ROTATING MACHINERY SERVICES, INC.

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THE FINISH LINE

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PROJECTS AT RMS

By Glenn Gaddis

It's been a very exciting and busy summer here at RMS. We currently have an order to manufacture two new RMS engineered centrifugal compressor assemblies complete, with lube systems, gas panels and a spare bundle assembly. Some of the other types of orders received this summer include:

Expander E148 Assemblies, DJ125 Blades, centrifugal Wet Gas Rotor repairs, centrifugal Air Compressor repairs, Butane Compressor Rotor repair, Axial rotor rebuild, Murray Steam Turbine Upgrade, FT4 Gas Turbine work, emergency breakdown Steam Turbine rotor repair, complete new Gas Seal Systems, Lube Oil systems and Steam Turbine control systems.

The diversification is great and we welcome all challenges. Our expertise goes without saying and our portfolio continues to expand.

RMS POWER SOLUTIONS

By Chot Smtih

I'm pleased to introduce myself as the new Manager of Shop Operations at RMS Power Solutions. I bring to RMS, thirty plus years of professional experience with Axial and Centrifugal Compressors, Gas Turbines, Steam Turbines, FCC Gas Expanders including extensive experience and technical expertise encompassing manufacturing, assembly, balancing, installation, alignment and trouble-shooting of Turbomachinery. I started my career with Ingersoll-Rand and later moved on to CONMEC and GE Oil and Gas (Conmec) with positions as Shop Supervisor, Manufacturing Process Specialist, and Lead Field Service Engineer. I most recently held the position of Senior Product Specialist at Dresser-Rand Inc.

I am fortunate to have the opportunity to work with a team with such a wealth of knowledge and experience on all turbomachinery and also excited by the task placed on me to assist in building and maintaining the shop operation and services offered by RMS to a world class standard. I welcome the opportunity to continue supporting your rotating machinery needs in the future.

Moving forward, I am planning the development and continued improvement in capability and capacity offered by our service team and shop. Most recently, we have increased our machining capability with the addition of a large lathe with the ability to swing 52" over the bed and 240" between centers. This machine will be operational as of November 1st. We have also added Ameritherm Induction Heating capability to our hydraulic tenon peening process to facilitate the peening of titanium blade tenons. The next major acquisition on the radar screen for the shop will be a vertical boring mill.

Stay tuned in the coming months for future capability upgrades to our service facility.

What's Inside

- Always wear Personal Protective Equipment, when required.
- Maintain a clean work area.
- Keep the walkways clear.
- Beware of your surroundings.

TURBOMACHINERY RULES OF THUMB

By Neal Wikert

GAS TURBINE

Blading

Z-notch: Laser build-up with Coastmetal 64 prior to coating
Coating: D-gun LC-1C for higher temperature applications.
Stellite 694 used for Z-notch cladding

Exhaust Systems

Expect 1-2" pressure drop from exhaust silencer.
Try not to have a flare exceed 45deg per side.
Velocities typically 5,000 to 10,000 ft/min. Over 10,000 the exhaust system itself generates noise.
Steps in the system are not desirable.

Inlet Systems

Velocities should be less than 5,000 ft/min.

Overhaul Intervals

Frame 5 Hot Gas Path 20,000 hrs.

Performance

ISO Conditions: 59F, Sea Level (14.697psia), 60% RH
NEMA Conditions: 80F, 1000ft

STEAM TURBINE WINDMILLING AND COOLING

By Sydney Gross

Although the steam turbine has been the workhorse of prime movers for over a century, there are some examples where its might is needed only briefly or partially and for the rest of the time, it is along for the ride at the expense of the rest of the train. Such examples include starter turbines, helper turbines and full extractions.

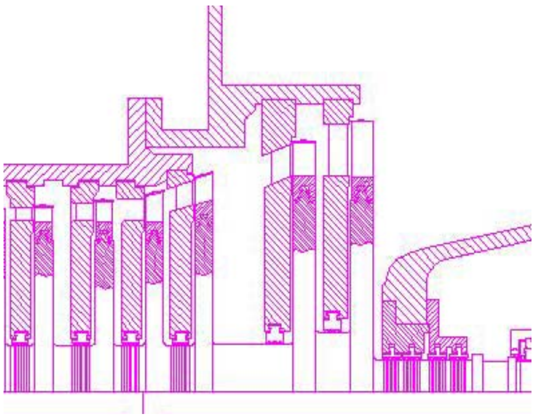
Starter turbines are typically used in applications that require the train be brought up to some percentage of speed before the main driver can take over. Examples include gas turbine trains, waste gas expander trains and some motor driven trains. In each case, the turbine must take the train from zero speed up to some speed at which the driver or process can be "lit off" or the motor started. Afterward the steam load goes to zero. Helper turbines may be used intermittently to supplement the main driver as the load demands. Extraction turbines may be run with full flow through the extraction and no power coming from the exhaust section. In each case, the turbine is considered to be "windmilling" and requires cooling steam.

Among the many losses that must be accounted for in axial turbine performance are windage losses. Windage losses apply to stages with partial or no admission and include the effects of disc friction and blade pumping. Disc friction is the centrifugating of fluid radially outward along the disc face, shearing viscous layers in the process. Because of the wheel and diaphragm construction of impulse turbines, disc friction can be a significant loss. Blade pumping is the movement of the fluid by the rotating blades. Both losses can be estimated as a function of wheel diameter squared and wheel speed cubed (refer to equation on page 3). When a rotating steam turbine or section of a turbine is closed to through-flow, the work in the form of heat in the fluid can increase the temperature continually until the design capabilities of the materials are exceeded.

The manufacturer will typically provide safeguards against this situation by designing features which will maintain a minimum flow through the machine when the governing valves are closed. *(Con't on page 3)*

Con't STEAM TURBINE WINDMILLING AND COOLING

By Sydney Gross



Such features include valve bypasses and mechanical stops to prevent valves from fully closing. A rule of thumb for cooling steam rate is approximately 5% of the design flow to remove the heated steam and avoid a potential failure.

$$HP_w = 38.0\rho(\frac{H}{D_m})^{1.5} D_m{}^2 (\frac{U_m}{100})^3$$

TEAM BLADERUNNERS DEBUT

By Tony Rubino, P.E

The RMS marathon relay team debuted on September 11, 2011 at the Lehigh Valley Marathon / Relay, which is a charity event hosted by VIA of the Lehigh Valley. The BLADERUNNERS completed the 26.2 mile event in 3:41:23 placing 48th out of 218 relay teams. The race occurred on an overcast and somber Sunday morning, which was the tenth anniversary of the World Trade Center attack. The race started at 7:00 am after opening ceremonies, which included a remembrance of 9-11. The race-course was situated primarily along the bank of the Lehigh River as the river wound from Allentown through Bethlehem to Easton, Pennsylvania. Team members in racing order were Sydney Gross, Tony Rubino, John Rubino, and Bob Klova. Amazingly, post race medical attention was not required.

Sydney has competed in numerous individual and relay distance races. Sydney's portion of this relay consisted of the first two legs and, at a total of 12 miles, was one mile short of a half marathon. Sydney's goal was to better an average time of a 9:00 minute mile which he succeeded in beating handily with an average time of 8:20 looking fresh as a daisy. Syd was ecstatic with his accomplishment and was ready to immediately begin replenishment of carbohydrates. Tony was a first time race participant and ran the 4.8 mile third leg. Tony had two lofty goals: finish the leg without the need for a stretcher and not get passed by a little old lady wearing an oxygen mask. When asked after the race about his accomplishment, he said, between gasps, that it was a great experience, was happy to have finished on his own two feet, and he was certain the half dozen or so little old ladies were not wearing oxygen masks! John was also a first time racer and a little nervous about competing, which is probably why he ran so fast. John completed his 5.8 mile leg with an average time of 6:58 per mile. John was very happy with his accomplishment. "Only one guy passed me and he looked like a serious runner because he was flying!" John is already anxious to do it again next year. Bob ran the final 3.8 mile leg which included a couple of pleasant uphill jaunts towards the end of his leg. Bob felt it was an exciting experience and was glad to have finished in a mostly vertical condition. "It was a great opportunity to do running I do not normally do". Bob spoke for all when he noted that it was great being a member of the relay team and participating with everyone in a very worthy cause.

Via of the Lehigh Valley is a non-profit human service agency that provides services for children and adults with disabilities like Autism, Cerebral Palsy, and Down Syndrome. Serving the community since 1954, Via's staff help individuals and families from birth through retirement focusing in Children's Services, Community Connections and Employment.

CENTRIFUGAL COMPRESSORS

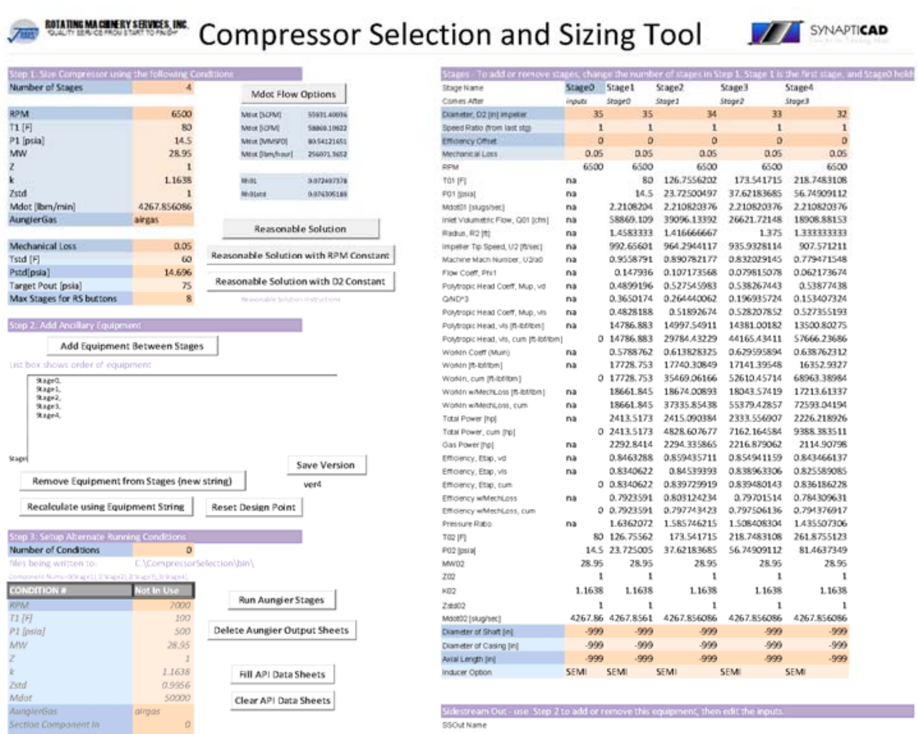
By Bob Huffman

In our last newsletter, we reported on RMS's implementation of the CompAero and Ansys/CFX suite of centrifugal compressor aerodynamic design tools. While CompAero is a very complete compressor design and analysis tool, it assumes that you have some idea of the basic stage and machine configuration you want to design, in simple terms the number of stages and the diameter of the stages you need for the particular application. This could be worked out within CompAero through iterations of designs to find the optimum configuration, but can be rather time consuming in the application engineering (quote) phase of a project.

With that in mind, RMS has recently completed the development of a front end compressor configuration tool to CompAero that is used to set the optimum number of and diameter of the stages to be designed. This tool in the format of an Excel spreadsheet is used in the application engineering phase to "rough" out the configuration of the machine enabling the application engineer to determine the number of stages and diameters of the impellers in the optimum stage configuration. The tool has the capability to model single section, multi-section and multi-body compressor trains. Balance line recycle, inlet – exit nozzle loses, side loads flows and interstage cooling can also be modeled. Once the compressor train model is set, the tool will calculate a single operation point's performance. If the user is happy with the result, then the next step is to execute a macro that will export the model to CompAero for initial detail stage design for each stage in the compressor. Those results are returned and a complete curve for the defined speed is generated. Off design points to account for multiple suction conditions or speeds can be defined and the results of those conditions will also be returned as complete compressor curve data.

These results provide a very accurate assessment of the overall performance of the purposed configuration of stages. The needed input files for CompAero are created by the spreadsheet tool enabling further refinement of the stage designs to be done directly within CompAero and later within Ansys/CFX.

The development of this tool will further enhance RMS's capability to support customer's centrifugal compressor application needs. We can provide quick design point performance estimations along with the optimum configuration for the number of, size of and style of (2D vs. 3D impellers) stages to meet your needs. We then can complete a more detailed assessment of the performance using CompAero and Ansys/CFX.



Con't CENTRIFUGAL COMPRESSORS

By Bob Huffman

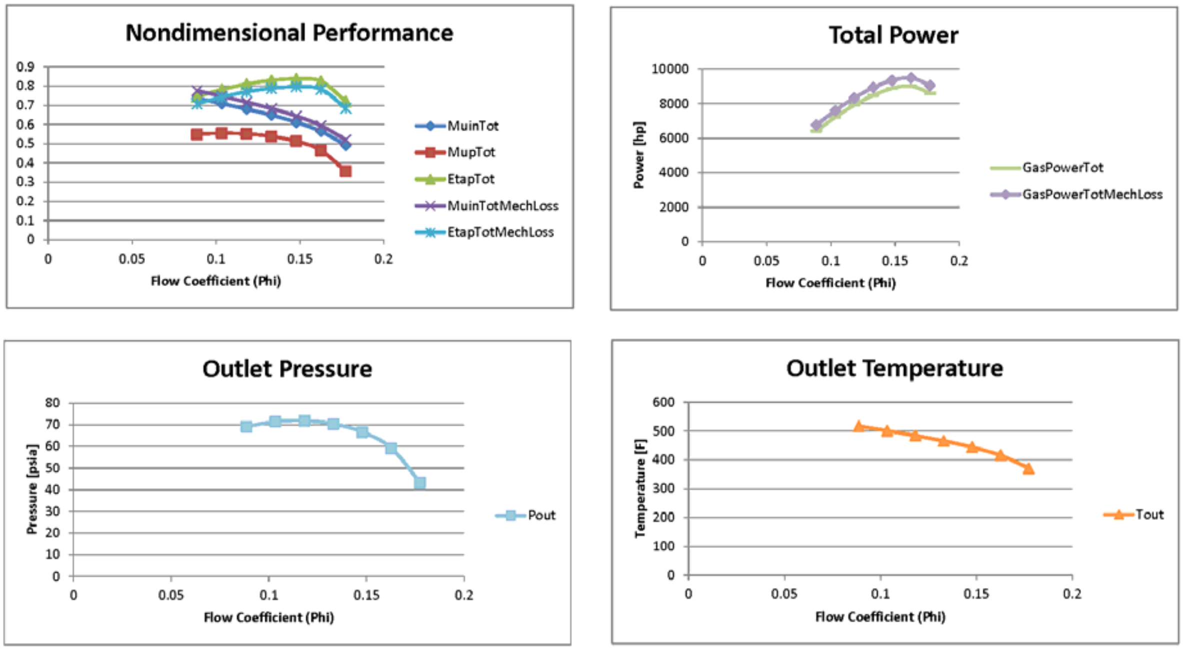


Figure 2, Typical output in non-dimensional and dimensional form for 4 stage air compressor.

RMS WELCOMES

By Kathy Ehasz

CHARLIE "CHOT" SMITH

Shop Manager / Field Services

Thirty years of professional growth experience with Axial and Centrifugal Compressors, Gas Turbines, Steam Turbines, FCCU Gas Expanders and other rotating equipment. Extensive experience and technical expertise encompassing Alignment, Assembly, Balancing, Installation, Manufacturing and trouble-shooting of Turbomachinery. Held positions with Ingersoll-Rand – Turbo Division, GE Oil & Gas, and Dresser-Rand, Inc.

ROBERT CURRY

Expeditor

Bob has 20 years of experience in supply chain management, including purchasing, logistics, order management, scheduling and expediting. This experience includes 4 years in the turbomachinery industry. Previously held positions at Dataflex, GE Capital ITS, BayGroup International and GE Conmec.

CHARLIE GANO

Shipping / Receiving

Charlie has 36 years of experience in the Turbo Machinery field with Ingersoll-Rand, GE Conmec and Dresser-Rand. Held previous positions of manufacturing shop expediter, production planner, manufacturing scheduler and supervisor of shipping and receiving.

JOHN CERIMELE

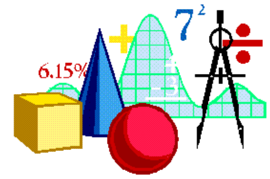
Shop Assembler

John has 31 years spanning Power generation forge machining, heavy nuclear forge machining, and large industrial motor repair,. Extensive dynamic balance rotor work. Held position with Bethlehem Steel, Crowder Jr Company, CONMEC, and turbomachinery for RMS in early stages.

QUALITY CONTROL

By Bob Dehart ASQ CQT

Our objective is to ensure that our measurement processes have adequate resolution and are both precise and accurate.



Capturing part geometry by traditional methods such as surface plate and hand tool measurements is time consuming and subject to inaccuracies. Solution? Add a FARO arm PCMM (portable coordinate measuring machine).

Blue tooth and Wi-Fi capabilities allow our PCMM to plug in anywhere (or not) and go everywhere.

Uses include checking relative angular orientation of keyways on shafts, capturing three dimensional geometry of blading and establishing process parameters for the peening of steam turbine rotor discs.

THE OBJECTIVES:

Define geometry and capture it in the form of a drawing or model.

Measure to verify design intent. Inspect manufactured parts to manufacturing drawings**.**

Analyze the impact of out of tolerance parts on schedules and resources.

Improve / enhance methods of measurement, documentation and evaluation.

Control processes, measuring methods and techniques to hold gains and to stimulate and propel results.

TURBOMACHINERY SYMPOSIUM 2011

By Dave Gober

RMS was an active participant in the 40th Turbomachinery & 27th Pump Users Symposium held September 12th to 15th in Houston, TX. We made a significant commitment with 10 RMS attendees ! Our theme this year was "Reverse Engineering" with Faro Laser ScanArm demonstrations. We hope you had a chance to stop by our booth.

The 2011 Symposium was another outstanding event for our Turbomachinery and Pump communities that was well represented with good attendance by both the visitors and hosts. We at RMS always enjoy meeting and interacting with both old and new friends and are optimistic for a continuing improved business climate as we enter 2012.

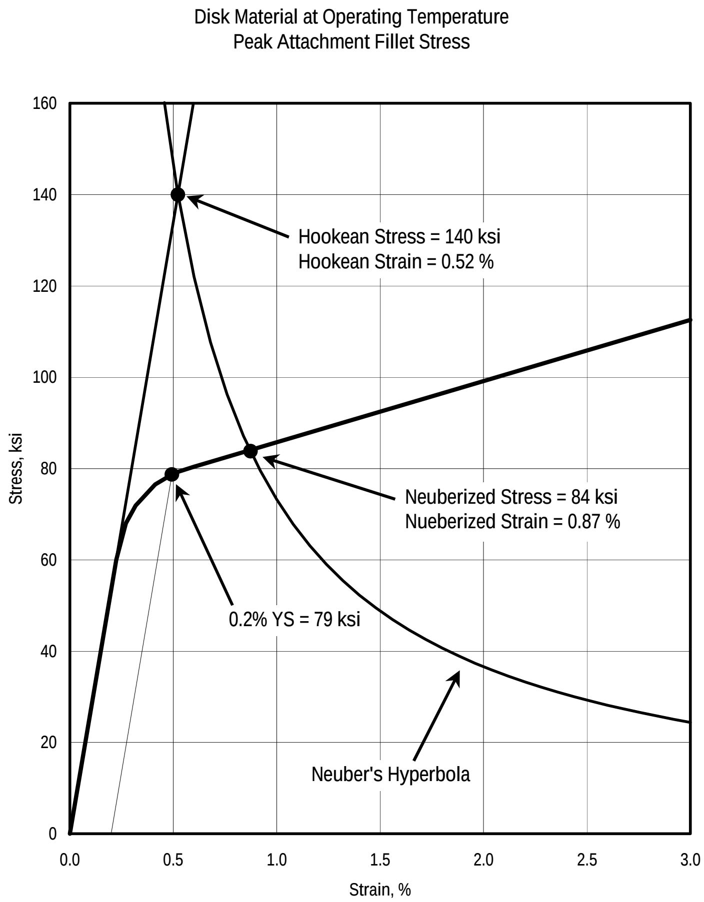
Thank you and kudos to Martha Barton and her staff for a job well done ! We look forward to seeing everyone in 2012.

NEUBER'S HYPERBOLA

By William Sullivan, PE

It is not unusual in the design of rotating turbomachinery components to encounter stress levels that exceed the tensile yield strength of the material at the metal operating temperature. This is particularly likely in the blade attachment areas of high-speed turbomachines. A high-speed machine is a machine where the blade tip velocities approach or exceed 1,000 feet per second.

Fortunately, the areas where the stress levels exceed the tensile strength are usually very localized (typically associated with fillets) and the "far field" average stress levels are well below the tensile yield strength. Therefore, there is rarely any risk of immediate fracture. However, there may be a risk of crack initiation in these highly stressed locations due to low cycle fatigue (LCF).



The stress analysis carried out during the design phase of blade and disk attachments use Hookean material properties. Hookean properties assume that there is no elastic limit and, therefore, no plastic deformation. In other words, during the calculations, the modulus of elasticity is assumed to extend indefinitely.

Once the analyst discovers that the local stress levels exceed the tensile yield strength of the material, they will want to get a rough idea of just what the local stress (and strain) levels really are. To do this quickly Neuber's rule is often used. Simply put, Neuber's rule is:

$\sigma \cdot \varepsilon = c$

Where:

σ = Stress, force/area
ε = Strain, deflection/length
c = Constant

This is the equation of a hyperbola and in this application it is called Neuber's hyperbola.

An application of Neuber's hyperbola can be seen in Figure 1. On Figure 1, a stress vs. strain plot for the material at operating temperature, an extended elastic modulus of elasticity and Neuber's hyperbola are plotted.

The calculated stress (σ) is plotted on the line representing the (extended) elastic modulus of elasticity. The elastic strain (ε) is, σ/E where E is the elastic modulus of elasticity.

Once the Hookean σ and ε are determined, the hyperbolic equation (i.e., Neuber's hyperbola) $\sigma \cdot \varepsilon = c$ is plotted.

The intersection point of Neuber's hyperbola with the stress vs. strain plot of the material is the corrected (Neuberized) stress vs. strain. Note that the stress value has decreased but the strain value has increased. At this point the analyst will compare the plastic (Neuberized) stress level with the tensile yield strength of the material. If the plastic stress is below a certain limit (which depends on the specific application of the turbomachine) then the risk of LCF crack initiation is acceptably low and no additional analyses are required. If the plastic stress exceeds the limit, then a complete elastic / plastic analysis will be conducted and the actual LCF life determined.

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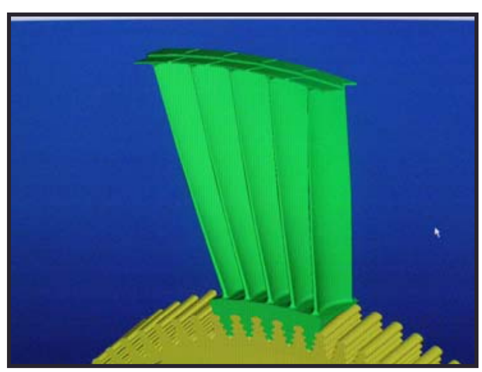
RMS TO PRESENT AT THE INDUSTRIAL APPLICATION OF GAS TURBINES

By Kathy Ehasz

Rotating Machinery Services, Inc. will be presenting at the Industrial Application of Gas Turbines (IAGT) in Baniff Alberta on October 17th—19th. The symposium draws an international audience while providing a forum for issues of special concern for the Canadian gas turbine operating environment.



The Symposium combines informative technical papers and presentations on the critical issues for industrial gas turbine operations – both power generation and oil and gas applications.

For more information on this conference you can visit their website at www.iagtcommittee.com