Verifying repairs, final inspection results

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This is the last in a series of four articles outlining the six critical steps to successful refurbishment of industrial gas-turbine (GT) parts. First two steps (published in the COMBINED CYCLE Journal, 2Q/2005) described onsite assessment of component condition and development of repair specifications. Step 3, guidelines for selecting the appropriate repair vendor(s) to meet your plant's specific needs, was presented in the 2006 Outage Handbook supplement to the 3Q/2005 issue. In the last issue, 4Q/2005, the vendor verification process for incoming inspection was covered. Steps 5 and 6, covering vendor verification during the repair, coating and inspections performed during the refurbishment process, and final inspection of refurbished components are described here.

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5. Verification during the refurbishment process

Step 4 offered guidance for proactive users during the initial inspection process—including metallurgical evaluation, disassembly, cleaning and stripping, post-weld heat treatment, and dimensional and nondestructive examination. That step complete, repairs now can be made where required; also, the components can be recoated. For a snapshot of key steps, refer to the flow chart included as part of the first article (Fig 2-1), which can be accessed at www.psimedia.info/ccjarchives.htm.

Preparation for welding, brazing, and coating. Before any of these processes can be performed, the surface must be prepared to ensure that it is free of cracks, coating, oxidation and corrosion products, and other contaminants. For weld repair, cracks generally are removed manually with air tools, followed by a liquid penetrant inspection to ensure that the end of the crack has been reached.

Next, the penetrant, developer, oil, and other contaminants are removed to enable proper welding. Note that that the removal of cracks is a critical task in Step 5 and the temptation for taking "time-saving shortcuts" should be avoided. Premature cracks can develop during pre-weld activities—such as heat treatment—or later during GT operation when preparation activities are rushed.

5-1. Fluor ion cleaning is one of the methods used to prepare components for brazing

A few repair facilities use the same prep processes for brazing as they do for welding. However, most rely on the hydrogen (for cobalt-based materials) and fluor ion (for precipitation-hardened nickel-base materials) cleaning processes (Fig 5-1). Their effectiveness on internal surfaces exposed by cracks only can be verified by conducting a metallurgical inspection of a representative sample processed with each batch.

Surface preparation using grit of controlled quality and size applied at the proper pressure is important. Use of new grit is recommended before coating application; metallic grit before brazing. The time interval between prep and the welding, brazing, or coating stages should be short and the environment controlled to prevent surface contamination. Keep in mind that outsourcing component cleaning to a specialty shop can be in vain unless extreme care is taken to ensure contaminant-free handling, packaging, and transport.

It is particularly important for the end user or its representative to ensure that the contractor adheres to its procedures and scope of work as the first batch of components is repaired, even if that means several visits or a prolonged stay. Items to include on your audit checklist: quality of personnel training, visual inspection of the end results, and the care displayed in handling components to prevent contamination.

5-2. Temperature control of the repair process is critical for achieving desired results

Welding. One of your tasks during the repair-facility selection phase was to verify independent qualification of both the welding process and the welders. Components repaired by trained and certified personnel following the parameters outlined in the qualification documentation generally assures that job quality and performance will meet expectations.

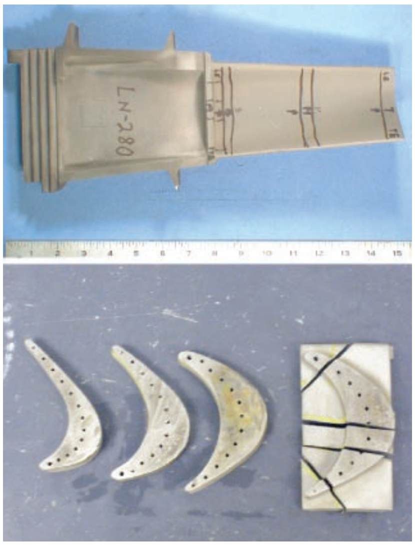
Welding using a low-heat-impact method is recommended to enable a high-quality repair. It minimizes component deformation and the size of the heat-affected zone (HAZ). Time constraints, such as those imposed by lead-time or commercial issues, sometimes suggests the use of a heat input that is higher than desirable. Caution is advised here: It can contribute to deformation or premature cracking at the HAZ (Fig 5-2).

Even components that can pass the final inspection may be of substandard quality if the welding process is rushed. An unannounced visit during weld repair is suggested to verify the repair facility's compliance with its procedures, quality specifications, and scope of work. A benefit of having complete confidence in the job being done comes at the end of the project when you might be able to save time by just reviewing the results of the final nondestructive examination rather than by witnessing the inspection.

Brazing raises quality concerns, particularly among end users having no experience with the process or the repair facility recommending it (Fig 5-3). Reason: Braze compositions and procedures typically are confidential and not disclosed to the customer. But even when disclosed, only limited metallurgical and mechanical data—such as stress rupture, ductility, and impact and crack resistance—are provided. Further, if weld repair is required after brazing it can be challenging.

However, the recent development of brazes containing boron and hafnium, which act as melting-point depressants, have been able to overcome most of the ductility and weld-repair concerns. If your contractor uses braze technology during the repair process (refer to Step 3), demand complete first-article test results. For later lots, verify use of the same procedure that was applied to the first article. Also, that proper inspection steps are in place—including metallurgical evaluation.

5-3. Quality is of concern with braze repairs because shops are reluctant to disclose process details



5-4. Destructive, metallurgical evaluation is suggested for evaluating coating quality

Coating. Today, most coatings used in repair processes are applied by thermal spraying. Diffusion coatings find greatest application on internal surfaces. At recent industry meetings addressing thermal spray coatings, the importance of repeatability was emphasized by several presenters. According to the experts, more than 3000 parameters can influence the quality of a thermal coating. Thus process repeatability should be a primary focus of your vendor audit. This includes making sure technicians performing the work follow instructions to the letter.

Monitoring of process quality and repeatability includes the following:

- Verify coating thickness using eddy-current, weight-gain, or physical measurement methods.
- Take bond-strength and metallurgical samples to confirm use of specified procedures.
- Perform a destructive metallurgical evaluation of an actual part (Fig 4-4) to evaluate coating quality. When this is not possible, verify that specifications for grit cleaning, time between cleaning and coating application, etc, are followed to ensure a quality equal to the quality demonstrated on the first article.

Pre-coat inspection. Finally, it is important to verify findings of inspections that cannot be conducted and/or corrected after coating and reassembly—such as area and check, harmonics, and wall thickness. The repair facility should provide these results to the end user or its representative for review.

6. Verifying final inspection

Quality records. Final step of any final-inspection verification should be a review of all quality records for conformance to specifications. Things to remember:

- Ensure that all records are signed by the appropriate technician, inspector, or engineer, and dated.
- Be sure documentation includes certificates for materials and specifics of all subcontracted processes.
- Verify traceability of materials—including weld filler and braze—to their certs.
- Confirm proper heat treatment based on recorded temperatures, time on temperature, heating and cooling rates, and quality of atmosphere.
- Check coating certifications, including metallurgical evaluations, and inspection documents—NDE (nondestructive examination), dimensional, flow, frequency, area, and harmonics, as well as moment-weight and sequence charts.
- Some of the quality records may reveal items out of spec or identify other concerns that should be addressed during final verification. Keep copies of critical records for your files.

NDE verification. Confirm the condition of your components as soon as practicable after final heat treatment. Inspection at this stage gives a good indication of workmanship and overall condition of your components. However, keep in mind that the new coating can limit the effectiveness of liquid-penetrant (PT) testing and mask cracking that could occur during heat treatment. PT and/or other NDE methods should be conducted after each heat treatment, but especially after the last one. Verify the quality of any touch-up work with PT and retain documentation.

Consider being present in person or through a representative during all final NDEs—or at least until good insight is obtained regarding practices in use at the repair facility during days, nights, and weekends. Keep an open mind regarding blend repairs versus weld repair if inspection results suggest rework: It's the quality of the repair that's important, not its appearance.

Dimensional verification of critical measurements—including roundness, clearances, height, thickness, throat openings, etc—provided by the repair facility is strongly recommended. The validity of these measurements depends in large measure on the dimensional accuracy of fixtures used as part of the repair process. Recall that fixture qualification was conducted as part of Step 4. True verification of dimensional accuracy comes when components are reassembled into the GT. Feedback from this work should be incorporated into your final report and factored into future decisions regarding vendor selection.

If specifications agreed upon with the repair facility are not achieved, for future projects you may want to consider making performance requirements less demanding and/or changing the scope of work. Alternatively, you might consider a new vendor.

Other. Depending on the component, other measurements may be needed to confirm the quality of work done—including cooling-air flow, frequency, moment weight, area, and harmonic checks. Well-defined specifications should be developed for these operations because industry standards typically are not available. Suggestion: Let the repair facility repeat some of the measurements required to be sure it can achieve an acceptable level of repeatability and that all measurements are within spec.

This information may be of greater value in the future when experience indicates what components are most susceptible to failure and when working with advanced components. Later review of quality records—such as heat-treatment charts—also may warrant a closer look at some of the repair and inspection processes used and possible changes to those processes. The value of lessons learned is that they can be incorporated into future repair work to improve quality.

The final visual. Before your components are loaded for shipment, conduct a final visual inspection to ensure that the parts are clean and not susceptible to handling damage. This is especially important for the fragile coating edges. Also, be award that the coating and the last grit cleaning operation can close up cooling holes. They should be inspected using wire, light, water, and/or air methods. Finally, be sure that shipping containers are sturdy enough to withstand the rigors of transport and that your components are well supported in these containers. CCJ