Selecting wash systems

AIRBORNE DIRT LEADS TO CORROSION, EROSION AND EVENTUAL FAILURE

Drew Robb

Dirt in air injected into the gas turbine can have a significant impact on the performance of the turbine. For instance, with airborne foulants running at 10 ppm in the inlet air, a GE Frame 9351 FA gas turbine would ingest 225 tons of dirt in a given year, says Cyrus Meher-Homji, a senior principal engineer at Bechtel Corporation in Houston. This material does not just foul the compressor blades and vanes, but also leads to corrosion, erosion and eventual failure. And as filtration systems will never catch everything, regular washing of the compressor is required to maintain proper operation.

Most gas turbines come with some sort of wash system from the OEM that recovers lost performance due to dirt. However, several third-party suppliers, such as Turbotect, Gas Turbine Efficiency, ECT, Conntect and FP Turbomachinery are offering systems that they claim perform better.

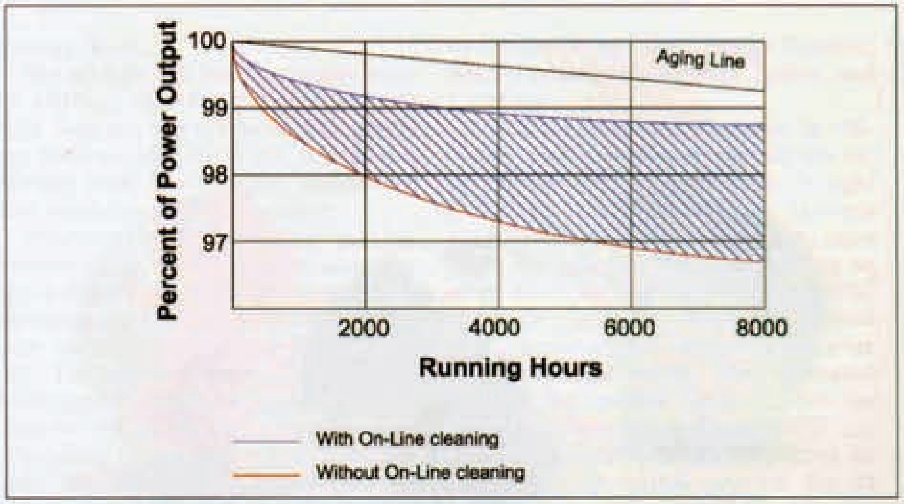

Figure 1: Above shows the typical impact of washing on turbine performance

On-line vs off-line

The design and performance of these wash systems varies tremendously between the OEMs and also between gas turbine models, says Meher-Homji. "Many end-users have installed improved on-line wash systems as retrofits — but operators under a Long Term Service Agreement are often prevented from doing these upgrades."

Selecting the best system for a particular turbine is not a simple matter, nor is figuring out the best practices in terms of washing patterns and fluids. Site conditions vary, depending on the air filtration system, wind direction, climate and local environmental conditions, such as whether there is a cement factory or an oil refinery next door, says Andrew Bromley, the vice president of operations at Turbotect (USA) Inc., the U.S. subsidiary of Baden, Switzerland-based Turbotect Ltd. "You have to optimize the program for your particular site and what is the best program at one plant may not be the best program at another."

Bromley believes there are many misunderstandings about this in the industry. Compressor washing has not been consistently handled by the OEMs over time, he says. "The result is that the end-users get a bit confused and lose confidence in the subject."

There are some basic factors that apply broadly to different categories of turbines. According to Bruce Tassone, President of Engine Cleaning Technologies, Inc. (ECT) in Bridgeport, Pennsylvania, temperature stability is more critical with aeroderivatives because the temperature gradient is spread across a shorter rotor. Heavy-duty turbines, he says, tend to have more organic fouling due to location, as well as the bearing lube oil systems leaking, particularly on the older units. There are also wide disagreements over nozzle design, use of cleaning agents, water pressure, water temperature and quantity of water to be used.

The first item to consider before selecting a wash system is whether the system will be used for on-line washing or off-line washing. While both involve spraying water into the moving turbine to clean up residues, they typically entail different design parameters.

Off-line and on-line wash systems are not the same thing; they have different physics each requiring specifically designed nozzles, different injection flow rates and different positioning, says Meher-Homji. "Achieving both objectives with one set of nozzles is questionable. Two sets of nozzles should be used — one for off-line and one for on-line."

Off-line washing or "crank washing" is done when the turbine is shut down and has cooled off but is rotating at low speed. The cleaning fluid is sprayed into the air stream and given some time to work before it is rinsed off.

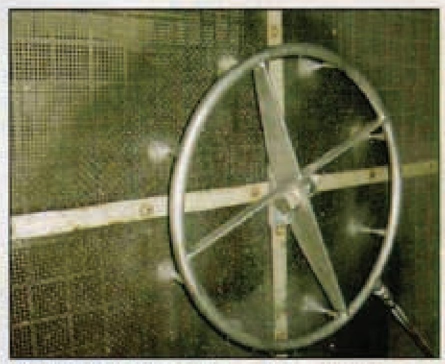

Figure 2: Nozzle arrays in a wash system

Source: ECT, Inc.

On-line washing is done by injecting water and cleaning agents into the air stream of a turbine operating at full speed. Off-line washing is done to clean a dirty compressor. On-line washing is used to keep a compressor clean for as long as possible.

Observers warn that operators should not allow the compressor to become dirty and then do an on-line wash, as doing so will push the dirt further into the turbine. The ideal procedure would be to start with a clean compressor after an off-line wash, and then do a fairly frequent on-line wash to keep the compressor as clean as possible.

On-line washes are typically performed every day, or every few days, depending on turbine usage patterns and ambient conditions. If the interval between on-line washing is too long, the benefits will not be seen, adds Meher-Homji. Frequent on-line washing also avoids sending 'slugs' of foulant into the combustion section.

Off-line wash schedules depend on when the turbine can be pulled out of service. This is particularly true for the larger-frame units that may take more than a day to cool down.

Off-line washing is still the best way to completely clean the compressor and give maximum power recovery, Meher-Homji continues. "Operators should perform off-line crank washing whenever convenient, during all scheduled outages."

Meher-Homji emphasizes the need to thoroughly rinse during off-line washing to ensure all salts and grease are flushed from the compressor casing. This would help prevent the dirt from getting redistributed onto the blading when the unit is brought back on line. He also suggests performing conductivity tests on the effluent water leaving the compressor drains and repeating the rinse cycle until the conductivity measurements stabilize. In addition to off-line and on-line washes, the compressor should be manually cleaned whenever possible to remove salt and carbon deposits.

Most manufacturers recommend using separate nozzle arrays for off-line and on-line washing. "Some people say you can use the off-line and on-line systems interchangeably, which we do not agree with," says Gregory Labas, president of Conntect, Inc. in Brookfield, Connecticut, USA. "They are completely different applications."

At least one firm, however, disagrees. Gas Turbine Efficiency AB (GTE) of Stockholm, Sweden uses a single set.

GTE uses a high-pressure system that by atomization produces a soft mist of water droplets just the correct size to travel with the airflow in order to penetrate the total gas path of the compressor and the turbine. "On- and off-line washing can be done with the same set of nozzles from one location," says Pär Krossling, GTE's managing director.

The next item to look at is nozzle design — droplet size, spray pattern and flow rate. Droplet size is critical for adequate cleaning, as well as avoiding damage to the compressor.

Large droplets will tend to remove the deposits better than the small droplets, but very large droplets also have a potential to cause a little bit of erosion of the blades," says Klaus Brun, manager for rotating machinery and measurement technology at the Southwest Research Institute (SWRI) in San Antonio, Texas. "These are customized engineering decisions that an operator needs to think through."

This is especially an issue if the blades have expensive coatings that can be damaged by droplet impact. Most systems produce droplet size from 80 microns up to 250 microns. If they are too large they will be more erosive, if too small, the air mass flow deflects the droplets and the water ends up streaming along the surface rather than being distributed in the air stream.

Conntect's Labas says that droplet size is not that critical of an issue when dealing with off-line washing since the air and rotor speeds are much lower and impact will not damage the blades. "When you do an on-line wash, however, you need a totally different nozzle design and totally different configuration," he says. The on-line nozzles are a much finer spray — less than 150 micron size — to avoid erosion.

While everyone agrees that the droplets in a wash system must be the proper size and evenly distributed, there is considerable disagreement over the quantity, velocity and temperature of those droplets

In on-line washing, small droplets can easily get deflected by the airflow and wind up on the plenum walls rather than cleaning the inlet guide vanes of the compressor. This is particularly a problem with large-frame turbines with a large inlet cross section. To address this, Turbotect has developed a new nozzle, the PSA Mk 3 (Figure 3), which contains two high-pressure air nozzles in addition to the water nozzle.

The water stream gets protected by the dual, flat air streams, so we are able to project the water droplets farther into the compressor inlet air stream, says Bromley. "That way, the droplets get to where they are needed instead of running off the plenum surfaces and concentrating at Inlet Guide Vane hub areas."

Nozzle placement

In addition to having the right types of nozzles, where they are placed affects the thoroughness of the wash. The spray pattern needs to be determined for each type of turbine. The correct nozzle placement is not always obvious, but often requires the use of Computational Fluid Dynamics (CFD) modeling (p. 12 Jan./Feb. 2007).

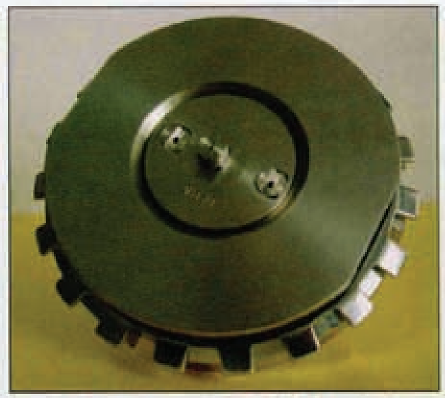

Figure 3: In Turbotect's PSA Mk 3 nozzle, the water stream is protected by dual, flat air streams, to ensure that the water droplets are projected into the compressor inlet air stream

Giving an example, Conntect's Labas explains that modeling on an LM6000 with one manifold showed that all the water would hit the cone. "We determined from CFD that we had to have a second manifold outside to get coverage from the root to the tip of the blade."

Modeling generally needs to be done only once for a particular turbine model, unless there is something unusual about the inlet design at a particular location. In most cases separate arrays are used for the on-line and off-line nozzles, however, ECT has a patent pending for a design that allows operators to change the nozzle tips in an array so the same array can be used for both types of washes.

While everyone agrees that the droplets must be the proper size and evenly distributed, there is considerable disagreement over the quantity, velocity and temperature of those droplets. On-line washing needs to be done with the highest possible water-to-air ratio, says SWRI's Brun. "By increasing the water amount and by having a very high water-to-air ratio, you are reducing the redepositing process."

Turbotect believes in minimizing water usage, using low-flow, low-pressure systems. More water does not necessarily mean better washing, but the nozzles must be correctly positioned to give efficient wetting of the IGVs, says Bromley. "If you can achieve good results by injecting less water, that is important."

GTE uses high-pressure systems, but ECT does not think they are necessary. We do not typically find that higher pressure gives us any benefit beyond the first or second stage, says Tassone. "Beyond the first or second stage, all the pressure and velocity is dissipated, so low- to mid-pressure systems work just as well as high-pressure systems."

GE and FP Turbomachinery

Consultants GmbH of Emmendingen, Germany, both heat the wash water before use. "Clearly, heated wash solution works better than a cold fluid," says Oliver H. Platz, manager at FP Turbomachinery. "We know this effect from home dishwashing; the tougher the dirt, the better the results when the temperature is set to higher levels."

But Turbotect feels this is overkill. We do not think heating is necessary if an efficient nozzle injection system and a good detergent are used, says Bromley. "It has been shown in CFD studies that droplets rapidly cool to air temperature anyway before they reach the Inlet Guide Vanes, especially on large machines."

Whatever choices one makes in terms of nozzle design, spray patterns, water flow, temperature or pressure, the compressor wash skid should be matched to meet those requirements.

A wash skid needs to be designed to deliver the correct flow rate and pressure of water to those nozzles, adds Bromley. "You cannot just take a wash skid that was designed for one system and expect it to work if you change the nozzles."

Use of fluids

Finally, let us take a look at the use of detergents in the washing cycle. Everyone agrees that they should be used in off-line washing, and manufacturers have largely replaced their solvent-based products with water-based ones due to environmental and safety concerns. When it comes to on-line washes most agree that only deionized or demineralized water should be used whenever possible.

Since the compressor is still running, it will evaporate whatever water is thrown in by the sixth stage at the latest, and redeposit the dirt downstream, says Brun. "If you have a heavy dirt or salt deposit in the later stages of your compressor, you will have a hard time getting those out even with off-line washing, and salt deposits will lead to surface corrosion which really makes life miserable."

There are, however, cases where detergents are necessary, particularly when oil or grease in the airstream act as glues to stick other foulants to the blades. This decision can only be made by testing at a plant to see what works best with its specific operating conditions.

If traces of oil and grease are present, the use of approved detergents is likely to improve on-line cleaning, even if contact time is small, says Bechtel's Meher-Homji. "However, if fouling material is completely water soluble, or water wettable with no oil and grease present, the use of demin water alone is often sufficient."

Recovering lost power

There are a number of options available for compressor washing, and there is considerable disagreement in the industry about what works best. The underlying issue is that there is no single best option for all types of turbines, all types of dirt and all operating schedules.

"People wish there was a book where they could just turn to p. 37 and it would tell them what they should do at their plant," says Bromley. "Unfortunately, it does not work that way, but there are people who know about this subject and who will work with them to help determine what is best for that particular plant."

It may take a bit of work, but finding the right cleaning solution is a cost-effective way to improve reliability, performance and efficiency. "Many millions of research dollars are spent to tickle out another percent or two of turbine efficiency," says FP Turbomachinery's Platz. "All that seems almost in vain when these machines are then run at five (or more) percent fouling-based losses after commissioning." TI