ROTATING MACHINERY SERVICES, INC.
VOLUME 10, ISSUE 1
JANUARY - MARCH 2014

THE FINISH LINE

PHONE 484-821-0702 FAX 484-821-0710 WWW.ROTATINGMACHINERY.COM

BUILDING EXPANSION

By Frank Marrone

We are very excited about the continuous growth of our company and cannot wait to get access to our 9000 sq. ft. shop expansion and 5500 sq. ft. 2 story office addition.

The shop addition will provide ample space for added capacity with its high bay and new 35 ton Crane with an additional 15 ton trolley. Our two story office addition will provide 15 new offices, 1 small conference area and 2 additional bathrooms on the first floor. The second floor provides additional space to be configured as offices, training or conference areas to best suit our business requirements.

Progress with construction was a real challenge throughout the winter. This year in the northeast brought snow nearly every week from January through February totaling over 60 inches of accumulation. We were well underway with footers in place by the end of December. Structural steel and walls were installed during January with roofing following in early February. Now under roof, all the real fun starts with plumbing, electrical and walls being roughed in and taking shape through March.

Despite all the weather, our contractor is pushing to have us in our new addition by the second week of May. It has been thrilling watching it all come together. The added capacity and capabilities will enhance our customer experience with improved work flows.

We look forward to having you visit us in the near future.

What's Inside

RMS IMPORTANT NUMBERS

HOUSTON SALES OFFICE:
Kurt Diekroeger
281-340-8520 (O)
713-898-1015 (C)

David Cummings
281-340-2056 (O)
832-444-0592 (C)

TENNESSEE SALES OFFICE:
Mike Spangler
865-981-9831 (O)
484-896-8438 (C)

RULES OF THUMB - MATERIALS

By Neal Wikert

High Temperature Alloys

Incoloy 800 - 30% Nickel, 20% Chrome material that offers good corrosion resistance, has high strength and resists oxidation, carburization and other harmful effects from high temperature exposure. The chromium imparts the resistance to oxidation and corrosion. The nickel maintains an austenitic structure so that the alloy is ductile. The nickel also contributes resistance to scaling, general corrosion and stress-corrosion cracking.

Inconel 718 Inconel 718 has some limitations from a corrosion-cracking standpoint above 400 degrees F. in certain environments namely salts and chlorides.

Inconel 718 for use as pins in steam turbines should be ordered to AMS 5663H, which calls for a RT minimum yield of 150 ksi, 185 tensile and 12% elongation, 15% R of A, and 1200 deg. F properties of yield 125, tensile 145, elongation of 12%, and an R of A of 15%.

Inconel 600 Inconel 600 can be used in the as-welded condition. There is no requirement for a PWHT to get mechanical properties. However, a stress relief would be required if the part is subject to stress corrosion cracking or for dimensional stability. Inconel 600 is non magnetic at room temperature.

AISI 347 SS The material will generally need to be stress relieved to accomplish dimensional stability.

Moderate Temperature Alloys

AISI 403 SS The difference between 403 and 410 stainless steel is the amount of Silicon.

403 SS (.5 max) 410 SS (1.0 max)

The silicon content is what forms the delta ferrite in the steel. At higher silicon content, the delta ferrite becomes extensive and networked. The delta ferrite is what causes stringers in the material.

403 Stainless steel has a propensity to embrittle at temperatures above 900 degrees F.

AISI 310 SS - 25% Chrome – 20 % Nickel grade is known to embrittle in high temperature service and is rarely selected for turbine applications. Above 800 deg. F. the precipitation of carbides at grain boundaries reduces corrosion resistance by promoting inter-granular attack. This phenomenon is known as "**sensitization**". 300 series stainless steels are also subject to stress corrosion cracking, particularly in the presence of chlorides.

LET IT SNOW!

By Dirk Paraschos

As we are all aware the cold weather and record breaking snow fall in the northeast this year caused many problems for businesses. Company closures, transportation delays, power outages and lots and lots of snow removal.

Almost everyone here at RMS is looking forward to spring weather. I on the other hand happen to be an avid skier and look forward to the start of winter. The earlier and more it snows the better for me.

This year has been exceptional for skiing in the northeast. The ski trails have been covered with good snow not the usual hard packed icy conditions we normally experience. We actually had, at times, 12" of powder like conditions to ski. My only complaint would be that the weather remained so cold for so long all season that we had very little opportunity to ski in spring type conditions. On the bright side, the local mountains are planning on being open until the middle of April. Hopefully, I will see you on the mountain.

ROTATING MACHINERY SERVICES - PRESS RELEASE

By Dirk Paraschos

Rotating Machinery Services, Inc. was recently awarded a project to modify and overhaul a 16,000 horsepower axial compressor for a major Pennsylvania refinery. The work was performed during a major process unit shut-down, which began in early February.

The upgrades and modifications to the equipment required the specialty engineering and shop skills provided by RMS. The major challenge was to complete the work scope in the short time frame allowed to meet the restart deadline. Accomplishing this task required detailed scheduling, engineering, and the preparation of all of the new components required to complete the overhaul.

Once the axial compressor spare rotor arrived at RMS, modification and overhaul work began in earnest. The work scope included disassembling the customer's spare rotor, machining and replacing the two rotor end-shafts, installing new 1st and 2nd stage discs, restacking the 12-stage rotor, installing new 1st and 2nd stage blades, and balancing the completed rotor assembly.

The full compressor was dis-assembled and inspected. RMS installed new inlet guide vanes, new 1st and 2nd stage stators, modified the bearing assemblies, and performed a precision-grind of the rotor blade tips for an optimum fit to the casing. The machine was then reassembled and shipped to the refinery for reinstallation, supervised by RMS. The project was completed successfully and on-time, meeting all of the customers' requirements.

RMS strives to continuously increase our capabilities to better serve our customers. We are presently in the process of expanding our machining capabilities, and shop space. The 9,000 square foot expansion of our shop will provide us the ability to work on larger and more complex equipment.

CONTROL VALVE SETTING

By Scott MacFarlane

There are two main styles of valve lift arrangements for multi-valve steam turbine valve racks. They are the camshaft arrangement and the straight lift bar arrangement. See Figure 1 and Figure 2 respectively for a reference. The camshaft configuration utilizes cams, bearings, levers, and bushings which are connected to the camshaft to regulate the position of each valve. An actuator drives a rack and pinion connected to the camshaft to dictate the position desired by the governor. The lift bar configuration utilizes a bar internal to the steam chest, with all the valves plugs and stems attached. They are all lifted together by an actuator through various linkages. However, the length of each valve stem is set at different heights for the valves to open in a desired sequence. The control valves and sequencing of the valves are crucial during start up, shut down and normal operations.

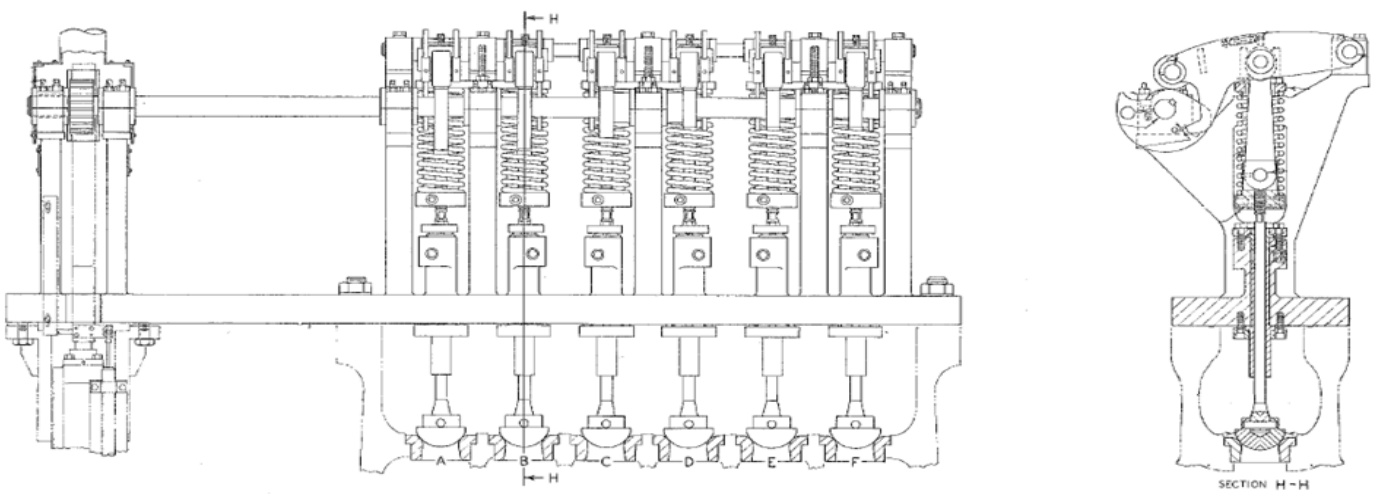


FIGURE #1

The main role of the control valves is to regulate the flow of steam into the turbine in a controlled and specific manner. For an individual vale, the lift height is linearly proportional to the amount of steam flow into the turbine over a limited range. After this range a dead band will occur if no additional steam enters into the system through the other valves. When the governor hits a dead band and calls for more power, there is little or no response to change in valve lift resulting in hunting. To avoid these dead bands, sequential valve configurations allow overlap between each valve to maintain a near linear flow versus lift ratio. If the overlap between valves is too great, a small change in lift can result in large changes in turbine power. Both the dead band and excess overlap scenarios can result in the governor no longer being able to effectively control the turbine. The flow versus lift ratio is commonly referred to as the regulation or R-Line. An example of a typical five valve regulation line can be seen in Figure 3.

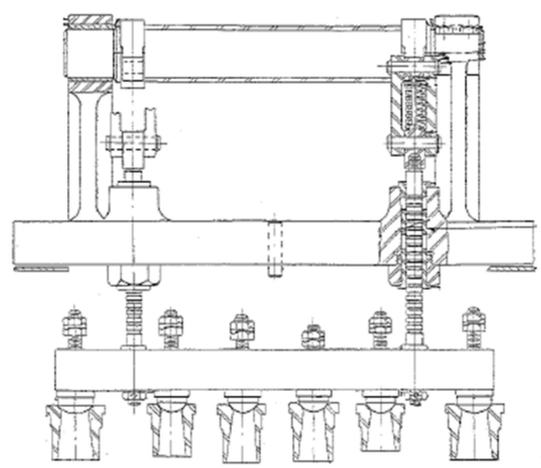


FIGURE #2

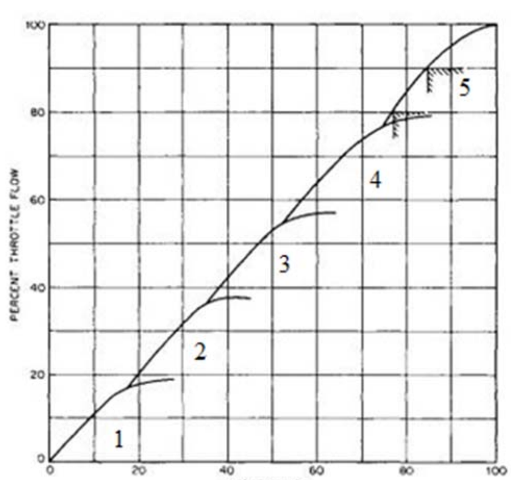


FIGURE #3

CONTROL VALVE SETTING *(Con't)*

By Scott MacFarlane

A good regulation line is established when the valve overlaps are set at the governing point of flow versus lift configuration. The pressure drop at the governing point varies by valve type and size but is typically between 7% and 13%. As an example the pressure drop for a valve fully open is approximately 2%.

The valve is considered fully open when the surface area of the valve seat opening equals the surface area of the lift cylinder. See Figure 4 for a reference.

The approximate fully open lift height can be calculated based on the following equations.

Surface Area Valve Seat Opening = $(\pi D^2) / 4$

D is the diameter of the valve seat opening.

Surface Area Lift Cylinder Exposed = πDH

D is the diameter of the valve seat opening.

H is the height the valve has lifted.

Setting the two equations equal to each other yields the following expression:

Approx. Full Open Valve Lift Height (H) = D/4

Understanding the sequencing and background of your valves can help prevent unstable operation. At each turnaround the valve height settings should be checked and if necessary, reset to design conditions.

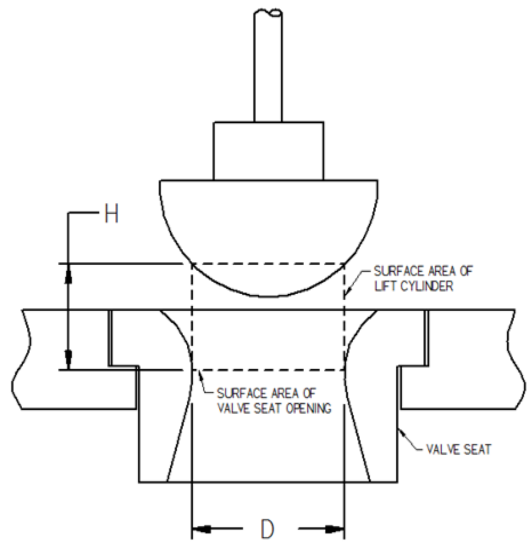


FIGURE #4

GOODMAN DIAGRAM

By William Sullivan, P.E.

The Goodman diagram is a chart used to show graphically the risk of high cycle fatigue failure of a component. For RMS, most Goodman diagrams or, more correctly, modified Goodman diagrams, address stress levels in blade roots, disk attachments and at the fillets where airfoils meet the blade root platforms.

A typical modified Goodman diagram for a rotor blade root is shown in Figure 1. The "Design Envelope" of this diagram shows both the maximum allowable alternating stress to avoid high cycle fatigue cracking and the maximum allowable steady stress to prevent excessive yielding across the necks (or to ensure adequate creep rupture life in high temperature applications).

The steady stresses are plotted along the X-Axis of the Goodman diagram. These stresses, which are mostly due to centrifugal load, are averaged across the necks of the attachment (See Figure 2).

The alternating stresses are plotted along the Y-Axis of the Goodman diagram. The alternating stresses, which are based on peak stresses at the fillets, are produced chiefly by the change in gas load as the blades pass through the wakes of the upstream vanes. For design work, the alternating stresses that would be caused by cycling the full gas load are plotted. This is done to ensure that there is sufficient margin for both off-design operation and unforeseen resonances. For failure analyses, much lower load changes are assumed, usually about 10% of the full gas load, to better replicate the actual vane wake passing effect.

GOODMAN DIAGRAM (*Con't*)

By William Sullivan, P.E.

The uppermost diagonal line on Figure 1 is the Goodman line. The line is drawn from the fatigue strength of the blade material on the Y-Axis to the engineering ultimate tensile strength (UTS) on the X-Axis. For steels and nickel base alloys, the fatigue strength is the stress level at which the fatigue life of the material is essentially infinite (greater than 10^6 cycles). As a rule of thumb, the fatigue strength is about ½ of the UTS for these materials.

The fatigue strength of a material applies to smooth, defect-free specimens. Sudden changes in thickness, machining marks, internal flaws, etc. all reduce the effective fatigue strength. The effective fatigue strength for turbine disks and blades averages about 60% of the perfect specimen fatigue strength. The actual reduction depends on the specific application, material and geometry.

The final design limit is based on a combination of expected load variation, material property variation, the presence of corrosives in the gas, the effect of wear and experience. After taking these additional factors into account, the design limit on alternating stress could range from 30% to 50% of the perfect specimen fatigue strength.

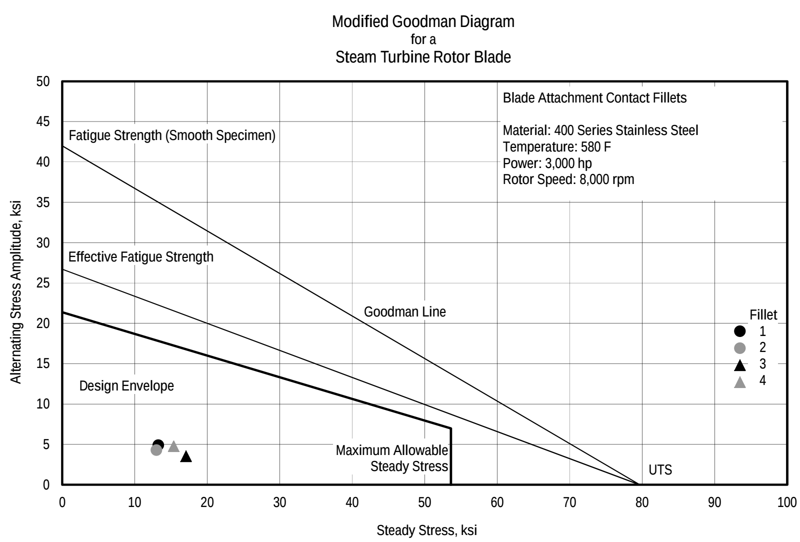


Figure 1

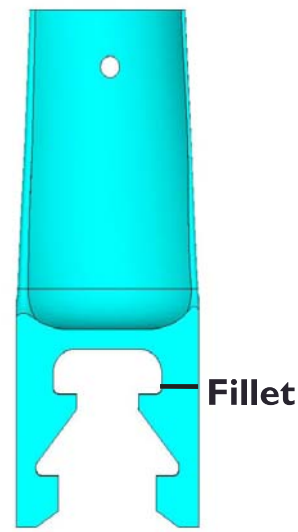


Figure 2

FARO ARM TECHNOLOGIES

By Dean Curtis

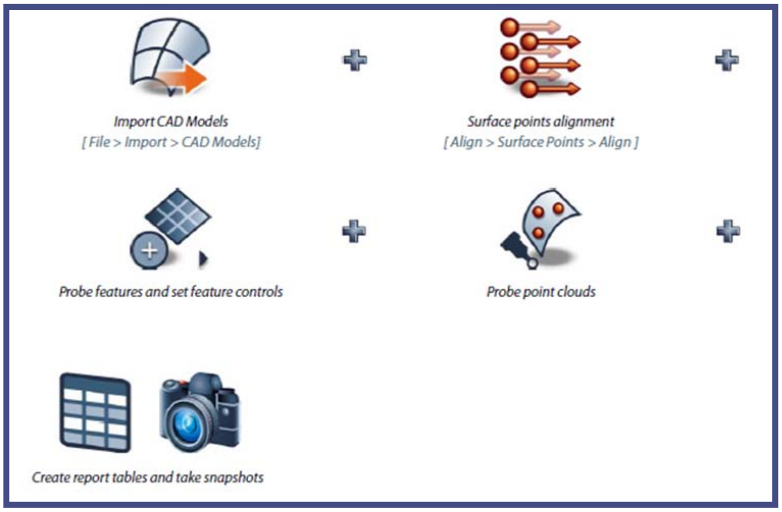
Our goal at RMS is to exceed customer expectations. We say what we can do, and we do that and then some. One of the most important components of insuring quality service for our customers is providing accurate and precise dimensional information as the basis of decisions to rework, re-create, or use as is existing parts. Our reverse engineering capabilities also depend on accurate information about existing initial conditions to provide our analysts with good input for their FEA models and subsequent decisions so they can produce accurate models of the equipment's as built performance. As time permits we also use the Faro arm to document ancillary parts to better be able to meet our customer's future needs. We maintain an extensive inventory of both virtual and real parts to rapidly respond to our customer's requirements.

To that end we use a Faro arm Coordinate Measuring Machine as one of our many inspection tools. The Faro arm is unique in its capability to quickly and precisely map the coordinates of a part within approximately .0014". We are then able to mathematically reproduce parts in software using the Faro arm and model it in SolidWorks where it is available for a variety of purposes such as documentation, reverse engineering, Finite Element Analysis, vibration studies, and ultimately, tool path generation.

FARO ARM TECHNOLOGIES *(Con't)*

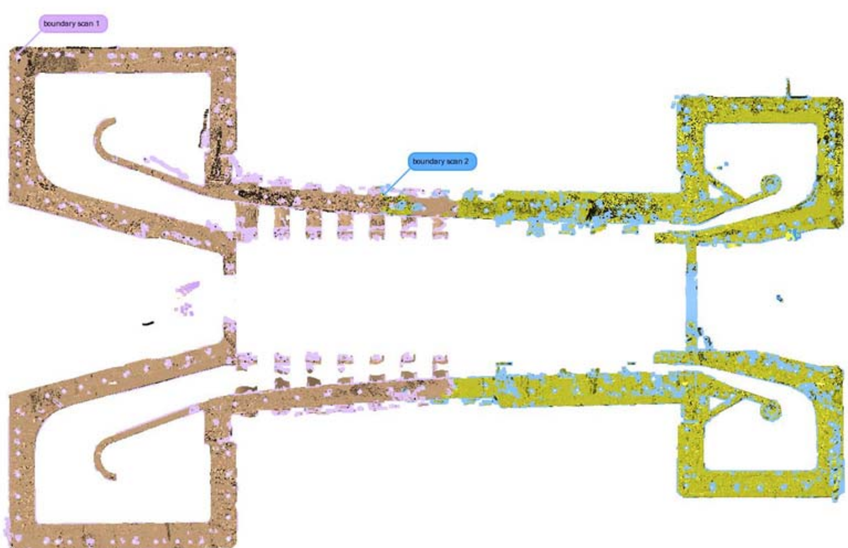
By Dean Curtis

The basic workflow for inspecting a part with the Faro arm is as shown below:

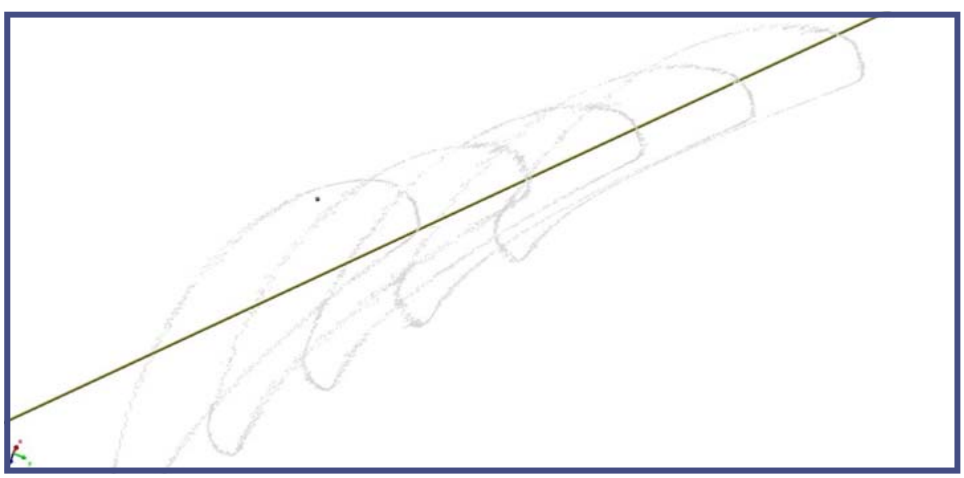


We have different probes available to us to measure surfaces, and features. We have a non-contact laser probe capable of recording a tremendous number of points per second, contact probes that provide fast and accurate checking of planar, spherical, cylindrical, toroid and other geometric features.

The laser probe is particularly useful for modeling flow paths and other irregular compound curved surfaces not easily defined. It is also a fantastic tool for modeling large bodies. For example, we recently scanned an entire flow path for a Frame 3 size Axial Compressor in for a re-rate. This approximately 12' overall length surface was modeled within .002 inches in about 4 hours.



Using the contact probes we can quickly document complex part features for inspection, re-work, or reverse engineering. Here is a 3mm probe scan of a first stage rotor blade leading edge. You can clearly see the leading edge erosive wear caused by catalyst particulates re-entering the air stream. This raw data was ultimately used in real time to drive the decisions regarding the re-rate of this machine eliminating long lead times, and generating a faster, less expensive, more efficient, and durable machine that is performing better than expected.



It is the integration of this type of technology with our highly experienced team of professionals with collectively over a thousand years of turbo machinery experience that enables us to provide our customers with industry leading quality, performance, and turnaround times. We consistently improve our processes to maintain our position at the forefront of our industry.

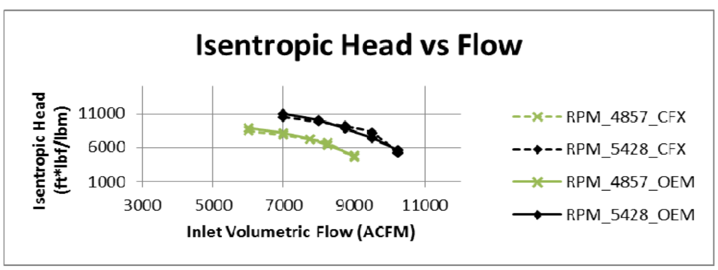
COMPUTATIONAL FLUID DYNAMICS

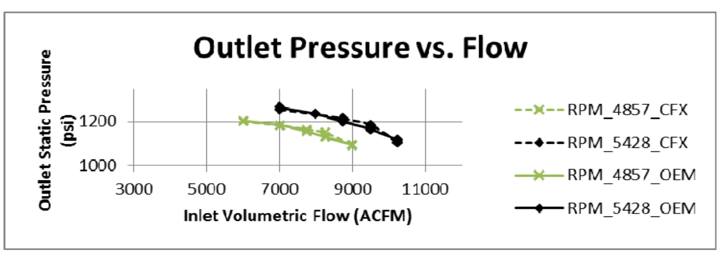
By Ryan Montero

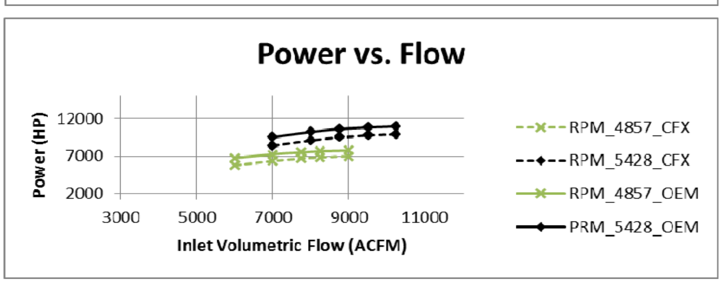
Current Computational Fluid Dynamics (CFD) software packages provide the user with the capability to accurately model the flow field through even the most complex of flowpaths. The flow is simulated by implicitly solving the viscous Navier-Stokes equations, vector equations which define fluid motion, over the domain specified by the user. Higher order CFD software has become increasingly popular as an engineering tool over the past few decades. Although the Navier-Stokes equations were produced in the 19th century, the computational power required to carry out the numerical solution has only become widely affordable recently. CFD software packages have proven useful as design tools in the Aerospace & Defense industry, the automotive industry, and many other fields where fluids are used for power generation. For turbo machinery, CFD analysis gives the user accurate predictions for flow conditions throughout the machine and expected machine performance. It also provides the ability to analyze and research more complex issues such as blade erosion and deposition.

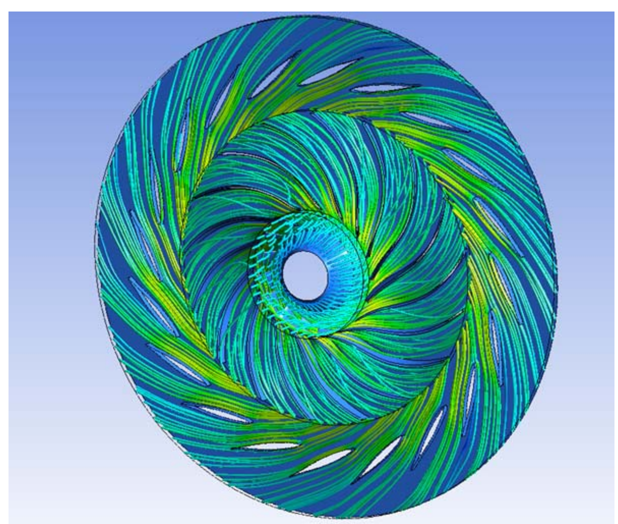
At RMS a performance study was done on an existing centrifugal compressor stage including the intake casing, rotating section, and diffuser. The goal of this analysis was to anticipate machine performance using the CFD software package called CFX. The parameters that were calculated by CFX were to be compared to existing values on a performance map of the existing machine in order to determine the OEM power map's expected intake and diffuser efficiency as well as expected mechanical losses. The CFX model consisted of the existing rotating section, and a simple intake and diffuser. Machine speed and mass flow rate were varied and relevant quantities such as power, outlet pressure, and thermodynamic head were recorded for each point on the speed line. These recorded values were then overlaid, for comparison, on top of the existing OEM map. It is worth noting that the power calculated by CFX is gas power only and does not include mechanical and other parasitic losses.

As anticipated the results showed that while the outlet pressure and isentropic head values matched well between the CFX analysis and the OEM map, the power plots were significantly different. The OEM map values for required power were consistently larger than the gas power values calculated through CFX. The difference gives the engineer useful information on how the OEM estimated mechanical and other parasitic losses.









NEW EMPLOYEES

By Kathy Ehasz

DAVID CUMMINGS
REGIONAL SALES MANAGER

David joins RMS as our Regional Sales Manager. He will be working out of our Houston office and covering territories in the southeastern US and parts of Houston.

David graduated from Texas A&M University with B.S. in Mechanical Engineering in 2010. He was previously part of a major turbomachinery OEM's management rotational program. The positions he held in the program were package engineer, project manager, and product manager. He has experience with centrifugal and reciprocating compressors, steam turbines, and auxiliary systems. David is looking forward to meeting and working closely with our customers to ensure all their Turbomachinery needs are met.

DEAN CURTIS
3D CAD DESIGNER

Dean Curtis has joined RMS, Inc. as our SolidWorks specialist. He is a recent graduate from Northampton Community College with an Associate's degree in Computer Aided Drafting and Design. He has over ten years of experience operating and maintaining turbo machinery at various altitudes and attitudes primarily on and above western Alaska. He brings a diversified portfolio of experience gathered in industries from aviation to water system technologies. He looks forward to continuing his career at RMS.

BLAINE CHRISTMAN
MACHINIST

Blaine has 25 years of experience which started at Ingersoll Rand (Allentown). He has also worked for CONMEC for 16 years, Precision Roll Grinders and Shiller Pfieffer (General Machine). Blaine looks forward to continuing his career with Rotating Machinery Services, Inc.

COLLEEN HERCIK
PURCHASING ADMINISTRATOR

Colleen has joined the RMS team as the Purchasing Administrator/Indirect Buyer. She brings 16 years of management experience as an Account Operations Manager where she was responsible for planning, directing and coordinating contracted operations for assigned accounts. Colleen is looking forward to beginning her new career at Rotating Machinery Services, Inc.

KERRY FRACK
NDT TECHNICIAN

Kerry has 35 years' experience in the NDT Field as a Level II in RT, MT, PT, UT & Comprente RSO. He was Vice President and part owner of a local NDT Co. in the Allentown area for 24 years. He has worked in the petroleum, chemical, pharmaceutical, pipeline, refinery, buildings, bridges, aerospace, navship & Asoue vessel industry over the years. He has joined the RMS Team to set-up their in house NDT Inspection Program. He looks forward to using his skills to further enhance RMS's capabilities.

WELCOME RMS NEW EMPLOYEES *(Con't)*

By Kathy Ehasz

MATTHEW MAKOS
SENIOR ACCOUNTANT

Matt has joined the RMS team as their Senior Accountant. Matt has over 13 years of accounting experience. He moved back to Bethlehem in July 2013 after residing in Anchorage and Kenai, Alaska for the last 23 years. He worked for Coghill Group PC (formally Mikunda Cottrell & Co. CPA's) doing small business accounting and providing general ledger support to the tax department until joining the RMS Team.

CHRISTINE DIAZ
BUYER / PURCHASING COORDINATOR

Christine Diaz has joined the RMS, team as a Buyer/Purchasing Coordinator. She has over 7 years' experience in Buying with FLSmidth and looks forward to continuing her career and growing in experience here at RMS. She is excited to be part of a growing company and looks forward to being a part of its future Success.

JEFF BARTHOL
SHOP ASSISTANT

Jeff has joined the RMS team as a shop assistant. Jeff brings with him over 16 years experience in the construction industry both residential and industrial.. His experience includes welding, mechanical, concrete, woodwork and operating equipment and large machinery.

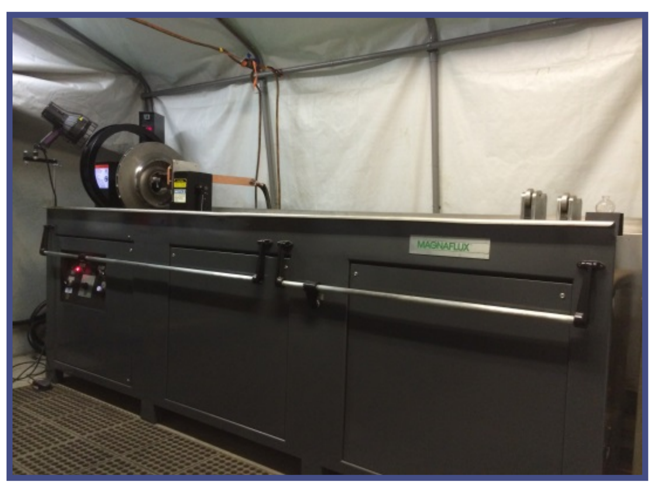
Jeff looks forward to being part of the RMS team.

NON-DESTRUCTIVE TESTING CAPABILITIES

By Tom Edwards

Following through on our plan to develop in-house **N**on-**D**estructive **T**esting capabilities, RMS recently purchased, installed and calibrated a Magnaflux 6,000 amp wet horizontal magnetic particle inspection unit. This unit is a three phase unit that provides maximum magnetization for finding surface and sub-surface defects. This equipment is used to inspect both new and existing components to ensure they meet RMS' and our Customers' acceptance criteria before being placed into service.

Further supporting our growth plan, we are also pleased to announce that Kerry Frack has joined the RMS team as our Lead NDT Technician. Kerry brings over thirty years of magnetic particle inspection, liquid penetrant inspection and radiographic examination experience to the organization. Besides managing the day to day NDT inspection requirements for our Customer's, Kerry will be providing NDT training and qualifying additional NDT technicians.



Magnaflux D-960R MPI

POWER RECOVERY TRAIN (PRT) ROUND TABLE IN NOVEMBER 2014

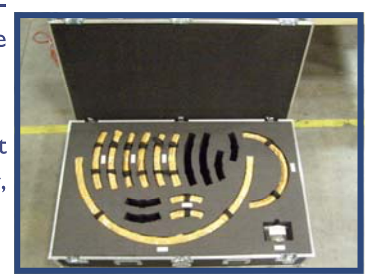
Rotating Machinery Services will be hosting a Power Recovery Train Round Table in November 2014. A welcome reception will be held on Wednesday, November 12, 2014. The round table will be held on Thursday, November 13 and Friday, November 14.

If you are interested in attending, you can download the registration form on our website at Rotatingmachinery.com/conferences or you can contact Don Shafer or Kathy Ehasz at 484-821-0702. If you have a topic, question or problem area for the Round Table, please email Don Shafer at dshafer@rotatingmachinery.com.
There is limited seating so please RSVP as soon as possible!

SPARE PART KITS BOXES

RMS offers various solutions for your spare part storage. Two of those solutions are part kit boxes and rotor storage containers.

The parts kit boxes are utilized for the cataloguing and storage of consumable spares used during machinery overhauls. The kits are customizable as required by the customer, and typically include the eye and interstage labyrinths, shaft end labyrinth seals and bearing case oil wiper seals. Some users have elected to include the journal bearings, thrust bearings, soft gaskets and small hardware.



The kits can be taken to the machinery deck or to the overhaul shop to support the machinery overhaul. Then you can either inventory the kit and order replacement parts, or send the kit box back to RMS for us to inventory and replenish it for you.

Each part can be preserved for long term storage within the kit box, and labeled with the part number. A laminated assembly drawing is included with each box showing the part number, location of the part on the machine and storage location within the kit box.

Having a specific storage location for each part, makes it easy to see what parts have been used. Part kit boxes can be supplied for your compressors, steam turbines, expanders, power turbines and gas turbines.

ROTOR STORAGE CONTAINERS

Spare rotors are often stored on metal stands or wooden crates making them susceptible to handling and environmental damage. There is an easy way to protect this valuable investment. A rotor storage container can be custom designed to fit your rotor. Utilizing clamps to secure the rotor in a cradle, these containers can be stored horizontally or can be stored vertically to reduce storage space and potential shaft bowing.

Containers come complete with nitrogen purge, vents fittings, and drains, are sandblasted, then primed with corrosion resistant epoxy, and finish coated with an acrylic polyurethane for long life.

For more information on the Spare Parts Kits or Rotor Storage Containers, please contact Herb Fischer or Jim Campana at 484-821-0702.

ROTATING MACHINERY SERVICES, INC.

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Bethlehem, PA 18020
Phone: 484-821-0702 / Fax: 484-821-0710
www.RotatingMachinery.com

PRODUCT LINES

AXIAL COMPRESSORS •
CENTRIFUGAL COMPRESSORS •
EXPANDERS • GAS TURBINES •
POWER TURBINES • STEAM TURBINES

RMS SUPPLIERS GENEROUS SUPPORT!

By Frank Marrone

Rotating Machinery Services, Inc. participated in the American Red Cross Lehigh Valley Grand Prix Fund Raiser Sunday, March 16th. Our team raised the second highest amount which could not have been done without our Suppliers support and sponsorship. This event is one of the American Red Cross of Lehigh Valley and Executive Forum of Lehigh Valleys largest fund raisers netting over $22,000. The donations raised will provide food and shelter in emergencies, assist members of our armed forces and their families, teach lifesaving skills and help collect precious blood and blood products.

Race starting positions were selected based on the amount of donations collected by each team. As a result of our Suppliers generous donations TEAM RMS started in second position.

The race is a 3 hour Enduro format that included 12 teams with 5 drivers per team requiring 9 driver changes and one gas stop car change. Finishing in 8th, we feel we were winners thanks to our Suppliers generous support. We'd like to thank:

Alliance Mechanical Insulation • Ameridrives • Amity Fabricators • Astro Machine Works, Inc. • B&G Manufacturing • Bearings Plus • Beaver Tool • BWC Technologies • Choice Precision Mancine, Inc. • Eastern Alloy • Frasier • Fusion • Hartman Enterprise, Inc. • James E. Dooley Co. • Johnson Brass • Joirles Office Supplies • Neutech • Pacesetters • Precision Roll Grinders • System 22 • Tooling Specialist Inc. (TSI)

RMS is active in many community programs and this is only one example of our involvement. We look forward to next year's event as RMS will certainly strive to be the top fund raiser for this forum.