Basic Technology Subjects

Energy Engineering Research Laboratory

Brief Overview

The Energy Engineering Research Laboratory is aiming to help achieve a "smart" society that produces and consumes electric power and heat more wisely, through R&D for thermal power generation and improvement in demand-side heat utilization systems and facilities.

Achievements by Research Theme

High Efficiency Power Generation

The temperature field analysis and management technology for the hot gas path parts of gas turbines and the evaluation technology of new liquid fuels are developed to achieve further improvement in the efficiency and operability of thermal power plants.

- For developing efficient film cooling techniques for turbine blades, the effects of internal ribs on film cooling effectiveness and heat transfer coefficients were experimentally investigated, and a method for obtaining higher film cooling performance was proposed (M11002) (M11006).
- Based on the surface temperature change during laser heating treatment, a simple and non-destructive evaluation method for TBC (Thermal Barrier Coating) thermal resistance, which is necessary to estimate the surface temperature of turbine blades, was established (M11009).

Advanced Fuel Utilization

For the diversification of energy resources and the improvement of the environmental friendliness of coal-fired power plants, the expansion of fuel species and measurement methods for trace elements are under development. The catalytic decomposition of volatile organic compounds (VOCs) is also studied, aiming at the extension of applications and verification for practical use.

- For bio-oil production from microalgae using dimethyl ether (DME) as an extractant, it was found that our extraction process, which has a higher energy-saving effect than conventional processes, has a higher prospect for realized use.
- To determine gaseous boron and selenium concentrations in coal combustion gases, methods for measuring their concentrations were developed. The method for boron is under discussion for prescription in JIS, and the method for selenium is adopted as a new work item of ISO.
- VOC decomposition technology using a ceria catalyst was applied to flue gases from printing and/or painting processes. The developed catalyst was found to have a high durability to silicone, which generally causes catalyst poisoning.

Heat Pump and Thermal Storage

We investigate and analyze the latest trends in heat exchangers, industrial heat pumps, and performance evaluation methods for various heat pumps.

- The current trend regarding the industrial use of heat pumps is to develop and commercialize steam and/or hot water production heat pumps as an alternative to steam boilers. However, as they use high GWP refrigerants, the development of heat pumps with low GWP refrigerants is needed.

Energy Conversion Engineering

Basic technologies that relate to the evaluation of thermal efficiency, fuel cells, and advanced material analysis, etc., will be developed to achieve energy savings on the demand side, as well as to improve operability and thermal efficiency on the power generation side.

- To evaluate the performance of a system that converts unused energy into electric power, EnergyWin, a type of thermal efficiency analysis software, was upgraded by adding a thermo-physical properties library for low-boiling-point refrigerant (M11007).
- To determine trace element compounds and to study their behavior contained in coal and coal ash, advanced XAFS (X-ray Absorption Fine Structure) analysis using SPring-8 was developed. This analysis enables the identification of the chemical structure of trace elements at lower concentrations than ever before in only a few minutes (M11012).

Innovative Numerical Simulation Technology

Comprehensive numerical simulation technology is being established by integrating multi-scale and multi-physical numerical methodologies in order to accurately evaluate performance and optimize the operating conditions of thermal equipment, such as pulverized coal combustion boilers, coal gasifiers, and gas turbines.

- To develop an efficient film cooling technique for gas turbine blades, a series of large-eddy simulations (LES) for an inclined round jet issuing into a crossflow were performed. Unsteady vortical structures were clearly captured, and methods to improve film cooling effectiveness were proposed (M11010).
- The Chemical Percolation Devolatilization (CPD) model was extended to consider tar formation, decomposition, and polymerization in primary pyrolysis and secondary decomposition processes (M11018). Moreover, a new char combustion model that takes the effects of radially distributed chemical species within a char particle into account was developed (M11011).
- A new de-NOx catalytic reaction model was developed that can capture the inhibition behavior of de-NOx reactions by the adhered ash particles layer on a catalyst surface in the de-NOx catalyst flow channels.

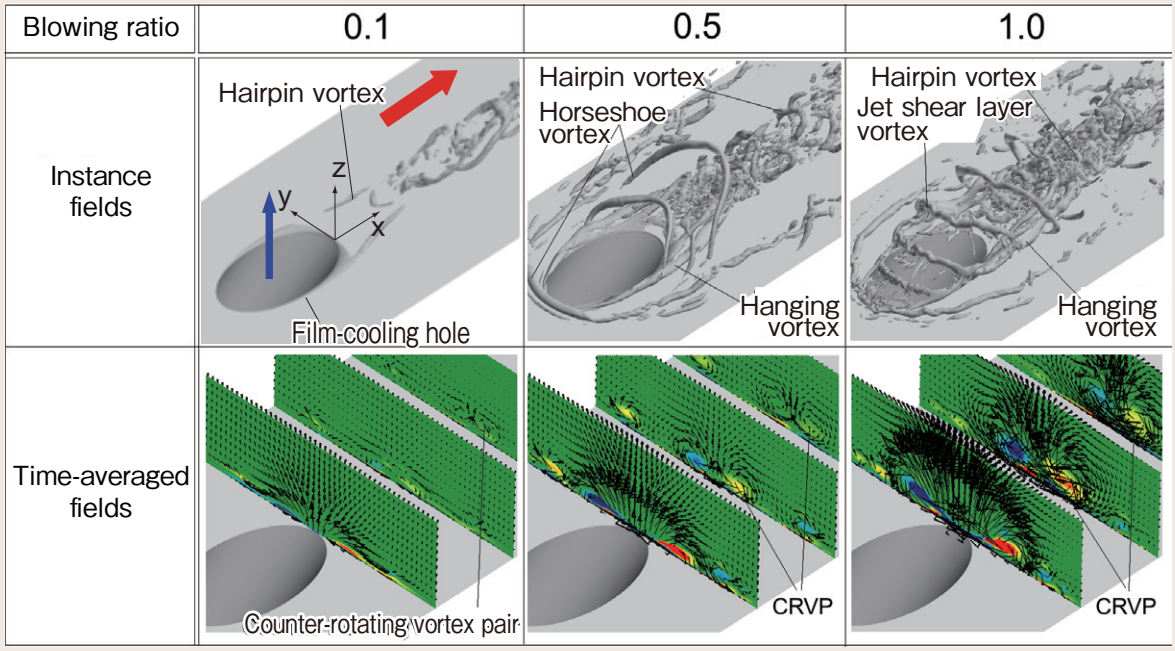

Fig. 1: Vortical structures around the film cooling hole

Vortical structures, which have strong influence on film cooling effectiveness, drastically change with the blowing ratio. It is thus important to control the unsteady vortical structures according to the blowing ratio. (Instance fields, red: crossflow, blue: film cooling flow) (time-averaged fields, arrow: velocity vectors, color: x-vorticity)