Basic Technology Subjects

Energy Engineering Research Laboratory

Brief Overview

The Energy Engineering Research Laboratory is aiming to achieve energy security as well as construct power and energy supply and demand systems, through R&D of clean and high efficiency thermal power generation technologies and advanced heat utilization systems.

Achievements by Research Theme

High Efficiency Power Generation

To decrease maintenance cost, and improve the operability and efficiency of thermal power plants, rational operation and maintenance technologies and the utilization technology of new liquid fuels for gas turbines and the boilers are under development.

- Nondestructive testing methods for thinning and sintering were established concerning damage and degradation (thinning, sintering and delamination) of thermal barrier coatings of gas turbine blades. Furthermore, a simple and nondestructive testing method for delamination was developed by combining laser heating with temperature measurement using infrared cameras (M12002).
- Miniature sample creep tests*1 have been performed to accumulate reference data for the specimen-size dependency of creep strength. The samples tested were taken from actually disposed boiler tubes experiencing long-term services. Improvements of testing techniques are currently required to develop an appropriate damage assessment of thin-walled boiler tubes and gas turbine buckets with complex geometries.
- Evaluation methods were investigated for liquid fuel degradation during storage. Regarding bio-fuels, degradation mechanisms such as oxidation and physical –chemical properties for evaluation were clarified.

Advanced Fuel Utilization

For the diversification of energy resources and improvement of the environmental friendliness of coal-fired power plants, studies are underway concerning combustion enhancement of low grade coals, evaluation and control of spontaneous ignition of solid fuels, measurement methods for trace elements, and manufacturing of solidification material using fly ash.

- In a waste water treatment, the removal performance of selenium from the waste water of a flue gas desulfurization depends on the existing form of selenium. We developed a new speciation method (limit of quantification: 1 μg/L) which can analyze Se(0) and Se(-II) in addition to the common forms of Se(IV) and Se(VI).
- To expand fly ash utilization, solidification material made of fly ash(FA) and shell waste powders was produced and applied to shoreline maintenance. The product was clarified to have highly compressive strength (M12007).

Heat Pump and Thermal Storage

For developing high-efficiency heat pumps and expanding their application areas, we investigate and analyze the latest trends in heat pumps innovation and related standards, and improve elemental technology of heat exchangers.

- The current development trend regarding commercial air conditioners is to improve the efficiency at low load where the load factor is 50% or less. This can achieve energy savings by an average of more than 30% per year. However, the current standard can't reflect this efficiency improvement and must be revised.
- Regarding the proposed frost-free heat pump, the solid desiccant coated heat exchanger was prototyped. Its heat and mass transfer characteristics were investigated experimentally. It was discovered that the heat exchanger must be designed with consideration to the ratio of the heat transfer rate and mass (water) transfer rate.

Energy Conversion Engineering

Basic technologies that relate to the evaluation of thermal efficiency, fuel cells, and advanced material analysis, etc., are being developed to improve operability and thermal efficiency of thermal power plants and geothermal power plants.

- In the development of a 40 MW AHAT*2 (Advanced Humid Air Turbine), CRIEPI contributed to the achievement of rated power by verifying the effect of air humidification quantitatively through the system analysis.
- An operating data analysis system for geothermal power plants was developed to evaluate the thermal efficiency of the system and the performance of individual equipment. This system was introduced in geothermal plants and used for performance analysis at periodic inspections and/or reconstruction.
- SOFCs (Solid Oxide Fuel cells) manufactured by five manufacturers were tested for an extended period of time*3. Dominant performance factors for SOFC degradation were revealed by performance factor analysis and a method to evaluate degradation performance was established.
- A high performance SOFC power generation system was proposed in which a half of SOFC module is operated at fixed power and the latter half follows the change of power output. A system analysis showed that the efficiency of the system varied from 51% to 54% (High Heating calorific Value of Natural Gas) depending on the power output (13,000-46,000kW) (M12004).

Innovative Numerical Simulation Technology

A comprehensive numerical simulation tool is being developed to solve issues in thermal power plants such as pulverized coal combustion boilers, coal gasifiers, and gas turbines.

- A numerical simulation was performed on a commercial pulverized coal combustion boiler using existing numerical models and was compared with the measured data. The result revealed that the development of physical and numerical models which had high scalability and accuracy were essential.
- A numerical model was developed to precisely predict temperature distribution on a gas turbine rotor blade by means of a large-eddy simulation (LES). It was found that the density ratio of the cooling flow to main flow and the film cooling hole's shape significantly affected the cooling efficiency.

*1 A testing method to evaluate degradation of highly damaged portions by sampling specimens smaller than a standard sample in size. Such samples taken from highly stressed portions in real components exposed to high temperature services.
*2 MITI subsidies project performed with Hitachi Ltd., Sumitomo Precision Products Co., Ltd. and CRIEPI.
*3 Commissioned research from New Energy and Industrial Technology Development Organization.

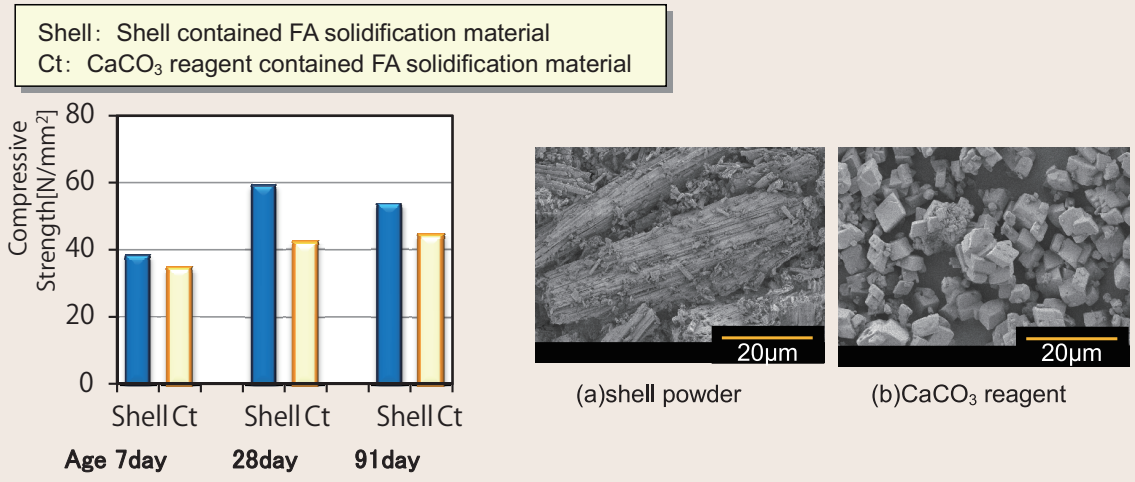

Fig. 1: Influence of shell powers on compressive strength of FA solidification material and SEM photographs of a shell powders and $CaCO_3$ reagent

The bar graph shows the compressive strengths of FA solidification materials with a shell powders and with $CaCO_3$ reagent. It was found that the addition of shell powders achieved higher compressive strength after the 28th in the material age. The SEM photographs shows that the shell powders have layered structures of calcium carbonate while the $CaCO_3$ reagent powders are in cubes. It is thought that the layered structure contributes to the improvement of the compressive strength of the solidification material.