Modeling of the flow in water turbine of the hydroelectric generator

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Overview

As Russia is a wide network of hydroelectric power for the most part built 40-50 years ago. The main objective of this work is the study of the hydraulic units to improve their performance. The efficiency of the hydraulic unit depends on the particular set of parameters such as the angle of the guide blades, orientation angle of the turbine blades for a given water pressure. This presentation demonstrates the results of the first phase of our work, in which the numerical simulation was carried out for one of the units installed at the Nizhny Novgorod hydropower plant depending on the single parameter – orientation angle of turbine blades.
General view of Nizhniy Novgorod hydro power plant
Cross-sectional view of the power plant
Laser measurements of the hydroelectric generator geometry

Plant was put into operation in 1956, drawings of the hydroelectric generator were lost.

Geometry obtained by laser measurements didn’t contain parametric CAD information only triangular tessellation with variety of geometrical features due to tear and wear, construction technologies and also other factors.
Number of errors in tessellated geometry exceeded thousand. Pierced, free and non-manifold edges, leaks and other issues, all demanded manual repair. Using embedded repair tools all problems were solved within a reasonable time without using Surface Wrapper tool, although using this tool in this task might be well justified. Also in preparing geometry 3D-CAD modeler was used. On the example of this task it is possible to appreciate seamless workflow process in STAR-CCM+.
Computer model contains 11 mln polyhedral cells.
Physical model

✓ Stationary
✓ Moving reference frame
✓ Incompressible liquid
✓ k-e turbulence model
✓ Without cavitation model
The table below contains calculation results for different angles of turbine blades orientation: loss of flow energy, heat release, turbulence energy, flow rate, efficiency, force moment and efficient power.

<table>
<thead>
<tr>
<th>angle</th>
<th>$W_{\text{mech}}$, MW</th>
<th>$W_{\text{term}}$, MW</th>
<th>$W_{\text{turb}}$, MW</th>
<th>Flow rate, m$^3$/sec</th>
<th>Efficiency</th>
<th>Force moment, H$\times$m</th>
<th>Power, MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>3'30</td>
<td>-36,4</td>
<td>11,3</td>
<td>0,02</td>
<td>221,7</td>
<td>0,69</td>
<td>3,8</td>
<td>25,1</td>
</tr>
<tr>
<td>6'30</td>
<td>-46,2</td>
<td></td>
<td></td>
<td>282,8</td>
<td>0,71</td>
<td>4,9</td>
<td>32,3</td>
</tr>
<tr>
<td>9'30</td>
<td>-50,4</td>
<td>11,0</td>
<td>0,08</td>
<td>314,0</td>
<td>0,79</td>
<td>6,1</td>
<td>39,9</td>
</tr>
</tbody>
</table>
This chart shows the total loss of energy flux, to efficient power and thermal losses. It can be seen that thermal losses are significant.
This graph shows the dependence of the efficiency of the orientation angle of the turbine blades. It is seen that the maximum is reached for an angle of 9.5 degrees. At first glance it seems that the larger the angle, the greater the efficiency. But in fact it is not true. The fact that in reality there are limits dictated by various factors. For example, the strength of any details.
Visualization

Streamlines

Vorticity
Threshold of the turbulent kinetic energy
Visualization

Pressure fields
Visualization

Velocity fields
Conclusion

In this work the we used STAR-CCM+ for modeling flows in hydroelectric unit with complex geometry obtained by measuring the actual generating units, and having a large number of topological features requiring attention. Usage of STAR-CCM+ allowed us to meet very tight time schedule, investigate peculiarities of the flow and confirm some of the main characteristics hydroelectric unit.
Thank you for your attention