 - 70th Conference of the ATI Engineering Association

# A local, un-structured, re-meshing technique capable of handling large body-motion in rotating machinery.

A. Bonfiglioli[a,1], R. Paciorri[b]

[a]Scuola di Ingegneria, Università degli Studi della Basilicata, V.le dell'Ateneo Lucano 10, Potenza, 85100, Italy
[b]Dip.to Ingegneria meccanica e aerospaziale, Università di Roma "La Sapienza" , Via Eudossiana 18, Rome, 00184, Italy

**Abstract**

In this paper we propose a simple, unstructured mesh generation technique that is capable of handling the large and complex blade motion that is encountered in certain rotating machines, such as vertical axis wind turbines or cycloidal propellers. The technique is characterised by localised re-meshing and interpolation, so as to keep the mesh generation cost and interpolation error as low as possible.



Peer-review under responsibility of the Scientific Committee of ATI 2015
*Keywords:* Rotating machines, Unstructured mesh generation, Arbitrary Lagrangian Eulerian

## 1. Introduction

In certain rotating machinery, such as the Voith Cycloidal Rudder (VCR), the blades undergo a fairly complex relative motion. When the hydrodynamic behaviour of these devices is numerically simulated by means of CFD, the shape and volume of the domain occupied by the fluid change with time and the large displacement of the wetted surface might even lead to topological changes in the computational domain. Under such circumstances, mesh deformation algorithms [1] might be inapplicable and overlapping grids [2] or global re-meshing techniques should be used instead. The time-dependent re-meshing of the fluid domain can however amount to a significant portion of the total computational cost. Moreover, the transfer of information between the grids generated at subsequent time levels or between overlapping meshes is likely to lead to conservation violation and loss of resolution.

We propose a mesh generation technique that is characterised by localised re-meshing and interpolation, so as to keep the mesh generation cost and interpolation error as low as possible.

In the proposed technique, a body-fitted, unstructured grid is attached to each of the moving blades and each blade, along with the grid that is attached to it, is allowed to move over a fixed, background triangulation that covers the entire computational domain. At each time-step, the cells of the background mesh which are overlap by the body-fitted grids are temporarily removed and local re-meshing is applied only in the neighbourhood of the outer boundary of the body-fitted meshes.

[1]Corresponding author: Tel. +39-0971-205203. *Email Address:* aldo.bonfiglioli@unibas.it.


Peer-review under responsibility of the Scientific Committee of ATI 2015
doi:10.1016/j.egypro.2015.12.022

**Nomenclature**

| | | | |
|---|---|---|---|
| $\alpha$ | angle of attack | $I$ | identity matrix of order $d+2$ |
| $\Delta t$ | time-step length | $k$ | reduced frequency |
| $\mathbf{w}$ | nodal grid velocity | $K_i^e$ | inflow parameter |
| $\mathbf{x}$ | array of the Cartesian coordinates of the grid-points | $M$ | Mach number |
| $\omega$ | angular frequency | $p$ | static pressure |
| $\Phi$ | Inviscid flux balance | $T$ | static temperature |
| $\Phi_i^e$ | signals sent to vertex $i$ of cell $e$ | $T^e$ | triangle $e$ |
| $\rho$ | density | $U$ | conserved variables |
| $c$ | airfoil's chord | $u$ | horizontal velocity component |
| $C^i$ | median dual cell | $U_\infty$ | freestream velocity magnitude |
| $d$ | dimension of the space | $v$ | vertical velocity component |
| $H$ | total enthalpy | $Z$ | parameter vector = $\sqrt{\rho}\,(1, H, u, v)^T$ |

As far as the discretization of the governing PDEs is concerned, an Arbitrary Lagrangian Eulerian (ALE) scheme is required in order to account for the non-zero grid velocities that arise within the body-fitted meshes and along their interface with the background, stationary triangulation.

## 2. The numerical method

The numerical method we propose consists in the loose coupling between an unstructured grid generator that is used generate computational meshes around the moving bodies and within the fluid domain and an unstructured CFD solver that is used to discretise the governing PDEs using the boundary-conforming and non-overlapping meshes created by the mesh generator.

The two codes are loosely coupled in the sense that the grid generator invokes the CFD solver as a black box. This has obvious consequences in terms of algorithmic simplicity, since it allows to re-use any existing gas-dynamic code, as long as its discretization is vertex centred.

In the next two sections we will describe the unstructured solver and the mesh generator algorithm.

### *2.1. The* `eulfs` *unstructured-grid solver*

The `eulfs` code is an in-house, unstructured CFD solver that has been developed over the last fifteen years: see [3] for a detailed description of its basic features and [4] for more recent developments. It relies on Fluctuation Splitting (FS), or Residual Distribution [5, 6, 7] schemes for the spatial discretisation. In the FS approach the dependent variables are stored at the vertices of the computational mesh which is made up of triangles in the 2D space, and tetrahedra in 3D and are assumed to vary linearly and continuously in space. The inviscid flux balance $\Phi^e$ (also referred to as the cell residual or cell fluctuation) is evaluated over each triangular/tetrahedral element $e$ by means of a conservative linearisation [8] based on the parameter vector $Z$, and scattered to the element vertices using signals $\Phi_i^e$. Within a cell $e$, the signals have to sum up to the net flux for conservation: $\sum_{i\in e} \Phi_i^e = \Phi^e$. The nodal residual is then assembled by collecting fractions $\Phi_i^e$ of the net fluxes $\Phi^e$ associated with all the elements by which the node $i$ is surrounded. The various FS schemes proposed in the literature differ by the way cell residuals are split into signals. In this paper,