POWER**Engineering**

Repairing Hot Section Nozzles Can Be Cost-Effective

An effective method for repairing hot section nozzle trailing edges is coming for large gas turbines.

By **Steve Blankinship**, Associate Editor

With recent natural gas price volatility, gas turbine plant owners are scrutinizing every aspect of operation expense to optimize performance, maintenance and life cycle costs. One area is the repair and refurbishment of gas turbine hot section components such as the combustion system, turbine buckets and nozzles.

Working closely with plant owners, refurbishment companies routinely make cost/benefit decisions to either scrap or refurbish components in the turbine's first stage nozzle, especially nozzle trailing edges. Buying entire replacement nozzle segments for these cobalt/nickel-based castings can be prohibitively expensive and require long service outages. In most cases, the purchase price can be an order of magnitude higher than the repair cost.

For General Electric B&E class gas turbines, the option of repairing nozzles with significant trailing edge erosion or damage instead of replacing them is often possible - and can be done for less money and in less time. The method is based on using trailing edge coupons that match the geometric dimensions and metallurgical properties of the existing part. Coupons lend dimensional control and sound material properties to refurbishments and are made from the base metal of the part being repaired.

The process can be fast, cost effective and is capable of improving component life compared to a typical weld repair process. The field-validated process is currently available for nearly all GE Frame gas turbines below F-class (including Frame 3, 5, 6B, 7E, 9E). And it will soon be expanded to other original equipment manufacture (OEM) gas turbines deployed worldwide, including GE 7FAs and 9FAs. The repair method's roots can be traced to the need to make early and frequent first stage repairs on

This Stage I nozzle segment has a coupon with trailing edge cooling holes as drilled with EDM process.

Photo courtesy of Frarendi.

turbines in countries where fuel supplies contain high levels of impurities that cause rapid and extensive nozzle erosion and corrosion. "A way had to be found to repair those nozzles rather than constantly buying new ones and replacing them," says Kevin Davis, president of Tipton, Indiana-based Frarendi. The company was founded in 1981 by Frank Dickinson with his invention of the Frarendi replacement coupon to repair gas turbines in Saudi Arabia.

"It worked very well," says Davis of the repair approach. Dickinson's technical expertise spans 55 years of specialization in super alloys and metallurgy. He worked for Haynes-Stellite, Eastern Stainless Steel, Moore Drop Forging and Nuclear Metals. His solution came as the gas turbine building boom in the United States was well under way.

Although domestic pipeline gas supplies are generally free of impurities, the high run times they experienced in the days of low natural gas prices soon began taking their toll. The typical time for first stage nozzle segments go into a service shop can be anywhere from 24,000 to 36,000 hours - about three to five years when running primarily in baseload service. Typically, repairs are easy the first time nozzles come to a repair shop. If just a little cracking is present, they can be welded. Damage caused by intrusion of minor foreign objects might also only require replacing small parts. Extensive trailing edge damage caused by foreign objects requires additional consideration.

Still, at best, welding is a Band-Aid approach, adequate for mending typical cracks found during inspection. Furthermore, weld fillers typically aren't as metallurgically sound as the base metal. By the second or third visit to the shop, enough erosion may have occurred to require a nozzle to either be replaced or repaired. And if substantial corrosion/erosion has occurred on the back end of the nozzle section, deterioration may be so extensive that weld repair won't work. And if damage from foreign objects has occurred, weld repair may simply be impossible.

Cooling Holes

Early gas turbine models did not have intricate cooling features in the first stage nozzles, so replacing components used to be much easier and less expensive. Then major OEMs such as GE and Siemens-Westinghouse started marketing combustion turbine technology using elaborate, complex and highly precise cooling holes drilled into nozzle surfaces and trailing edges. The holes were designed to exhaust the cooling air from inside the first stage nozzle and lay a film of cooling air on the outside surfaces of the nozzles, protecting them from impinging hot gas coming from the combustors. Although these design changes have allowed gas turbines to run at higher temperatures and with greater efficiency, they have increased the complexity and cost of repairs. A more cost effective refurbishment solution was needed.

Even severely damaged nozzle blades can be cut out and a trailing edge coupon dropped into place ready for welding.
Photo courtesy of Frarendi.

"The trailing edge coupons manufactured by Frarendi are delivered complete with these intricate cooling holes already machined into the part," says Davis. The hole geometry is created by using an electro-discharge machining (EDM) process, which allows cooling hole geometry to cases, the cool hole geometry needs to be precisely created in the coupons. In some shaped or non-circular. The EDM process, done correctly, allows such holes to be created.

"We make it easy for them by proving the coupons ready-to-use so they can take it from there," Davis said. "It's a fast, cost-efficient way to salvage a nozzle that previously would have had to be scrapped."

Creating the holes precisely can be deceptively difficult. Companies with EDM capability must be well versed in the process - from tooling and equipment design, electrode plunging methods and years of "lesson learned" experience.

"These just look like small holes," says Davis. "But in the service shop world, one or two of the holes not being just right can impact the way the part holds up. So getting the holes right is critical."

He describes that without the right coupon, a person making such a repair could weld in a block of nozzle alloy, then attempt to EDM the holes back into the structure as best they could. "Trying to create the holes on an eroded, damaged end is extremely difficult," he says. "Refurbishing shops found that such repairs gave them fits."

Refurbishment shops want a repair process that is simple, quick and produces predictable, high quality results. They also want a process that can all but eliminate the need to buy new nozzle segments. “We make it easy for them by proving the coupons ready-to-use so they can take it from there,” says Davis. “There’s no licensing, special process, additional know-how required and they don’t need any special tools. They simply cut out the damaged section and weld in the new coupon. The coupons are made of high quality investment castings with tight geometry and sound metallurgy to ensure that performance is not compromised. It’s a fast, cost-efficient way to salvage a nozzle that previously would have had to be scrapped.”

The coupon is created by geometrically characterizing the OEM nozzle inside and out, generating solid models in a CAD/CAM system and working with investment casting houses to make the actual coupons. They are made of the same super alloy - FSX-414 for example - as the original base metal of the nozzle being repaired. FSX-414 is a high quality, castable, weldable cobalt/nickel-based material that has been used in the industrial gas turbine world for decades.

In addition to repair needs stemming from an aging gas turbine fleet, changes in the way gas turbines are presently cycled also places greater stresses on first stage nozzles than just letting them run. That accelerates the needs for repairs. The use of various forms of syngas, at a trend that might increase in the future if natural gas prices remain high, could also shorten required repair intervals. Refueling using LNG, hydrogen-based fuels or other synfuels would also allow units to run longer hours, thus boosting repairs. The increasing use of landfill gas can also increase corrosion-driven repairs.

Fixing Bigger Machines

Repair techniques currently available for GE F-class stage 1 nozzle turbines are weld repair or activated diffusion healing (ADH), which is similar to a braze repair of small cracks and has its limitations. Recently, refurbishment shops have been asking for a coupon to use in repairing 7FAs. Davis says that 7FA owners, squeezed on their O&M budgets, are coming to the repair shops saying they don’t care to spend large amount of money to get new nozzle segments if they don’t have to.

7EA nozzle segment and the 7FA SLA trailing edge coupon pix being taken this week.

“They are demanding the refurbishment shops to offer a more cost competitive way of fixing them, and will give them their business if they do.”

Frarendi plans to deliver a solution for repairing 7FA nozzles.

The new coupon recently moved from the plastic “stereolithography” form to the casting stage and will be available this summer. The company is also planning a fix for the Siemens-Westinghouse 501D5, a model of gas turbines that began service in 1982 and is currently deployed worldwide. A fix is also in development for GE’s 9FA fleet. The company has streamlined its production process and can deliver on customer requests in as little as 12 to 16 weeks, says Davis.

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The coupons are sold in sets based upon the number of vanes in a machine. Partial sets are sold when a coupon repair isn’t needed on every nozzle. “We offer maximum flexibility for the service shop,” says Davis. “They decide what they need to do and how costly and extensive the repair needed.”

Frarendi will also provide support to any refurbishment facility using its coupons and will work with any refurbishment house to develop and deliver coupons for unique needs. **Ω**