There is still plenty of time to register for this year’s Turbo Expo in Seoul, South Korea. Now in its 61st year, ASME Turbo Expo is recognized as the must-attend event for turbomachinery professionals. Whether you are a student, professor, engineer, or other industry professional, we have something for you. The show floor will feature a number of new exhibitors, making this one of our most diverse expos yet. Walk the floor with your complimentary drink and see how they are making an impact in turbomachinery. With the new keynote/plenary format, you will get the chance to attend three panel sessions with high-profile industry leaders – bring your questions. The women in turbomachinery will have a dinner on Tuesday night. Students or early career engineers can network with peers at the mixer on Wednesday night. Since the advance program is online, you can look over the technical sessions and decide now which ones to attend. The sessions explore a variety of new technologies that are paving new ground in the gas turbine industry. See which ones spark your interest. Facility tours that showcase the industry’s advancement and progress will be offered throughout the Expo. Bringing a guest? They may like to immerse themselves in Korean culture with a tour of a palace or show. You also can come a day early and attend one of the five pre-conference workshops for a small additional registration fee. See you in Seoul!
2016 Keynote and Plenary Panel Sessions

MONDAY KEYNOTE: ENERGY AND PROPULSION IN THE INFORMATION AGE

Panelists

Eric Gebhardt  
Chief Platforms & Operations Officer  
Current, powered by GE

Thomas W. Prete  
Vice President, Engineering  
Pratt & Whitney

Daniela Gentile  
CEO  
Ansaldo Sviluppo Energia

Moderators

Tim Lieuwen  
Professor  
Georgia Institute of Technology

William A. Newsom, Jr.  
Executive Vice President of Sales & Marketing  
Mitsubishi Hitachi Power Systems Americas, Inc.

TUESDAY PLENARY: ASSET OPTIMIZATION AND MONITORING IN THE INFORMATION AGE

Panelists

Maria Sferruzza  
Turbomachinery Contractual and Maintenance Services GM  
GE Italy

Eisaku Ito  
General Manager  
Mitsubishi Heavy Industries R&D

Paul Stein  
Director, Research & Technology  
Rolls-Royce plc

Moderators

James R. Maughan  
Technical Director, Aero-Thermal and Mechanical Systems  
GE Global Research

James M. Free  
Director  
NASA John H. Glenn Research Center

WEDNESDAY PLENARY: GAS TURBINE MANUFACTURING IN THE ENERGY AGE

Panelists

Vinod Philip  
Chief Technology Officer  
Siemens Power and Gas

Akimasa Muyama  
Executive Vice President & Head of Turbine Products  
Mitsubishi Hitachi Power Systems

Richard A. Dennis  
Advanced Turbines Technology Manager  
U.S. Department of Energy National Energy Technology Laboratory

Moderators

Karen A. Thole  
Department Head of Mechanical and Nuclear Engineering  
Professor of Mechanical Engineering  
Pennsylvania State University
ASME IGTI Welcomes New Board Members

ASME International Gas Turbine Institute is pleased to announce the appointment of three new board members with terms beginning this July.

James R. Maughan was born in Schenectady, N.Y., and is a second-generation GE employee. He received a B.S. from Brigham Young University, and a M.S. and Ph.D. from Purdue University, all in mechanical engineering. He joined GE in 1989 at the Corporate Research Center, in Schenectady, working in the area of low-emissions combustion research, aircraft engines combustion, and gas appliances. He joined GE Energy in 1997 to lead the introduction of low-emissions combustion systems into GE gas turbines, and held subsequent leadership positions in GE’s gas turbine, steam turbine and energy services units. He was later global manager of energy-related research at GE’s Research Center, general manager of Controls and Power Electronics in Salem, Va., and became general manager of Product and Warranty Service for GE Wind Energy in 2007. He began his current role as technical director of Aero-Thermal and Mechanical Systems in 2013 where he supports all of GE’s industrial businesses and leads a global team of researchers in the development of breakthrough technology in combustion, aerodynamics, fluid mechanics, heat transfer, and mechanical systems. Dr. Maughan will be serving a three-year term and will also serve as treasurer.

Timothy C. Lieuwen is a professor in the School of Aerospace Engineering and the executive director of the Strategic Energy Institute at Georgia Tech. Dr. Lieuwen is a top international authority on clean energy, particularly low-emissions combustion. He has authored or edited four books and more than 300 papers. He was appointed by the Secretary of the U.S. Department of Energy to the National Petroleum Counsel, and is editor-in-chief of an American Institute of Aeronautics and Astronautics book series. Dr. Lieuwen has served in leadership positions with IGTI, including the IGTI Board and the Combustion, Fuels, and Emissions technical committee for over 15 years. Dr. Lieuwen is a Fellow of ASME, a Fellow of AIAA, and has been a recipient of the AIAA Lawrence Sperry Award and the ASME Westinghouse Silver Medal. Dr. Lieuwen will be serving a one-year term as the TECC liaison.

Anestis I. Kalfas is an associate professor in Turbomachinery. He teaches at the Laboratory of Fluid Mechanics and Turbomachinery of the Department of Mechanical Engineering at the Aristotle University of Thessaloniki. Dr. Kalfas received his Ph.D. in Turbomachinery aerodynamics from Cranfield University in 1994 and his degree in mechanical engineering from Aristotle University. He worked as a research associate at the Whittle Laboratory, University of Cambridge, and as an aircraft engineer in the Hellenic Air Force. He has been a senior scientist at the Turbomachinery Laboratory of the Swiss Federal Institute of Technology in Zurich since July 2000, where he lectured in Turbomachinery Design. Dr. Kalfas is active in the areas of axial steam and gas turbine aerodynamics, gas turbine performance and power plant optimization, boundary layer transition, and turbulence and novel aerodynamic probe technology. Dr. Kalfas will be serving a three-year term.

ASME IGTI would like to thank the three outgoing board members for their participation and contribution to the organization. Thank you professor Seung Jin Song from Seoul National University, Dr. Allan Volponi from Pratt & Whitney, and Dr. Anthony Sheard from AGS Consulting!
Power Services, a GE Power business, recently shipped from the Greenville, S.C., facility its first two F-class gas turbine life-extended rotors, building upon a foundation of experience gained by executing more than 20 E-class rotor life-extensions (RLEs).

Rotor Life Extension Solution
The GE F-class gas turbine rotor service interval is defined by an envelope of 5,000 factored fired starts (FFS) and 144,000 factored fired hours (FFH) of operation (see GER3620 and TIL 1576). Operation beyond this service interval results in increased risk to the rotor structure. Operators are presented with a choice of two strategies to effectively deal with this increased risk profile: risk-measurement and risk-management.

Risk Measurement
Risk-measurement is characterized by an inspection strategy that varies in scope, from a superficial inspection without disassembly, to a more-rigorous disassembly with full inspection, but in all cases without any replacement of higher-risk components. Upon return to service, this RLE approach is typified by a monitoring regimen wherein degradation of the rotor condition serves as a proxy for risk. Under this approach, some independent service providers (ISPs) offer life-extension advice based on inspecting a single feature only, such as the forward rabbet fillet of the first-stage turbine wheel. Experience has shown that additional features require inspection, but these features that require inspection, including rabbet fillets on wheels other than on stage one, cannot be inspected without a complete rotor disassembly. Requirements for follow-up inspections – such as those that require additional major inspections and rotor swaps – limit risk-measurement strategies based on inspect/repair and re-use. It also forces operators to accept higher risk via exposure to non-inspectable flaws in higher-risk components. In fact, since most critical failure modes are associated with non-inspectable flaws, this is a major limitation of the risk-measurement approach. GE’s RLE provides benefits that exceed those provided through a risk-measurement scope.

Risk Management
OEMs possess domain knowledge such as engineering, manufacturing, and material data that enable a more-comprehensive risk management strategy. GE uses a tiered risk-management approach that incorporates a portfolio of three available options: replacement-in-kind, performance upgrades, and life-extension. These can be applied individually or in concert to best suit an operator’s specific strategic objectives. Each rotor is uniquely characterized by the combination of its particular configuration and operational history. Based on a thorough analysis of this history, components deemed low-risk are thoroughly inspected and returned to service. Medium-risk components are thoroughly inspected and repaired, to increase their fatigue/creep life. Higher-risk components are replaced during the re-build process, since this is the most important method for providing lower operating risk during extended operation. During reassembly, cold section blade clocking is reset for improved compressor durability, consistent with US patent 8,439,626. GE’s F-Class RLE portfolio offering provides for one or two maintenance-interval (MI) extensions on hours, and one MI extension on starts. This is equivalent to as many as 96,000 additional FFH, or up to 2,400 additional FFS, without requiring any follow-on inspection, by virtue of the replacement of higher-risk components. Figure 2 demonstrates GE’s approach to designing RLEs.
GE’s RLE Upgrade Approach

Expanding the value of an RLE upgrade also requires that it is executed at the right point in the rotor’s life. As stated above, the medium-risk components can have their fatigue/creep life-extended through a repair process. However, fatigue-damaged areas can increase in size over time, and can exceed repair limits if operated past GER3620 service limits. RLE upgrades should therefore be performed between 96,000 and 144,000 FFH, or 2,500 and 5,000 FFS, in order to ensure that the upgraded rotor can attain an ultimate 240,000 total FFH or 7,400 total FFS.

Inspection Methods

The Greenville service shop has the advantage of collaboration with the new-make manufacturing team to ensure that current assembly/disassembly techniques and tooling are applied. This co-located collaboration has been especially beneficial in the development of the inspection and re-build portion of the life-extension process for the initial F-class rotors. GE applies normal shop methods such as Fluorescent Penetrant and Magnetic Particle Inspection (MPI), and Wheel Bore UT Inspections, augmented by Eddy Current Inspections for selected features. The compressor rotor is analyzed by UT examination for selected wheel bores, combined with MPI. Replicas are taken in certain locations to check surface integrity, in combination with hardness checks. Lessons-learned in Greenville are migrated to satellite service shops located globally.

F-class Experience

GE’s F-class gas turbine rotor experience began in Greenville in 1988 with the first F-class rotor assemblies and has accrued over the next 30 years with many rotor repairs, part replacements, and re-builds, resulting in company-proprietary tooling designs and processes. In anticipation of an aging F-class fleet, GE engineering and manufacturing have collaborated to offer rotor life-extension services for the F-class. This experiential learning has yielded the development of an effective rotor disassembly sequence, proprietary heating and cooling methods for rotor disassembly, and the evolution of disk-inspection and repair-procedures. Supplementing this manufacturing and design experience is, for a typical F-class gas turbine, an average of more than 10 years of monitoring and diagnostic operational data. This includes transient and steady-state temperature data that have been validated with base-load engine testing to generate boundary conditions for predictions of rotor thermal behavior. GE believes that this understanding of thermal transients is key to assessing rotor life, and that these analyses in support of RLEs form vital inputs in selecting part-replacement and repair strategy. This analytical approach is specific to each unit, as it is a function of that unit’s specific configuration and operational history. For the two rotors evaluated to date, there have been no unexpected issues uncovered from the part inspections as compared to analytical predictions.

Looking Ahead

The first two F-class extended-life rotors shipped from Greenville were completely disassembled, with all components inspected, and repaired or replaced as appropriate. The GE process is based on unit-specific operational experience, validated analysis, and learned-out manufacturing techniques. This process is a differentiator that customers are welcome to observe in Greenville or in other global locations, in preparation for extending the life of their GE E or F-class gas turbine rotor, or any similar rotor technology.
In axial flow gas turbines, discs in the compressor and turbine support and position rings of rotating blades and transmit energy to or from engine shafts. Their rotational speeds and power levels are high, so that each disc, composed of an inner bore, a web and an outer rim, are made of high-strength alloys, carefully manufactured to be as defect free as possible.

Typically records are kept on operation for both aviation and non-aviation engines. Depending on the record keeping system used by government, airlines, OEMs, and users, gas turbine discs are retired before they reach a critical state that might lead to their failure.

Gas turbine lore and legend has it that there are large warehouses storing many of these expensive used discs, particularly those from high usage applications, such as popular single aisle aircraft jet engines, many military jets, and high-sales electric power gas turbines. The thought is that many of these discs, presumably with significant life left, could be resurrected for future use. The means of resurrection might be some reliable reevaluation process (combining a new life law with testing, or a new yet-to-be discovered metallurgical procedure).

Let us look at just how feasible this concept might be. First, let us briefly consider what a disc failure can bring about. Then we can look at the disc life laws and the procedures used to retire them. We will end with an assessment of what is the possibility of their resurrection, i.e. the return of these discs to active service after their “certified” life has ended.

A Turbine Disc Failure

In an earlier column [1], I reported on the inflight turbine disc failure of a Rolls-Royce Trent engine on Qantas Flight QF32 on November 4, 2010. The super jumbo four engine Airbus A380 had just taken off from Singapore, bound for Sydney.

About 6 minutes after takeoff at 7,500 feet altitude over the Indonesian island of Batam, the Trent 900 intermediate pressure turbine disc on engine No. 2 failed, sending engine parts shrapnel through the engine nacelle and the left wing. Passengers saw several perforations take place on the upper surface of the wing above engine No. 2, resulting in one hole as large as 65 by 80 cm.

Now powered by three of the four engines, the A380 circled to dump fuel (which was also leaking out of two wing tanks, above the failed engine). The Qantas plane then returned to Singapore, to land without thrust reversers, using emergency pressurized nitrogen to lower landing gear since the hydraulic system had been compromised by the uncontained engine failure. Controls to engine No. 1 had been damaged, so that the pilots were unable to shut it down after landing. Airport firefighters flooded engine No. 1 with foam to shut it down, further increasing the overall damage cost.

Fortunately, all Flight QF32 passengers and crew were safe and uninjured after the uncontained turbine disc failure. We can see that armed with enormous rotational kinetic energy, the disintegrated parts of a failed disc (see Fig. 1) and its blading become dangerous flying projectiles.

Disc Lifing Approaches

Vittal, Hajela, and Joski [2] review current approaches to gas turbine life management. They point out the high reliability and safety of modern gas turbines is largely due to a combination of improved materials, conservative design and maintenance philosophies, and improved life prediction capabilities.

However, there are significant safety and economic concerns involved in the use of life predictions applied to extend disc life. For instance, disc cracking caused by the most common failure modes of low and high cycle fatigue, creep, and manufacturing
defects is difficult to predict, so that statistical methods must also be relied upon.

One probabilistic life management algorithm [2] is the Life-To-First-Crack (LTFC) approach. LTFC is based on the premise that a safe service disc life can be gotten by testing a sample of engine discs in a spin pit.

It is assured that the discs are initially defect free. To get a life standard time, a disc is removed from spin pit operation, at a time just before the appearance of a fatigue-initiated “engineering crack” greater than 0.38mm in length, with a 95% confidence. This leads to a safety procedure whereby aircraft engine turbine discs are being retired at a time when one in 1000 discs has initiated a short fatigue crack of 0.38mm. This implies that over 99.9% of these expensive, high-strength alloy discs are retired before their useful life has been expended. The 1/1000 life limit is a “safe life” approach that is considered conservative [3] and even quite wasteful [2]. (It is a possible supply source for the large warehouses referred to earlier).

An alternate, newer life management algorithm is Retirement For Cause (RFC). RFC [2] allows an aircraft engine disc to be used for the full extent of its safe fatigue life, bypassing the conservatism of the LTFC algorithm. The new safe life is based on fracture mechanics analyses at critical disc locations, the engine service cycle and the inspection/overhaul cycle. A key element in RFC is the ability to predict crack initiation and growth in a probabilistic manner.

These very brief explanations of LTFC and RFC serve to give a flavor of two disc lifing models. These and newer life laws are used by the military, OEMs, government agencies, and gas turbine operators.

Disc Resurrection Prospects
Suppose you are in charge of an MRO (maintenance, repair and overhaul) for an airline company. It has a supply of used turbine discs, stored after removal from service, based on the airline’s lifing policy. You know that currently there are no metallurgical procedures to restore their life by removing any residual cracks. Should you drill holes in the used discs, assigning them to scrap, or consider their resurrection in the company’s fleet?

If the company has a complete set of operating and service records on the discs and are comfortable with the OEM design criteria used to predict disc service life, you might choose to consider resurrection. Then, should you inspect all the discs for surface distress and cracks, and possibly test one to failure in a spin pit? What is the company’s liability if an accident occurs, caused by a failure of an resurrected disc engine?

These are some of the considerations to be made if used discs are to be returned to service after their certified life. Another resurrection path is the question of appropriating used discs to manage safe continued operation from unexpected field damage until new discs become available.

As the reader can see, disc resurrection may be an attractive prospect, but lots of questions need to be answered before gas turbine users, be they military, airlines, or non-aviation, adopt the practice.

References


We will certainly provide continuity and report on actual positive changes and cooperation in today’s complex and dynamic world. The outcome of the Task Force activities was presented to the IGTI Board, Tim Graves (director of conferences & events), and Mike Ireland (associate executive director of engineering) by Bobby Grimes (senior vice president, TEC sector) who chaired the Task Force. A healthy and constructive discussion arose, and I trust that I will be able to report on actual positive changes in the next few months.

At the moment I am considering several areas where we could focus our efforts and our resources, though no decision is taken yet about new directions. We will certainly provide continuity with respect to the goals pursued by my predecessor, namely improvements to our Turbo Expo conference in terms of the experience of the attendees, selectivity in the paper review process, and expansion with new technical events and activities both in terms of disciplines and geography. In this respect, once the proper organization is in place, I would like to resume efforts related to organizing a conference on aero engines operation and maintenance in Asia and a conference targeting industrial gas turbines and aero engine users in South America.

As for new ventures, I would like to stimulate cooperation with divisions or groups in other segments, as I see a great potential for cooperation on interdisciplinary topics. Such collaboration would lead to workshops or webinars on specific areas, or to full fledged conferences in case of extensive interest. As an example, I was recently contacted by our Tim Lieuwen in order to discuss opportunities for cooperation at the intersection between advanced manufacturing and gas turbines, together with representatives of the Design, Materials and Manufacturing Segment. Workshops or webinars of course should not be only on cross-fertilization topics, but every IGTI committee should consider it, and I know of some ideas for a webinar on turbine design that have been discussed by the ORC Power Systems Committee. ASME webinar facilities are a solid starting point.

Two ideas that I am entertaining and that I would like to discuss soon with the board are 1) the possibility of awarding grants for mini-sabbaticals either of academics in companies, or vice versa; and 2) the establishment of a global competition dealing with a technological challenge with inspiring principles (see, for example, the World Solar Challenge, http://www.worldsolarchallenge.org).

As a side note, I would like to bring your attention on an opportunity that not many of us are aware of: if you are an ASME member, and have selected IGTI (Code #22) in your membership form, you are entitled to a one-year subscription to either the ASME Journal of Turbomachinery or the ASME Journal of Engineering for Gas Turbines & Power for only $85.00 USD (application form at https://community.asme.org/international_gas_turbine_institute_igt/w/wiki/4029.honors-and-awards.aspx)

In conclusion, I am happy to report that our first Turbo Expo conference in Asia is on track to become a success, with a number of high quality papers, technical sessions, and tutorials that will be roughly comparable to that of recent editions, if not greater. The number of applications to our recently streamlined Young Engineer Turbo Expo Participation Award (YETEP) has substantially increased to 86 (66 in 2015, 24 in 2014, 22 in 2013). We will confer up to 20 YETEP awards and up to 40 IGTI SAC travel subsidies to students who actively contributed to the growth of committees.

I very much look forward to meeting you all at Turbo Expo 2016 in Seoul!

---

As you know from the March issue of GGTN, a Task Force was formed in order to provide recommendations about the best organizational model, staffing, and volunteer-staff arrangements. The result of the choices cannot be underestimated, even if they are less apparent to the typical volunteer, as they will influence how our community continues on the trajectory of past successes, and even increases its impact and cooperation in today’s complex and dynamic world. The outcome of the Task Force activities was presented to the IGTI Board, Tim Graves (director of conferences & events), and Mike Ireland (associate executive director of engineering) by Bobby Grimes (senior vice president, TEC sector) who chaired the Task Force. A healthy and constructive discussion arose, and I trust that I will be able to report on actual positive changes in the next few months.

At the moment I am considering several areas where we could focus our efforts and our resources, though no decision is taken yet about new directions. We will certainly provide continuity with respect to the goals pursued by my predecessor, namely improvements to our Turbo Expo conference in terms of the experience of the attendees, selectivity in the paper review process, and expansion with new technical events and activities both in terms of disciplines and geography. In this respect, once the proper organization is in place, I would like to resume efforts related to organizing a conference on aero engines operation and maintenance in Asia and a conference targeting industrial gas turbines and aero engine users in South America.

As for new ventures, I would like to stimulate cooperation with divisions or groups in other segments, as I see a great potential for cooperation on interdisciplinary topics. Such collaboration would lead to workshops or webinars on specific areas, or to full fledged conferences in case of extensive interest. As an example, I was recently contacted by our Tim Lieuwen in order to discuss opportunities for cooperation at the intersection between advanced manufacturing and gas turbines, together with representatives of the Design, Materials and Manufacturing Segment. Workshops or webinars of course should not be only on cross-fertilization topics, but every IGTI committee should consider it, and I know of some ideas for a webinar on turbine design that have been discussed by the ORC Power Systems Committee. ASME webinar facilities are a solid starting point.

Two ideas that I am entertaining and that I would like to discuss soon with the board are 1) the possibility of awarding grants for mini-sabbaticals either of academics in companies, or vice versa; and 2) the establishment of a global competition dealing with a technological challenge with inspiring principles (see, for example, the World Solar Challenge, http://www.worldsolarchallenge.org).

As a side note, I would like to bring your attention on an opportunity that not many of us are aware of: if you are an ASME member, and have selected IGTI (Code #22) in your membership form, you are entitled to a one-year subscription to either the ASME Journal of Turbomachinery or the ASME Journal of Engineering for Gas Turbines & Power for only $85.00 USD (application form at https://community.asme.org/international_gas_turbine_institute_igt/w/wiki/4029.honors-and-awards.aspx)

In conclusion, I am happy to report that our first Turbo Expo conference in Asia is on track to become a success, with a number of high quality papers, technical sessions, and tutorials that will be roughly comparable to that of recent editions, if not greater. The number of applications to our recently streamlined Young Engineer Turbo Expo Participation Award (YETEP) has substantially increased to 86 (66 in 2015, 24 in 2014, 22 in 2013). We will confer up to 20 YETEP awards and up to 40 IGTI SAC travel subsidies to students who actively contributed to the growth of committees.

I very much look forward to meeting you all at Turbo Expo 2016 in Seoul!

---

**ASME IGTI Awards & Scholarships**

**2016-2017 IGTI STUDENT SCHOLARSHIP**

The deadline to submit an application is June 15, 2016.

In the 2016-2017 school year up to 20 scholarships at $2,000 (USD) each will be awarded to qualifying students registered at an accredited university (either in the U.S. or elsewhere).

**2017 DILIP R. BALLAL EARLY CAREER AWARD**

Nominations for the 2017 award are due to igitiawards@asme.org by August 1, 2016.

The Early Career Award is intended to honor individuals who have outstanding accomplishments during the beginning of their careers. The recipient of the Early Career Award will be honored at Turbo Expo 2017.

For more detailed information on these opportunities, please visit: