International Gas Turbine Congress 2007 Tokyo

Executive Summary

The 9th International Gas Turbine Congress, sponsored by the Gas Turbine Society of Japan (GTSJ), was held over six days from December 2 (Sun) to 7 (Fri), 2007, at the Keio Plaza Hotel, Shinjuku-ku, Tokyo. This congress, with newly obtained cooperation from the European Turbine Network (ETN), was implemented with the considerable cooperation of societies from China, South Korea, Britain, France, Germany, and Italy, including the ASME International Gas Turbine Institute (IGTI), the Japan Society of Mechanical Engineers, and the Japan Society for Aeronautical and Space Sciences, following on from the last congress.

In managing the congress, an organization committee was established as a provisional organization in the society, as well as the last congress, under which an executive committee was set up as a working organization. It was determined that the executive committee was constituted by the general affairs, program, exhibit, events, and financial committees as in the past. In the operation and considering the current economic circumstances, cost reduction efforts were implemented by minimizing outsourcing to vendors and other means.

The number of participants registered was 497 persons in total (413 persons from Japan and 84 persons from seventeen other nations), which was almost the 500 persons initially expected as participants.

As an event that pumps up the congress, a welcome reception, banquet, and technical tours were planned, all of which were popular and produced very successful results.

The exhibition was held in the exhibition hall (Hana Room) and foyer on the 4th floor of the Keio Plaza Hotel main building. The exhibition hall presented displays from 39 organizations focusing on a gas turbine, turbo-charger, associated equipments, and numerical analysis tools. The total attendance during the four-day exhibition exceeded 3,900 persons with great and successful results from the plans for implementing special events by volunteer exhibitors every day. Furthermore, in the foyer on the 4th floor, research activities by university laboratories (12 laboratories from 9 universities + GTSJ) was introduced in a panel session.

The number of total papers adopted by this international congress was 156, 102 of which were from Japan and 54 from other countries. Although the number of papers adopted from other countries decreased slightly when compared to the last congress due to cancellations and other reasons, it indicated that the papers were numerous, supported by a total of over 1,300 participants in the sessions.

The sessions were divided into the followings: (number)

- Keynote Speech	5
- Invited Lecture	1
- Forum	1
- Panel Discussion	1
- Technical Sessions	148

The following five keynote speeches were delivered:

(1) The Role of Gas Turbines in the Global Energy and Environment Resolution (Mr. Ichiro Fukue)
(2) High Fidelity Integrated Numerical Simulation of Gas Turbine Engines (Prof. P. Moin)
(3) Opportunities for Advancing High Temperature Structural Materials (Dr. R.E. Schafrik)
(4) Challenges and Technological Chances for the Aero Engine Industry: The European Path Forward (Prof. Dr.-Ing. K. Broichhausen)
(5) Proactive Approach for Engine Reliability Improvement (Mr. Shigehiro Sugiura)

The forum, entitled "Current Status and Future Strategy of Electricity and Energy Supply in Asian Countries," following on from the last congress, introduced the electric power situation in India, China, South Korea, Thailand, and Japan. In addition, an Invited Lecture entitled "Educating the Next Generation of Engineers—A Call to Action" was presented as a special program this time.

The Panel Discussion, entitled "Global Environment Problems, Energy Consumption and Contribution of Gas Turbine Power Systems," was conducted by two chairpersons and five panelists, where persons from ETN, the U.S. DOE (Department of Energy), Japanese government, and industry, provided topics on gas turbine contributions to recent energy and environmental problems.

The technical sessions provided a wide field of technical presentations on the development of actual machines; cooling technology; CFD technology; axial fans, compressors, and turbines; centrifugal compressors and turbines; blade oscillating problems; fuel diversification; combustor developments and simulations; unstable combustion; noise; heat transfer and transition problems; coating technology; operation and repair technologies; control and measurement technologies; new material developments; material evaluations; micro gas turbines; atomic power and power generation plants; new cycle technology; and other themes, with active questions asked.

In the events conducted during the congress, about 100 persons participated in the welcome reception, and 140 persons attended the banquet in the Concord ballroom of the Keio Plaza Hotel.

The technical tour offered Tour 1 and Tour 2, which visited different places. Nine persons participated in Tour 1, visiting the Showa drainage pump station and the National Institute for Materials Science, and 43 persons went on Tour 2, visiting Futtsu and Kawasaki thermal power stations operated by Tokyo Electric Power Company.

As stated above, owing to the domestic and overseas collaborating and cooperative societies, related corporations, and associated persons, the number of participants registered was 497 and 156 papers were adopted, which was almost the target. Since the 3rd congress in 1983, the international congress has been held on the same scale once every four years, without interruption, and has lived up to its name as an international congress. This can be interpreted as a sign that this international congress is globally recognized as the sole international congress on gas turbines in Japan.

Session Program

1. Overview

1.1 Status of Paper Adoption

The number of adopted papers was 156 as a result of refereeing. The number of the papers for technical sessions was 148. The number of adopted papers decreased by only four compared to the last congress. The number from overseas was fifty-four, which represented a decrease of nineteen, and the number from Japan was 102, an increase of fifteen, from the last time. The rate of papers from overseas, which are desirable as an international congress against the whole number of the papers, remained at only thirty-five percent.

1.2 Keynote speech

In order to obtain a wide range of knowledge on the latest trends in gas turbine-related academic research and technology, we planned and requested five keynote speeches. We invited three speakers from overseas, which was the same number as that of the IGTC '03.

1.3 Forum

Following IGTC '03, we set up a session titled "Forum," which did not necessarily require the submittal of original papers, and provided a forum for the exchange information on relevant themes. We planned one forum, where two chairpersons were assigned to encourage active discussions.

1.4 Panel Discussion

We set up a panel discussion on the theme of "Global Environment Problems, Energy Consumption, and Contribution of Gas Turbine Power Systems." We requested five panelists representing regions that have accepted the challenge of addressing global environment problems, and they presented the trends in the industrial worlds and political approaches in Japan, Europe, and the U.S., respectively. Two chairpersons were assigned to encourage active discussions.

1.5 Organized Session and Invited Lecture

We did not arrange an organized session at IGTC '07 because, at present, unique technology issues or promising technology trends in the future were not seen in the adopted papers. We planned to deliver a lecture on educating engineers in the plenary session by courtesy of Dr. D. C. Wisler, the former chairman of IGTI, who works for GE.

1.6 Session Program Summary

We arranged the whole session program incorporating the above plans. We allocated 30 minutes for each presentation since IGTC '03 and offered a plan free from the constraints of time, for instance, taking a longer break for lunch, which arrangement is based on opinions obtained from IAC (International Advisory Committee of GTSJ) members after IGTC '99. We implemented the sessions in six rooms running in parallel in the same manner as IGTC '03, since the number of papers this time was almost same as that of the previous congress.

2. Session Summary

2.1 Keynote Speech

Keynote Speech 1

Subject: The Role of Gas Turbine in the Global Energy and Environment Resolution

Speaker: Mr. Ichiro Fukue (MHI Mitsubishi Heavy Industries, Ltd.)

Chairperson:Prof. Osamu Kawaguchi (Keio University)

Although it was 9 o'clock Monday morning, a large audience gathered in the main auditorium. In recent years, social concerns about environmental problems, in particular, CO_2 emissions into the atmosphere, have been growing, and some worry about the future of gas turbines that use fossil fuels as energy sources. Under such circumstances, Mr. Fukue's presentation must have raised some argument as the first keynote speech, the first thing in the morning and on the first day of the congress, although it did not lead to active questions.

Mr. Fukue first compared an early heavy-duty type gas turbine developed in the 1960s with the latest 1500°C class gas turbine, and made reference to the increasing temperatures of gas turbines and technological progress over the past forty years. Then, turning the story around, he referred to the new orders and future prospects of renewable energy, such as recent windmill power and solar batteries. He highlighted the fact that the potential of renewable energy on the earth is significantly high, noting that new construction capacity of windmills will exceed that of gas turbines within five years at the earliest. On the other hand, he indicated that the unit price per kilowatt of gas turbine power generating facilities is one-tenth of that of windmill facilities and that the amount of CO_2 emissions from gas turbines is approximately one-half that of coal-burning power generating facilities, in addition to the short construction period for gas turbines. Accordingly, gas turbines will continue to perform the central role in thermal power generation as handy power supplies with relatively low environmental loads.

From such positioning, he concluded that gas turbines are also required to pursue further higher efficiency hereafter and that we should work on the development of advanced technologies, such as a 1700°C class gas turbine, IGCC, combined cycle with fuel cells, and a Brayton cycle application to the nuclear power field in relation to high-temperature gas reactors.

Keynote Speech 2

Subject: High Fidelity Integrated Numerical Simulation of Gas Turbine Engines

Speaker: Prof. Parviz Moin (Stanford University)

Chairperson: Prof. Susumu Teramoto (Tokyo University)

Although Computational Fluid Dynamics (CFD) has been applied and has already become a mature technology, it requires know-how—tuning parameters through repeated comparisons with test results or devising data evaluation techniques—to use CFD as far as gas turbines because of quantitatively insufficient reliability. An effort to fundamentally improve CFD reliability independent of know-how has been conducted; however, a common recognition has not been established yet on how far the reliability of gas turbine CFD will be improved hereafter. Professor Moin has advocated a large-scale simulation for aircraft gas turbine as part of the U.S. ASCI project for nearly 10 years, and he is well known for the numerical simulation of fundamental turbulent flows. His speech talked about how far, if a group excelling in numerical simulations challenges for a gas turbine CFD with a large-scale computer, it will be possible to simulate the gas turbine.

In his speech, the results of simultaneously simulating all the flow channels of the fan, LPC, HPC, combustor, HPT, and LPT in the PW6000 by using an unsteady simulation were presented. The simulation scale results in two weeks of continuous calculations using 1,000 CPUs in a cascade are modeled in the compressible structured-grid RANS codes (SUmb), and the combustor is modeled in the incompressible unstructured-grid LES codes (CDP) by which the whole number of grids leads to 16 to 75 million points. In order to conduct a large-scale analysis, the maintenance of peripheral codes is also important; therefore, a library was newly developed to connect SUmb and CDP data in computers running in parallel, and a load balance for the parallel computation was devised to allow scalable acceleration even for parallel computers with 1,000 or more CPUs. The simulation technology development on the combustor portion is particularly enhanced, and the micro-atomization and combustion model of liquid fuels are uniquely

developed. Furthermore, the fundamental research of verifying the model used for calculation is conducted in parallel with these large-scale analyses; for instance, a direct simulation of the micro-atomization process was performed using adaptive grids in the verification of the micro-atomization model.

On the whole, it was not clearly indicated what kind of improvements had been obtained through this large-scale simulation. However, it projected an image of examining the required technologies by implementing the whole analysis of the gas turbine and of carefully working on the technical issues one by one, as is done in university laboratories. In addition to admiration for the impressive results obtained by the numerical simulation, efforts to realize them were incomparable to those in our research scales, which resulted in making us think about it as researchers engaged in the numerical simulation of gas turbines.

Although the lecture was comparatively fundamental, many in the audience gathered for active questions even after the speech.

Keynote Speech 3

Subject: Opportunities for Advancing High Temperature Structural Materials
Speakers: Dr. Robert E. Schafrik (GE Aviation)
Chairperson: Dr. Yomei Yoshioka (Toshiba Corporation)

A structural material has played an important role in determining the turbine inlet temperature of aircraft engines. Looking back on the history of aircraft engine development, Dr. Schafrik introduced future approaches to material technology, in addition to the role they played and the advancements.

Aircraft engines have changed a great deal since the Wright brothers' engine with a pressure ratio of 4.7 and 25 HP to the GE90-115B with a pressure ratio of 42 and a thrust of 115,000 lbs. As for materials, strength and weight savings are required under high-temperature environments, where major innovative changes have been made.

Only stainless steel was available as heat-resistant materials at the start of engine development, and this reason made commercialization very difficult. However, the search for excellent high-temperature strength materials started in the 1950s, thereby leading to the development of Ni-based and Co-based super alloys. Over the sixty years since then, a large number of super alloys have been developed, among which the γ'-phase precipitation hardened Ni-based alloys are dominant for high-temperature components and highly manufacturable γ"-phase hardened alloys for moderate high-temperature ones. In the above development, technological innovations in dissolving, casting, bonding, and forging were accomplished in addition to machining technology.

While, super alloys had raised the issue of degradation as the operating temperature moved higher. For this reason, the development of oxidation-resistant coatings had been energetically conducted. Furthermore, thermal barrier coatings were developed to meet the demand for higher temperatures, which succeeded in lowering the surface temperature and controlling the heat gradient in combination with internal cooling.

Such challenges for improving heat-resistant temperatures have been continuously conducted for a wide range products, from composite material casings, R104 disks, new alloy blades, GE-1014 shafts, and TiAl low pressure turbine blades, which will be put to practical use before long to alloys such as Nb-Si alloys that focus on future use.

The development cycle for a new jet engine has been further shortened in recent years. For this reason, shortening the development periods and reducing costs are strongly in demand, in addition to performance improvements, and material fields are no exception to these demands.

Dr. Schafrik provided a solution for the above issues: taking design needs into consideration in the early stages of material development and concentrating resources, eliminating gaps between R&D and practical applications by considering manufacturing technology and degradation while in use, and developing alloy development tools using material models. In addition, he gave us his point of view, saying that collaboration between OEMs (original equipment manufacturer) and participation in exploiting a new domain by universities and national laboratories are increasingly becoming significant.

Keynote Speech 4

Subject: Challenges and Technological Chances for the Aero Engine Industry: The European Path Forward
Speaker: Prof. Dr.-Ing. Klaus Broichhausen (Bauhaus Luftfahrt)

Dr.-Ing. G. Wilfert (MTU Aero Engines)
Chairperson: Prof. Eisuke Outa (Waseda University)

BL (Bauhaus Luftfahrt) is a think tank to which MTU and EADS capitalize under the auspices of Bayern State, and they handle the future concept and strategy of the aircraft industry, such as technological developments and product commercialization, cybernetic systems, and economic effects. The speaker was inaugurated as the chairman of this organization from the executive vice president of the MTU Company in 2006. The lecture was delivered on the present situation and future targets of the aircraft industry in Europe, according to the following aspects.

(1) Present Situation of the Aircraft Industry

Against the backdrop of such versatile topics as supersonic aircraft as a symbol of eventual commercial planes, zero emission targets, and the steep rise in oil prices, the present situation was summarized as follows: installation plan for the geared turbofan (GTF); economic success of the B787 and A380; thirty percent reduction in fuel consumption compared to 1991; about a one-tenth reduction in the airport noise in the 85 dB region owing to the introduction of the A319; and a fifty percent reduction in fuel consumption and over 20 dB noise reduction, resulting from a high-bypass ratio up to the GP7000 and Trent 900 for the past fifty years. Furthermore, it was also addressed that at present, engine management and fuel costs dominate most of the operation costs.

(2) Trends and Challenges

Although fuel costs total fifty percent of all aircraft costs due to oil price increases, if moderate, it is expected that in aircraft production 15,800 ship sets will be in service for the next twenty years until 2022, and in new engine production, more than 38,000 sets will be in service, over which the economic effects were addressed. It was explained that the Europe ACARE targets are to attain a fifty percent reduction in CO_2, a fifty percent reduction in noise, an eighty percent reduction in NOx, and a twenty percent reduction in fuel consumption during the above period.

(3) Opportunities for Technology Development Enhancement

The targets will be accomplished by developing component and system technologies on conventional turbofan engines until circa 2020, and thereafter by new cycles and new system engines for which development has already started.

For conventional models, the following are to be implemented: optimally integrating a fan and a compressor ensures the integrity and safety of mechanical structures and optimum weight; optimally combining a trans-sonic stage and casing treatments suppress surges and improve overall stage characteristics, such as stable highly-efficient level and resonance damping; optimizing a whole engine structure and unsteady simulation of surges accomplishes operability improvement, efficiency improvement, and high-level defect-free; and taking measures against both far and near acoustic field sounds, in order to reduce overall noise by 20 dB, by introducing low-noise swept fans, intake scarves, active-type fan stator blades and liners, and chevron-type nozzles.

For advanced engines, a road map of reduction in CO_2 emissions was introduced and the following are to be implemented: the ACARE target of a twenty percent reduction compared to the present value is achieved by an advanced concept engine and Inter-cooled Recuperative Aero (IRA) engine; and a thirty percent reduction through the practical application of the Open Rotor (OR). As for NOx, a potential to achieve the ACARE target of an eighty percent reduction compared to CAEP level 2 is indicated through reduction evaluations of IRA, ATF, GTF, OR, and Inter-Cooled (IC) engines in the range of pressure ratios from 10 to 70. The ACARE target on the noise reduction is to attain -10 dB reduction by 2020, and in OR engines the challenging target is to reduce the noise below that of the turbofan and to determine an effective airframe installation method (Dream Open Rotor), and in the SILENCER VITAL engine further reduction is expected. Although sustainable flights require a fifty percent reduction in fuel consumption, twenty percent of which by developing GTF and further thermal management engines, twenty percent compared to the A380 by developing new concept aircraft, and ten percent by operation management are assigned.

(4) Development Milestones in Europe

SILENCER ('01-'07), EEFAE-ANTLE ('05-'05), and EEFER-CLEAN ('00-'05) in the fifth plan have already checked the feasibility of the engines, and VITAL ('05-'08) and NEWAC ('06-'10) in the sixth plan will verify component performances. DREAM ('08-'10) and CLEAN SKY in the seventh plan will demonstrate the future model engine, thereby leading to a proposal for realizing green engines.

In the SILENCER project, fifty-one organizations, such as airlines, universities, and research centers, cooperated and reduced the sound level by 6 dB by improving sound sources of engines and airframes, through the development of Squid nozzles and low-noise fans, the active control of fan stator blades, and reduction in sound from landing gears. EEFAC-ANTLE is a project led by RR (Rolls-Royce) with eight organizations involved, demonstrated improvements in conventional cycle engines, and targeted a twelve percent reduction in CO_2 and a sixty percent reduction in NOx. RR's high-load high-pressure compressor, ITP's high-load low-pressure turbine, AVIO's variable intermediate pressure turbine, and rear flame design by VAC are exemplified. In the EEFAC-CLEAN project propelled by MTU and other six organizations, a technical verification was implemented on the advanced cycle of a GTF and recuperated engine, aiming at medium to long-term use. The GTF targets a fifteen percent reduction in CO_2 and a sixty percent in NOx, and the IRA does twenty percent in CO_2 and eighty percent in NOx. A compact heat exchanger and high-speed low-pressure turbine developed by MTU, active-type surge control compressor by Snecma, high-temperature turbine rear frame by VAC, and double circular tube combustor by Snecma and AVIO were introduced.

In the VITAL project, sixty organizations including universities, led by Snecma, participate and target a seven percent reduction in CO_2 and a 6 dB reduction in noise, where a double counter-rotating fan and GTF will be developed. In NEWAC led by MTU, forty organizations cooperate and aim at a six percent reduction in CO2 and a sixteen percent reduction in NOx. The following are envisioned: a prospect of large improvements in thermal efficiency with the IRC engine up to the pressure ratio of 30; by CRTF with flow control core or GTF with active-type control core up to the pressure ratio of about 50; and by intermediate cooling core engine over 50. The active control core engine features air injection active-type surge control in the front of HPC, active-type clearance control in the subsequent stage of HPC, a low NOx PERM combustor, and the active control of combustor cooling air.

In the seventh DREAM project, led by RR, a radical engine system design will be verified. The targets are a twenty-five percent reduction in fuel combustion, a 3 dB reduction in noise, and the validity verification of alternative fuels, to which the open rotors of direct linkage type and geared linkage types are intended to be tested.

CLEAN SKY aims at building a green engine road map and proposing a step toward an engine demonstration. RR and Snecma lead the project, and an airframe to be tested will be selected from various choices such as wide/narrow bodies, regional, and helicopter, as well as from the standpoints of overall integrity in the exhaust gas, noise, weight and electric system. A novel module technology and innovative architecture will be incorporated.

In terms of capacity and sustainability, the future option was defined as "People Mover," and his presentation was closed showing the BL's conceptual picture.

Keynote Speech 5

Subject: Proactive Approach for Engine Reliability Improvement
Speaker: Mr. Shigehiro Sugiura (Aviation Engineering & Business Consultant)
Chairperson: Dr. Yoshitaka Fukuyama (JAXA)

Mr. Shigehiro Sugiura worked for All Nippon Airways Co., Ltd., until December 2006, during of which he had been successively in the aircraft engine engineering division and involved with European and American engine makers (OEM) in relation to the JT8D, RB211-22B, CF6, PW4000, and other engines, based on which experiences this presentation was requested. This speech was the first time for him in this society from user's point of view and its content was valuable. The following provides the outline.

In present aircraft engines, on-condition maintenance philosophy is employed, and monitoring tasks are implemented periodically in order to prevent failures. However, it is impossible to detect all the failure factors in advance; therefore, the reliability of the whole fleet is maintained by investigating the causes after failures, and then developing monitoring techniques. On the other hand, when there are no monitoring techniques, safety operations are supported by forcibly dismantling engines where faults are anticipated, followed by an overhaul and part exchanges. Thus, Mr. Sugiura pointed out that the present reliability management program is a follow-up approach (Reactive) such that after a fault, the cause is investigated, and then technical remedial actions are

implemented. For this reason, a fleet leader of airlines with many hours or cycles of operation is destined to experience the first fault due to aging, and suffers a huge negative impact on productivity and economics until engine makers take effective measures in each case.

Even twin-engine aircraft, in terms of economic needs, fly over the ocean for a longer range (Introduction of ETOPS: **E**xtended **T**win Engine **O**peration**s**); therefore, it has become an increasingly critical issue to sustain and improve engine reliability. Mr. Sugiura said that a more proactive approach (Proactive) is required in order to further sustain and improve reliability in comparison with present conditions because the conventional follow-up (Reactive) reliability management program has a limit.

In the speech, taking an example of failure factors on the HP turbine blade of the RB211-22B engine, and of failure factors on the HP turbine blade of the CF6-80C2, which happened twenty years later after the above failure, Mr. Sugiura introduced an actual example of proactive reliability management programs that he proposed to GE, explaining the similarities between them. This proactive reliability management program was introduced as the "Sugi Method" in the PW4000 WTT (Working Together Team), and that view is also adopted as the leading indicator at GE.

Hereafter, a business approach, which focuses on the standpoints of users more than those of the preceding makers, is mandatory so that Japanese makers will become OEMs ranking with European and the U.S. makers, in which sense this was a valuable lecture.

2.2 Forum

Subject: Current Status and Future Strategy of Electricity and Energy Supply in Asian Countries

Speaker: Prof. Sane Shrikrishna Kashinath (IIT Bombay)
Prof. Weiguang Huang (Chinese Academy of Sciences,)
Dr. Dal-Hong Ahn (Korea Electric Power Research Institute)
Mr. Prutichai Chonglertvanichkul (Electricity Generating Authority of Thailand)
Mr. Zengo Aizawa (Tokyo Electric Power Company)

Chairperson: Mr. Takao Sugimoto (Kawasaki Heavy Industries, Ltd.)
Mr. Koji Yasuda (Hitachi, Ltd.)

Although it is expected that the economic growth of Asia will be the most remarkable in the world hereafter, a recent rise in the price of energy (issues of resource securing) and the response to the problems of environmental preservation may become a drag on the economic growth of Asian nations. In the beginning of the forum, the chairperson brought up the energy consumption prospects and issues in Asia, which is expected to significantly grow in future, and after that, speakers delivered speeches from their respective specific fields.

Prof. Shrikrishna of India, the first presenter at the podium, made a presentation entitled "Future Electricity Needs and Supply in India — a GT Perspective." He pointed out that socio-economic development is necessary on primary issues, such as local poverty problems, rapid economic growth, and industrial advances, which India faces. In order to facilitate the diffusion of small gas turbine combined-cycles with small environmental loads against coal-fired boilers dominating the society at present, GT community needs to think of how the gaps can be bridged with affecting factors except technology, having comprehensive views on not only technologies but politics, society, values, international frameworks, and influences on the global environment.

Prof. Huang of China, the second presenter at the podium, stated issues facing Chinese society where energy supply depends on coal. The following were reported: in particular economic growth is remarkable and the amounts of energy consumption are increasing rapidly; electric power demand is predicted to reach 950,000 MWe in 2020; although the ratio of present thermal power generation is eighty percent or higher, even if it can be lowered, it is anticipated to remain seventy percent at most according to the plan; and even under present conditions, weak acid rain with pH 5.6 or less is measured in an extensive area of the eastern part of China. Based on the above, it was stated that clean coal technology by IGCC, the construction of nuclear power plants, and hydrogen fuel use will be dominant. With respect to IGCC, the history of development in China was presented, and it was introduced that the national development PJ of co-generation, which has both functions of manufacturing methanol and generating electric

power, is in progress.

The third presenter, Dr. Ahn of Korea, explained the following: experiences on measures against the problems of gas turbine hot parts and the status of development of IGCC from the standpoints of electric power research institute; in particular, measures by employing monitoring systems against combustion oscillation in low NOx combustors. Furthermore, with respect to IGCC development, it is planned that after the IGCC plant in the 300 MW class is built by 2012, about four IGCCs in the 600 MW class will be built in 2013 or later, in the medium to long term prospect, and the South Korean version of the U.S. FutureGen is aimed at 2020 or later.

The fourth presenter, Mr. Prutichai of Thailand, addressed the electricity planning of Thailand as follows: sixty-six percent of fuel for present power generation comes from natural gas, and forty-eight percent of the overall installed power plants is gas turbine combined cycles; although natural gas is significantly emphasized in Thailand, an annual increase of five percent or higher in electricity demand is expected in 2007 or later. Therefore, although natural gas plants will be increased hereafter, it is also intended that coal conventional plants and nuclear power plants will be incorporated in the plan; and furthermore, a purchase of electric power from private electric power companies, and a purchase of hydraulic generating power from neighboring countries are also brought into view.

The last presenter, Mr. Aizawa of Tokyo Electric Power Company, as a representative of Japan, described the milestone of reducing petroleum fuel thermal power generation and increasing natural gas thermal power and nuclear power generation as measures against the oil crisis of the 1970s, and the history of continuously leading technical developments, particularly in natural gas thermal power generation, aiming at maximum efficiency in the world. A MACC2 power plant with the combustion temperature of 1500°C class, Kawasaki thermal power plant No. 1 system, and Futtsu thermal power plant No. 4 system were introduced as the latest examples. Furthermore, a coal-gasification combined cycle, which is a national project, was also mentioned, and it was proposed that four points—further higher efficiency, the diversification of fuels, higher reliability, and lower costs—will be required for gas turbines hereafter. Moreover, he closed his presentation by saying that he would like to spread the latest technologies to Asian countries through the Asia Pacific Partnership Program and contribute to alleviating environmental problems in the world.

Discussion was opened to the audience on the whole floor after the five presentations from the panelists. Among questions, though it asked as a direct comment from a user, was which gas turbine is more excellent of two companies mentioned in the presentation. However, the discussion did not become heated because of the constraints of time. Finally, the chairperson summed up the discussion in the session saying, "Gas turbine engineers still have a lot of things to do for global environmental protection."

2.3 Panel Discussion

Subject: Global Environment Problems, Energy Consumption and Contribution of Gas Turbine Power Systems
Speaker: Dr. Tony Kaiser (Alstom)
Mr. Christer Bjorkqvist (ETN-European Turbine Network)
Mr. Richard A. Dennis (U. S. Department of Energy)
Dr. Shozo Kaneko (Clean Coal Power R&D Co. Ltd.)
Mr. Kazunori Nagai (NEDO)
Chairperson:Dr. Mikio Sato (CRIEPI)
Prof. Kenichiro Takeishi (Osaka University)

In the last session of the last day of the congress, a panel discussion was conducted on the theme of this subject. Having the above five panelists, we requested each of them to provide some topics, and finally the chairperson summed up the discussion as a whole. It was beneficial in thinking about the role of gas turbines contributing to global environmental problems and energy security, in addition to having vigorous questions on each topic from the audience on the floor. The presentations from each panelist are summarized below.

Dr. Kaiser of EU introduced an EU project entitled, "The European Efforts to make CO_2 Capture and Storage (CCS) commercially viable by 2020," aiming at zero CO_2 emissions from fossil fuel power generation by 2020. It was reported for instance that Carbon Dioxide Capture and Storage (CCS) is essential in order to attain zero CO_2 emissions from fossil fuel power generation, and the CCS demonstration project is planned on a large scale throughout EU whole area.

Mr. Dennis of the U.S. DOE presented the lecture entitled, "US DOE's Advanced Turbine Program—Coal Based Power Systems with Carbon Capture," presented the following: a study of costs and thermal efficiency in the FutureGen project including the development of CO_2 recovery Integrated coal Gasification Combined Cycle (IGCC) and other studies, as well as a report on the energy situation and power situation of the United States, such as the amounts of power generation by fuel and the amounts of CO_2 emissions in the United States; and moreover, with respect to gas turbine technology developments, the outline and budget of technology development on the next-generation gas turbine in the U.S., such as "Next-Generation Gas Turbine Program" and hydrogen combustion turbine development by Siemens."

Furthermore, Mr. Bjorkqvist of ETN made presentation entitled, "European Energy & Research Policy—Opportunities and challenges related to Gas Turbines," and reported on the energy policy of the EU, the introduction target of renewable energy, energy technology required to reduce CO_2 until 2020, 2030, and 2050, and the role of gas turbine technology.

From Japan,Dr. Kaneko of CCPower R&D and Mr. Nagai of NEDO provided topics.Dr. Kaneko presented the "Contribution of Gas Turbine for Efficient and Clean Use of Coal" and reported the outline of an IGCC demonstrator progressing in Japan and other topics. He also reported that IGCC is important in view of increasing available coal kinds and also in preparation for CCS in the future, and it is expected that a commercial machine using a 1500°C class gas turbine and dry gas purification will have the transmission end efficiency of 46% (HHV standard).

Mr. Nagai of NEDO made presentation entitled "Outlook for Energy supply and Demand in Japan and Gas Turbine Technology Development Prospects," and reported the role of gas turbines in the technological strategy of Japan, as well as the introduction of energy situations and future prospects in the world and Japan, and of Japan's "New National Energy Strategy," which was announced in May 2006.

In conclusion, the following were summarized: (1) It is essential to reduce CO_2 emissions that originate from energy in view of measures against global environmental problems, as well as it is increasingly becoming a critical issue to ensure energy security because of the rapid increase of energy demands in Asian countries such as China and India; (2) Although it is also necessary to use coal with its abundant deposits hereafter, when using coal with high CO_2 emissions, it will be inevitable to apply technologies like IGCC and CCS; and (3) Gas turbine technology is a cornerstone of highly efficient power generating systems in the future.

2.4 Invited Lecture

Subject: Educating the Next Generation of Engineers
- A Call to Action

Speaker: Dr. David C. Wisler (GE Aviation)

Chairperson:Prof. Toshinori Watanabe
(University of Tokyo)

Although serving as the vice-chairman of ASME at present, Dr. Wisler had served as the chairman of IGTI before IGTC '03, and thereafter successively served as the vice-chairman of ASME in charge of IGTI. In organizing the previous IGTC, he made significant contributions to the resumption of cooperative relationship between GTSJ and ASME/IGTI. Furthermore, at this IGTC, assuming the role of the contact point of the ASME/IGTI side, he proactively called on members to participate in IGTC '07 at the chairman meeting of Turbo Expo 2006 and other opportunities.

At this IGTC, we set up a framework for invited lecture separately from the conventional keynote speeches, and invited Dr. Wisler to present the lecture on the above subject. He has a coordinating role in the University Strategic Alliance Program at GE, which conducts basic research in collaboration with universities throughout the world. Through those activities, he considers issues and desirable attitudes in that researchers, engineers, and students from different countries, who differ in their values and educational backgrounds, conduct research and development together, and on which he has addressed at the lectures of ASME or other opportunities. Furthermore, differences in values between the industrial world and the academic society, and means by which the above gaps can be bridged, have been often mentioned hitherto. The lecture this time was also similar, pointing out that in relation to the training of engineers with the next-generation global viewpoints, it is necessary to extract important points including industry-university cooperation and to put them into action in education.

As important points, by which gaps between the industrial world and academic society in their values and action principles can be bridged, the following

were noted: it is unable to grasp the engineering world where various solutions exist on the basis of such a value axis in the academic world that leads them to pursuing a sole solution; it is significant to educate students so that they can find a higher value in working together as a team; global competitiveness must be acquired; and an activity called "business," which is bound by its schedule and budget frame, must be understood. Moreover, it was proposed that it is good for university teachers to have work experience in companies, for instance, to take a sabbatical to work for companies. Finally, as a call to action described in the subject, it was pointed out during the closing lecture that it is necessary to challenge the technological problems with diversified factors, to build up research and development team with high functionalities, to enhance international competitiveness, to understand business as mentioned above, and for industry and universities to cooperate.

Although Dr. Wisler's lecture is lauded for his unique lilting speech, in this lecture he walked around the crowded site equipped with a pin microphone, and delivered an extremely humorous speech. A story of comparing engineers' disposition in various countries was also told, which was interesting. It was explained that Japanese engineers have a high sense of belonging to their organizations, and a strong will toward achieving missions. What do you think of it?

The session was filled to capacity, resulting in an impassioned lecture. In particular, some engineers from manufacturers stated that it was interesting because the story was not usually told.

2.5 Technical Sessions

(1) Diagnostics/ Control/Instrumentation

Four papers were presented at the diagnostics/control/instrumentation session.

TS-157 was a paper about an on-line measurement system for measuring the blade tip clearance and vibration, which proved that system integrity had already attained a high level. In TS-158, the control system for the low-calorific gas-fueled micro gas turbine was designed by H∞ control, and the control characteristics were compared and verified with those by PID (proportional integral differential) control and other controls. TS-159 detailed the current status of software development for engine control systems in accordance with the guidelines of FAA approved RTCA/DO-178B. TS-160 deals with dynamic characteristics identification by measuring pressure oscillation in combustors, though it was presented by others.

Although it is hard to say that the session had so many participants, we have not had many opportunities for hosting sessions in this field in Japan; therefore, questions were followed up with vigorous answers.

(2) Structure/Vibration

Although four papers were scheduled to be presented in the structure and vibration relations, the last paper presentation was cancelled, resulting in a total of three paper presentations.

The first paper, addressed from Japan, is a presentation relating to causes and measures against gas turbine failures that were experienced on-site by a manufacturer. The primary factors in the failures that occurred over a long period of operation were as follows: deposition of foreign matter, wear, and corrosion, which were detected in the form of abnormal vibration in many cases. This paper featured the introduction of failure cases that occurred over a long period of operation and the measures to address the failures, which presentation is considered a rare example. (TS-071)

The second paper, from Korea, theoretically studied the stability limit of cascade flutter, and the relationship between forced exciting force acting on cascades and the mistuning of cascades. This paper featured, in calculating aerodynamic forces, the formulization of using standing-wave solutions in addition to traveling-wave solutions used as before, and comparison of both results. (TS-072)

The third paper, from Japan, was an introduction of an example relating to a vibration design on a 40 kW class high-speed generator directly linked to a turbocharger, and an analyzed rotor was supported by a three grooved-cylindrical bearing in the turbocharger. In designing high-speed generators, this paper can be used as a reference. (TS-073)

Furthermore, the cancelled paper was a theoretical study submitted from Poland about the temperature characteristics and stability of journal bearings, and a parameter study about cylindrical bearings focused on the temperature of supplied oil. (TS-074)

Although the number of participants who took part in the session was not so many, there were many questions.

(3) Aerodynamics

Again this time, the aerodynamics field was the biggest, and forty-eight papers were divided into fifteen sessions.

In the field of axial fans and compressors, the following were presented in relation to aerodynamic design: the multi-stage effects of bow or sweep of blades(TS-049), the effects of forward-sweep (TS-050), the introduction of design technology on a compressor for the next-generation gas turbines (TS-051), an advanced compressor/transonic fan design by a new design concept (TS-052, TS-053), and the development of a counter-rotating fan (TS-054). In relation to stall control: an experimental research on rotating stall (TS-055) and research on the stall inception of a variable pitch fan (TS-057) were presented.

In relation to loss analysis and loss reduction, the following were reported: a numerical analysis research on the loss of an axial compressor (TS-041), a loss reduction by end wall contouring (TS-042), the effects by clocking (TS-043), interference between tip clearance and shock waves (TS-44), as a problem of near-stall flow, the effects of tip clearance (TS-045) and unsteady phenomenon (TS-046), furthermore a numerical simulation on a compressor with the pressure ratio of 2.5 (TS-047), and an aerodynamic research on a lift fan for VTOL aircraft (TS-048).

In relation to centrifugal compressors, the following were addressed: a flow pattern at the inlet part of transonic rotor blades (TS-034), a numerical analysis research on low solidity diffusers (TS-035), a surge control by jet flow from inducer tips (TS-030), performance improvements by the cutback of volute (TS-031), rotating stall suppression by jet flow parallel to diffuser walls (TS-032), and performance improvements and noise reduction by diffuser vanes with tapered shape (TS-033).

In the field of axial flow turbines, the following were described: as the latest aerodynamic design technology, a basic design evaluation technique on a high-load low-pressure turbine for aircraft engines (TS-058), research on performance improvements by counter-rotating a high-pressure- and low-pressure-turbine (TS-059), and turbine design technology for the next-generation gas turbines (TS-060). Moreover as application examples of numerical simulation, the following were reported: leakage flows over rotor blade tips (TS-061), effects of upstream wake on unsteady flows on the blade surface of a low-pressure turbine (TS-062), a relationship between the vortex from a blade trailing edge and base pressure (TS-063), and a low-pressure turbine simulation by LES (TS-064). Furthermore, others were presented as follows: a performance prediction method on variable nozzle turbines (TS-065), performance evaluations on a high-load turbine for hypersonic turbojets (TS-066), and the axial gap dependence evaluation of a turbine nozzle and rotor blade (TS-067).

On the other hand, in relation to radial turbines, the following were addressed: a performance prediction on a mixed flow turbine without nozzles (TS-027), a CFD analysis on the scroll/nozzle portions of a variable turbine for automotive turbocharger (TS-028), and an optimization study in consideration of the internal heat transfer of micro gas turbines (TS-029).

In relation to CFD application and tools: mesh morphing technology for improving the productivity of CFD analysis (TS-037), an analysis on hydrogen fuel jet combustion from turbine blade holes (TS-038), a gas turbine behavior analysis in near stall condition (TS-039), and CFD applications for cavity flows between turbine rotor and stator blades (TS-040).

In relation to engine noise: low noise technology in an Eco-engine project (TS-024), a CFD analysis of fan tone noise by rotor/stator blades interference (TS-025), and a jet noise analysis by LES (TS-026). In relation to aero-mechanics (aeroelasticity): the resonance analysis and measurement of turbine blades (TS-021), a basic analysis on a single blade mode flutter (TS-022), and a forced response analysis on compressor blades (TS-023). As a new domain this time, the following were introduced: the icing of gas turbines (TS-068), condensation on turbine cascades (TS-069), and the innovative defrost method of pre-cooled turbojet engines (TS-070).

(4) Heat Transfer

In the heat transfer field, a total of sixteen papers were presented in five sessions. They consisted of six in total for Film Cooling I and II, four for Blade Cooling, three for External Heat Transfer & Transition, and three for Impingement Cooling.

Film Cooling Session: TS-106 reported that the effects of new-shaped (arrowhead-shaped hole) film cooling holes were evaluated through tests and analysis, resulting in the high performance of the new shapes. In TS-107 and TS-108, in relation to fan-shaped film cooling, a test and measurement on liquid crystals and the analysis evaluation of k-ε model were introduced, followed by discussion about the

effects of a corner roundness, which is inevitably incorporated in the manufacturing process. TS-109 presented a PIV test and measurement and the analysis evaluation of k-ε model on film cooling jets with circular and diffusion shapes. Detail phenomena, such as the reduction in the mixture of mainstream and film cooling jet stream by the diffusion shapes, were clearly measured by the PIV with oil tracer. Also in TS-110, a comparison/evaluation between analysis and tests on film cooling jets with circular and diffusion shapes was reported. It was concluded that with respect to time mean velocity and its variation distribution, a good coherence between analysis and measurements was obtained by using LES in analysis. TS-111 conducted a comparative evaluation of a circular jet flow between RANS/LES analysis and test results, resulting in LES superior to RANS. This was considered because diffusion in the transverse direction is more accurately simulated by resolving the detailed vortex structure.

Blade Cooling Session: TS-112 reported a test research that applied combined cooling structure to the leading edge of blades. It can be expected to reduce about twenty-five percent of cooling air at maximum by combining impingement and pin fins in showerhead cooling structure. In TS-113, in relation to tabular combined cooling structure, PIV test measurements and analysis on the internal flow were comparatively evaluated. The circulating flow caused by the presence of impinging jet was confirmed in both the test and the analysis. In TS-114, the dependence of cooling performance in the combined cooling structure on the pin allocation was analyzed in depth, using a transient liquid-crystal measurement technique. It proved that the major difference in cooling performance, as had been reported before, was driven by the difference in pin allocation. TS-115 reported the results of test research on film cooling, envisioning gas turbines for the next-generation power generation system. It describes the effects by the secondary flow and other factors through the tests and measurements on the film-cooling efficiency of end walls of stator and rotor blades (in rotating state) in addition to flat plates for a wind-tunnel, using PSP (pressure sensitive paint) for the film-cooling measurements.

External Surface Heat Transfer and Transition Session: TS-119 reported a detailed structure inside horseshoe vortex that occurs in flows proximate to the leading edge of blades and its effects on heat transfer by using PIV, the naphthalene sublimating method, and DES (Detached Eddy Simulation). TS-120 described the effects of the pressure gradient, the degree of turbulence, and the wake flow direction in relation to bypass transition caused by the upstream wake on flat plate boundary layers. TS-121 reported an attempt to analyze external surface heat transfer coefficient by LES. Although the boundary layer transition was well predicted by LES and resulted in good coherence with the heat transfer coefficient, LES requires a very large-scale analysis.

Impingement Cooling Session: TS-116 studied the dependence of two-dimensional jet impingement cooling on turbulence promoters (libs and dimples) by the naphthalene sublimating method. TS-117 evaluated the effects of jet impingement cooling to concave surface equivalent to the leading edge of blades and of the libs by liquid crystal thermometry. TS-118 reported the test results of jet impingement cooling to inclined target plates.

Although just the number of lectures decreased greatly compared to that of the last congress (26 papers), no less than 50 participants gathered at the session for a vigorous discussion.

(5) Performance

In the performance field, a total of twelve papers were presented in three sessions. In the modeling and dynamic simulation session (Session C-3 Modeling & Dynamic Simulation), five papers were stated as follows: an analysis on turbo shaft engine performance for helicopters using a platform for commercial model base designs (TS-101), an evaluation of the core engine performance of pre-cooled turbo jet engines up to Mach 5 by CFD (TS-102), a study on the differences between the results that were modeled on the test results of a high-pressure turbine at low temperature and the test results at high temperature (TS-103), the simulation results of flight conditions in relation to the research and development status of a Virtual Jet Engine (TS-104), and the evaluation results of the performance and fuel consumption of a new blade cooling system under flight conditions using the Virtual Jet Engine (TS-105).

In the power plant related session (Session F-6 Power Plant), four papers were presented: a simulation to evaluate economic efficiency by comparing combined cycle performances between air cooling and steam cooling for blades (TS-094), simulation results of performance on the combined cycle of a re-heat cycle gas turbine by making a

simulation model based on released specifications and operational data (TS-095), results of comparing and evaluating various working fluids on Rankine cycles envisioning biomass use (TS-096), and in HAT (Humid Air Turbine) cycle, the simulation of a cycle where exhaust gas is discharged by the exhaust compressor after the exhaust gas is once expanded to a negative pressure (TS-097).

In the novel cycles session (Session F-8 Novel Cycles), three papers were presented: results of comparing a combined cycle system, which applied the chemical looping combustion (CLC) method using iron oxide, to IGCC (TS-098); a system for aircraft engines where a three spool structure was adopted and electricity was generated by using the medium pressure spool (TS-099), and a system which employs a two-stage compressor and turbine with respect to 20 W class cocoon-type ultra micro gas turbines (TS-100).

(6) Product Development/Operational Experiences

In the product development/operational experiences, a total of twenty papers were presented in six sessions. In the verification tests relating to new technologies, seven papers were addressed in two sessions (A-1, B-3). With respect to what is called the AHAT (Advanced Humid Air Turbine) system, which replaces the intermediate cooling system of the HAT (Humid Air Turbine) cycle by the WAC (Water Atomization Cooling) system that atomizes water into the air intake, the test results of a pilot plant (TS-012, TS-013), and the development tests of a transmission for generators directly driven by an aircraft engine (TS-014) were presented.

Furthermore, as developments aiming at higher-efficiency and energy saving, the following were stated: TS-008 introduced various new technologies under development in the national project for 1700°C class gas turbines, TS-009 is on operational experiences of a 8 MW class hybrid gas turbine that uses both metal and ceramics aiming at applications to highly efficient cogeneration systems, and TS-010 on VOC (Volatile Organic Compounds) recovery gas turbine cogeneration that recovers VOC recognized as the causative substance of photochemical oxidants, and burns it in a 2 MW class gas turbine combustor to make effective use of the VOC chemical energy.

In relation to combined cycle power plant, three papers were presented in one session (B-4) as follows: with respect to a combined cycle system (2 GT + 1 ST configuration) built for IPP (Independent Power Producer) and started operation in June 2006, TS-005 is on the features of its primary components, the overview of the operational control system, and the results of the test operation; TS-006 on the introduction of the latest 1450°C class gas turbine in relation to building up more lines to the existing commercial combined cycle system; and TS-007 about a combined cycle system called MACC (More Advanced Combined Cycle) using a 1500°C class gas turbine in which the latest technologies, a steam cooling combustor, a steam cooling turbine, and rotor blade tip clearance control technology were introduced.

In relation to new model developments based on the existing models, four papers were presented in one session (A-6) as follows: TS-001, TS-002 are about performance improvements by the changes of rotor blade materials, the improvements of rotor blade seal structure, the reduction in the aerodynamic losses of rotor blades, and the improvements in aerodynamic performance of compressors and turbines; TS-004 relating to a larger-capacity of standby power generator for emergency by retrofitting the existing gas turbine into twin packages; and TS-003 on various tests including engineering correspondence and endurance tests in applying an aero-derivative gas turbine to a marine power engine.

In relation to micro gas turbines and turbochargers, five papers were presented in two sessions (B-7, B-8). The demonstrated operation of a cogeneration system which combines a MGT (Micro Gas Turbine) with a heat storage system using PCM (Phase Change Materials) was reported (TS-017). As for papers on higher-efficient MGTs, two were stated (TS-016, TS-019). A turbine was optimally designed and manufactured with the goal of applying the HAT cycle concept to MGT, and as the first step, the performance test results under dry conditions were introduced (TS-016). TS-019 was a sequel to the MGT with a tunneled-type compressor/turbine presented at IGTC '03. Although it finally aimed at a ceramics product, in this paper performance test results at room temperature were reported on equipment allocating a metal tunneled-type compressor and a turbine on the same axis. Furthermore, test facilities, envisioning its use in developing various new systems based on MGT (for example, a combination with fuel cells) was reported (TS-015). In particular, test results on how the volume in and between each element effects the performance and operation were explained.

With respect to a turbocharger, downsizing design

for improving transient response, charging pressure, and exhaust emission was described (TS-018). It was reported that optimizing the aerodynamic design of the compressor and turbine led to preventing performance degradation in the downsizing.

In relation to gas turbine engines for aircraft, a study to establish a strength evaluation method at the bolted joints of rotating bodies was presented (TS-020). In fan blades with a very small hub diameter, it is of importance to establish the strength evaluation method at the bolted joints because the unbalance at the time of blade out becomes enormous. It was reported that a good coherence was found between the results by three-dimensional elasto-plastic FEM analysis and the tensile test results.

(7) Materials

In the materials field, presentations relating to twenty-three technical papers were presented in eight sessions: one session on the material development of super alloys, one session for respective subjects on strengthening and degradation mechanisms, inspection and life evaluation technologies, and repair technology, two sessions on the environmental degradation of materials and coatings, one session on the development and practical application of thermal barrier coating and ceramics, and one session on operation.

In the materials development, the following presentations were made: first on the fourth generation single-crystal alloys that were alloy-designed based on electronic theory (TS-075), on a single-crystal alloy excellent in thermal fatigue strength for 1700°C class gas turbines (TS-077), and for micro gas turbines, on the development of materials improved for directional solidification and general casting use based on a single-crystal alloy YH61 (TS-076).

In the session of the strengthening and material degradation mechanism and inspection and life evaluation technologies of super alloys, the following presentations were made: on behaviors about creep degradation of three alloys with different γ'-phase volume fractions (TS-088), on a technique for evaluating the degree of material damage by quantitatively measuring the changes in crystal direction distribution resulting from creep damage accumulation of the materials using the electron backscatter diffraction pattern (EBSP) method (TS-089), on a nondestructive evaluation technique for the degree of microstructure changes by quantitatively measuring three dimensional diffraction patters with the imaging plate X-ray diffraction (IP-XRD) method (TS-090), on a proposition where different asymmetry in the tensile and compressive creep strength of three single-crystal alloys with different amounts of Re was caused by the forming-easiness of a deformation twin (TS-091), on a virtual jet engine integrating a material simulation using the Phase-field method (TS-092), and on the evaluation results of applying the regenerative heat treatment technology to the two-stage rotor blades of 1300°C class gas turbines (TS-093).

Moreover, presentations in the repair session were as follows: on repair limits analyzed by FEM for a repair of the trailing edge portions of GE MS6001B first-stage rotor blade using laser powder welding (TS-152), on a repair condition set-up using solidification analysis to partial melting portions, and on verification by coupon tests with the goal of developing a laser repair technology on single crystal blades (TS-153).

In the environmental degradation session, TS-079 presented on a thermodynamic prediction method for high-temperature corrosion based on burner rig test results using fuels with the amount of Na+K in the fuel changed, followed by vigorous questions. Furthermore, the following were stated: TS-080 is on the corrosion of metal coating, TS-81 on a technique for estimating metal temperatures by changes in the thickness of diffusion layer formed between a coating layer and a base material, TS-082 on the oxidation suppression method of bond layer surfaces, which is one of delamination factors of thermal barrier coating (TBC), TS-083 on the prediction method for delamination resistance and remaining life, and TS-084 on the suppression phenomenon of thermal fatigue caused by penetrating cracks of TBC.

In the thermal barrier coating/ceramics session, TS-085 is on a low thermal conductivity TBC for 1700°C class gas turbines, and TS-086 and TS-087 on the application and verification of MGC (Melt Growth Composite) to combustor tiles or turbine nozzles .

Moreover, in the operation session, the following were explained: TS-154 is on the operational optimization of gas turbines based on the creep life evaluation program of rotor blades, TS-155 on health monitoring and life management, and TS-156 on the reliability evaluation method of life cycles.

(8) Combustion

The total number of presentations relating to combustion and combustors totaled twenty-nine: three in session E1 (Fuel flexibility), three in F1 (Combustor development I), three in F2 (Combustor development II), five in E3 (Combustor modeling and numerical simulations), four in F3 (Micro gas turbine combustion), four in E4 (Flowfields and instability of combustor), three in F4 (Atomization and emission), and four in F5 (Combustor developments for small aircraft engines). Compared to 2003, it increased by four in session and by twelve in presentations, and for instance, in particular, significantly increased in presentations from overseas, from two the last time to nine, which reflects the increasing global concerns with environmental problems relevant to combustion and fuel flexibility.

Therefore, it is often the case that reports relating to combustor developments deal with the reduction in NOx emissions, as described below: TS-135 describes a research that uses EGR (exhaust gas recirculation) in order to reduce NOx emissions in the 1700°C class high-temperature combustors in the future; TS-134 on a cluster-type burner that is a low NOx steam-injection burner, but the emissions of carbon monoxide CO still remains low even if it injects a lot; TS-130 is on a development of a user-driven, dual-fuel-type low NOx combustor in which either gas fuel or liquid fuel is available; from Russia, TS-131 is on fuel nozzles relating to low NOx burners for aircraft; and likewise, TS-132 is on a research that suppresses CO emissions and combustion oscillation by adequately keeping the holding residence time in commercial low NOx combustors aiming at the NOx emissions of 5 ppm or less.

At present in Japan, engine development for small aircraft is in progress as a NEDO project. As research on combustors for the above project, the following were presented: TS-140/TS-141about a RQL (Rich-Burn Quick-Quench Lean Burn) type that is dominant in current low NOx combustors for aircraft, TS-142 on a Lean Burn type that is expected to be dominant hereafter because of its high NOx reduction capability, and TS-143 that features low cost due to its simple structure.

In the fuel flexibility session, the following were stated: TS-148 on a combustor balancing low NOx and stable combustion by adding hydrogen to natural gas aiming at gas turbine combustors for power generation; research TS-149 on a combustor using woody biomass fuels that are promising as compatible with CO_2 problems; and TS-150 on fuel oil containing many coal residue and the emission of carbonaceous particulate matter.

Moreover, with respect to micro gas turbines, which are expected as a simple mobile power source, TS-144/TS-145 dealing with combustors of 200 W to the several-hundred watt class , and TS-147 dealing with combustors for 10 W to 60 W class ultra micro gas turbines were presented. TS-146 on combustors using biomass fuels is also in progress at the lab level.

Research that uses CFD for combustor development is also active as follows: TS-124 conducted combustion analysis for commercial low NOx combustors and verification with NOx emission results, and TS-123 performed a large-scale analysis by applying Large Eddy Simulation, which may determine the course of combustion CFD in the future. TS-125 predicting liner wall temperatures, which is important in the life design of combustion systems, by using CFD was also reported.

A high-quality report was also presented in fundamental studies relating to combustion. TS-136 studied the relationship between vibration suppression and NOx emissions by conducting optical measurements with respect to the active control technology of combustion oscillation resulting from premix combustion. TS-138 evaluated a relationship between the strong swirl motion of swirl flow and mixture, using optical measurements by PLIF and CFD analysis of mixing by LES, and TS-137 conducted LDV measurements of the flows in a damp diffuser used for aircraft combustors. From China, TS-139 on optical measurement results of flow fields at non-burn/burn of methane fuel diffusion flames was reported.

In relation to the atomization and spray of fuels, the following were presented: TS-127 on atomization characteristics of fuel nozzles which are used for a mini jet engine, TS-128 on fundamental experiments and numerical analysis relating to liquid jet breakup process and impinging atomization of fuel, and TS-129 on experimental studies about the diameter distribution of atomizing droplets and soot generation for spray flame. In conclusion, although technical sessions relating to combustion and combustor were considered satisfactory in both quality and quantity, more active questions/answers would be preferable in the sessions.

Exhibition

The exhibition of the International Gas Turbine Congress Tokyo 2007 was held in the Hana Room and foyer on the fourth floor of the Keio Plaza Hotel main building over the four days of December 3 (Mon) to 6 (Thu). A total of thirty-nine organizations participated, compared to the previous thirty-six at the last congress (Table 1). Furthermore, twelve university laboratories and this society GTSJ displayed research findings in the foyer in front of the hall, similar to the last time (Table 2). Besides, as the first plan, we implemented special presentation events by eight exhibitors on the same site in order to pump up the exhibition. The total attendance figure was 3,915 persons, which was an increase of 180 persons compared to previous the 3,735 ones (Total time of the conference: 32 hours), and it was very well attended. This successful result came from the factors, such as administrative arrangement: the site was a prominent location with the sufficient geographical advantage of Tokyo/Shinjuku; prior activities, such as sending invitations to the exhibition, were conducted in order to attract more guests; opening ceremonies during the congress were held; and special events by exhibitors making the best use of somewhat wider space compared to the last time were implemented, and powerful exhibitions such as an actual jet engine.

[Table 1 Exhibitors List - Corporations]
[Table 2 Exhibitors List - University Laboratories]

Technical Tour

The technical tour was divided into two courses and carried out on the last day of the congress, December 7. Tour 1 visited Metropolitan Area Outer Underground Discharge Channel (Kasukabe-city) and the National Institute for Materials Science (Tsukuba-city). The tour attended by nine persons in total, seven persons including three from overseas and two event committee members. After arriving at Metropolitan Area Outer Underground Discharge Channel, we received a brief overview of the facilities while watching videos and models in the office, they visited the drainage tunnel and drain pump/gas turbine package for its drive. We were all surprised at the size of the drainage tubes, which are also used for TV programs and commercials. Furthermore, we were allowed to observe the inside of the pump and gas turbine package for driving the pump, thereby leading to a deep understanding of its mechanism. After lunch, arriving at the National Institute for Materials Science, we had a coffee break and received a brief overview of the institute in the seminar room. Then, we visited the experimental facilities. The following cutting-edge development technologies were introduced: a vacuum heat treatment furnace for the precision casting of nickel-based single-crystal, research and development test equipment for the new coating system (TBC), and evaluation test equipment for creep strength/thermal fatigue characteristics. Although, in questions/answers, we had an eager question from an overseas participant, they corresponded respectfully.

Tour 2 visited Futtsu and Kawasaki Thermal Power Station operated by Tokyo Electric Power Company. The tour attended by forty-three persons in total, forty persons including fourteen from overseas, two event committee members, and one general affairs member. After departure, taking the Aqua-line across Tokyo bay by bus to Chiba on the opposite shore from Kawasaki, we arrived at Futtsu Thermal Power Station. An English version video about the power station was displayed in the conference room, followed by active questions/answers with correspondence personnel. Then, we toured the power station for two hours in the morning. After lunch, we arrived at Kawasaki Thermal Power Station on schedule. A Japanese version video about the power station was displayed in the conference room, followed by questions/answers, and we looked at a plant command room. Although we were not able to see the power generating facilities themselves, we toured from outside the bus. We are extremely grateful to the staff at both places for their understanding and cooperation with these tours.

Conclusion and Acknowledgements

(Eisuke Outa, Executive Committee Chair)

In 2005 when we started to prepare the international congress, it was a time that domestic business was on the upward trend and China showed a proactive stance toward industrial development. With increasing concerns about the global environment and energy consumption, news events, such as the A380, B787, and the development of a fuel-efficient next-generation aircraft engine, were capturing public attention. In Europe, GT users' network, ETN, was created, and under the slogan of zero emissions, developments were

systematically undertaken regarding effective coal utilization, the integration of GT research, and engineering education. In addition, we heard that in U.S. research on hydrogen combustion was shifting toward commercialization.

It was especially pertinent to hold the 9th International Gas Turbine Congress in times such as these. Therefore, we expected more participants from both Japan and other countries and felt the need for a congress with an atmosphere where participants from various fields could be more satisfied. It is a primary goal that academic sessions achieve a successful outcome, for which the session environments of the keynote, forum, panel, technical exhibition, reception/banquet, and hall are essential, and in order to create these environments, we made a detailed plan, negotiated, and implemented it in each executive committee over two years. We were concerned that one of them was a generation change.

However, the preparation went smoothly, and the atmosphere in each session hall was harmonious, owing to much participation by honorary members in addition to overseas participants. It was felt that the gas turbine industry including aircraft engines was becoming consolidated by its flagship companies, which resulted in making requests to these companies to bear heavy burdens regarding participation in the sessions and exhibitions. In addition, the following were also considered lost, that is, ripple effects that will spread from the gas turbine industry, and major opportunities by which the potential inherent in the system for environmental improvements will be recognized. It can be said that the expectation of more participants from overseas was betrayed. Most people from overseas are IAC members, who can also be said to be frequent visitors who have friendly relations with the International Gas Turbine Congress, and are repeaters from the previous congress in 2003, with especially younger generation participants unnoticed. In the next international congress in another four years with further progress in the generation change, it is desirable to take measures to encourage participation from other countries. Regarding income and expenditures, which are difficult to predict until the last minute, the final accounts were unexpected, owing to grants from various sectors and precious aids from the corporate members of the society.

Finally, we had about 500 participants. This depends heavily on the corporate members of the society that encouraged in-house employees to register, in addition to significant support from the organization committee members, executive committee members, and society directors. I would like to thank them most sincerely. However, as the executive committee chief, I also hang my head in shame because we had quite a few overseas participants compared to last time and the number of presentations from overseas remained only about one-third of the total. A device would be required so that public relations, such as a call for papers to overseas cooperative societies or corporations, announcements, circulars, and the society website, can become more effective.

Although various issues to be reflected will be assumed by the executive members of the next international congress, it seems that this international congress was successful. We had many attendants until the final day of the congress and many impressive presentations. Although young researchers or engineers dominate the sessions, these people will also play active parts in international conferences in foreign countries or the next congress and disseminate advanced technologies, which can be said to be one of the missions of this international congress. I think it was a substantial international congress in addition to its high-quality technical exhibition.

In appreciation for the executive committee members who worked over a long period of time, for the organization committee members who had provided supports, and for society directors, I would like to thank them in the final report of the international congress. Also, I am deeply grateful to the Society secretariat for appropriate correspondence in spite of the heavy burden besides the regular Society business. Furthermore, I appreciate the Keio Plaza Hotel for offering its cooperation as a place for the congress, and companies for efficiently handling the tasks of registration, exhibition, and hall operation.

Finally, I would like to memorize the contribution of late Prof. Shimpei Mizuki, a Vice-chair of the Executive Committee. Despite his great effort for IGTC 2007, he passed away in August 2007 before accomplishment of the congress. On behalf of the Executive Committee, I pay my last respects to him.

Table 1 Exhibitors - Corporations

Japan Aerospace Exploration Agency	Endevco Corporation	SUMITOMO PRECISION PRODUCTS CO., LTD
Tycothermal Controls	WOOD GROUP	SHINKAWA Electric.Co., Ltd.
WOODWARD GOVERNOR JAPAN, LTD.	Nippon Donaldson, Ltd.	SEAL TECH,INC.
DIA PRECISION CASTING CO., LTD.	NTN Corporation	Suzuki Seiki Kogyosho Co., Ltd.
FLUENT ASIA PACIFIC CO.,LTD.	MEE INDUSTRIES INC.	National Institute for Materials Science
Maruwa Electronic Inc	FUJI TECHNO INDUSTRIES CORPORATION	NACHI-FUJIKOSHI CORP.
PARKER HANNIFIN CORP.	Concepts NREC	AIKOKU ALPHA Corp.
Advanced Design Technology Ltd.(ADT)	SHINWA CORPORATION	KYOKUTO BOEKI KAISHA LTD.
Mitsubishi Heavy Industries, LTD.	ZUNONO.INC./KULITE SEMICONDUCTOR PRODUCTS. INC.	Kinzoku Giken Co., Ltd.
Honeywell Japan	KAWASAKI HEAVY INDUSTRIES, LTD.	TOSHIBA CORPORATION
JAPANESE AERO ENGINES CORPORATION	ISHIKAWAJIMA PRECISION CASTINGS CO.,LTD.	I H I Corporation
Hitachi Plant Technologies. Ltd.	Hitachi, Ltd.	JAPAN vilene COMPANY, LTD.
SANKYO INTERNATIONAL	VINAS Co., Ltd.	Hitachi Nico Transmission Co., Ltd.

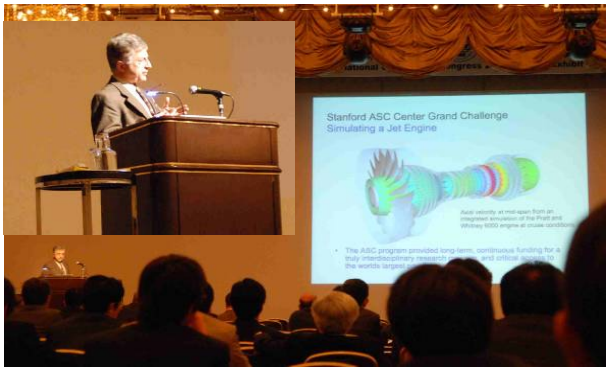
Table 2 Exhibitors – University Laboratories

University of Tokyo, Jet Propulsion Laboratory (Watanabe-Himeno Laboratory)
Tokyo Metropolitan University, Environment-Oriented Materials Assurance Engineering Laboratory (Yoshiba's Laboratory)
Tokyo University of Agriculture and Technology, Yoshida,T. Laboratory
Tokyo Metropolitan University, YUASA Laboratory
Osaka University, Thermal Science and Engineering Laboratory & Combustion Laboratory
The University of Tokyo, Kaneko・Yamasaki Laboratory
Gas Turbine Society of Japan
Kyushu University, Fluid Energy Systems Lab. (Hayami Lab.)
Iwate University, Aerospace Research Division, Funazaki's Laboratory
Tokyo University of Science, Honami Laboratory
Kyoto University, Thermal Engineering Laboratory
Tokyo University of Science, Yamamoto CFD Laboratory
Waseda University, Fluid Engineering & Turbomachinery Laboratory

Entrance

Reception

Keynote Speech 1:
Mr. Ichiro Fukue



Keynote Speech 2:
Prof. Parviz Moin

Keynote Speech 3:
Dr. Robert E. Schafrik

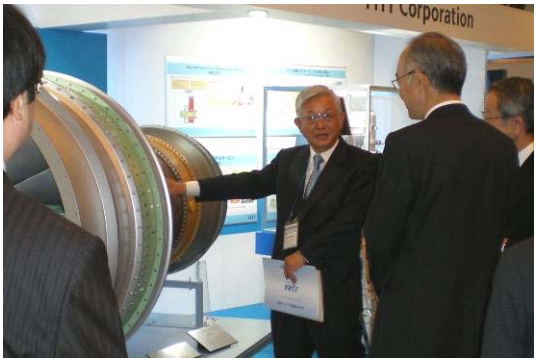
Keynote Speech 4:
Prof. Dr.-Ing. Klaus Broichhausen

Keynote Speech 5:
Mr. Shigehiro Sugiura

Forum

Panel Discussion

Invited Lecture:
Dr. David C. Wisler



Exhibition

Welcome Reception

Banquet