The development of Design Methodology for High-performance Turbomachinery Blades and Components using Large-scale Aerodynamic and Structural Interaction Analysis

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Abstract

Power generation systems that employ steam turbines produce more than 60% of the global supply of electricity, and the global electricity generation is projected to increase by a factor of about 1.7 by 2035. Consequently, the development and practical realization of technologies required to enhance the efficiency of steam turbines for power generation should be encouraged to meet the electricity demand while limiting and reducing global greenhouse gas emissions.

The aim of this project is to increase steam turbine efficiency with the development of high-performance blade and exhaust hood design methodology using large-scale aerodynamic and structural interaction analysis.

Main components of steam turbines are turbine stages that consist with stator blades and rotating blades. Aerodynamic optimum designs of stator blades are already introduced in many designs of actual operating commercial steam turbine units. However, aerodynamic optimum designs of rotating blades are still difficult due to high centrifugal force and vibration stress on rotating blades. The current project focuses on rotating blades and exhaust diffusers that affect the flow field just downstream of last stage long blades.

The large-scale high-accuracy CFD analysis of unsteady wet steam flows has been successfully introduced for simulations of low pressure exhaust diffuser using the Earth Simulator of Japan Agency for Marine-Earth Science and Technology. This year' s research results show that the diffuser domain analysis using measured static pressure distribution near the diffuser exit can provide static pressure recovery coefficients with enough accuracy for design use even if the calculation domain is only the exhaust diffuser without outlet domain.

The unsteady flow analyses of the typical designed last stage with the measured downstream static pressure distribution as the outlet boundary condition were conducted using a package software. The blade outlet static pressure circumferential distribution caused negligible effect on the last stage unsteady flow characteristics.

The large-scale parallel computing Finite Element Analysis of turbine blades with inter-connection parts has been also successfully introduced on the Earth Simulator. The calculation result shows that the eigen frequencies of the present group of loosely-connected six rotating blades correspond well to the existing measured data. For the aerodynamic and structural interaction analysis, the software module that transfers the calculated data with CFD to the traction data for the rotating blade surface boundary conditions was developed and the accuracy of the software was verified using model turbine data.

Keywords: aerodynamic and structural interaction analysis, steam turbine, efficiency, blade, unsteady aerodynamic force