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Design Optimization of Turbomachinery by using 3D Inverse Method and its Application Examples

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Abstract. Since the 1990s, Ebara Corporation, where the presenter belongs, has been working with Professor Mehrdad Zangeneh of the University College London on research of practical application of the Professor's 3D inverse design method for developments of turbomachinery. In the 3D inverse method, the blade geometry is computed for a specified distribution of blade loading (pressure jump between the blade). Since the introduction of the 3D inverse method, it has been used in the development of pumps, compressors, fans, and turbines, regardless of whether they are centrifugal, mixed flow, or axial flow. In this lecture, an overview of 3D inverse design method will be firstly presented, and examples of turbomachinery development using 3D inverse design method, Computational Fluid Dynamics (CFD), and optimization techniques. Since the 3D inverse design method makes it possible to control the pressure distribution on the blade surface, the initial idea of utilizing it was to suppress secondary flows caused by the pressure distribution inside the impeller and improve the performance of centrifugal/mixed-flow pumps and compressors. By suppressing the secondary flow through blade loading distribution, examples show the wake region caused by the accumulation of low-energy fluid at the impeller outlet was improved, and the efficiency of the pump and compressor was improved. In designing axial flow turbines, by specifying the streamwise blade loading distribution and the spanwise work distribution in the blade, it became possible to perform a fully three-dimensional design, replacing the previous design method of stacking two-dimensional profiles. As examples of multi-objective optimization, the design of a high specific speed mixed flow pump and an inducer will be introduced. For the high specific speed mixed flow pump, the design point efficiency, stall characteristics, and shutoff power were set as objective functions, and the response of the design parameters to objective functions was investigated. After that, a multi-objective genetic algorithm was used to enable a trade-off design between the objective functions. In addition, a new "mass customization, hydro design method" will be introduced that also considers specific speed as a design parameter. In the inducer design, the results of the optimum design using cavitation performance and cavitation instability characteristics as objective functions will be explained. In the design process, the effect of cavitation generation was not included during the inverse design computation, and a CFD evaluation process was required. Finally, a "cavitation inverse design method" that can control the load distribution under cavitation occurrence will be presented.