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HARMONIC BALANCE NAVIER-STOKES CFD ANALYSIS OF TIDAL STREAM TURBINE WAVE LOADS

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The cost of tidal stream energy is still too high, partly due to overly conservative turbine design, adopted to cope with load uncertainty due to the harsh marine environment. Navier-Stokes (NS) Computational Fluid Dynamics (CFD) can reduce this uncertainty by more accurately accounting for complex flow physics, but the runtime of time-domain NS simulations is still high, particularly for industrial application. Several tidal turbine load conditions, however, can be viewed as periodic, and in this circumstance, the unsteady NS equations can be solved in the frequency-domain. The use of the harmonic balance (HB) NS CFD technology, a nonlinear frequency domain first demonstrated for turbomachinery unsteady flows [5], was later shown to substantially reduce also the runtime of NS CFD analyses of wind turbine unsteady periodic flows [4]. In the present study, ongoing work on the application of the HB NS CFD technology to the rapid and accurate prediction of tidal stream turbine loads due to surface gravity wave-induced loads will be presented. The starting platform to develop a novel incompressible harmonic balance NS CFD code, is the COSA compressible code [4]. To develop the novel incompressible harmonic balance NS CFD code, a density based formulation has been adopted, making use of three alternative approaches: a) Chorin's baseline artificial compressibility method [3], a more general formulation using a local artificial compressibility parameter [2], and one using full precondition [6]. The presentation will discuss advantages and disadvantages of all approaches, with emphasis on algorithm design, and will present detailed comparisons of the compressible and newly developed incompressible capability for viscous three-dimensional test cases. The potential of using the harmonic balance approach to reduce the analysis runtime of tidal turbine unsteady flows will be assessed by considering a turbine test case similar to that analyzed in [1] with ANSYS FLUENT time-domain simulations. The test case is that corresponding to the unsteady flow past a turbine rotor caused by a harmonic perturbation of the inlet velocity.

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