ROTATING MACHINERY SERVICES, INC.

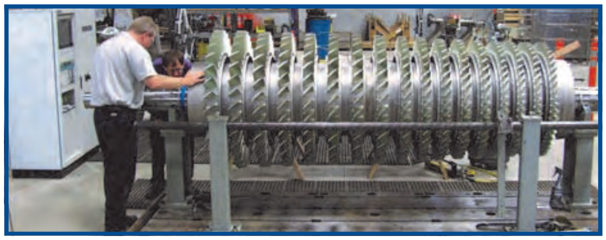
VOLUME 5, ISSUE 3
July—September 2009

THE FINISH LINE

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

What's Inside

POWER SOLUTIONS



The RMS Power Solutions shop has proven to be a well organized and an effective operation. Over the past few months, we have strengthened our capabilities in several areas. Shop personnel have attended training at Schneck and are better prepared to address rotor balancing challenges. We have added a new hydraulic torque wrench and hydro testing module to our equipment inventory.

The RMS Power Solutions shop has processed several major projects in the past few months with deliveries on time and to 100% customer satisfaction. The projects include re-blading of steam turbine rotors, the complete refurbishment of a forced draft fan and emergency overhaul to a nitric acid expander that included a major flow path modification.

We are making plans for many increased capabilities and will initiate them as required by our customers needs. We continue to be a vital support for our engineering services group and the support is reciprocal.

API 687 SEMINAR SCHEDULED AT RMS IN NOVEMBER

The API Rotor Repair Course will be held at our facility on November 2 through Friday, November 6, 2009. The course is based on API standard 687, covering the minimum requirements for the inspection and repair of rotating equipment rotors, bearings and couplings used in the petroleum, chemical and gas industry services. The 4 1/2 day course, starts at 7:30 am on Monday and finishes at noon on Friday. If you are interested in attending, more information is available on the API website at http://www.api-u.org/rotorrepair.html. Hotel rooms at the Marriott Courtyard, Emerick Blvd, Bethlehem, PA are available at our Corporate Rate of $119.00 per night.

FIND A PENNY, PICK IT UP...

This is what Neal Wikert has been doing for over 50 years. At the young age of 8, collecting coins caught the interest of a young boy and continued throughout the years. His two favorite coin collections are his Lincoln Head penny collection and Indian Head penny collection.

Neal's Lincoln Head collection consists of every Lincoln head penny made. He has roughly 300 different Lincoln Head pennies, made in Denver, San Francisco and Philadelphia. His Indian head penny collection dates back to the civil war in 1865.

Just ask him about any penny, but be prepared to sit for hours because he can tell you the condition, give you the history and value of the coin.
So the next time you see a penny remember the saying…*"Find a penny pick it up, all the day you will have good luck."*

Up Coming Conferences 4th Quarter

GRC 2009
Annual Meeting
Reno, Nevada
Oct. 4 - 7

*****

API Conference
Bethlehem, PA
Nov. 2 - 6

RULE OF THUMB - GENERAL

By Neal Wikert

Flange Slotting

The purpose of keyhole slotting the O.D. of a flange in high temperature machinery is to eliminate the ability of the outer portion of the flange to carry hoop stress. Doing this reduces thermal stresses by allowing the cooler outer portion of the flange to expand less than the hotter bore region. The end result is less long-term distortion. Slotting every third bolt hole is a good rule of thumb and slotting more often provides safety margin.

SHCS removal:

Heat the head of the cap screw until cherry red. Allow cap screw to cool momentarily so that heat can soak down the threads. Turn to remove. Cap screw will loosen.

Hex nut removal:

To remove hex nuts, heat one of the hex flats until red and break nut loose. On Allen head bolts, heat down in the Allen head and break loose. This heat effectively loosens the nut and gives room for corrodents to move.

Gears – Helical

Gears are generally manufactured from 4340 through hardened to a Brinell range of 340 – 370. Above a surface speed of 7000 ft./min. the gear teeth need to be ground to give the part the accuracy needed for spinning at these speeds.

Performance

Standard conditions:

ISO:	59 deg. F, Sea Level (14.696 psia), 60% R.H.
NEMA:	80 deg. F, 1000 ft (14.17 psia)
API:	60 deg F, 14.7 PSIA, Dry (0% RH)

STEAM TURBINE - BUILT UP OR SOLID?

By Sydney Gross

It's a perennial topic that continues to resurface as new people enter the turbomachinery field from various disciplines. Why have two different rotor constructions, built-up and solid?

First, what do we mean by the two types of rotors? A built-up or disc-on-shaft or stacked rotor is an assembly of a shaft and separate bladed discs. The discs are fixed to the shaft by an interference fit and keys at the disc bore. The keys are a back-up. Discs are typically located axially by steps in the shaft, sleeves or rings shrunk in grooves. The rotor is usually assembled vertically by heating the discs and lowering them over the shaft to the correct position or lowering the shaft through the disc. With a solid rotor the shaft and discs are machined from a single forging and the discs are bladed after machining is complete. Combinations of the two exist but are very uncommon.

Comparable built-up rotors can be manufactured in less time than a solid rotor for several reasons. The lead times for disc and shaft forgings are less than a solid rotor forging and the discs can be bladed while the shaft is being machined. Additionally, errors in machining and assembly are more easily accommodated. So why bother with a solid rotor to begin with?

Built up rotors are speed and thermally limited by the fit of the disc to the shaft. At some speed the disc bore will grow due to centrifugal force to the point where it can no longer transmit the torque produced in the blading. The interference fit is also sensitive to rapid heating of the turbine since the mass and thickness of the disc is small compared to the shaft and is directly exposed to the steam. When the disc fit is lost, the vibration will increase and bad things may result. Why not increase the interference fit? The interference fit is limited to yielding of the bore and shaft when the rotor is assembled and the ability to disassemble the rotor at some future point. Typical interference fits are 0.002" per inch of diameter although some manufacturers favor heavy fits on the order of 0.003" per inch of diameter.

Built up rotors are typically used up to about 7000 rpm. API 612 requires purchaser's approval for a built-up rotor when blade tip speeds exceed 825 feet/second at MCOS or when inlet steam temperature exceeds 825°F. Most turbine manufacturers have their own criteria which are generally more conservative.

MODE SHAPES OF PACKETED BLADES

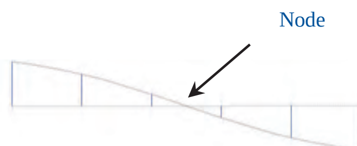
By William Sullivan

Before proceeding further into the interference diagram, we probably should look at some packeted blade mode shapes because it is examining the likelihood of exciting (or, preferably, not exciting) these modes that the interference diagram is most useful. To do this we constructed and analyzed a simple finite element model of a packet of six shrouded blades. The first twelve mode shapes are listed to the right.

For the first mode, all six blades are moving together. The motion is roughly parallel to the rotor axis. Therefore, this is called an axial mode. The second mode is the first tangential mode. Again, all blades are moving together but this time they are moving perpendicular to the rotor axis, or tangential to the disk. The third mode is another axial mode. However, for this mode, the blades on either end of the shroud are moving in opposite directions. If one were to look down at the shroud, it would look somewhat like the letter "X". Hence, this is sometimes called the "X" mode. The plots below show this and three other "letter" axial modes: the "U", "S" and "W" modes. Note that for the "X" mode, there is a node (a location where there is no movement) at about the center of the shroud. For the "U" mode there are two nodes, for the "S" mode, there are three nodes, and so forth. (For six blades there can be no more than five nodes.)

Mode	Freq Hz	Shape	
1	1460	Axl - 1	
2	1616	Tan - 1	(Fixed-Free)
3	1692	Axl - 2	(X)
4	2310	Axl - 3	(U)
5	3351	Axl - 4	(S)
6	4138	Tan - 2	(Fixed-Fixed)
7	4661	Axl - 5	(W)
8	5782	Axl - 6	
9	5848	Tan - 3	
10	6307	Tan - 4	
11	6436	Tan - 5	
12	6471	Tan - 6	

First Axial Mode

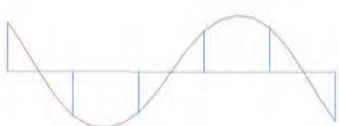


Second Axial Mode

The "X" Mode

Third Axial Mode

The "U" Mode

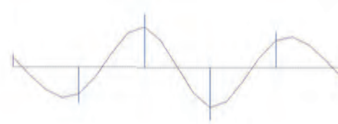


Fourth Axial Mode

The "S" Mode

Fifth Axial Mode

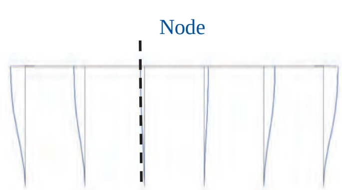
The "W" Mode



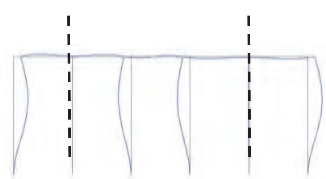
Sixth Axial Mode

The tangential modes also are grouped by the number of nodes in the mode shape, although the nodes aren't as obvious. The first three tangential modes are shown below. For these modes, the view is parallel to the rotor axis.

First Tangential Mode



Second Tangential Mode



Third Tangential Mode

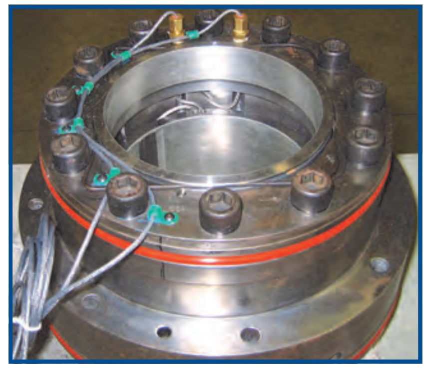
The large frequency shift from the first to second tangential mode (1,616 Hz to 4,138 Hz) is because in the first mode the shroud is moving with the blades and adds essentially no stiffness to the system. However, in the second, and all of the higher modes, the shroud is constraining blade tip movement and, therefore, is contributing a significant amount of stiffness to the system. Essentially, from the first to second tangential modes, the blades moved from a fixed-free system to a fixed-fixed system.

COOPER RF2B BEARINGS UPGRADE

By Tony Rubino

A mid-western utility company compressor station utilizes a Cooper RF2B-24 two stage compressor in a gas storage application. The compressor provides inlet pressure boost (supercharging) to 2 or more downstream reciprocating compressors. The RF2B compressor operates seasonally, usually only during winter months. During a 2008 inspection, it was discovered that the compressor end journal bearing had catastrophically failed. The majority of the babbitt had separated from the steel-backing ring in what originally appeared to be a simple failure of the bond from the babbitt to the steel backing ring. Further investigation revealed that failure of the impeller end bearing had been a recurring event at this facility since 1993. At one time, the failure had been severe enough to damage the journal area of the rotor.

In September 2008, RMS provided a new bearing with anti-whirl features, larger clearance and increased oil flow. The bearing was not instrumented with either RTDs or thermocouples due to time constraints. A spare bearing was not ordered at that time pending validation of the new design. Subsequently, the new bearing was installed and appeared to have met design goals by reducing bearing operating temperature based on oil drain temperature measurements. However, compressor operation was still limited due to having to estimate bearing babbitt temperatures.



The bearing was returned to RMS in June of 2009 for inspection and installation of bearing temperature instrumentation. Installation of bearing temperature detectors is expected to provide increased operational control and compressor output. At inspection, the bearing looked as good as new with no signs of damage. RMS reworked the bearing and bearing housing to install two RTD's as well as fluid seal fittings. RMS also provided site installation drawings to address the necessary site rework to the compressor casing. The bearing has been installed and test run but the RTD's were not integrated into the control system at the time of the test. Operation is expected to begin in November with a spare bearing order to follow immediately after.

CUSTOM TAILORED COUPLING GUARDS

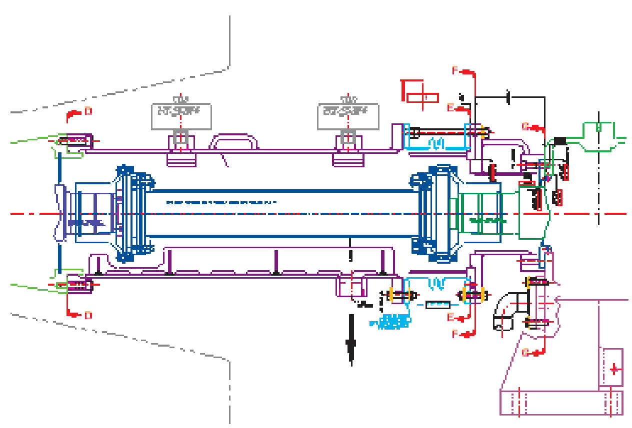
By Tony Rubino

A Midwest refiner recently performed coupling replacement on their FCCU power recovery train. The machinery in the train includes four bodies: a GE steam turbine, an IR4013 axial compressor, a Westinghouse induction motor-generator, and an IR E-148 expander. The new Goodrich diaphragm couplings have substantially larger hub flange diameters requiring new coupling guards to suit. RMS was selected to provide the new guards complete per API and the end user's own engineering standards.

RMS inspected the existing coupling guards while the train was operating to create a baseline layout of the train including bearing housing interface flanges, lube oil supply piping and lube oil drain piping. The RMS inspection data were supplemented by end user provided photographs, instruction book drawings, and coupling drawings provided by Goodrich. The guards were designed using RMS design practices to ensure adequate ventilation to prevent excessive windage and heat generation. The manufacturing and assembly drawings were then developed from the layout. An additional benefit of the layout process was that a coupling interference and lack of a baffle plate were discovered. Since the compressor shaft ends are recessed into the casings, it was not possible to install one of the couplings with the compressor casings fully assembled. If an emergency coupling change were required in the future, either the compressor casing would have to be split or either the compressor or motor would have to be moved to facilitate installation of the coupling. This was unacceptable to the end user which necessitate a coupling redesign. Due to RMS' discovery, the coupling change was completed well in advance of the turnaround. RMS was also able to incorporate a baffle plate in one of the guard adapter to minimize the windage and oil misting in the plain end compressor bearing housing.

The end user opted to include several product upgrades. Stainless steel bellows type expansion joints were used to provide positive sealing and prevent the oil leakage sometimes found with the o-ring type seal. All connections were integrally flanged per the end user's specifications. Coalescing demisters were also provided along with tubing that routed the coalesced oil back to the guard drain lines. Besides the design and manufacturing of the guards, RMS supplied all fasteners and necessary drawings for a total solution.

The guards were installed in September and are operating very satisfactorily per design intent.



FCC EXPANDER FLOW PATH EROSION - PARTICLE SEPARATOR PERFORMANCE

By David Linden

Evaluating the performance of a Third Stage Separator (TSS) can be difficult since the catalyst exiting the FCC process varies significantly over time and changes with various operating modes and parameters. In addition, the catalyst in use can be a blend of several different types of catalyst and catalyst additives that have variable physical properties and concentrations. TSS performance evaluations are generally done via simultaneous Iso-kinetic Tests of the TSS inlet, outlet and underflow lines. It should be remembered that an Iso-kinetic test is a snap shot in time of variable process conditions. Iso-kinetic test details will be elaborated on in future RMS newsletters.

Performance evaluations of Third Stage Separators (TSS) involve measuring the amount of particulate entering the TSS and comparing it to that exiting. The inlet conditions are often used to evaluate the performance of the regenerator cyclones. The outlet conditions are of high interest since this is an indication of the particulate entering the downstream gas expander. The evaluation considers either the total mass or quantity of particulate entering and exiting the TSS, as well as the particle size distribution.

Quantity – The quantity of particulate exiting the TSS is generally measured on a mass flow/hour basis. In order to normalize the data and to be able to compare different size operating units, the mass flow of catalyst is often converted to a parts per million basis (PPM). PPM equals (pounds of catalyst / pounds of flue gas per hour)*10^6. A typical 80K BPD FCC regenerator will discharge approximately 263 lb/hr of catalyst into the TSS. At a flue gas rate of 750,000 lbs/hr, the TSS inlet loading would be 350 ppm. If the regenerator has deteriorated, the catalyst losses increase and loadings in excess of 500 ppm can be experienced.

A properly operating TSS will remove a majority of the entering catalyst and the outlet is likely to be in the 100-ppm range for the above example. This would correspond to 75 lbs of catalyst per hour entering the gas expander. Catalyst loadings in excess of 120 ppm into the expander will cause flow path wear and reduce the expander operating time.

Catalyst loading data is often presented in catalyst mass per standard cubic feet (lbm/SCFM) or in metric units - milligrams per normal cubic meter (mg/Nm^3).

Distribution – The catalyst particle distribution is very important when evaluating the TSS performance. Typical catalyst distributions (both inlet and outlet) can be seen in the following Figure #1. The Figure #1 plots represent both modern and properly operating FCC regenerator cyclone and TSS performance. From the plots, it can be seen that the TSS is very efficient at removing the larger catalyst particles (10 microns and larger). Conversely, the efficiency drops off quickly for particles less than 10 microns in size.

It can also be seen that providing a single overall TSS efficiency number is of little value since it is so dependent upon particle distribution. If all of the inlet particles were large (>20 microns), the TSS overall efficiency would be close to 100%. If all of the inlet particles were small (<1.0 microns), the overall efficiency would be 25%! For reference, overall TSS efficiencies are typically in the 50 to 60% range.

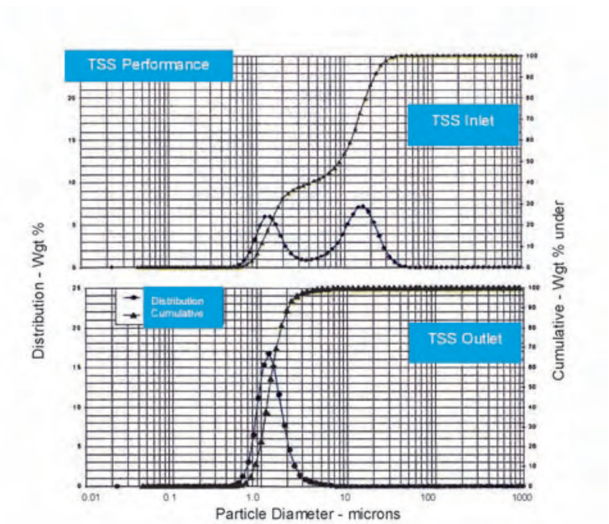


Figure # 1 – Typical TSS Performance (Inlet and Outlet)

By evaluating both the overall quantity and particle distribution, one can assess the TSS performance. Abnormal particle distributions can also identify deterioration or damage to either the regenerator cyclones or TSS internals. For example, an increase in the quantity and the level of fines in the TSS inlet might indicate a catalyst attrition problem in the regenerator. An increase in particle size out of the TSS might indicate wear or a mechanical issue allowing catalyst to bypass the swirl vanes or cyclones.

In order to assure long-term reliable expander operation, periodic (typically once or twice a year) testing of the TSS is recommended. The test data interpretation is best conducted by experienced personnel.

In our next newsletter, we will discuss the effects of particle loadings on the expander.

MESSAGE ON SAFETY

By Matthew Konek

Rotating Machinery Services is committed to accident prevention in order to protect the safety and health of all our employees. Injury and illness losses due to hazards are needless, costly and preventable. A joint management/worker safety committee continues to meet on a monthly basis to discuss safety topics, safety improvements and suggestions. Employee involvement in accident prevention and the support of our safety committee members help in keeping RMS a safe and healthful workplace. RMS is proud to announce that we are 12 years accident free.

Rotating Machinery Services, Inc.

2760 Baglyos Circle
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 WELCOMES ...

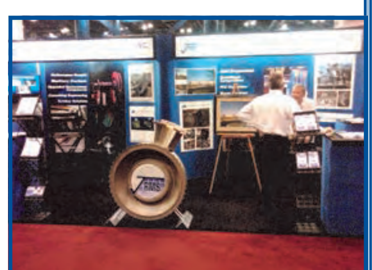
RUSSELL ESPENSCHIED, P.E.
REGIONAL SALES MANAGER—NORTHEAST

Russ has twenty-eight years of turbomachinery experience, including sales and application engineering, project development, field service for equipment installation and start up, new plant construction, environmental compliance, engineering management, and Lean Six Sigma. Experienced with centrifugal, axial, screw and reciprocating compressors; nitric and FCCU expanders; power turbines; lube and seal oil consoles and other auxiliary systems. Russ will be responsible for technical sales engineering and customer support functions.

Previously held sales, application engineering, and engineering positions for Ingersoll-Rand and Aviall Company. Russ can be reached at 484-821-0702 Ext. 332 or on his cell phone at 484-896-8438.

38TH TURBOMACHINERY SYMPOSIUM

by Russ Espenschied



2009 proved to be another excellent Turbomachinery Symposium with good attendance by both the hosts and visitors. We at RMS enjoyed meeting old and new friends and appreciate the optimism expressed concerning the potential for an improved business climate as we move into 2010. Thank you once again to Martha Barton and her outstanding staff for a job well done!.

Our Turbomachinery community was well represented and it was a pleasure to see such a good turnout!