

Unit No.4–1 Higashi Niigata Thermal Power Station Operating Status – 1450 °C Class Gas Turbine Operation –

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Since environmental problems are global issues, high thermal efficiency combined-cycle power plants are being expected to contribute to energy resource saving. Mitsubishi Heavy Industries, Ltd. installed a large-capacity, high-efficiency combined-cycle power plant equipped with the world's first 1450 °C class turbine inlet temperature gas turbines for Unit No.4–1 at the Higashi Niigata Thermal Power Station of Tohoku Electric Co., Inc. On the basis of higher heating value, it provides 50.6% thermal efficiency at the generator terminal, and began commercial operation in July 1999. Its successful operation and high reliability were confirmed in its first inspection after 10000 hours of operation.

1. Introduction

Currently, environmental problems have become global issues, including the establishment of CO₂ reduction targets for global warming prevention. Accordingly, as a part of global promotion of energy saving, the field of thermal power generation has increasingly focused attention on the excellent overall thermal efficiency of the combined cycle system. These systems consist of a gas turbine and a steam turbine driven by the steam produced from a gas turbine exhaust gas heat recovery system. In a combined cycle power plant, a remarkable improvement of the overall plant efficiency can be expected by using a higher temperature and higher performance gas turbine, since it is the main engine of the plant. Therefore, the combined cycle system is both superior in economy and able to largely contribute to the reduction of CO₂ emission.

In 1984, Mitsubishi Heavy Industries, Ltd. (MHI) installed the world's first large capacity combined cycle plant equipped with a 1150°C class inlet temperature gas turbine M701D as the main engine for Tohoku Electric Co., Inc. Higashi Niigata Thermal Power Plant No. 3. This plant achieved a record-breaking overall thermal efficiency of 44% (higher heating value [HHV] base at generator terminal). Ever since then, MHI has been working to develop even higher temperature gas turbines, as a result, it installed the world's first 1450°C class inlet temperature gas turbine M701G as the Higashi Niigata Thermal Power Plant No. 4–1. This plant started commercial operation in July 1999, and achieved the world's top class thermal efficiency over 50%.

In this report, the features of the M701G gas turbine and its operational data including the shop actual load tests and trial operation are introduced.

2. Features of the M701G gas turbine

The M701G gas turbine is a high temperature and high performance gas turbine with a 1450°C class turbine inlet temperature, developed and designed by applying the latest high temperature gas turbine technology verified by various component tests in "Development Research of High Efficiency Gas Turbine" project carried out as a cooperatively with the Tohoku Electric Co., Inc. as well as following the basic structure of the 1350°C class M501F/701F gas turbines (**Fig. 1**). The performance and reliability of the latest applied technology have been verified by the component and verification tests following the schedule shown in **Fig. 2**, and the results of these tests were applied to the design.

2.1 Compressor

In order to achieve a larger capacity, higher pressure ratio, and higher efficiency, a newly designed and developed axial flow type compressor using MCA (Multiple Circular Arc) blades/vanes and CDA (Controlled Diffusion Airfoil) was applied. The aerodynamic performance of the latest type airfoil was verified by the cascade test and a model compressor with an about 1/3 scale airfoil.

2.2 Turbine

The turbine is an axial flow four-stage high-performance turbine, and can cope with the higher load increased by the higher turbine inlet temperature.

In order to enhance the creep strength and thermal fatigue strength of the turbine blades, the first and second stage blades apply Ni base super alloy CM247LC directionally solidified so as not to produce grain boundaries to the centrifugal force direction, with the grain growing direction controlled in casting. The creep strength of this alloy is superior to the conventional blade material, IN738LC ordinary cast,

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Fig. 3 Higashi Niigata Thermal Power Station, Tohoku Electric Power Co., Inc. (panoramic view of plant)

ing the advanced aerodynamic and cooling design, through the component test on heat transfer such as the film cooling characteristics, the aerodynamic characteristics and cooling performance were finally verified by measuring metal temperatures and pressures in a rotating state, under the actual condition realized by the high temperature rotation model test facility using a 3/5 scale airfoil.

2.3 Combustor

The basic combustor design concept follows a proven conventional design ensuring the reliability. The combustor, like conventional ones, employs a design having eight main nozzles arranged around a pilot nozzle located at the center so that the diffusion flame formed by the pilot nozzle stabilizes the premixed flame. In order to realize stable combustion over the whole load range, a combustor bypass valve system is provided so that the fuel-air ratio in the combustion zone can be precisely controlled by bypassing a part of the air flowing into the combustor to the downstream of the combustion zone.

In order to achieve a NO_x level as low as conventional turbines with increased combustor outlet gas temperature by 100°C in the premix combustor, the amount of combustion air needs to be increased, which causes a shortage of cooling air. Therefore, the world's first closed type steam cooling system was adopted. The combustor is cooled by steam produced in the steam generator, and then, hot steam after cooling is recovered to the steam cycle to contribute to the improvement of the overall thermal efficiency of the combined cycle plant. The performance and reliability of this cooling system were verified in both

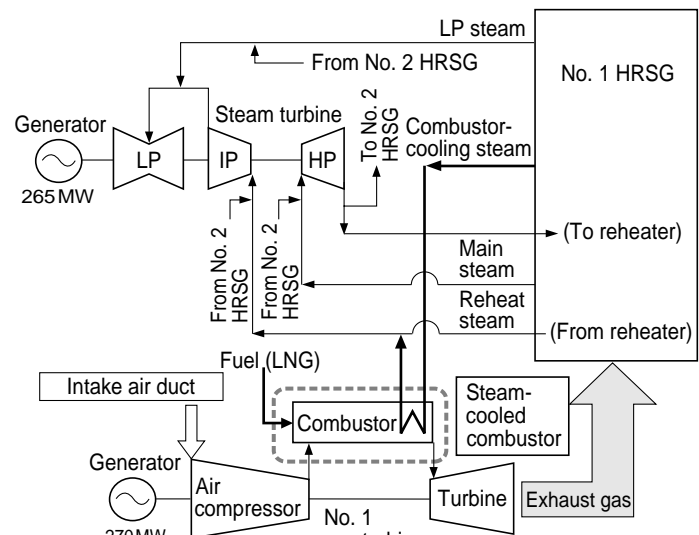


Fig. 4 Steam cooling schematic diagram

atmospheric and high-pressure combustion tests.

3. Composition of the Higashi Niigata Thermal Power Station No.4-1

Tohoku Electric Power Co., Inc. Higashi Niigata Thermal Power Station Unit No.4-1 is a heat recovery large capacity combined cycle power plant employing the world's first 1450°C class inlet temperature gas turbines. The plant is a multi-shaft type plant equipped with one unit consisting of two M701G type gas turbines, two heat recovery steam generators, and one steam turbine. It has an output of 805 MW at an atmospheric temperature of -1°C. A panoramic view of plant is shown in **Fig. 3**, the steam cooling system schematic diagram in **Fig. 4**, and the specifications of the gas turbine power generation

Table 1 Specifications of the gas turbine power generation components

Gas turbine	
Q'ty	2 sets
Type	Single-shaft open-cycle type (M701G)
Fuel	LNG vaporized gas
Output	270 MW (at an atmospheric temperature of -1°C)
Inlet temperature	1 450°C
Rotating speed	3 000 rpm
Generator	
Q'ty	3 sets (including steam turbine-driven generator)
Type	Horizontal-shaft tubular rotary field type
Capacity	332 000 kVA
Voltage	23 000 V
Power factor	90% (delay)
Frequency	50 Hz
Rotating speed	3 000 rpm

components in **Table 1**.

4. Trial operation results and first periodical inspection results

Preceding the field trial operation, in order to confirm the performance and reliability, 50% load operations were performed in the shop actual loading test in the spring of 1998. Special measurements were carried out on the items shown in **Table 2** to obtain detailed data on the starting and load-changing characteristics, and the efficiency and reliability were confirmed to be as specified.

Also in the field trial operation started in October 1998, the special measurements mainly on the metal temperatures of the hot parts were carried out and their high reliability was again confirmed in the field. Furthermore, in the plant performance test carried out in May 1999, a plant thermal efficiency of 50.6% (HHV base at generator terminal) was achieved proving an efficiency exceeding the planned.

The main results of the trial operation are as follows:

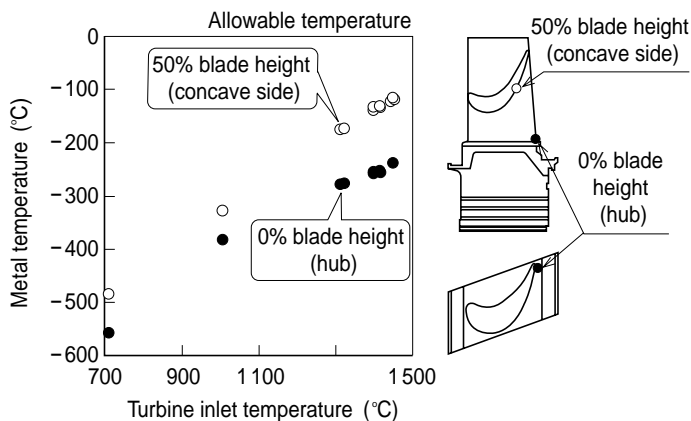
Thermocouples were attached to the steam-cooled combustor and turbine first stage blade, and first and second stage vanes to measure their metal temperatures. The measured metal temperatures of the turbine first stage blade and vane are shown in **Figs. 5** and **6**. The metal temperatures of the hot parts such as the turbine blades/vanes and the combustor were confirmed to be lower than their designed allowable operating temperatures.

In the combustor, NO_x, CO, UHC, combustion fluctuation, and vibration stresses were measured to confirm the excellent performance and reliability of the premixed combustor.

The axial differential expansion between the rotor and casing was measured at the turbine shaft end. The tip clearance was measured for the turbine first stage blade. The metal temperatures of the casing and blade ring were also measured to confirm the defor-

Table 2 Special measurement items for the shop actual loading test

	Measurement item
Performance	Intake air flow rate Intake air temperature/ pressure Exhaust gas temperature/ pressure Fuel flow rate Generator output Turbine component performance
Metal temperature	Combustor liner Turbine 1st stage blade Turbine 1st, 2nd, 3rd stage vanes Bearing Casing Blade ring Exhaust gas diffuser
Pressure/vibration	Compressor vane Combustor liner Rotor shaft vibration Rotor torsional vibration
Others	Cooling air flow rate, pressure, temperature Thrust force Exhaust gas characteristics Differential expansion between rotor and casing Tip clearance Noise Lubricant temperature

**Fig. 5 Measurement result of turbine 1st stage blade metal temperature**

mation amounts of the casing and blade ring. No problems were observed with the casing deformation amount given from the axial differential expansion, tip clearance, and metal temperatures of the casing and blade rings, when starting after a long time stop and restarting after shut down from a full load operation during trial operations under various operation conditions.

The shaft vibration characteristics were confirmed to be stable at start and during steady speed operation.

The reliability of the thrust bearing was verified by measuring the thrust force and drain oil temperatures.

Measurement of the cavity temperatures confirmed that the cooling air system operated normally and there was no back flow of high temperature gas into the various cavities in the turbine.

From July 8, 1999 when commercial operation

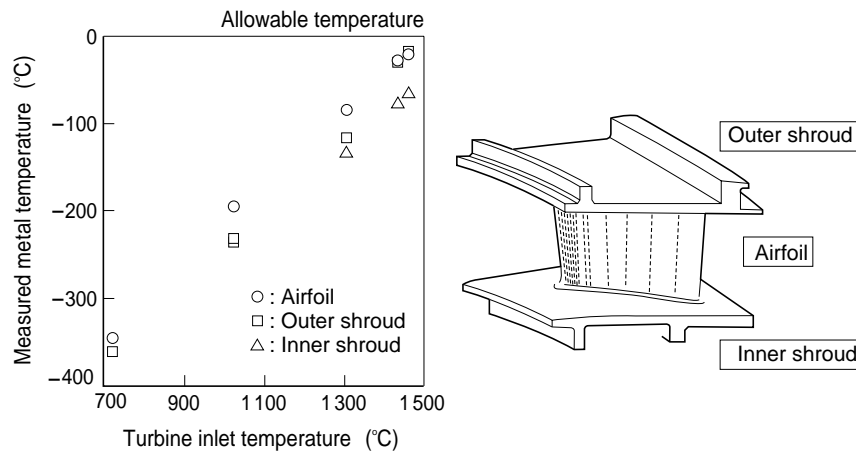


Fig. 6 Measurement result of turbine 1st stage vane metal temperature

started, the unit continued successful operation till September 2000 when the total operating time reached about 10000 hours (including the trial operation period), and the first periodical inspection was performed. The inspection covered the almost all the major parts such as compressor blades and vanes, turbine blades and vanes, combustor, fuel nozzle, etc. The compressor was found to be in good condition with no defects such as cracks on the blades and vanes or irregularities on the bearings. The combustor was detected no defects such as burning, deformation, or cracks on the combustor swirler assembly, combustor liner, combustor supports, and air bypass system. All turbine blades and vanes were removed and carefully checked including cooling holes, and were detected no cracks, clogging of cooling holes, etc.

5. Conclusion

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Thermal Power Station No.4-1 equipped with two 1450°C class high-temperature high-efficiency M701G type gas turbines started the trial operation in October 1998 and recorded an overall thermal efficiency of 50% or more (HHV base at generator terminal). Commercial operation started in July 1999. The results of special measurements carried out in the shop actual loading tests and the trial operation demonstrated fully satisfactory mechanical reliability and performance.

The results of the periodical inspection implemented after 10000 hours of operation indicated excellent conditions were maintained in the major components, and verified their reliability in long term operation.

In the future, M701G type gas turbines are expected to contribute largely to society in saving energy and reducing CO₂ emissions as the main engine of high-efficiency combined cycle power plants.