Regarding Flaws in A. Thakker and M. A. Elhemry (2007) 3-D CFD Analysis on Effect of Hub-to-Tip Ratio on Performance of Impulse Turbine for Wave Energy Conversion

by

Fergal HOURIGAN
Nordic Aviation Capital A/S, Ireland

Two major flaws present themselves in the paper Thakker, A. and Elhemry, M. A. (2007). 3-D CFD Analysis on Effect of Hub-to-Tip Ratio on Performance of Impulse Turbine for Wave Energy Conversion, THERMAL SCIENCE: Vol. 11 (2007), No. 4, pp. 157-170.
The first is the form of the non-dimensional performance parameters. These are at odds with the accepted performance parameters for turbomachinery published in textbooks, Massey, 1971 and the literature, Curran et al., 1998, Thakker et al., 2001. Also the presence of multiple geometric parameters in the definition of the non-dimensional performance parameters invalidates the assumption of geometric similarity and also renders the comparison of geometrically dissimilar turbines impossible.

Invalidity of non-dimensionalising performance parameters

Page 161 of Thakker and Elhemry, 2007 gives the following non-dimensional equations:

$$C_{\mathrm{T}} \quad \frac{T}{\frac{\rho(v_{\mathrm{a}}^2 \quad U_R^2)bl_{\mathrm{r}}zr_{\mathrm{R}}}{2}} \tag{1}$$

$$C_{\mathrm{A}} \quad \frac{\delta pQ}{\frac{\rho(v_{\mathrm{a}}^2 \quad U_R^2)bl_{\mathrm{r}}zv_{\mathrm{a}}}{2}} \tag{2}$$

$$\phi \quad \frac{v_{\mathrm{a}}}{U_{\mathrm{R}}} \tag{3}$$

$$\eta \quad \frac{T\omega}{\delta pQ} \quad \frac{C_{\mathrm{T}}}{C_{\mathrm{A}}\phi} \tag{4}$$

These were used to non-dimensionalise experimental and computational results, which were then compared.

* Author's e-mail: fergal.hourigan@gmail.com

These equations are invalid for the purpose of non-dimensionalising experimental results for turbomachinery. The correct equations for turbomachinery can be found in other journal papers such as Curran *et al*., 1998, Thakker *et al*., 2001.

Massey, 1971, gives a list of common dimensional parameters which includes parameters of the generally accepted form for turbomachinery, but those of the form shown above used in Thakker and Elhemry, 2007, do not appear there. Further, the generally accepted forms can be easily obtained from first principles.

Specifically, the inclusion of geometric parameters such as blade span, b, chord l_r and the number of blades, z, in the dimensionless parameters undermines the assumption of geometric similarity that underlies the non-dimensionalisation of experimental data.

Further, the inclusion of such parameters renders invalid any comparison of geometrically dissimilar turbines on the basis of C_T and C_A: two geometrically dissimilar turbines with the same performance would exhibit spurious differences in C_T and C_A due to the inclusion of the geometric parameters noted above.

Consider two turbine geometries which can be distinguished from each other on the basis of the blade chord length, blade span, and number of blades. For the purposes of argument, let the performance of the turbines be identical. When the values of C_A and C_T are calculated according to the definitions above, differences at the same value of flow coefficient will be found due solely to the dependence of C_A and C_T on the details of the geometry of the turbines. However, if the accepted forms of non-dimensional pressure drop and torque are applied, no difference in performance between the turbines will, correctly, be found.

The forms of non-dimensional torque and pressure drop presented in Thakker and Elhemry, 2007, have no basis in engineering science.

Invalidity of computational fluid dynamics (CFD) results

There are two grounds for concern with the computational work:

(1) The quality of the computational work is justified on the basis of a comparison of computational and experimental values for efficiency alone.
(2) Some of the results demonstrate that the work is not grid independent.

I shall take it that the absolute requirement for grid independence is accepted. In figure 3 in Thakker and Elhemry, 2007, pp. 162, results for efficiency *vs*. flow coefficient obtained computationally at different grid resolutions for three different turbine geometries are presented.

It is not sufficient to use efficiency to study the grid independence of the performance of the turbine, at least one other parameter would be needed, either a non-dimensional torque or non-dimensional pressure drop. More usually, non-dimensional torque and non-dimensional pressure drop would have been studied.

The reason that considering efficiency alone is unsatisfactory since substantial, but similar, errors in torque and pressure drop would be masked by considering efficiency only. A difference between computational and experimental results of, say 50% in torque and 50% in pressure drop could produce a value of efficiency exactly equal to the experimental results if the computational results are in the correct proportion. The comparison of one other performance parameter is required to evaluate the quality of the simulation.

A study of the grid independence of the results is presented. Confusingly, the authors appear to present these results as demonstrating that grid independence has been achieved

whereas the results are not consistent after successive refinements of the grid in the case of two of the geometries.

In Thakker and Elhemry, 2007, pp. 162, fig. 3(a) shows the results for a 0.6 hub-to-tip ratio turbine. The results are consistent after a third refinement of the grid, demonstrating grid independence. Figure 3(b) shows the results for a 0.55 hub-to-tip ratio turbine. The results appear to be quickly diverging at the higher grid refinement level. These results are not grid independent.

Figure 3 (c) shows the results for a 0.5 hub-to-tip ratio turbine. The results are not consistent after successive refinements of the grid, again the results appear to be quickly diverging at the higher grid refinement level. The computational results are not valid for the 0.5 and the 0.55 hub-to-tip ratio turbine geometries.

Conclusions

Thakker and Elhemry, 2007, contains serious deficiencies regarding the non-dimensionalisation of the experimental results. The form of dimensionless performance parameters used are not compatible with the accepted forms and can be shown to be invalid.

The computational analyses of the fluid flow using CFD of the 0.5 and the 0.55 hub-to-tip ratio turbine geometries are invalid since they have been shown to be not grid independent.

References

[1] Thakker, A., Elhemry, M. A., 3-D CFD Analysis on Effect of Hub-to-Tip Ratio on Performance of Impulse Turbine for Wave Energy Conversion, *Thermal Science, 11* (2007), 4, pp. 157-170
[2] Thakker, A., Frawley, P. Sheik Bajeet, E., CA9: Analysis of a Stall Resistant Aerofoil in View of Wave Power Conversion, *Proceedings*, 11th International Offshore and Polar Engineering Conference, Stavanger, Norway, 2001, Vol. 1, pp. 614-619
[3] Curran, R., Whittaker, T. J. T., Stewart, T. P., Aerodynamic Conversion of Ocean Power from Wave to Wire, *Energy Conversion and Management, 39* (1998), 16-18, pp. 1919-1929
[4] Massey, B. S., Units, Dimensional Analysis and Physical Similarity, Van Nostrand-Reinhold, London, 1971

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