

HARMONIC BALANCE METHOD FOR TURBOMACHINERY APPLICATIONS

GREGOR CVIJETIĆ*¹ and HRVOJE JASAK^{1,2}

¹*Faculty of Mechanical Engineering and Naval Architecture,
Ivana Lučića 5, 10000 Zagreb, Croatia,
gregor.cvijetic@gmail.com, hrvoje.jasak@fsb.hr*

²*Wikki Ltd, 459 Southbank House, SE1 7SJ, London, United Kingdom, h.jasak@wikki.co.uk*

Keywords: *Harmonic Balance Method, Unsteady Non-Linear Periodic Flow, Turbomachinery, foam-extend*

Harmonic Balance method for non-linear, temporally-periodic incompressible flows is presented in this work. Assumption of a time periodic flow allows us to formulate $2n + 1$ coupled steady state problems using Fourier series expansion. By solving $2n + 1$ steady state problems, we obtain a flow field with transient effects [1]. Fourier series expansion is the core of the Harmonic Balance method, therefore the accuracy of the method depends on the number of specified harmonics, n . Moreover, the accuracy of the method also depends on the periodic nature of the problem. The implementation is carried out in a second-order accurate, polyhedral Finite Volume framework developed within foam-extend, a community driven fork of the OpenFOAM toolkit.

The method was previously successfully validated and verified on pitching airfoil and pitching wing test cases [2]. Its applications will now be further extended to include moving mesh and multiple frequencies, and presented on pumps and turbomachinery cases. Harmonic Balance results will first be compared against conventional steady state solver using Multiple Reference Frame (MRF) approach. Head, efficiency and power will be compared, as well as the flow field details at specific locations of interest. Additionally, Harmonic Balance method will be compared against conventional transient solver, discussing the accuracy and simulation speed-up. Furthermore, the results obtained with all three numerical approaches shall be compared with available experimental data. Both 2D and 3D turbomachinery test cases will be presented.

Harmonic Balance should provide an efficient compromise between accuracy and efficiency as it is capable of capturing transient flow features, while still providing a significant CPU time decrease. Steady state methods lack transient effects, but provide reasonable CPU time savings. On the other hand, transient simulations usually require unacceptably large computational resources in order to achieve periodic steady-state solution. For future work, Harmonic Balance method combined with adjoint optimisation approach shall be considered. This should offer significant improvement in the area of adjoint optimisation as it will include the transient effects.

References

- [1] K. C. Hall, J. P. Thomas, and W. S. Clark, "Computation of unsteady nonlinear flows in cascades using a harmonic balance technique," *Aiaa Journal*, vol. 40, no. 5, pp. 879–886, 2002.
- [2] G. Cvijetic, H. Jasak, and V. Vukcevic, "Finite volume implementation of the harmonic balance method for periodic non-linear flows," in *54th AIAA Aerospace Sciences Meeting*, 2016, p. 0070.