



RMS
Rotating Machinery Services, Inc.

The Finish Line

VOLUME 12

ISSUE 2

APRIL - OCTOBER, 2016

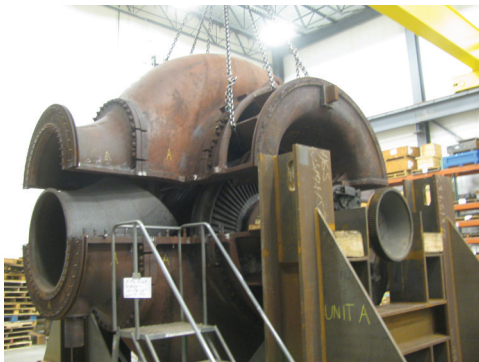
RMS NEWS

WORTHINGTON ER224 JET GAS EXPANDERS

By Scott MacFarlane

RMS was contracted to refurbish two complete Worthington ER224 Jet Gas Expander (JGE) assemblies. The JGE's, driven by Pratt & Whitney GG4 aero-derivative engines, were formerly used as power generation "peakers" but are repurposed and will be used for "Black Start" emergencies in the future. Under RMS Field Service direction the expanders were removed from service in November/December of 2015. RMS Field Service returned in May of 2016 to direct the reinstallation. As a customer specification, each expander was to be returned in a zero hour condition at 95% OEM specifications.

As part of the refurbishment, the expanders were completely disassembled including the rotors being destacked and debladed. All components of both expanders were completely disassembled and inspected in RMS' shop. Their condition was documented and sent to the customer with a recommended repair workscope. Once approved and due to the tight schedule, RMS quickly devised a strategy for around-the-clock engineering, repairs and reassembly.



Upon initial inspections, several components from both expanders were identified as being in critical condition and needed to be either repaired or replaced. Every major casing component required extensive repair through blending, remachining, weld repairs, metal stitching and/or stop drilling. In addition, all outer casing hardware was deemed non-reusable and needed to be replaced. Because of the CNC machining capability throughout the RMS shop, we were able to replace over 700 custom studs and several other crucial components to help complete the rebuild. All in all, almost every component on each expander was either repaired or replaced by RMS.

The Worthington ER224 JGE's were completely reassembled within OEM specifications and reinstalled in the field in May of 2016. The refurbished JGE's had successful startups with vibration levels for both expanders well below 1mil.

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TECH TALK

AC COMPRESSOR TRAPPED BUSHING SEALS

By Rob King and John Decker

RMS was recently contracted by a major US refinery for field engineering support during a trapped bushing seal (TBS) change out. Utilizing our previous 30 years of OEM TBS seal operation and maintenance experience, the seal components and installation process were validated, seals installed and compressor restarted to resume operation. This series of articles was developed as an overview of the TBS.

The trapped bushing seal is a liquid film compressor seal first developed and patented by the Allis Chalmers Corporation in the 1960's with continued design improvements by the AC Compressor Corp. through the early 1990's. With the market for new equipment shifting to dry gas seals in the last twenty years, the trapped bushing seal was slowly phased out from new installations. Since the seal design was used with good success over a wide window of time, there remains a sizeable fleet of AC Compressor Corp. equipment still utilizing the dependable trapped bushing seals. While replacement parts for trapped bushing seals are available, the necessary technical support and engineering expertise, from both customer internal and OEM sources (when the inevitable issues arise) becomes more difficult to find as maintenance intervals grow longer between outages.

In order to become familiar with the TBS, a brief introduction to the main components is provided in this newsletter article, while later article segments will focus on seal operation and the auxiliary support systems. The major parts of the seal, listed in order of installation are the process labyrinth, stator, seal impeller, stepped dual bushing, and the seal cage.

The process labyrinth is located furthest inboard and thus installed first. It functions as a typical pressure reducing element, separating the process from the seal. It may have provisions for application of a buffer gas to a central located annulus. Buffer gas is used in applications where it's undesirable for oil vapors (inherently present in the inboard drain/vent cavity) to diffuse into the process and also to keep process gas from back diffusing into the seal cavity. If buffer gas is required, it needs to be compatible with the process, and a small buffer gas skid is required to control the flows ensuring the desired outcome is achieved.

The stator is located outboard of the process labyrinth, and is typically made from aluminum for its heat transfer properties. A series of drilled oil passages are present near the OD of the stator for efficient heat transfer to the cooling oil that flows through the seal. The stator has a shoulder and "fingers" at the bore near the impeller; at assembly there must be careful attention paid to maintain the required clearances in order to achieve the pumping action of the seal. The stator bore near the shaft is machined with "wind back" features similar to female threads and thus are directionally different for each end of the machine.

The seal impeller is installed following the stator and is the principle rotating part of the TBS, typically made from stainless steel materials. It becomes fixed to the shaft by the use of a pusher/puller fixture ring to set the seal impeller on to its interference fits, and is secured to the shaft with a seal nut at assembly. The impeller has controlled clearances to the bushing and stator allowing for development of the pumping characteristics of the seal. At installation, the axial position of the impeller relative to stator (controlled with a custom fit spacer ring) must be carefully set in order to achieve the desired axial clearances.

The stepped dual bushing is at the heart of the seal and thus has many features associated with it. Typical materials are aluminum for some low pressure applications, though a Ni-resist material is used for the majority of cases. The bushing is "trapped" within the assembly, located axially in between the stator and seal cage and over the seal impeller. The bushing is a static component with controlled clearance (similar to journal bearing clearance) relative to the impeller, with the clearances being critical to seal performance. Clearances to the cage and stator are more generous, with O-rings used in-between which allow the bushing to "float" with the shaft in operation. A stepped shoulder in the bushing bore creates one side of the "pumping cavity" as the part interfaces with the impeller during operation. Often the bushing has pressure dam features machined into the bores which aid in the stabilization of the bushing, due to the hydrodynamic effects of the rotating impeller and static bushing acting similar to a bearing. *(continue on page 3)*

TECH TALK

AC COMPRESSOR TRAPPED BUSHING SEALS *con't*

By Rob King and John Decker

Within the bushing there is typically a small cross-drilling oil passage for pressure equalization on the outboard side, resulting in an overall light pressure loading bias in the outboard axial direction. Flatness and controlled surface finishes are needed at the interface of bushing and cage to create a static sealing face which prevents leakage around the outside of the bushing. During operation a torque inherently applied on the bushing due to oil film shear forces in the bores. Older style seals may utilize an anti-rotation pin and an axial o-ring to prevent bushing rotation, whereas later designs rely on o-ring radial friction to prevent the bushing from rotation. The necessary friction comes from the “squeeze” of the two o-rings at the bushing OD along with the axially loaded surface previously described.

The seal cage is the last of the main TBS components installed. The seal cage is typically constructed of steel for high strength since the differential pressure across it is equal to the seal oil pressure. The cage provides the seal oil inlet, recirculation flow annulus, axial sealing face, and provides containment of the inboard seal components within the cavity. A shear ring set, sized to handle the overall axial load due to pressure bias, is installed outboard of the cage completing the assembly in the machine.

To learn more about the trapped bushing seal, look for the remaining articles in the TBS series within upcoming RMS newsletters. These articles will directly focus toward seal operation and the auxiliary support systems required. The RMS engineering team is always happy to support customers with questions on their compressor seals.

STEAM TURBINE DOVETAIL STYLE SHROUD INDICATIONS

By Scott MacFarlane

Crack-like indications are often discovered during the NDT inspection process of dovetail style shrouds. These indications generally take one of two forms: a crack in the rolled-in band starting between adjacent blades or a crack in the parent blade metal in the area of the dovetail groove.

The indications in the rolled-in bands occur at the edges between adjacent blades. A photo of such an indication is shown in Figure 1. The inception of these indications is due to relative displacement between blades resulting in high stress and cracking in the band (Figure 2). It is known that the initiation site may be formed during the installation of the blades when the shrouds are machined after installing the bands. Tool pressure during machining has been observed to deflect the integral shroud blade tips which are cantilevered from the airfoil tip (Figure 3). The problem is more significant on later stages where longer blade lengths reduce structural stiffness.

The most effective means of preventing these cracks is to stabilize the blade tips during the assembly and machining process which leads to a superior wheel assembly without the introduction of pre-cracks in the bands. There are different means of accomplishing this task which, RMS has developed its own proprietary process. (*continue on page 4*)

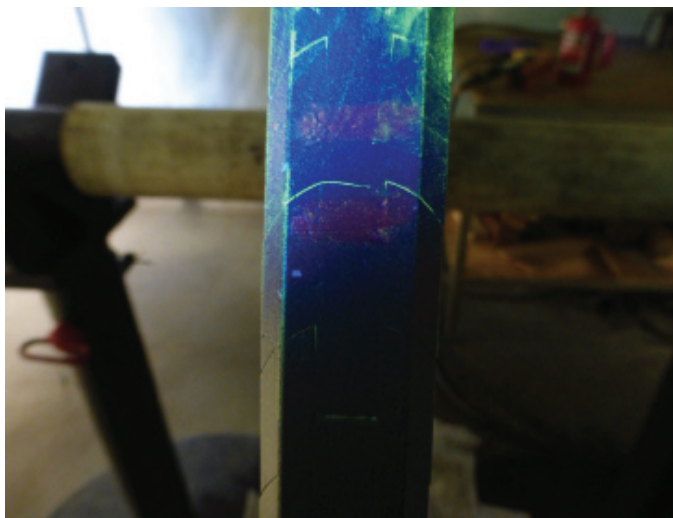


Figure 1



Figure 2

TECH TALK

STEAM TURBINE DOVETAIL STYLE SHROUD INDICATIONS *con't*

By Scott MacFarlane

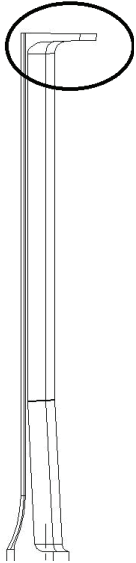


Figure 3

The other type of crack-like indication shows up in the blade parent material at the edge of the dovetail slot next to the adjacent blade. Figure 4 shows the raised edges where the material has cracked and Figure 5 shows areas where that metal has broken away leaving a void.

RMS has determined through structural analysis that these indications in themselves are not an immediate danger to the rotor blade operation. Depending on the extent, there may exist sufficient parent material in the remaining dovetail to adequately prevent individual blade movement. Many of these indications have been observed but there has been no documented failure as a result.

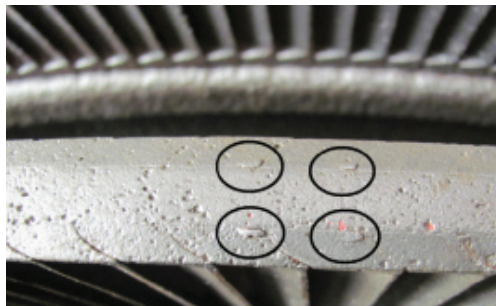


Figure 4

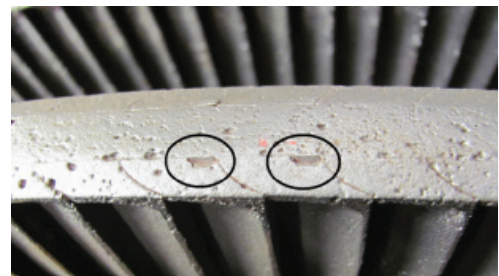


Figure 5

Regardless, any observed cracking in the dovetail style shroud configurations should be addressed to reduce the chance of further damage or machine failure.

METALLURGICAL REPLICA CAPABILITY

By Christopher Sykora

In last quarter's article I hinted at RMS' new capabilities for in-house metallurgical replica creation as part of a Remaining Life Assessment (RLA). While RMS has been involved with metallurgical replicas for many years through the use of outside metallurgists, we have recently brought the labor intensive process of creating the physical replicas in-house. So what are these replicas anyway? They are thin films of acetate that are pressed onto the metallic surface in order to replicate the microstructure of the part in a local area. These replicas can then be viewed under a powerful microscope back in a metallurgist's lab and can also be maintained for years in order to compare with future replicas. They are a key part of the nondestructive metallurgical assessment section of the RLA.

Unfortunately, it's not just as easy as sticking the acetate film on the part. You didn't think this was like playing with silly putty and newspaper clippings did you? There is a five step process for each replica desired. The first step is to do rough grinding of a small (1-2" square) area on the part with 60-120 grit sandpaper. This step removes the large surface imperfections like grit blasting dimples or corrosion pitting. The second step is to do fine grinding on the same area with progressively finer grit sandpapers, down to 600 grit. Each level of sandpaper should be removing the fine scratches from the previous level. The third step is to use a diamond polishing compound to further refine the surface finish of the replica area until it is a mirror finish. This is the most time consuming step and one must be careful not to scratch the area with other tools once it is polished. You can see an example of a polished area in Figure 1 (*next page*). Cleanliness in between all of the sandpaper and polishing is a key to the process. RMS has procured a complete kit of metallurgical preparation materials specifically designed for creating these replicas.

The fourth step is the most dangerous and nerve testing, since if done incorrectly, it means going back to sandpaper grinding again. This step is chemical etching of the metallic surface in order to reveal the microstructure. Some of the chemicals used for this process are powerful acids, so extreme care must be taken and all proper PPE must be worn. The acids must be mixed carefully in the correct proportions and then swabbed onto the surface for just the right amount of time. Unfortunately, the amount of time etching and even the chemicals best suited for the job is dependent on the type of metal being replicated.

(continue on page 5)

TECH TALK

METALLURGICAL REPLICA CAPABILITY *con't*

Luckily RMS has gained significant experience on recent jobs with multiple alloys and is fully supported by a very experienced metallurgist who has worked with RMS personnel for over 30 years. The final step of replication is actually applying the thin acetate film to the surface of the etched metal. The acetate is softened with a special chemical, pressed onto the surface, and then forms a reflected replica of the surface of the metal. You can see some example images of a Waspaloy replica (Figure 2) versus a photomicrograph of actual Waspaloy metal (Figure 3).

Replicating the microstructure of the metal allows for an experienced metallurgist to evaluate the size of the grain boundaries, look for precipitates, sigma phases, and carbides, and search for evidence of creep damage. Changes in any of these properties of the microstructure relative to a newly forged sample could be indicative of in-service damage from exposure to high temperatures for long periods of time. RMS is excited to have the capability to create these replicas in-house in order to better control the schedule of our Remaining Life Assessments. We are also pleased to have a relationship with such an experienced metallurgist who can provide best in industry evaluation of these replicas and other metallurgical functions.



Figure 1

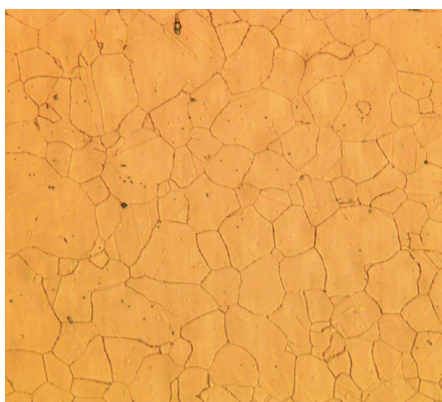


Figure 2

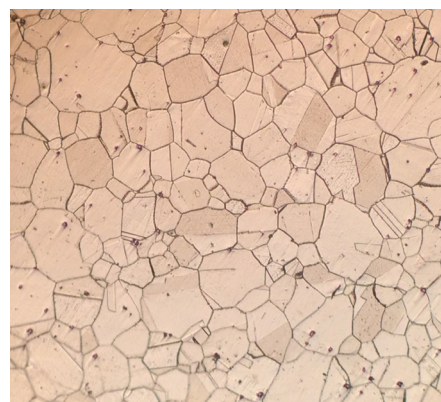


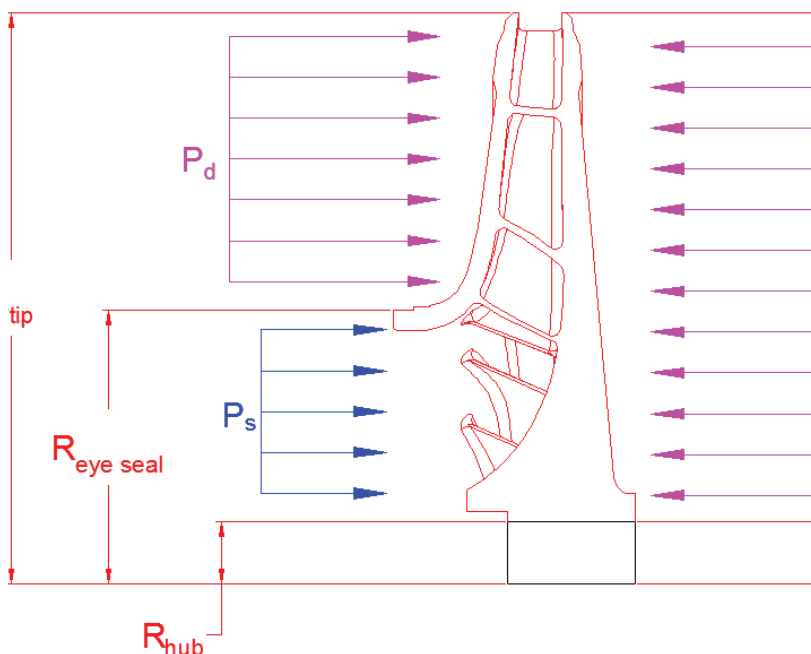
Figure 3

SIMPLE THRUST CALCULATION FOR CENTRIFUGAL COMPRESSOR IMPELLORS

By Eric Dunlap

When designing a new centrifugal compressor stage for a rerate application it is critical to consider how the new impeller will change the thrust load acting on the rotor and whether the existing thrust bearing is adequate for the new load. Impeller geometry, inlet pressure, and discharge pressure each play a major factor in the thrust load exerted on the impeller.

The figure on the right shows an illustration of the pressures acting on an impeller. The pressure on the discharge side of the impeller can be assumed to be equal to the impeller discharge pressure, P_d . The pressure on the suction side of the impeller, above the eye seal, can also be assumed equal to the impeller discharge pressure. Below the eye seal, the pressure is equal to the impeller suction pressure, P_s . By multiplying these pressures by the cross sectional area on which they act on the impeller one can calculate the thrust force acting in each region. The sum of these thrust forces is
(continue on page 6)



TECH TALK

SIMPLE THRUST CALCULATION FOR CENTRIFUGAL COMPRESSOR IMPELLERS *con't*

the net thrust force acting on the impeller due to the pressure differential.

$$Thrust = [P_d * \pi * (R_{tip}^2 - R_{hub}^2)] - [P_d * \pi * (R_{tip}^2 - R_{eye}^2)] - [P_s * \pi * (R_{eye}^2 - R_{hub}^2)]$$

This equation can be simplified to:

$$Thrust = (P_d - P_s) * \pi * (R_{eye}^2 - R_{hub}^2)$$

The figure and equations show that the net thrust force will push the impeller towards the suction end of the machine and is dependent on the difference between the discharge and suction pressures and the eye and hub seal diameters. Larger pressure ratios will result in larger thrust loads acting on the impeller and will increase the required capacity of the thrust bearing. In scenarios where the thrust load is increased beyond the capacity of the existing thrust bearing it will need to be upsized when the rerate components are installed.

STEAM TURBINES

By Sydney Gross & Scott MacFarlane

In previous issues, we discussed over speed trip sensing (Volume 6, Issue 3, July – September 2010) and API recommendations (Volume 8, Issue 1, January – March 2012). In this issue we will discuss steps that need to be taken to execute a conversion to an electronic tripping system from a mechanical system.

First it needs to be defined what functions in addition to over speed will be converted from the existing systems to the new electronic system. It is critical to recognize that the governing system, low oil pressure trip, manual emergency shut down and rotor axial position systems may be inter-related and affected by the modification of the speed tripping system. A good example can be seen in Figure 1, a cross-sectional view of a governor case. In this example the oil dump valve latch is connected to the overspeed lever, low oil pressure diaphragm and the hand trip knob. In addition, the action of the oil dump valve causes the governor valve to close.

Once the system changes have been decided; we can look at the physical changes to be made to the turbine. Aside from removing the old obsolete parts there are parts that need to be added. Not only do the electronic speed sensing components need to be added, but also the removal of the obsolete parts exposes holes, passages and cavities that may need to be plugged or covered. In order to sense speed electronically, a notched wheel must be added to the rotor along with provisions to hold the speed sensors. In the example shown in Figure 1, changeover of all the systems to electronic gives one as clear a slate as can be hoped for in the retro fit world but, in this case, the existing governing system remained in-tact. Apart from maintaining the governor closing function, there are spatial considerations that go with retaining the governing system, namely working around the governor gears.

All of these conceptual changes need to be dimensionalized in order to make manufacturing drawings. With the machinery running, how do you get the dimensions? Much of the information comes from the published material supplied with the machine including P&IDs and control schematics. Other dimensions can be obtained from spare parts such as rotors and valves. Service records often contain valuable dimensions as well as photos that can fill in blanks. (continue on page 7)

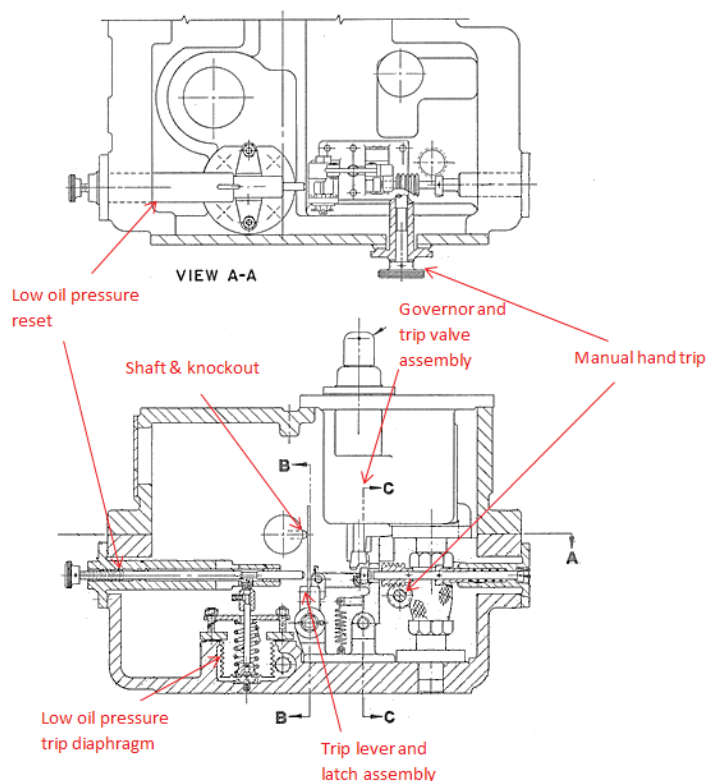


Figure 1

TECH TALK

STEAM TURBINES *con't*

Finally, measuring the operating machine allows for external dimensions to be obtained. Naturally, some features will have to be measured and machined at the time of the turnaround.

Aside from the control programming aspects, it is important to consider the effects of the changes to the rotor on the rotor dynamic characteristics. Typically these effects are negligible but occasionally the speed wheel modification adds enough overhung moment to require some design tweaks.

WHY WORRY ABOUT DOWNSTREAM

By Christopher Sykora

If you have been reading a structural analysis report that covered vibrations of multistage compressors or turbines lately, you might have noticed something referred to as “downstream excitations” on the Campbell or Interference diagram. A common question is “What are downstream excitations and why should we care about them if they are downstream?” First, recall that an excitation is a source of forced vibration (typically rotor imbalance and/or flow disturbances) that could potentially excite damaging resonant vibrations in the rotor. These excitation frequencies will cause resonance if they match the natural frequencies of any components of the rotor. Figure 1 shows an example of upstream & downstream stator vanes.

It is usually pretty easy to imagine how the flow disturbances from upstream stator vane wakes could have an influence on the rotor blades that are just downstream. Just picture the wakes behind a boat that are bumping into a swimmer being towed behind the boat. These wakes can be strong and would be noticed by even a swimmer that was fairly far behind the boat. The same is true for aerodynamic wakes coming from the trailing edge of airfoils in a compressor (see Figure 2). This trailing wake is relatively strong and travels far downstream due to the separated, turbulent flow behind the airfoil (although the aerodynamic designer attempts to minimize this turbulence for best efficiency).

However, it can be harder to envision how stator vanes that are downstream of the rotor blade rows could have an impact on the blades ahead of them. It isn't as obvious why this is considered on the Campbell diagrams. Is this just being extra conservative? The answer depends on how closely the stator vanes follow the preceding rotor blade row. If you look carefully again at the streamlines surrounding the airfoil shown in Figure 2, you will notice that they tend to bend around the leading edge of the airfoil. This effect occurs upstream, before the streamlines even reach the front of the airfoil. This effect isn't as strong as the turbulent flow coming off the back of the airfoil, but if the rotor blades are close enough to the leading edge of the stator vanes, then they will certainly experience this “extra” flow disturbance. Thus it is required that this also be considered in the vibration evaluations. Axial compressors and steam turbines generally have stator vanes close enough that downstream is always included. For centrifugal compressors, the distance downstream can be larger, so this is weighed when deciding whether or not the downstream excitations should be included.

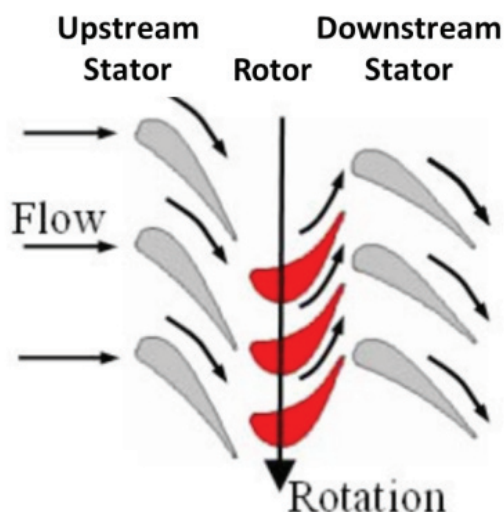


Figure 1

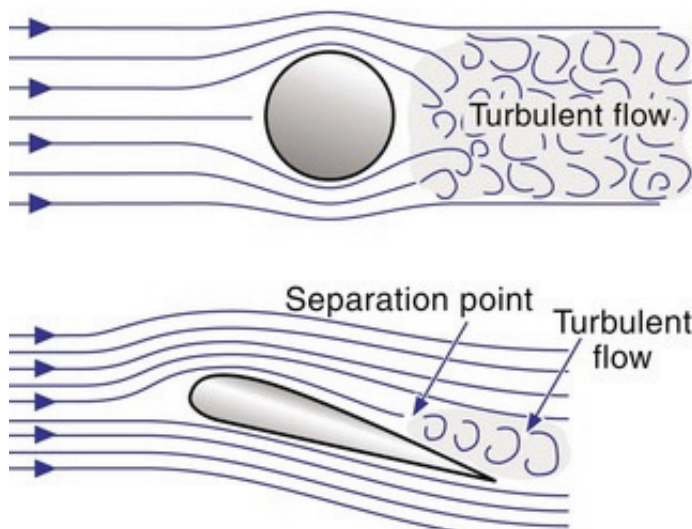


Figure 2

SPOTLIGHT ON:

MEET OUR NEW STAFF MEMBERS



Charles Mineo - Senior Accountant

Charles has 25 years' experience in the Accounting field. He has had roles in the finance departments of Coca-Cola, Dun and Bradstreet, Agere Systems, and most recently MAM Software based out of Allentown. He has a diverse work experience in both manufacturing and the service industries ranging from startup companies to Fortune 500 organizations. He graduated from the University of Pittsburgh. He is very excited to be part of the RMS team and expand his knowledge within this niche industry.



Donald Ferraro - Quality Control Inspector I

Don joined RMS in June, as a quality control inspector. In his words *"I enjoy working for such a successful company, and with a team of great people!"* Prior to joining RMS, Don was employed with a local company for 29 years, designing and drafting automated machinery, utilizing 3D CAD software Autodesk Inventor, and also working as a machinist as needed.



Will Ard - Lead Field Service Technician

Will Ard joins RMS with 20+ years of experience in the machine shop and as a field service representative. He specialized in the power recovery trains for CONMEC then on to service and repair of AC, GE, Nuovo Pignone and Elliott equipment.



Rusty Lewis - Purchasing Agent

Rusty joins RMS with thirty years of experience in procurement of engineered buyouts, commodities and services directly related to the power plant industry.

He previously held positions in the procurement field as Strategic Sourcing Manager, Purchasing Manager, Commodity Buyer, Buyer and Expeditor at SPX Heat Transfer LLC, Lehigh Consolidated Industries and Ingersoll-Rand (Turbo Machinery Division). Responsibilities included strategic sourcing, negotiation and material procurement, supplier evaluation, selection and qualification. Liaison between Engineering, Project Management and Quality for all Supplier communications.

RMS COMMUNITY INVOLVEMENT

By Gabrielle Koltisko



Throughout the month of October, RMS raised donations for Breast Cancer Awareness. Fundraising began with a donation jar being placed in the cafeteria along with educational literature for the staff. As the month progressed, RMS continued fundraising efforts by holding events such as a tricky tray basket raffle and "Wear a Pair, Save a Pair" jeans day, in which the staff could donate to dress down for a day in the office. Both RMS Bethlehem and Appleton culminated their fundraising efforts through a group lunch event where staff members were encouraged to wear pink to show their support. RMS Bethlehem was graced by a guest speaker, Debbie Weber, a nurse, counselor of breast cancer victims and a breast cancer survivor herself. The guest speaker's presentation allowed the staff to truly connect with the cause.

Overall, RMS staff was able to fundraise \$1,030.00 within the month and a contribution match by executive management team brought the grand total to \$2,060.00! The funds will be donated to a local charity, Mama Mare Breast Cancer Foundation. This small volunteer run foundation provides support services to breast cancer patients and their families as well as funding biomedical research being conducted in search for a cure.

RMS's Team Blade Runners were involved again this past September in the Lehigh Valley Health Networks' VIA Marathon of which proceeds benefit local children and adults with developmental delays and disabilities. This year's relay team consisted of (left to right) Bob Klova, Tony Rubino, (supporter Hayden Gross), Roger Barlow, Sydney Gross and Chris Sykora (missing from picture).



TURBO TOONS "Happy Halloween"

By Marc Rubino



EMPLOYMENT OPPORTUNITIES

Rotating Machinery Services has proven experience in the Turbomachinery industry both in technical expertise and providing our customers with undeniable excellent customer service. We are growing rapidly and have the following positions available. Turbomachinery experienced preferred.

Please check out our web site under Career Opportunities for further details. www.RotatingMachinery.com

- Shop Supervisor
- Project Manager
- Quality Inspector
- Applications Engineer
- Rotor Assembly Technician

We are looking for exceptional people to be part of our growing team! RMS believes that our employees drive the success of the company and we strive to provide challenging and stimulating opportunities.

Please email resumes to HR@rotatingmachinery.com or mail to:

Attn HR Department
Rotating Machinery Services, Inc.
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