Air-Water Multiphase Turbulence Flow in Low Rotation Tub-Type Water Wheel Vessel (Corrections on RANS Model)

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Introduction

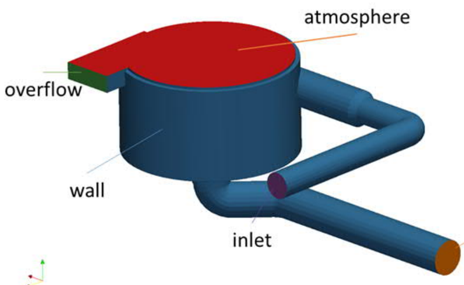
A low rotation tub-Type water wheel is one of the small-scale hydroelectric power plant. The water wheel is durable and suitable for developing countries. Vortical motion is formed by incoming water flow from the side and outgoing flow from the bottom of the vessel.

Air-water multiphase flow in a tub-type water wheel vessel is simulated with RANS turbulence models. The effect of rotation/curvature and density gradient corrections on a standard k-ω SST model with VOF method was investigated. In this study, water flow without blades is considered for the sake of simplicity.

Fig.1 Low Rotation Tub-Type Water Wheel with and without blade

Simulation Method

OpenFOAM v4.1, interFoam
Number of cells: 1 770 000
Turbulence Models: RANS
- kOmegaSST (OpenFOAM standard)
- kOmegaSSTRC (ancolli[1]): Rotation/Curvature corr. [2]
- kOmegaSSTBuoyancy (Devolder[3]): Density Gradient corr. [4]
- kOmegaSSTBuoyancyRC (present study): RC + Density Gradient corr.



Vessel:
diameter 1 m
depth 0.55 m
Flowrate:
65 t/h
$Re = 1.1 \times 10^5$ at inlet

Fig.2 Simulation model

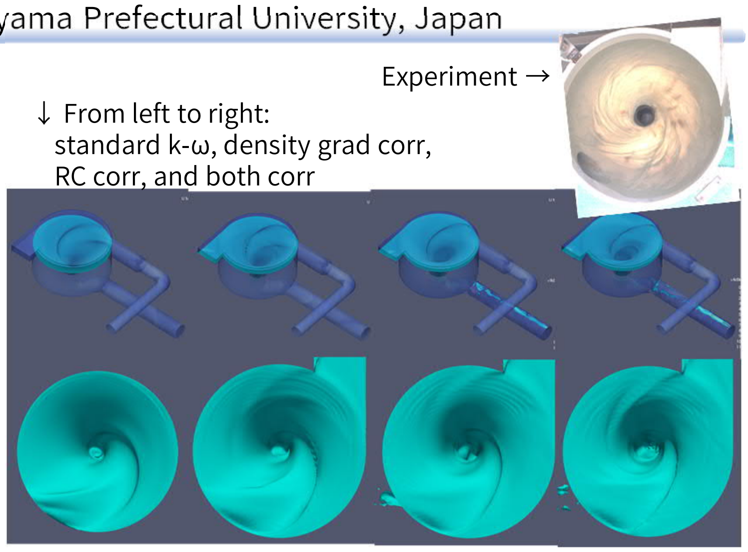


Fig.3 Water surface predicted with various turbulence models

Simulation Results

Standard k-ω model shows poor performance in reproducing the water surface structure observed in the experiment. The correction effects of rotation and density variation improved the performance as shown in Fig.3. Superimposing both corrections improved results. Comparisons of water height and circumferential velocity distributions with experiments support this effect.

Figure 4 investigates the effect of rotation and density gradient correction terms. Strong depression due to rotational and density gradient is observed near the water surface.

Conclusion

The performance of k-ω SST model is improved by adding rotation and density gradient correction terms. Contribution from rotation correction is larger among them.

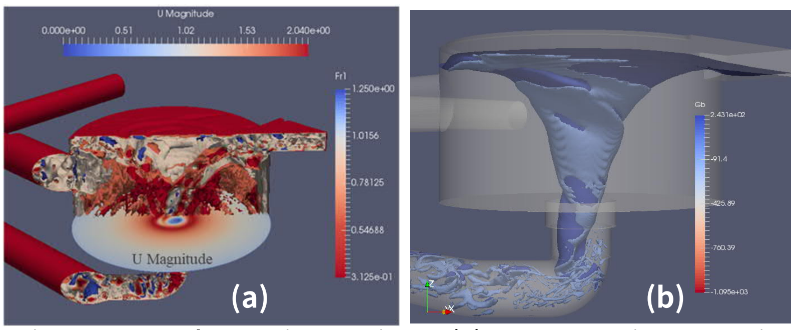


Fig.4 Strong depression regions: (a) RC correction term is effective in red region where rotating velocity is large. (b) A steep density gradient around water surface depresses turbulence with the effect of the buoyancy term.

References:
[1] https://github.com/ancolli/kOmegaSSTCC
[2] Shur et al.(2000), AIAA J., 38, 784-792.
[3] https://github.com/BrechtDevolder-UGent-KULeuven/buoyancyModifiedTurbulenceModels
[4] Devolder et al.(2018),Coastal Eng. 138, 49–65.

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