global
Gas Turbine News
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ATLANTA, GEORGIA USA /// ASME INTERNATIONAL GAS TURBINE INSTITUTE

ASME SETTING THE STANDARD
IGTI
mechanical engineering

ASME Turbo Expo 2012 Plans Under Way

TURBO EXPO
Turbine Technical Conference & Exposition
Presented by ASME International Gas Turbine Institute

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Join us at the Bella Center, June 11-15, 2012, in Copenhagen, Denmark!

The 2012 conference theme is *Reliable Gas Turbines Operating in Extreme Environments.* The topic was chosen because the expanded use of gas turbines into new market segments—which includes extreme environments—requires the consideration of new and more comprehensive design and operational attributes. Innovative solutions for ensuring reliable energy extraction from turbines even in extreme environments are critical for power generation and propulsion.

Keynote

The 2012 opening session will take place on Monday, June 11, at 10:15 a.m. in the Bella Center. We will mention ALL keynoters in the next *Global Gas Turbine News (GGTN).* Additional details will be announced in the February issue of the *GGTN.*

Conference

This fall a record number of abstracts – more than 1900 - were submitted for the 2012 conference. IGTI is continuing to grow its tracks in the areas of steam turbines, fans and blowers, and renewables (solar and wind). An additional topic of supercritical CO_2 power cycles was also added for this year's conference.

Applications for the Young Engineer Travel Award are now being accepted through March 1, 2012. The Young Engineer Travel Award is intended for young engineers at companies, in government service, or engineering undergraduate or graduate students in the gas turbine or related fields, to obtain travel funding to attend Turbo Expo to present a paper of which they have authored or co-authored. To apply, please visit www.turboexpo.org.

Visas

Every international visitor should check with his or her local consulate regarding visa and entry regulations for Denmark. Please do this well in advance of the conference. If you require a letter of invitation to Turbo Expo as a part of a visa application, you must submit a written request to IGTI via email or fax no later than March 30, 2012.

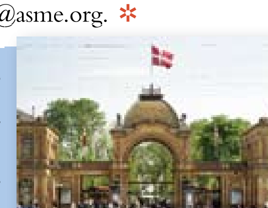
Exposition

Space is still available in the Expo hall. When you exhibit at Turbo Expo, you will be among other key industry players. Exhibiting at Turbo Expo will maximize your ROI by placing your company in front of a focused target market, enabling you to generate high-quality leads to achieve your marketing objectives.

Exciting brand-enhancing sponsorship packages are also available! Packages are designed around your particular corporate goals and are an extremely effective way for your company to really stand out from the crowd – before, during and after the Show.

To insure your company's participation in the 2012 exposition, contact IGTI at +1-404-847-0072 x1646 or via e-mail at igtiexpo@asme.org. ✲

Welcome to Copenhagen!



A number of international magazines have named Copenhagen one of the world's leading cities. It is a compact city, and most hotels, restaurants, sights and shops are within walking distance of each other.

Sometimes referred to as "the City of Spires", Copenhagen is known for its horizontal skyline, only broken by spires at churches and castles, such as Christiansborg Palace and Rosenborg Castle. Copenhagen has a wide array of museums, including the National Museum and the National Gallery. The two oldest amusement parks in the world - Tivoli Gardens and Dyrehavsbakken - are also located in Copenhagen.

A green city with many parks, Copenhagen and the surrounding areas have three beaches. The beaches are supplemented by a system of Harbour Baths (recreational swimming facilities) along the waterfront. Other recreational activities include bicycling: Copenhagen is known as one of the most bicycle-friendly cities in the world.

In addition to a wealth of attractions, Copenhagen offers a variety of restaurants and places to shop. The city has been increasingly recognized internationally as a gourmet destination. As for shopping, Strøget & Købmagergade are the longest shopping streets in Copenhagen (Strøget is actually Europe's longest).

There is something for everyone in Copenhagen, and we hope to see you there in June! ✲

View From The Chair

By Klaus Brun, Ph.D., Chair, IGTI Board

Klaus Brun, Ph.D., is the Manager of the Machinery Section of Southwest Research Institute in San Antonio, Texas.

Welcome to the *Global Gas Turbine News* (GGTN), the quarterly newsletter of the International Gas Turbine Institute (IGTI). I hope you all are busy preparing your papers, panels, tutorials, and technical sessions for the upcoming Turbo Expo in Copenhagen, Denmark. In Vancouver we had the largest ever North American Turbo Expo -- both in number of papers (almost 1000) and in attendance (over 3000). The Vancouver Convention Centre was a truly magnificent venue for our conference, and our Vancouver hosts provided us with first class treatment. Thank you very much to the city of Vancouver, and thank you to the members of the local liaison committee whose organizational support made this such a great success for IGTI. A special thanks also to our corporate sponsors. Without your support Turbo Expo would not be possible.

During Turbo Expo 2011 we learned that Judy Osborn, who faithfully served IGTI for the last 16 years and who was a critical part in making ASME Turbo Expo such a success over many years, has decided to retire and move on to less stressful endeavors such as painting and traveling. We will sorely miss Judy, but we wish her all the best in her well-deserved retirement. In addition, our Managing Director, Mike Ireland, has been promoted to ASME Director, Engineering Research and Technology Development, and has located to the ASME New York office. I would like to congratulate Mike on his advancement and wish him all the best in his new position. In the meantime, we have initiated the process to find a successor for Mike in the IGTI Atlanta office.

As noted in the last edition of the GGTN, my mission for this year is to work on improving IGTI's services to our members and the gas turbine technical community. In line with this mandate, the IGTI Board held a special two-day thought-leader meeting in October in San Antonio, Texas. At least one member from each of the IGTI technical committees participated in order to have a good representation of the entire IGTI community. During this meeting, the principal theme was "The direction of IGTI and how we can improve our organization for our members." There were multiple break-out sessions and group discussions to develop actionable recommendations on how to enhance our institute.

Also, we organized the first IGTI European Gas Turbine Training Week (similar to the IGTI Training Weeks we have held for the last three years in North America). This inaugural event was held November 7-11 at Helmut Schmidt University in Hamburg, Germany. I want to thank Southwest Research Institute's event co-sponsors, Helmut Schmidt University and Solar Turbines, for making this training opportunity feasible.

Please let me know if you have any ideas, comments, or concerns about the direction of IGTI or Turbo Expo. In addition, on page 62 of this issue, you will find an article about ASME's recent Blade Mechanics Seminar, which is an example of a small specialty conference. This year IGTI took the initiative that its Technical Committees would organize and conduct well-attended technical symposiums separate from Turbo Expo. IGTI offers its help and experience in arranging these specialty symposiums.

You can drop me a note at klaus.brun@swri.org or call me at 210 522 5449. ✲

CALENDAR OF EVENTS

JANUARY 9-13, 2012
Rotating Equipment Selection for Oil and Gas Production
Cranfield University | Bedfordshire, UK
http://www.cranfield.ac.uk/soe/shortcourses/gas-turbine/

JANUARY 16-20, 2012
Ultra Low NOx Gas Turbine Combustion Course
University of Leeds | Weetwood Hall Conference Centre & Hotel
Contact: CPD Unit, 0113 343 8104
Email: cpd@engineering.leeds.ac.uk
Web: www.engineering.leeds.ac.uk/short-courses

FEBRUARY 13-24, 2012
Gas Turbine Courses at Cranfield University
Cranfield University | Bedfordshire, UK
http://www.cranfield.ac.uk/soe/shortcourses/gas-turbine/

Feb. 13-15: Introduction to Fatigue and Fracture Analysis
Feb. 16-19: Prime Movers for Oil, Gas Power & Process Industries
Feb 20-24: Propulsion System Performance and Integration

FEBRUARY 27- MARCH 2, 2012
IGTI Gas Turbine Training Week (USA)
Southwest Research Institute | San Antonio, TX USA

Feb. 27-28: Introduction to Gas Turbines & Centrifugal Compressors
Feb. 29: Root Cause Failure Analysis
Mar. 1: Rotordynamics and Blade Dynamics
Mar. 2: Performance Testing and Field Dynamics Troubleshooting

For more details and to register, visit http://igti.asme.org.

MARCH 5-9, 2012
Gas Turbine Appreciation
Cranfield University | Bedfordshire, UK
http://www.cranfield.ac.uk/soe/shortcourses/gas-turbine/

APRIL 18-20, 2012
International Conference on Fan Noise, Technology and Numerical Methods
Congress Centre of CETIM | Senlis, France
More details: http://www.fan2012.org/

APRIL 30- MAY 4, 2012
Mechanical Integrity of Gas Turbines
Cranfield University | Bedfordshire, UK
http://www.cranfield.ac.uk/soe/shortcourses/gas-turbine/

JUNE 9-10, 2012
***ASME International Gas Turbine Institute* TE12 Turbo Expo Pre-conference Workshops**
Bella Center | Copenhagen, Denmark

June 9:
- Technology & Applications of Turbine Coatings
- Gas Turbine Failure Analysis

June 9 & 10:
- *New!* Introduction to Optimization Methods and Tools for Multi-disciplinary Design in Turbomachinery
- Advances in Turbines Aero-thermo-mechanical Design & Analysis

June 10:
- *New!* Gas Turbine Rotor Life Management
- *New!* A Primer on CHP Technologies
- Basic Gas Turbine Metallurgy and Repair Technology

JUNE 11-15, 2012
ASME Turbo Expo 2012
Bella Center | Copenhagen, Denmark | www.turboexpo.org
IGTI's flagship event comprises a major gas turbine conference and exhibition.

OCTOBER, 2012
6th International Gas Turbine Conference - "The Future of Gas Turbine Technology"
Brussels, Belgium
http://www.etn-gasturbine.eu/igtc.aspx

JULY 30 - AUGUST 1, 2012
48th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit and 10th International Energy Conversion Engineering Conference
Hyatt Regency | Atlanta, Georgia | www.aiaa.org

JUNE 3-7, 2013
ASME Turbo Expo 2013
San Antonio Convention Center | San Antonio, Texas
IGTI's flagship event comprises a major gas turbine conference and exhibition.

ASME IGTI Professional & Member Development

By Shirley Barton, IGTI Professional & Member Development Manager

Member Services

Young Engineer Travel Award

IGTI offers several travel awards to students and young engineers employed in industry or government to attend ASME Turbo Expo **to present papers of which they are authors.** For more detailed information please visit the IGTI web site at: http://igti.asme.org/Honors/Young_Engineer_Travel_Award.cfm

Congratulations to our 2011 IGTI Student Scholarship Winners!

- Shriram Jagannathan, Texas A & M
- Perry Johnson, U. of Central Florida
- Bhupendra Khandelwal, Cranfield
- Rohit Kishore Belapurkar, Ohio State
- Moresh J. Wankhede, U. of Southhampton
- Neil Jordon, Baylor
- Uyioghosa Igie, Cranfield
- Kathryn Kirsch, Penn State
- Stephen T. Clark, Duke

For more detailed information please visit the IGTI web site at: http://igti.asme.org/Honors/IGTI_Student_Scholarship.cfm

IGTI Technical Committee & Leadership Directory (Who's Who)

The *IGTI Technical Committee & Leadership Directory* (formerly *Who's Who*) is a dynamic membership directory for the members of IGTI Technical Committees and other IGTI leadership groups and programs. This interactive membership database is an important networking resource for professionals throughout the global turbomachinery community. Members are encouraged to maintain their profiles and keep them current. Did you know that you can communicate with your entire committee by utilizing this tool? You can post meeting minutes, conduct polls, list upcoming events your committee is hosting, post committee news, etc. It could be your mainstream to networking with your members if you make them aware of it and start utilizing it. For more detailed information please visit the IGTI web site at: http://igti.asme.org/Networking/Whos_Online_Directory.cfm

The ASME International Gas Turbine Institute Scholarship Award

The ASME International Gas Turbine Institute awards one $4,000 scholarship every year based on superior academic performance and demonstrated interest in the gas turbine, propulsion, or turbomachinery industries to an undergraduate or graduate student. Applicants must be ASME Student Members in good standing at the time of application. If you are not a member and would like to join, visit: Student Online Member Application.

Applications for each academic year are accepted online each year only from January 15 through March 1, after which the online application is closed.

Please visit: http://www.asme.org/Education/College/FinancialAid/Details_Requirements.cfm

Professional Development

IGTI European Training Week

- IGTI has partnered with the Helmut-Schmidt University in Hamburg, Germany to conduct its first European Training Week November 7-11, 2011. IGTI would like to thank Helmut-Schmidt University, Southwest Research Institute and Solar Turbines Incorporated for hosting this highly successful event.

IGTI US Training Week

- IGTI will partner once again for the fourth year with Southwest Research Institute to offer four hands-on training workshops the week of February 27th to March 2nd, 2012 at the SwRI facility in San Antonio. For more detailed information please visit the IGTI web site at: http://igti.asme.org/Education/Short_Courses_2.cfm

Turbo Expo Pre-conference Workshops

- IGTI will continue its successful partnership with the von Karman Institute (VKI) to offer two workshops: ***"Advances in Turbines Aero-thermo-mechanical Design and Analysis"*** and ***"Introduction to Optimization Methods and Tools for Multi-disciplinary Design"*** in conjunction with Turbo Expo 2012 in Copenhagen.

- Turbo Expo 2012 in Copenhagen will also be the venue for five other workshops. Back by popular demand, IGTI will offer: ***"Technology and Applications of Turbine Coatings,"*** ***"Gas Turbine Failure Analysis"*** and ***"Basic Gas Turbine Metallurgy & Repair Technology."*** New this year are ***"Gas Turbine Rotor Life Management"*** and ***"A Primer on CHP Technologies."*** For more detailed information please visit the IGTI web site at: http://igti.asme.org/Education/Short_Courses_2.cfm

IGTI Webinars

The Fall brought 3 outstanding webinars:

- Wind Turbine Tutorial
- Concentrating Solar Power
- Ethics Webinar

Please contact Shirley Barton, *bartons@asme.org*, regarding information on:

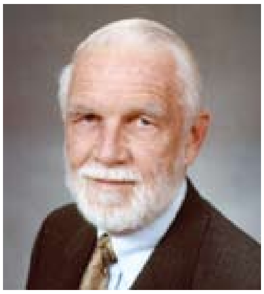
- Navigating IGTI "Who's Who" Directory
- Committee Member Updates
- Volunteer Opportunities
- IGTI Awards and Scholarships
- Training & Development

If you have a topic you think will be of value to the turbine industry and would like to present it in a webinar format or a "face-to-face" format, please contact Shirley at bartons@asme.org. ✲

Featured Column: ***As the Turbine Turns...***

First IGTI Forum on Jet Engine Volcanic Ash Ingestion

By Dr. Lee S. Langston, Professor Emeritus of Engineering, University of Connecticut



Langston is a former editor of the ASME Journal of Engineering for Gas Turbines and Power and has served on the IGTI Board of Directors as both Chair and Treasurer.

Airborn ash thrown into the atmosphere from volcanic eruptions poses a significant threat to the safe operation of gas turbine powered aircraft. At Turbo Expo '11 in Vancouver last June, IGTI's Aircraft Engine Committee sponsored our first session on "Volcanic Ash Effects on Aircraft Propulsion Systems."

Since the early 1980s there have been a number of volcanic eruption close calls, with passenger plane inflight engine shutdowns occurring due to ash ingestion. In even the worse cases, the pilots have been able to restart shutdown engines and then land safely. Perhaps because there have been no ash ingestion induced fatalities to date, the incidents typically cause a flurry of attention at the time, followed by an ebbing away of interest.

The recent April 2010 eruptions of the Icelandic volcano Eyjafjallajökull (E15) however has gotten more widespread attention than earlier incidents, even though no jet powered commercial aircraft actually flew through an E15 ash cloud.

Erupting first under an ice cap, on April 14, 2010, E15 ejected ash clouds as high as 30,000 feet, directly into some of the world's most traveled air space. Authorities in the United Kingdom, when alerted to the E15 eruption, quickly went through calculations necessary to predict the aircraft separation distances and flight path diversions that would be necessary for the 800 daily transatlantic flights that use UK airspace.

It became evident from their calculations that commercial aircraft would be in danger of running out of fuel or having to land, in some cases, in places ill-equipped to handle heavy traffic. (Remember that the 1977 Tenerife Airport disaster, the deadliest accident in aviation history with 583 fatalities, occurred when Spanish authorities diverted air traffic because of bomb threats.)

With concurrence of other airspace regulators and aircraft OEMs, North Atlantic airspace was shut down from April 15-23, 2010. As I reported earlier this year[1] 100,000 flights and 8 million passengers were affected, with losses to all concerned estimated at $5B.

The ash ingestion session took place on Tuesday afternoon, June 7, 2011, appropriately on the Pacific volcanic "Rim of Fire," with the 11,000 foot active volcano Mt. Baker, just to the southeast of Vancouver. It consisted of a panel of experts assembled by session chair and Turbomachinery Committee past chair Aspi Wadia of GE Aviation and myself. Interest by attendees was high for the panel had an audience of 200 plus (standing room only) for a good part of the three-hour session. The seven panel members represented the European and North American air traffic regulators, the US Air Force, the airlines, airframe and engine manufacturers and the IGTI research community.

Padhraic Kelleher, UK Civil Aviation Authority's Head of Airworthiness and Yves Cousineau, Senior Engineer with Canada's National Aircraft Certification Branch both discussed regulatory aspects of dealing with the E15 eruption, providing a view from both sides of the Atlantic.

Panel participants from left to right are: Lee Langston, Manfred Paul, Douglas Kihm, Charles Stevens, Yves Cousineau, Michael Dunn, Roger Dinius, Padhraic Kelleher, and Aspi Wadia

Charles Stevens, Chief of the Turbine Branch at the US Air Force Research Laboratory at Wright-Patterson AF Base reported on the military view of the ash ingestion problem. He raised the possibility of using an array of unmanned air vehicles (UAVs) to measure ash concentrations, after an eruption has occurred.

Manfred Paul, representing Lufthansa Airlines, and having a long background with their aircraft maintenance engineering and engine overhaul, discussed an airline view of the ash ingestion threat.

Douglas Kihm of the Boeing Company gave an airframe OEM perspective and presented a video that Boeing uses to recommend to pilots how to deal with ash cloud encounters.

Roger Dinius, a Chief Consulting Engineer at GE Aviation reviewed aspects of an OEM's perspective on jet engine volcanic ash ingestion, showing examples of engine damage by ash ingestion.

Representing the research part of the picture, Michael Dunn, Professor and Director, Gas Turbine Laboratory at Ohio State University gave a presentation on a large body of laboratory data and analysis of what actually happens to engines as volcanic ash is ingested. Dunn and his co-investigators carried out Calspan Laboratory (Buffalo, N.Y.) experiments from 1980 to 1996 involving the measurement of the effects of various kinds of volcanic ash on the actual performance of a number of different models of jet engines and components.[2] The Dunn research and the consensus of our panel indicated that 2 mg/m^3 is a conservative upper limit on atmospheric volcanic ash density for safe jet aircraft flight.

Dunn's ash ingestion research was sponsored by the US Defense Nuclear Agency. Much of it has been published in ASME papers, but Mike was able to present classified results, recently released for open literature publication. *Journal of Turbomachinery* Editor David Wisler, a panel audience member, has invited Mike to submit a paper that would deal with the recently declassified engine ash ingestion data.

In summary, this first IGTI full technical session on jet engine volcanic ash ingestion was timely and well received. Expert panel members were able to present their perspectives to an audience for who "the rubber hits the road" – i.e. those engineers and managers who will deal directly with the mitigation of aircraft engine volcanic ash ingestion. ✻

References

1. Langston, Lee S., 2011, "Jet Engines and Erupting Volcanoes," *Global Gas Turbine News*, April, p. 51.
2. Langston, Lee S., 2010, "Asking for Trouble," *Mechanical Engineering Magazine*, July, pp. 28-30.

Centrifugal Compressor Transient Modeling

By Augusto Garcia-Hernandez, Southwest Research Institute

Centrifugal compressors are used extensively in the pipeline and gas processing industries to move large flows of gas from low pressure pipes or sources to higher pressure pipelines, process vessels, or storage locations. Over a wide range of operating conditions, centrifugal compressors are efficient and reliable for compressing and moving gas. There are a large number of centrifugal compressors in operation in our industry and more are being designed and installed every week. However, there are several limitations on the operation of centrifugal compressors and one of the most significant is the low flow limit known as surge. The transient behavior of compressor stations, particularly under rapidly changing conditions, is of vital interest to compressor station operators. Predicting transient behavior is an important factor in designing protection systems for events such as emergency shutdowns.

Currently, computational models are very common and useful for providing quick, reliable, and cost-effective solutions to real problems. In general, pipeline models include a lot of detailed and specific information of the real system being modeled. Therefore, it is important that these data be accurate in order to ensure the predictive capability of the computational model. However, computational simulations have some level of uncertainty and inaccuracy due to the use of simplifications, assumptions, and numeric calculations. Therefore, model developers have to adjust, refine, and validate their models to simulate more accurately the real process and events. Models are validated by comparing the simulation results to known steady-state and transient parameters at various other operating points. However, sometimes this is not an easy task, since poor or no data are available for the tuning process.

Modeling

Transient and steady state flow modeling of centrifugal compressors, pipeline systems and other fluid transient responses are performed with a variety of one-dimensional and three-dimensional fluid dynamic codes. These codes include in-house non-commercial codes that use the full Navier Stokes fluid equations, method of characteristics or similar finite difference solution techniques transient pipe flow simulations. All computer codes whether in-house or commercially available have the same basic requirements to solve for transient pressures and flows in piping sections as well as other responses of the system. The equations in the computer programs allow for the determination of pressure and flow at each time step at each end of interior section of pipe. The conditions at the ends or nodes of the first and last section of pipe (non-interior points) are determined by boundary conditions. Correct implementation and interpretation of boundary conditions is critical to the accuracy of the solution.

All of the process piping that connects a compressor to scrubbers, coolers, or recycle valves between a large volume source or main pipeline and a final delivery pipeline or discharge volume must be divided into sections with designated lengths and diameters. The choice of time-scale and length-scale will also influence the accuracy and precision of the solution (as well as the stability of the model in the case of rapid transient effects or abrupt area changes). The piping solution techniques provide a method for defining pressure and flow at each point in the system at each time step, as affected by initial and boundary conditions.

Centrifugal Compressors Transient Modeling

Transient simulations of centrifugal compressors are very helpful for validating or designing existing or new anti-surge systems. Commercial codes provide a tool to model rapid trips of centrifugal compressors in order to avoid energetic and potentially damaging surge events. These simulations account for the actions of anti-surge valves, control system responses and the capacitance function of upstream and downstream piping. The simulations require modeling of small pipe sections, very small time steps, and full details in terms of compressor performance curves, recycle, and other valve characteristics. Figure 1 illustrates the effects of anti-surge valve changes on the transient performance of a centrifugal compressor during an emergency shutdown event as well as its comparison with real transient data collected at SwRI.

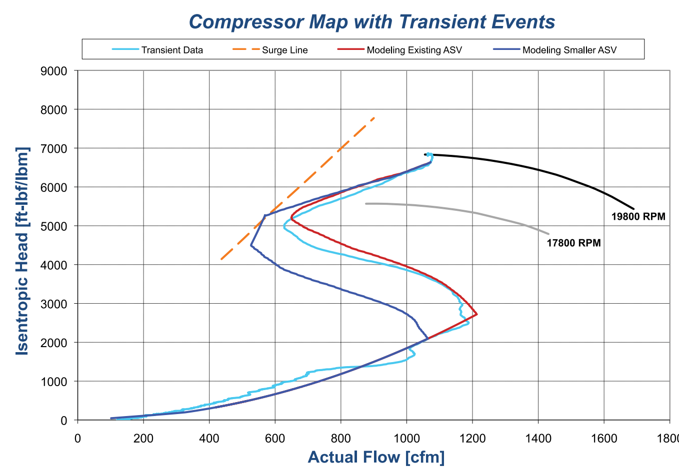


Figure 1. Effect of ASV Modification on Transient Path of Compressor During Emergency Shutdown Event.

The factors that determine if a damaging surge occurs when a compressor trips includes recycle valve sizes, response and opening times, piping size and arrangements, location of the compressor on its operating map, and many other factors. Detailed simulations that account for all of these factors are necessary to design surge control systems that avoid high energy damaging surge. Centrifugal compressors experience surge whenever they are suddenly tripped, however, controlling the head and total energy of the surge event by reaching a sufficient recycle valve opening and a low enough head before the surge occurs is the objective of transient simulations.

Compressor systems, as they normally operate, contain a significant amount of stored energy as represented by the volume and pressure in the discharge piping compared to the suction piping. Controlling the release of this pressure energy is critical to reducing the energy or severity of surge. Therefore, several important features of any transient modeling program are controls or routines that adjust and affect the system response to controller inputs based on operating conditions. In the transient flow model, a valve controller can be simulated simply as a stroke rate or completely as a full integral, proportional, and derivative controller which is dependent on compressor head and flow.

Conclusions

Simulation of a compressor station or large transmission pipeline before proceeding with the detailed engineering specifications is often more cost-effective than having to modify the system at a later time based on overlooked system issues. For both new and existing pipeline systems, accurate modeling based on validated codes and experienced modelers will help to avoid significant costs in redesign for the operating company. *

Today's Reverse Engineering Cycle for Turbine Blades

By Samuel Shock, Engineering Manager, Triax Turbine Components (www.triaxturbine.com)
Robert Wilburn, Project Manager

In today's turbine engine market, finding spare parts to keep legacy engines operating can be a challenge. Reverse engineering and manufacturing is often the best solution for providing cost effective aftermarket parts for overhauling and repairing existing gas turbine engines. Aftermarket parts typically provide the end user a 30-40% cost savings as compared to OEM options.

With today's technology, reverse engineering is a more precise method than previous mechanical practices. No longer do companies have to rely on legacy data or subjective manual measurements to reproduce parts.

The following six categories can be utilized to break down the reverse engineering process:

I. PRODUCT INVESTIGATION AND RESEARCH

First, by understanding the intended purpose and operational constraints of the original component the design team can determine the parameters that influence the final product.

On rotating turbine engine blades, these design decisions begin with a detailed investigation of weight characteristics, metallurgical analysis and vibrational interaction. In addition, there are also other considerations, including an investigation of the overall assembly and service histories before any reverse engineering can take place. This will allow the parameters of the project to be properly defined.

II. DATA COLLECTION

Once the parameters of the project have been outlined, empirical data is captured with traditional measuring equipment and the use of 3-Dimensional digital scanning.

Figure 1: White light scanning fringe pattern being projected onto a 1st stage turbine blade for dimensional data collection.

Digital scanning may consist of either laser or structured light scanning. Laser scanning utilizes a laser single point or an oscillating beam in conjunction with a camera to triangulate the distance to the object. Points are created where the laser interfaces with the part and 3D point cloud data is created. In structured light scanning, such as white light scanning, a fringe pattern is projected on the part and multiple cameras utilize a focal distance to measure the variations from in the fringe to create the point cloud data.

Some scanning systems are portable, such as hand held units or tripod mounted systems, and others are fixed such as CMM mounted systems. The most important factor in selecting the system is matching the accuracy and precision of the system with the parts being scanned. With turbine blades the trailing edge radius typically dictates the precision of the system needed to accurately capture the geometry. White light scanning systems project millions of points per shot, and on small components can be accurate to +/- 0.0003." Many commercial laser scanners are accurate to within +/- 0.001."

Figure 2 – Representation of the typical setup of a white light scanner being used to collect dimensional data from an injected wax pattern. This data will qualify the wax tooling to be used in the investment casting process.

III. DATA PROCESSING

Once the point cloud data has been collected it will need to be processed and converted to a stereolithography (stl) file to begin the modeling process. This step requires evaluating the scanned meshed data and starting the process of converting the mesh to surfaces. The reverse engineering software is utilized to evaluate the mesh data to determine how the surfaces are created. The surface can be placed at a minimum, average or maximum level based on the topography of the mesh. Some software allows the creation of sketches directly on the mesh which can be extruded to create a solid body. Additionally bodies created (solid or surface) can be checked against the mesh data to insure the accuracy of the part.

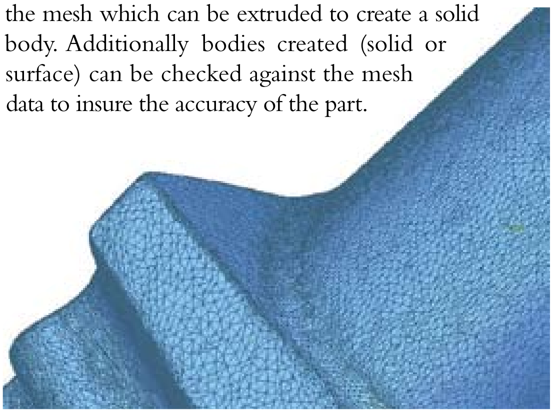


Figure 3 – An auto-surfaced 3D mesh display of a compressor turbine blade platform being prepared for FEA evaluation.

IV. DATA PREPARATION

Any additional work required to process a fully-formed CAD model will depend on the application. For example, if we are looking for a space claim model or if we need to run finite element analysis (FEA), we'll utilize the format as received from the reverse engineering software.

However, if the application requires a fully parametric model and supporting drawings, the reverse engineered model needs to be transferred to a CAD package. The data can be manipulated to create nominal tolerance conditions, correct any symmetry issues and add geometric definitions in the model.

Figure 4 – Dimensional accuracy comparison of a R/E CAD model compared to a scanned legacy part.

V. DATA VALIDATION AND TOLERANCING

The CAD model must now be validated to ensure it meets the specified requirements. For a turbine blade, the contours of the free form surfaces, and their relationship to the machined surfaces, can be inspected on a scanning

...continued

Reverse Engineering . . .

CONTINUED FROM PAGE 60

CMM to compare the new CAD model to the physical OEM part. A secondary means of verification is to use validation software to compare the new CAD model to the original OEM scan data. Within the verification software there are multiple options of alignment to generate the comparisons. Alignment by the machined surfaces allows for the validation of the airfoil's position relative to the root, or alignment by the airfoil surfaces to validate the accuracy of the lofted airfoil surfaces.

Using this validated CAD model, dimensional tolerances are established to generate manufacturing drawings. Typically a part reverse engineered within the tolerance constraints of the OEM sample lot is acceptable, but sometimes additional requirements may be imposed. For turbine blades rotating at high RPM's in elevated temperature environments, the parts may also require bounding by frequency, fatigue and creep comparisons.

Understanding the nuances of the part's design intent, fabrication method, interaction with mating parts and their affect on downstream components will aid in developing realistic dimensional tolerances and critical to quality dimensions.

VI. FABRICATION AND FIRST ARTICLE APPROVAL

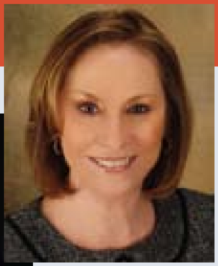
Once a physical part has been reproduced, qualifying the operational safety of the new component is one of the last steps in getting it to market. Many of the characteristics established and developed within the reverse engineering process will need to be verified with first article parts. This may include dimensional inspections, destructive analysis, and/or performance testing. To establish pass/fail criteria for first article testing, physical testing may also need to be performed on the OEM parts sample lot.

Having a good plan and knowing the final expectations will greatly increase the success of a reverse engineering project. ✲

About Triax Turbine Components

Triax Turbine Components (TTC), which acquired the assets of Dynamic Turbine LLC (DTL) and Triumph Precision Casting Corp (TPCC), specializes in the reverse engineering service, investment casting, and the machining of hot section turbine engine components. TTC has extensive experience with producing "airfoil" shaped components and has manufactured blades and vanes for a wide range of aerospace and industrial gas turbine engines.

Long-Time IGTI Staffer Judy Osborn Retires



The ASME International Gas Turbine Institute is sad to announce the retirement of long-time staff member, Senior Program Manager of Events and Member Services Judy Osborn. Osborn was honored during Turbo Expo 2011 among the hundreds of engineers who have worked with her throughout the years. She has been with IGTI since 1996, completing more than 15 years of service to ASME and the IGTI community. During her tenure at IGTI Osborn has overseen all aspects of the organization (conferences, expositions, volunteer services, and workforce development) but is best known for her staff leadership role in support of Turbo Expo.

Osborn holds a degree in communications from the University of Georgia and has more than 30 years of experience in working with non-profit associations, providing organizational and logistical support for meetings, publications, and member services.

"What I've enjoyed most during my time at ASME IGTI are the people," says Osborn. "My fondest recollections will be of the various individuals from all over the world with whom I've become acquainted and interacted. This includes volunteers, program participants, co-workers, and those throughout the association and event management industries. We've definitely had many fun and memorable experiences together."

"Certainly, another one of the perks of the job for me has been the international travel," Osborn added. "It would be impossible to select one place over another as a favorite because I greatly appreciate the opportunity to see and do so much."

"It has been tremendously satisfying to see Turbo Expo continue to mature and maintain success over the years and to know it is fulfilling important objectives for engineering professionals. I am particularly gratified by the successful development of the networking event for women in the turbomachinery community. I have constantly sought to foster additional and pertinent platforms for enhancing each participant's experience and career development as well as to contribute to the advancement of the field."

"I wish each person success and happiness. I will not miss the day-to-day work routine, but I will absolutely miss all of them."

Upon retirement, Osborn will focus on her hobbies, which include painting, bowling, and traveling, as well as spending time with her family.

She will be missed at Turbo Expo 2012 in Copenhagen and beyond! ✲

Networking and Blade Mechanics

By Dr. Jaroslaw Szwedowicz, Program Manager Technology and Methods, Alstom Power, Switzerland | Associate Editor, ASME *Journal of Engineering for Gas Turbines and Power* | Chair of IGTI "Structures & Dynamics" Committee, ASME Swiss Section

When 100 experts have a chance to exchange ideas on a highly focused topic, the result is a very successful seminar. The 2011 program of the 16th annual Blade Mechanics Seminar[1] gathered over 100 engineers and scientists to discuss various HCF (High Cycle Fatigue) issues of aero and industrial turbine and compressor airfoils. A keynote speech on the "Impact of Rotordynamics on Blade Vibrations" opened the seminar and explained the state of the art of rotor-blade interactions. This lecture also pointed out future challenges for rotor train and blade dynamics due to anticipated instabilities in an electrical network powered by a combination of steam and gas turbines as well as solar- and wind-farms. Afterwards the 11 presenters demonstrated different HCF problems and their mitigations based on either the traditional redesign approaches or advanced solutions, such as frictional damping technology or intentional blade mistuning.

The HCF problems of turbine blades are most likely as old as the first design of Parson's steam turbine in 1884. Based on a five-year investigation of 227 GE steam turbines with ratings above 5 MW, Wilfred Campbell (1924) created the first resonance criteria for bladed discs. At that time, disc assemblies were analyzed with Rayleigh's or Dunkerley-Southwell's approach, simple analytical methods that either overestimated or underestimated the real blade frequency, respectively. Therefore, the resonance frequencies of the analytically designed freestanding blades were often measured in the spin pit. To avoid those frequencies, the redesign strategies of a M-mass reduction or a K-stiffness increase of the vibrating blade (Fig. 1) were generally applied.

The blade mass was usually decreased by slightly cutting the airfoil tip. However, this approach generated bigger radial clearances between the blade tip and casing, which downgraded the stage performance. In the 70s and 80s, 1D perturbation methods were developed; they removed thin layers of material from the suction and pressure sides of the airfoil.

A commonly used method for increasing stiffness was a lacing wire, which was circumferentially threaded through a hole of every airfoil. Sometimes as many as three lacing wires could be found in old steam turbine stages. Another method, applied to avoid large diameter wires, was staggered zigzag pins. However, each blade required two holes, which reduced the airfoil section and could generate significant notch stresses. Therefore, winglets were later employed on the longer blades, or cover bands at the airfoil tip. These bands were attached to the blade tip by riveting. To avoid problems of rivet creep or accelerated corrosion at the interface, blades with integrally machined shrouds are employed today. Shrouded blades enclose the flow and improve the aerodynamic efficiency of the stage better than a lacing wire. But even today, lacing wires and damping pins are applied to engines operating with variable rotational speed, such as turbochargers or industrial steam turbines.

Nowadays HCF blade analysis is still based on the Campbell diagram (Fig. 1). Taking advantage of the continual increase in computational capabilities, analysis has advanced from the Transfer Matrix Approach used in the 60's and 70's through the 3D Finite Element Method, which appeared during the 80's and on to the latest methods, such as the Modal Synthesis approach, which includes frictional sliding on the blade interfaces. For that reason, the new strategies of D-damping leverage or/and D-detuning (Fig. 2) are of importance in the modern dynamic analysis of turbine and compressor blades.

Friction damping technology has already gathered 30 years of design experience (Szwedowicz, 2010) and can effectively reduce the resonance amplitude of interest by using under-platform dampers or by optimizing the shroud coupling. The most recent detuning technology for the disc assembly is based on intentional mistuning of every blade with respect to the critical engine order (see EO in Fig. 1). This design strategy breaks up the excitability criterion of the disc assembly expressed with $EO = n N \pm j$, where $j = \{0, 1, 2, \ldots, J^\star\}$ with $J^\star = N/2$ or $J^\star=(N-1)/2$ for an odd or even number N of blades in the stage, respectively. In other words, the intentional blade mistuning disorders the n-th nodal diameter mode shape of the vibrating disc assembly. Then, instead of the major resonance response of the tuned disc assembly (Fig. 1), individual resonances of the mistuned blades are excited; these superimposed responses result in smaller resonance amplitudes, as illustrated in Figure 2. This technique is currently used for blisks whose vibrations depend mainly on the airfoil geometry and are not influenced by the manufacturing tolerances of the blade assembly. The successful application of this method requires sophisticated simulation methods to confirm that other resonances of the mistuned disc assembly are not amplified, as they would be in cases of uncontrolled mistuning (Whitehead, 1988).

Besides discussion on these topics, the participants also visited an exhibition organized by 8 seminar sponsors. Everybody was able to examine real turbine vanes representing different phases of the reconditioning process used for hot gas turbine components.

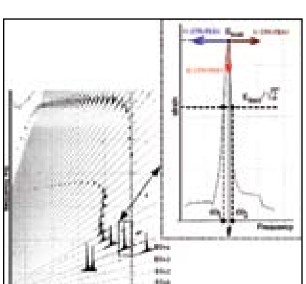


Fig. 1 The measured Campbell diagram of the shrouded blade and a Resonance Response Function indicated strategies for changing the blade resonance frequency f (see M- and K-one) or for reducing the resonance blade amplitude ε_{max} (D-one), where EO denotes Engine Order, ε is the measured strain

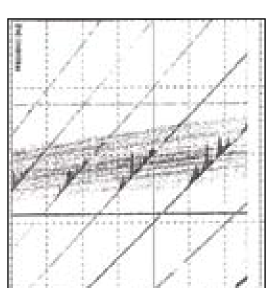


Fig. 2 The measured Campbell diagram of Resonance Response Functions of a mistuned disc assembly for different excitation orders EO

[1] http://project.zhaw.ch/de/engineering/blade-mechanics-seminar.html

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