Among the highest recognition accorded engineers for accomplishments in turbomachinery

Dr. David Japikse, founder, chairman, and senior technical director of Concepts NREC, is the honored recipient of the 2008 SAE Cliff Garrett Turbomachinery Engineering Award. The award was established in 1984 to perpetuate the recognition of Cliff Garrett for the inspiration he provided to engineers and his many contributions as an aerospace pioneer.

In a congratulatory letter to Dr. Japikse, James E. Breneman of the award committee wrote, “After reviewing the nominations, the Garrett Award Committee identified your long-term contributions as the most outstanding in this field. Please accept my personal congratulations, along with those of the entire committee on receiving this distinguished award.” As a requirement of acceptance, Dr. Japikse will write a paper and deliver a lecture. He has chosen the topic Turbomachinery Performance Modeling to present a broad critical review that covers all areas of turbomachinery design and development.

In accepting the award, Dr. Japikse replied, “I am honored and pleased to accept on behalf of the many colleagues who have helped me along the path of this profession, and I look forward to representing Concepts NREC while giving my presentation at the 2009 SAE World Congress.”

Everyone at Concepts NREC is very proud...
Commentary continued

Concurrently has prompted many progressive companies to quickly adopt new business methods that demand an even higher level of support from their suppliers.

A PLM approach to turbomachinery design

As a full-service turbomachinery resource, we are typically asked to address a variety of challenges that may call for meeting delivery and price targets, for rapid design and innovation to capture market opportunities, for meeting regulatory compliance, or for developing products with the best chance of market success. And in their holistic approach to turbomachinery development, our customers now discuss issues of “lifetime value” and “product lifecycle management” (PLM) when defining “enterprise” solutions.

Customers want CAE and CAM tools that integrate well with their own engineering conventions and manufacturing planning, that complement their business-process management style, and provide solutions that fit within the framework of their global enterprise. They want to know how well we can leverage our advanced technology tools, methodologies, and application experience to enhance their architecture for innovation, engineering, manufacturing, and customer service.

This refined and all-inclusive strategy is the new face of business in the turbomachinery industry. More so than before, designers want tools capable of superior results at lower costs plus responsive support from early conception to final product. They want to achieve a thoroughly integrated and well-balanced solution that deals concurrently with all multidisciplinary data. And for a bottom line, each one would likely claim “the pursuit of high-quality solutions” to be a cornerstone of their business success.

Enterprise solutions in turbomachinery

We are a turbomachinery company, exclusively, with over fifty years of experience developing breakthrough products and methods that represent the best efforts of literally hundreds of world-class engineers. That is the level of turbomachinery knowledge imbedded in CN’s Agile code that is missing from other CAE systems. That is the proprietary data needed to provide both the initial parameters to begin the design process and the methodology to guide the detailed design through analysis and manufacture. And that is the depth of experience needed to facilitate a true PLM design within multiple boundaries.

In the aerospace industry, high fuel and material costs are being countered with more efficient designs that also meet stringent quality and certification processes, and are balanced to favor reliability. Manufacturers of industrial equipment are facing similar cost and regulatory issues plus tough competition from products outsourced to lower-cost countries. So an optimal design might favor first cost and reliability.

CN’s involvements in the development of energy-generation systems and energy-conservation equipment reveal more of the same need for enterprise thinking with PLM solutions. Equipment operating within the carbon cycle must address all product lifecycle issues including fluctuating prices for fossil fuels plus stringent regulatory and safety standards. The innovative turbomachinery solutions required by several emerging green technologies typically balance designs towards efficiency, reliability, and an effective value proposition.

Facilitating a balanced design

The workflow for a turbomachinery design or redesign begins with concurrently developing and simulating iterations of the virtual product to address all requirements and optimize the most-desired features. To arrive at a properly balanced design among several interacting technologies, however, the parameters that affect each feature must easily be changed to rapidly evaluate new iterations. More importantly, the total implications of a change to enhance one feature must be easily assessed and the consequences addressed.

Some turbomachinery designers may only need specialized design tools as a form of collaborative engineering to solve specific challenges or complete their product-lifecycle architecture. For these users, highly

CAE Graphics Seen As Works of Art

Users of Agile Engineering® design tools sometimes consider the resulting graphical output images to be worthy of artistic critical acclaim. These are a few examples of the art form submitted by Concepts NREC engineers.
The true cost of design software

That twenty-year-old editorial took another strong and now well-proven position that the more specialized the software, the more cost effective it should be. The corollary is also true: The more generalized the software, the greater the hidden costs. So, the true cost of software is actually a function of user training, engineering time for customization, and other expenses attributed to achieving practical operation and anticipated results. Actually, these necessary expenses represent the bulk of the software’s true cost – up to 82% of the total cost of implementation according to one independent study.

For most turbomachinery design, generalized software rarely achieves the quality needed for a thorough and professional engineering analysis, and the purchase most always requires far more additional investment than anticipated. That is because general-purpose CAE and CAM tools are in fact general until manually specialized to a particular problem – always at additional (and sometimes great) expense. Even then, the results rarely match the benefits of a tool focused on pumps, compressors, turbines, or fans, and grown from the vast experience of many specialists.

The irony too often encountered: When applying a general-purpose tool to any turbomachinery problem, you are actually creating a specialized tool, but doing it manually. And sometimes the effort is at greater expense and for lesser results than buying the specialized tool.

In nearly all applications, a strong case can be made for the benefits of achieving optimal results that take advantage of all savings. Still, too often the potential of a breakthrough solution through a more sophisticated approach is lost by designers who have learned to get by on the basic tools they have – even when it comes down to an educated guess at the solution rather than analyzing data for physics-based answers.

Proven economics

The most profound issue in the choice of engineering software may be this: At stake are not just thousands of dollars, but millions of dollars and more. Specialized tools best optimize the selected objectives that will help your product thrive now and in the future. Whether using a complete turbomachinery design system or integrating a dedicated tool into an existing design process, purchasing specialized turbomachinery software has proven to be good economics. For some companies, the considerable development time saved, or the ability to use less expensive materials can alone quickly offset the cost of the software.

When reviewing objectives for a more effective turbomachinery design or machining process, consider how you can best support your customers’ enterprise thinking and lifetime value solutions. What are your common expectations to pursue innovation and produce best-in-class products? And how will you both benefit from a fully integrated turbomachinery design system with built-in experience and intelligence?
Simms principles for success

In 1988, with nearly twenty years experience designing turboexpanders and boil-off gas compressors, Jim decided to follow a vision that led to the formation of his own business. “As a small and focused company with top-class outside support, I believed we could better understand customer problems and solve them more effectively than the larger, more cumbersome companies where I had previously worked.”

Jim further explained, “This business operates on a few basic principles that haven’t changed since we started. Most importantly, business is personal. Customers expect a knowledgeable response and an effective solution without surprises — not a routine reply from a ‘customer service’ rep.”

“Initially, we provided only diagnostic and design services, although we occasionally manufactured a wheel through an outside vendor. But I had always envisioned in-house production as an opportunity to better control our rapid-response advantage. It would also bring our organization up to the latest technology that I had been reading about for many years in Concepts NREC’s SpinOffs newsletter.”

“If we were going to grow by being more productive, we came to the realization that we needed the best turbomachinery tools. Five years ago we took action and purchased a 5-axis mill capable of cutting up to fifteen-inch wheels. Unfortunately, the toolpaths generated by a local consultant frequently had errors that resulted in expensive delays, expensive fixes, and sometimes cut-off blades.”

“The frustration of time and cost just to generate a workable toolpath program was the push we needed to consider licensing our own CAM software. The turbomachinery intelligence provided by Concepts NREC was the pull. I admired what I had read about MAX-PAC™ software and wanted to bring us to that higher level of intelligence and understanding in order to produce better parts while reducing production costs. It seemed our only obstacle might be the impact of cost on our limited resources.”

“After explaining our CAM requirements, Concepts NREC offered (and I accepted) a 30-day trial license. I was immediately impressed to discover how quickly we could achieve an excellent toolpath. We then leased the program with an option to purchase, and Concepts NREC provided a free part program with a one-week turnaround — including the NC postprocessor.”

“That was something our company could financially handle to bring us up to par with the latest CAM capabilities, and something that immediately elevated the prestige of Simms Machinery.”

In addition to acquiring Concepts NREC’s MAX-PAC CAM software for machining turbomachinery, Simms has also purchased AxCent® CAE software for blade design. “We’re just getting started with the analysis portion of the design software and studying the full capabilities of the program,” explained Jim Simms.

Simms Machinery International recently built a new, larger custom facility in anticipation of “winding up” the business. “We continue to operate and grow with state-of-the-art capabilities supported by a few favored suppliers — among them, Concepts NREC. I’ve certainly learned through experience that if you’re not moving up, you’re sliding down.”

What is a turboexpander?

The name Turboexpander describes a single-shaft machine in which a radial-inflow expansion turbine drives a centrifugal compressor. When used in a gas processing plant, the primary function is to very efficiently generate refrigeration in the process gas stream. The heat energy extracted from the gas stream in the expansion turbine is converted to mechanical energy that powers the process compressor.
CAM Helps Launch Successful Startup

Only two years after starting Kinner Manufacturing, Ray Kinner is pleased to announce his business is a success – and growing. Considering his shop only machines blades, Ray’s direct approach to entrepreneurship is an excellent example of how a small manufacturing startup using specialized CAM software can quickly begin producing quality parts.

“My strategy assumed the obvious,” claims Ray Kinner. “First, I knew that quality-oriented companies with bladed products needed sources for more parts at the best cost. I’ve seen companies grow and sometimes survive on the quality and price of parts provided by their suppliers. Second, I also knew that I had to immediately impress these companies, and to do that, I needed the best CAM software developed specifically for machining blades.”

That perception proved to be correct. “Acquiring a 5-axis mill and MAX-5™ machining software gave us the confidence and the security to take on some pretty tough jobs as well as routine work,” Ray explained, “and our customers have kept coming back for more.”

Ray Kinner grew up in the machining business. In the 1960s, his father started a shop in the San Francisco Bay area, and years later when the business was sold, Ray briefly joined the new owner. “I had had ten years experience running MAX-5 toolpaths on 5-axis mills,” according to Ray, “and I knew how to make the best possible blades with good cutting-cycle times.” So with the encouragement and help of friends, Kinner Manufacturing was launched in 2007 with one 5-axis mill, a one-year license for MAX-5 CAM software, and a plan to attract customers wanting quality machined blades for fans, compressors, pumps, and turbines.

“I was pleasantly surprised at how easy it was to get started,” claimed Kinner. “For basic hardware, we began with a lathe and a balancer to complement the 24-inch mill, and I chose MAX-5 software because it is simply the best CAM software for blading. All other CAM programs I have used may hit the same points and be in tolerance, but MAX software by far has the best blending between points and clearly produces the nicest blades.”

To attract customers, Ray looked at industries that used the type and quality of bladed parts he had been machining. It also made sense to seek out customers who were using Concepts NREC’s Agile design software because of its direct integration with MAX software. “Our first customer was a major OEM supplier of turbomachinery components for locomotive and marine applications who had been my dad’s customer,” Ray explained. “They were using Concepts NREC design software and wanted a seamless link to a manufacturing supplier for precision ruled-surface impellers.”

“Another of our early customers designs and manufactures super-efficient fans using Agile design and CAM software. They have their own high-end, in-house machining capability but wanted to farm out some part work – especially to a shop running MAX toolpaths so there would be no data translation issues. We began producing prototypes that gained the customer’s confidence, and we expect to also machine the production parts.”

Now satisfied that he is producing the best possible machined blades, Ray continues to reduce cutting-cycle times by using different cutting strategies supported by MAX features. “This software is very versatile,” claims Ray, “and we found the support from Concepts NREC to be excellent. Their CAM developers and in-house users clearly relate to what we’re doing.”

As Kinner Manufacturing enters its third year, Ray reports they are running at capacity and ready to add a second 5-axis mill. Kinner has also licensed the full suite of MAX-PAC™ tools that cover flank milling, point milling, and milling one-piece shrouded impellers. “The need for rotating bladed parts is increasing as I expected,” says Ray. “We’re meeting that demand with the trifecta of turbomachinery design — better parts in less time at lower cost.”

Workshops Offer Hands-On Training in Latest Design Tools

As turbomachinery design, engineering, and manufacturing continue to make evolutionary advances (as well as occasional dramatic discoveries), fresh understanding quickly leads to new methods. CN’s popular Design Software Workshops offer an opportunity for current and prospective Agile design software users to obtain hands-on training in the latest versions of these versatile and powerful turbomachinery design and analysis tools. Participants typically return to work more motivated to take on new challenges and eager to explore innovative solutions.

Design Software Workshops are conducted at various locations worldwide and draw a diverse and active group of both experienced and novice designers. Potential users interact directly with CN design engineers and software developers as well as current users to facilitate a complete exploration of the software’s capabilities and planned enhancements. Workshop participants are also eligible to receive the software for a 30-day trial license.

A current schedule of workshop locations, dates, and fees is posted at www.conceptsnrec.com/education.
Improved Flow Model for Vaneless Diffusers

This topic is based on a technical paper, *Vaneless Diffuser Advanced Model*, by Oleg Dubitsky and David Japikse, originally presented at ASME Turbo Expo 2005.

A new periodic vaneless diffuser model has been developed that affords much-improved impeller modeling of both total pressure and flow angle along the diffuser radius. While the older models are approximately correct near the end of very long vaneless diffusers, this better-calibrated, two-zone periodic model was necessary to understand the inlet flow and developing flow downstream of an impeller.

The principal reason for pursuing this work, however, was to obtain a good model of vaneless diffuser performance in order to interpret historical sets of equations for two-zone impeller modeling (for which only limited test data is available). The issue was how to calculate conditions at the exit of the impeller using measurements by a single three-hole probe traverse while assuming appropriate skin-friction variations at the sidewalls. Or in reverse, the issue was how to predict flow conditions at the exit of a short vaneless space (at the inlet of a vaned diffuser) for the known two-zone results at the impeller exit.

Previous theories and models

A significant contribution was made by Dean and Senoo (1960) with emphasis on the rotating wake behavior in the vaneless diffuser. Their theory predicted a significant, reversible work transfer between the primary (jet) and the secondary (wake) flows leaving the impeller and entering the vaneless diffuser.

Dean and Senoo assumed the flow to be incompressible, steady, and issuing from an impeller so that no circumferential variations in flow angle for either the primary or the secondary zone existed, although the flow angles were different for each. As the two zones enter the vaneless diffuser, they must have a common border, and there must be a force acting between the two zones to induce the velocity vectors to become parallel. This force rotates at impeller speed in absolute space and leads to a fluctuating pressure at each point in the diffuser and consequently a reversible work transfer between the two zones.

Analyzing the accepted model

In using data presented by Dean and Senoo to develop new analytical models, a wall shear stress was established for primary and secondary zones, and a set of conservation equations were then written to describe the entire flow field and model the change in pressure through the diffuser.

Comparing the change in total and static pressure measured for a Dean and Senoo blower application versus the theoretical model computed from the new equations, the evident conclusions were profound:

- Inlet distortions can have significant influences on vaneless diffuser flow behavior.
- It is impossible to predict the behavior of a diffuser receiving distorted rotating inlet flow using simple axisymmetric flow models.
- A rotating distorted flow in a vaneless diffuser leads to a significant pressure work transfer between high- and low-velocity regions.
- The mixing shear stresses between jet and wake (primary and secondary) regions are less important than wall shear stresses in governing flow behavior.

This comparison, plus examples using other methods, illustrates a basic problem: Assuming a steady flow, there is no skin friction that can be used to model the flow field. Likewise, single-zone models fail to correctly predict the difference between total and static parameters. That is tragic, because this is the system of modeling used by the turbomachinery industry for the past fifty years.

Developing a new model

Upon thorough examination, it was discovered that existing models and historical equations fail to provide useful integrity. Rarely have detailed traverses been made at multiple radial locations from which careful examination of the change in total pressure and flow angle, with radius, can be deduced.

Recognizing the importance of this multiple location data, a number of stages were selected for further detailed laboratory traverse investigations. All known available data were collected for twenty-four different stages with in excess of 150 individual traverses comprising 37 speed line sets of multiple location traverse data and 26 speed line sets of single location traverse data. In studies, several examples demonstrate closure modeling of computations for the new model, not blind prediction.

Consequently, a new model has been developed that considers mass, momentum and energy interactions, mixing between primary and secondary zones, plus friction with the walls of each zone. The objective was to extend the two-zone modeling approach (used very successfully for the impeller) well out into the vaneless diffuser.

The impact on future design

When the comparison of the old and new models is taken into consideration, it is clear that there is a substantial improvement in modeling accuracy. Even though the historical model is approximately correct at the diffuser exit and can be used with care in limited cases, it is expected that certain future designs will require the integrity and greater accuracy of this new model.

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