Polygonal Prism Mesh in the Viscous Layers for the Polyhedral Mesh Generator, PolyGen

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1. Introduction

Polyhedral mesh has been known to have some benefits over the tetrahedral mesh [1]. Efforts have been made to set up a polyhedral mesh generation system with open source programs SALOME [2] and TetGen [3]. The evaluation has shown that the polyhedral mesh generation system is promising [4:5]. But it is necessary to extend the capability of the system to handle the viscous layers to be a generalized mesh generator. The STAR-CCM [6] mesh in Fig. 1 is a mesh example with the polyhedral volume mesh and the polygonal prism viscous layer mesh.
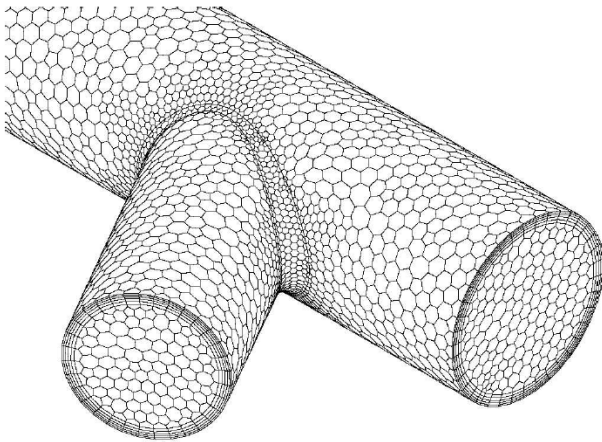

Fig.1. Mesh by STAR-CCM for Merged Pipe

A brief review to the previous works on the mesh generation for the viscous layers will be made in section 2. Several challenging issues for the polygonal prism mesh generation will be discussed as well. The procedure to generate a polygonal prism mesh will be discussed in detail in section 3. Conclusion will be followed in section 4.

2. Conventional Mesh Generation for the Viscous Layers

In general, the mesh generation for viscous layers is relying on the extrusion process. For example, the procedure for the tetrahedral mesh generation process induces the extrusion of the surface triangular mesh.

The procedure to generate tetrahedral mesh with triangular prism viscous layer mesh is started with surface triangular mesh for whole surfaces. Then, identifying the faces with viscous layers and the in-out faces is second task. Faces, F1, F2 and F3 are in-out faces for the merged pipe in Fig.2. Rest of faces, F4, F5 and F6 are viscous faces. Triangular meshes on the

viscous faces are extruded into the pipe body up to predetermined layer thickness yielding prism cell layers. The triangular meshes on the in-out faces are contracted radially to accommodate the extrusion of the viscous layers. The mesh generated for the merged pipe and its clipping view are shown in Fig.3.
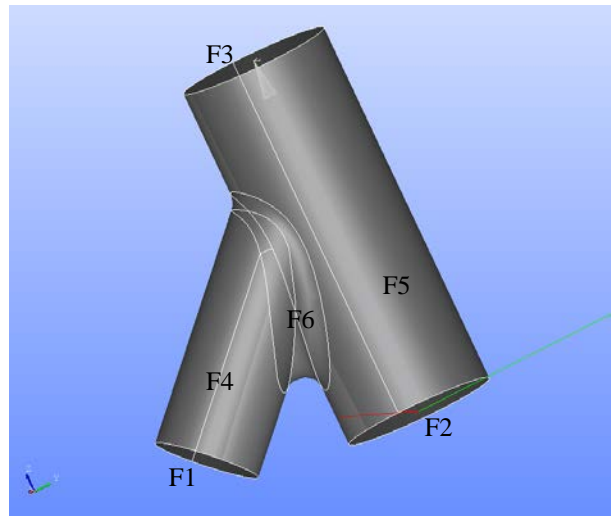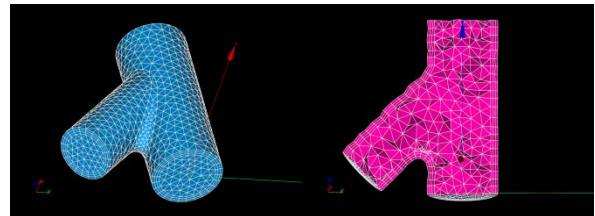

Fig.2. Merged Pipe

Fig.3. Tetrahedral Meshed Merged Pipe

Direct extension of this procedure to polyhedral mesh generation cause several problems. As noted several times in the previous papers [4:5], PolyGen assumes the Gabriel property for the boundary cells and faces. But, extrusion and/or contraction process may destroy that property.

One way to get around this problem may be adjusting (reducing) the geometrical shape first; meshing the modified geometry; and then, extruding the polygon up to the original viscous surface. Even though this procedure works all right in principle, it is a little awkward with respect to the general mesh generation process. Also, it may be doubtful if it can handle the complicated geometry. For example, it is not clear how to handle the surface like fillet F6 in Fig.2. Therefore, other new method is devised and it will be presented in detail in section 3.

3. A New Method of Mesh Generation for the Viscous Layers

New method is to use the conventional surface triangular meshing and extrusion/contraction process, as they are. But next step is to use the extruded/contracted surface mesh, which most probably does not have Gabriel property, as a geometry data instead of using it for volume mesh generation. Triangular surface mesh can be converted to geometric data through STL (Sereolithography) data format. Then, the STL data are used to generate the surface mesh with Gabriel property. The newly generated surface mesh is, then, used to generate polyhedral volume mesh and polygonal surface mesh using PolyGen. Finally, the generated polygonal surface meshes on the viscous faces are extruded up to the original geometrical surfaces.
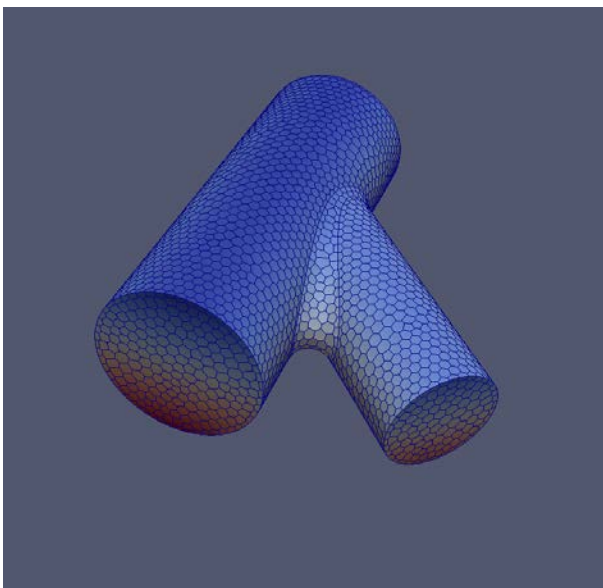

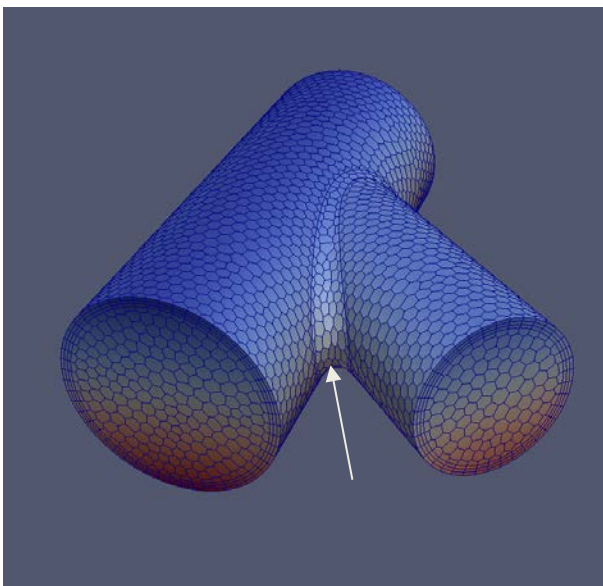Fig.4. Polyhedral Mesh for the STL Geometry

Fig.5. Completed Polyhedral Mesh by Extrusion

Fig.4 shows the polyhedral mesh for the STL data of the merged pipe. A challenging issue is to find the best direction of the extrusion of the polygons. If they are not properly determined, final extruded polygons are in bad shapes especially on the complex face like fillet F6 in Fig.2. One way to determine is to take the direction of the averaged normal vectors of the faces that incident on the polygonal vertex. Total and clipping views of the generated mesh by this method are shown in Fig.5 and Fig.6 respectively. Polygons at the position indicated by white arrow in Fig.5, where saddle point shape is prevailed, show some irregularity. This means the extrusion direction is not so good.

Another way of determining extrusion direction is to use the extrusion direction of the STL data. But an extensive accounting of the direction vectors data is necessary through whole process of mesh generation steps.
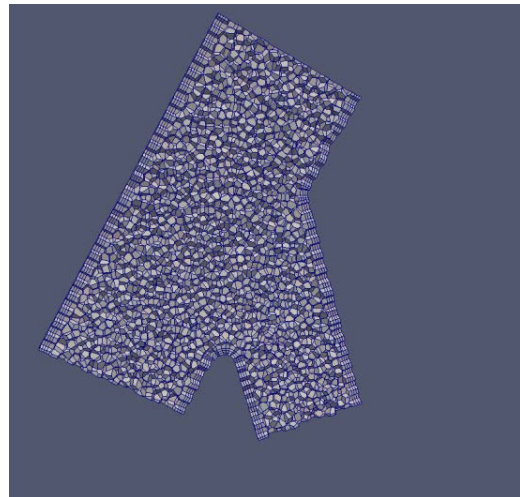

Fig.6. Clipping View of the Final Polyhedral Mesh

4. Conclusions and Further Works

A procedure to generate meshes in the viscous layers with PolyGen has been successfully designed. But more efforts have to be exercised to find the best way for the generating meshes for viscous layers. Using the extrusion direction of the STL data will the first of the trials in the near future.

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