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Unstructured Hybrid Meshing Features in PADRAM

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ABSTRACT

Design optimisation of turbomachinery components is becoming feasible nowadays with the progress in CFD computation. One of the key technologies for the success in aerodynamic optimisation is robust meshing tool to handle complex geometries. In addition, the quality of mesh has to be considered because it highly affects the CFD results. The aim of this research is to provide unstructured hybrid meshing capability within PADRAM [1] to variety of real geometry in engine design. The PADRAM is originally a structured multi-bock mesh generator, and it is used as a part of design optimisation system, SOPHY (SOFT-PADRAM-HYDRA), in Rolls-Royce and its University Technology Centres. It has been applied for various optimisation problems and has successfully generated meshes for various geometries. In order to extend the meshing capability to more complicated geometries such as multi-passage and multi-shaped airfoil configuration, unstructured meshing capabilities have been developed within PADRAM.

Since the unstructured meshing is required to be rapid and robust for optimisation purposes, the concept to create three-dimensional mesh is based on mapping technique rather than full three-dimensional volume meshing. By using the initial structured mesh as the background mesh for unstructured meshing, the unstructured mesh is generated on selected blocks based on Delaunay triangulation. The layer meshes in a particular block are mapped, for example, from the mid-section layer mesh by applying UV parametric mapping technique. The 3D mesh is then created by connecting adjacent layers via prisms and hexahedra. Thus, the mesh creation is fast and the cells are well connected without any negative cells. Hybrid unstructured mesh is accomplished by coupling structured and unstructured meshes, e.g., airfoil block is kept structured (O-mesh) and other blocks are meshed unstructured. This can maintain the quality of mesh in the boundary layer, and provide more flexible meshing capabilities in other regions. As shown in Fig. 1, the mapping of middle unstructured plane to other layers can be done along radial or theta-wise direction according to the necessity.

In addition to the above basic idea to generate unstructured hybrid mesh, various techniques have been implemented for avoiding negative volume as well as controlling mesh density and mesh quality. When the geometry is complicated, such as integrated

Strut and Vanes configuration which has many short airfoils (vanes) along the strut, this basic procedure may fail to produce unstructured mesh due to invalid topology of background structured mesh. Therefore, one of the techniques implemented in unstructured PADRAM is a “merging” technique. A new block, MERGE, which is created by merging LHS, BLADE-H passage and RHS blocks, has been created within PADRAM to avoid invalid inter-block boundaries. This improves the cell quality across the block boundaries in the unstructured meshing. The 3D blades may have large variations in their shapes and their positions across the stream sections, normal mapping technique may not work well for this type of configurations and so a fast and dynamic mapping technique based on Delaunay Graph Mapping [2] has been implemented for unstructured 3D meshing. By using merging and Delaunay graph mapping techniques, 3D mesh for Vanes and Strut configuration has been successfully created. The Delaunay graph mapping is highly robust, and it can map the mesh successfully to other layers even when there is large deformation and large change of geometries occurs. Figure 2 shows mesh of a turbine blade having bumps at hub and tip sides with wake clustering.

The quality or density of mesh can be controlled through many parameters such as minimum and maximum sizes of triangles, expansion ratio, edge division parameters, etc. The mesh can be clustered through point and line sources to generate high-resolution mesh around the specified region such as wake regions. Similarly, automatic wake clustering feature has been implemented. This refines the mesh at the trailing edge region of each airfoil to capture wakes.

Hybrid unstructured meshing has successfully been applied to various 3D geometries in turbomachinery and some of its capability will be presented.

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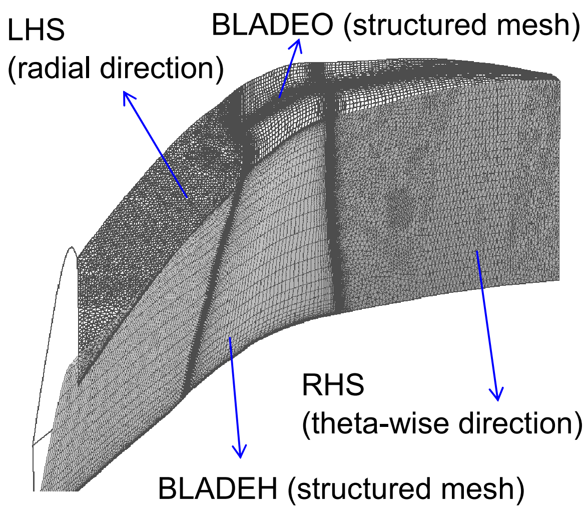

Fig. 1 Unstructured hybrid meshing

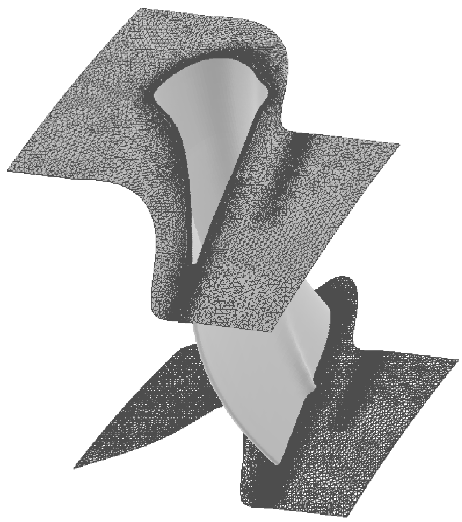

Fig. 2 turbine blade with bump function