The 12th GTSJ Awards

Dissertation Awards

"Optical Blade-Tip Clearance Sensor for Non-Metal Gas Turbine Blade"

Yukio MATSUDA and Takeshi TAGASHIRA
The Institute of Space Technology and Aeronautics,
Japan Aerospace Exploration Agency

Journal of the Gas Turbine Society of Japan, Vol.29, NO.6, 2001.11 (in Japanese)

"Development of A Grain Defect Resistant Ni-Based Single Crystal Superalloy YH61"

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Metallurgical Research Lab., Hitachi Metals, Ltd.

Proceedings of IGTC'03 Tokyo, TS-124

Technology Award

"Research and Development of Gas Turbine Components using Advanced Materials"

Advanced Material Gas-Generator (AMG) Project

Mikio Hiromatsu, Representative,
Former Senior Managing Director of Research Institute of AMG

Incentive Award

"Unsteady Flow at Midspan in a Turbine Rotor due to Rotor-Stator Interaction"

Takayuki MATSUNUMA
National Institute of Advanced Industrial Science and Technology (AIST)

Journal of the Gas Turbine Society of Japan, Vol.30, No.4, 2002.7 (in Japanese)

Dissertation Award

Optical Blade-Tip Clearance Sensor for Non-Metal Gas Turbine Blade

Yukio MATSUDA, Takeshi TAGASHIRA
The Institute of Space Technology and Aeronautics,
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Because of its measurement principle, the conventional blade tip clearance sensor cannot be applied for non-metallic rotor blade (ex. Ceramics). We produced an optical blade tip clearance sensor that does not require any special devices or experimental process, only using the reflection of the light.　This paper describes the details of the optical tip clearance sensor and the results of its performance proof experiments.

The tip clearance measurement system is composed of sensor head, CCD, signal processor, and PC. The Sensor head, install on engine casing, is composed of laser diode (LD), miller, object lens and image guide. 1.

First, light from laser diode is squarely bent by the miller, and then is projected to the blade tip through object lens, and finally the reflected light makes a spot on an optical incidence side of the image guide through the same object lens and a image guide lens. This spot position is detected by CCD electrically.

The resolution of this tip clearance sensor is determined by characteristic of the CCD, which becomes approximately 6.5μm, and the measurable distance is 1.664mm. The output of LD is 10mW, and is attenuated to 4.0mW by the converging lens, object lens, and the heatproof protection glass.

As a result of static characteristic examination, accuracy became ±20μm, with 1.4mm for measurement range. The tip clearance measurement experiment was done with the high-speed rotational disk, which could rotate up to 24,000rpm at maximum (350m/s at its surrounding). The disk has imitational blades, which are 3mm in height, 2.44mm in length and 5mm in width. According to the test results, the tip clearance is constants until 15,000 rpm, and gradually decreases as revolution increases. The maximum clearance change is approximately 90μm.

Dissertation Award

Development of A Grain Defect Resistant Ni-Based Single Crystal Superalloy YH61

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Hitachi Research Lab., Hitachi, Ltd.
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Metallurgical Research Lab., Hitachi Metals, Ltd.

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Application of SC buckets and vanes in aero-engines has significantly improved the engine performance. In the field of industrial gas turbines (IGTs), application of SC components is necessary for improving the efficiency of IGTs due to increases in gas-firing temperature. Although this demand is common to all IGT manufacturers, DS buckets and vanes are still the mainstream technology for IGTs especially in the case of heavy-duty machines. The main reason why SC components have not been widely adopted for IGTs is the casting problems of the SC for IGTs. Grain defects such as low angle grain boundaries (LAB), high angle grain boundaries (HAB) and recrystallization tend to occur in IGT buckets or vanes, since their sizes are larger and their shapes are more complicated than those of the aero-engines' components. Because of these reasons, the casting yield of the SC for IGT is significantly lower and their cost is higher than the DS components.

If the resistance of SC superalloys to LAB or HAB is increased, higher yields and lower costs can be realized for SC buckets and vanes in IGTs. In order to meet these demands, a new concept SC superalloy, YH61, which contains some amount of grain boundary strengthening elements such as carbon, boron and hafnium, has been developed. The solution heat treatment conditions were also found to affect various properties of the SC with and without grain defects. Increasing the solution-heat-treated area was found to have a positive effect on the strength of a defect-free SC but harmful for the strength across a grain boundary. The solution heat treatment condition for YH61 was determined after considering compatibility for properties of both the defect-free SC and the SC with grain defects. As a result of the optimization for content of grain boundary strengthening elements and the solution heat treatment condition, creep strength of YH61 was found to be equivalent to a second-generation SC superalloy although YH61 showed moderate grain boundary strength. Hot corrosion resistance of YH61 was superior to that of a second-generation DS superalloy under the whole experimental temperature range and to that of a 14% chromium containing conventional cast (CC) superalloy, which is currently used in some IGTs, when the test temperature was 1000OC.

The above results can be considered to show that YH61 is sufficiently applicable to IGTs. We hope this new alloy will contribute to increasing the efficiency of IGTs by improving affordability of SC casings for IGTs.

Technology Award

Research and Development of Gas Turbine Components using Advanced Materials

Advanced Material Gas-Generator (AMG) Project
Mikio Hiromatsu, Representative,
Former Senior Managing Director of Research Institute of AMG

The AMG project was conducted with an investment of approximately 9.8billon yen aiming at establishing basic key technologies for the next generation high performance gas turbine featuring advanced materials from 1993 to 2002.

The conceptual study of advanced gas-generator was carried out in order to clarify technical issues and define requirements for each component. Candidate materials for the advanced gas-generator were selected to suit to operating temperature and required strength for various components based on the conceptual study. High efficiency compressor, high temperature turbine and low NOx emission combustor were developed in order to utilize potential of various advanced materials. High speed and high temperature bearing and mechanical seal, and advanced control system of gas turbine were also developed to reduce gas turbine weight significantly.

The conceptual study of gas turbine, development of the high performance components and application tests of materials for engine components were conducted by the research and development staffs transferred from the three major aircraft engine manufacturers in Japan. They are namely Ishikawajima-Harima Heavy Industries (IHI), Kawasaki Heavy Industries (KHI) and Mitsubishi Heavy Industries (MHI). Ceramic matrix composites (CMC) were developed by the staffs from Ube Industries and Mitsubishi Materials. Development of high temperature polymer matrix composites (PMC) were carried out by the staffs from Yokohama Rubber Co. and Ti-Al inter metallic compounds by researchers from Ishikawajima-Precision Casting and Sumitomo Metal Industries. The R&D staffs of the mechanical components were from Eagle Industry Co., Nippon Seiko (NSK) Ltd., NTN Co. and Minebea (NMB) Co. Control systems were developed by the personnel from Yokogawa Electric Co. and Shinko Electric Co.

This project was one of the excellent examples succeeded to achieve distinguished results by the cooperation of several different industries. This success was made possible to work together aiming at a single target to achieve technical innovation for the advancement of gas turbine.

Incentive Award

Unsteady Flow at Midspan in a Turbine Rotor due to Rotor-Stator Interaction

Takayuki MATSUNUMA

National Institute of Advanced Industrial Science and Technology (AIST)

Journal of the Gas Turbine Society of Japan, Vol.30, No.4, 2002.7 (in Japanese)

With the new generation of recent small gas turbine engines, low Reynolds number flows have become increasingly important. Blade Reynolds numbers for the turbine stage of such gas turbines can drop below 105. For example, the Reynolds numbers of the turbine cascades of 300 kW industrial ceramic gas turbines developed in Japan are approximately 6×104 because of the increased viscosity caused by high turbine inlet temperatures and miniaturization of the cascade, and they are considerably smaller than the Reynolds numbers of conventional gas turbines. At these low Reynolds numbers, the boundary layer is dominated by laminar flow and is susceptible to flow separation, which is accompanied by increased loss and reduced performance. Small-sized gas turbines for aircraft propulsion also encounter the low Reynolds number problem at high altitudes where the air density is low.

In this study, the unsteady flow field at midspan in an axial-flow turbine rotor at low Reynolds number (Reout,RT=3.6×104) was investigated experimentally using a laser Doppler velocimetry (LDV) system. The time-averaged and time-dependent distributions of velocity, flow angle, vorticity, turbulence intensity, and Reynolds stress were analyzed in terms of both absolute and relative frames of reference. In the relative frame of reference, the nozzle wake had a slip velocity relative to the mean flow, which caused the wake fluid to migrate across the rotor passage and accumulate on the rotor suction surface. The effect of the nozzle wake on the flow field inside the rotor was determined qualitatively and quantitatively. The flow separation occurred at the rotor suction surface because of the low Reynolds number. The position of the separation onset fluctuated periodically as much as about 10% of the rotor axial-chord by the rotor-stator interaction. The turbulence in the wake region was anisotropy, and it exhibited strong Reynolds stress.