The Development of High-performance Blade and Exhaust Diffuser Design Methodology 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 rotor 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 rotor blades are still difficult due to high centrifugal force and vibration stress on rotor blades. The current project focuses on rotor blades and exhaust diffusers that affect the flow field just downstream of last stage long blades.

The high-accuracy large-scale CFD analysis of unsteady aerodynamic forces of turbine blades has been successfully introduced using the Earth Simulator of Japan Agency for Marine-Earth Science and Technology. This analysis has been also introduced for simulations of low pressure exhaust diffusers and has been proved at the 8.2% diffuser inlet wetness condition with the measured data in an actual operating steam turbine. 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 calculated centrifugal stresses are verified comparing with the conventional analysis results.

Keywords: large-scale simulation, steam turbine, power generation, efficiency, blade, unsteady aerodynamic force