Six steps to successful repair of GT components

By Hans van Esch, TEServices

This is the first in a series of four articles outlining the six critical steps to successful refurbishment of industrial gas-turbine (GT) parts. First two steps—onsite assessment of component condition and development of repair specifications—are presented below. The second article (next issue) will provide guidelines for selecting the appropriate repair vendor(s) to meet your plant's specific needs; the third will describe the vendor verification process for incoming inspection; the last, vendor verification of repair, coating, and inspections performed during the refurbishment process of your components.

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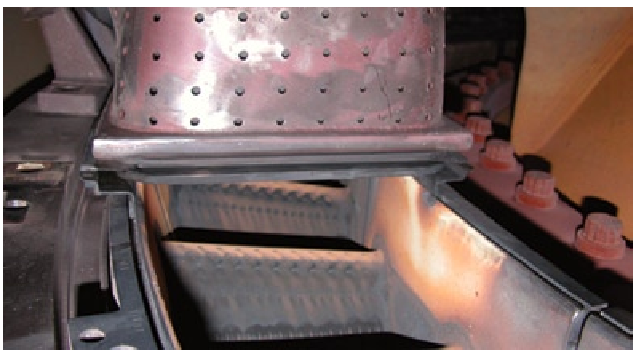
1. How to assess the condition of GT parts onsite

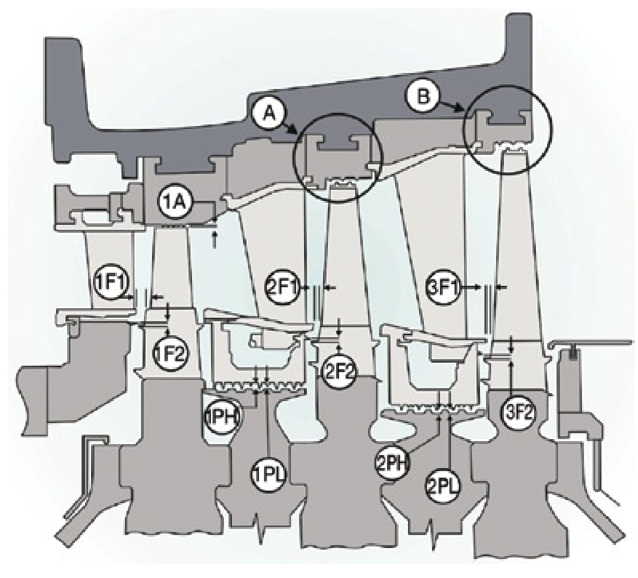
Owners and operators that take a proactive role in defining gas-turbine (GT) repair and coating requirements ensure receipt of quality refurbished parts at a competitive price. Plus, top-quality components are conducive to maximizing the time between overhauls, thereby reducing O&M costs.

Refurbishment of components should begin with parts inspection and condition assessment at the plant before disassembly (Fig 1-1). The information compiled is helpful in selecting the repair and coating vendor, developing the repair and bidding specifications, and avoiding rework caused by fit-up problems.

Checking dimensions. Before removing any parts, check clearances at critical locations (Fig



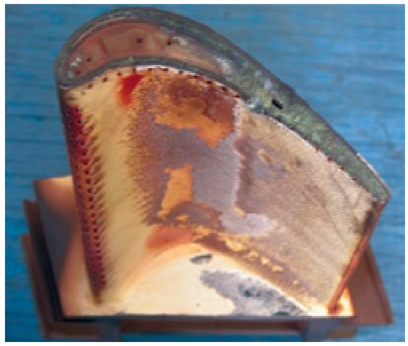
1-1. Onsite inspection of nozzles and transition piece provides information helpful for selecting a repair and coating vendor (above)



1-2. Checking of clearances at critical locations prior to disassembly is extremely important. Impact of creep is to close clearances; wear increases clearances (right)

1-3. Slow rotation of the turbine rotor causes blades to "rock," opening clearances between blade roots and mating rotor slots. Blade rock should be measured during or prior to disassembly (left)

1-4. This bucket requires some TLC. Note wear, "bare" spots where coating has flaked off, and cracks (right)



1-2). Recall that hot-section components are subject to creep, which causes them to deform and reduce as-built clearances. This is especially true for unsupported components that are exposed to high temperatures and stresses—such as shrouded blades (second-stage buckets) and second-stage vane segments (also known as nozzles).

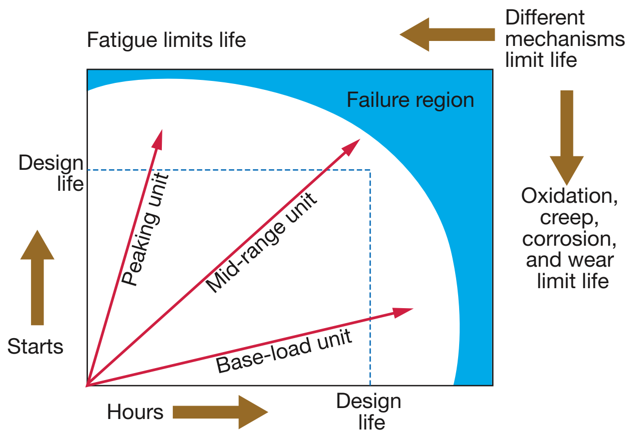
Wear can increase clearances beyond those recommended by the OEM (original equipment manufacturer). It occurs most often where a rotating part rubs a stationary component, such as at blade-tip and angle-wing locations. Wear also results from prolonged slow rolling of the turbine rotor on turning gear. So-called "blade rock" is caused by an increase in clearances between blade roots and the mating root slots in the wheel (Fig 1-3). The problem gets worse with time.

In most cases, manuals provided by the OEM describe in detail how plant staff can measure clearances and blade rock. Alternatively, a repair vendor or consultant can assist plant staff. The data gathered, coupled with a thorough visual inspection, helps determine if dimensional correction is necessary. Such work can involve blade-tip and angle-wing restoration, correction of downstream deflection (DSD), restoration of blade segments (shroud blocks), and/or application of an anti-rock coating.

The information compiled also is valuable in the verification both of dimensions taken during the repair vendor's incoming inspection and of its proposed repair process. Doing the job correctly the first time avoids late deliveries and time-consuming fit-up problems during reassembly.

When evaluating the proposed repair process, avoid the temptation to save money by taking shortcuts. For example, restoration of a component and not its matching partner (such as bucket and shroud block) can lead to problems during startup and/or abnormal operating conditions.

Visual inspection. Regular borescope inspections are valuable for periodic monitoring of parts condition. Findings can be confirmed and any deterioration—such as deposits, erosion, oxidation, corrosion, melting, wear, impact damage, etc—can be better evaluated with the naked eye or with aid of a magnifying glass when components are disassembled. Keep in mind that visual inspection by itself can be misleading and should be used primarily as a tool for identifying areas in need of further assessment.



1-5. Assessment of equipment condition should determine the need for refurbishment, not theoretical assumptions based on starts and operating hours as shown

Evaluation of information compiled during the visual examination and dimensional checks is particularly helpful for identifying damage that may require further analysis before final decisions are made regarding parts replacement or reconditioning. When component deterioration is so severe that it dictates the overhaul cycle, a root-cause analysis is in order. This should be conducted before any work, such as cleaning, is performed on the components that might compromise the investigation. Detailed operating data are needed to fully understand why the damage occurred.

Your repair vendor may be capable of such metallurgical analysis. If not, an independent laboratory can conduct the damage assessment. The laboratory selected should have a good understanding of GTs in general, as well as specific knowledge of your engine type and running conditions. Such analysis often provides guidance on how to improve component performance. Thus the repair work specified and the selection of a coating to accommodate actual operating conditions should increase the life of the part and extend the time between overhauls.

Importance of operating history. The actual number of starts, type of shutdown (normal or trip), and hours of operation are used by the OEM to determine when it believes an overhaul is necessary (Fig 1-5). This calculation can be further defined based on theoretical assumptions such as firing temperature and fuel. It is not in the best interest of most owners and operators because results often suggest overhaul earlier than may be necessary. When overhauls are governed by an OEM's long-term service agreement, you may have no other option.

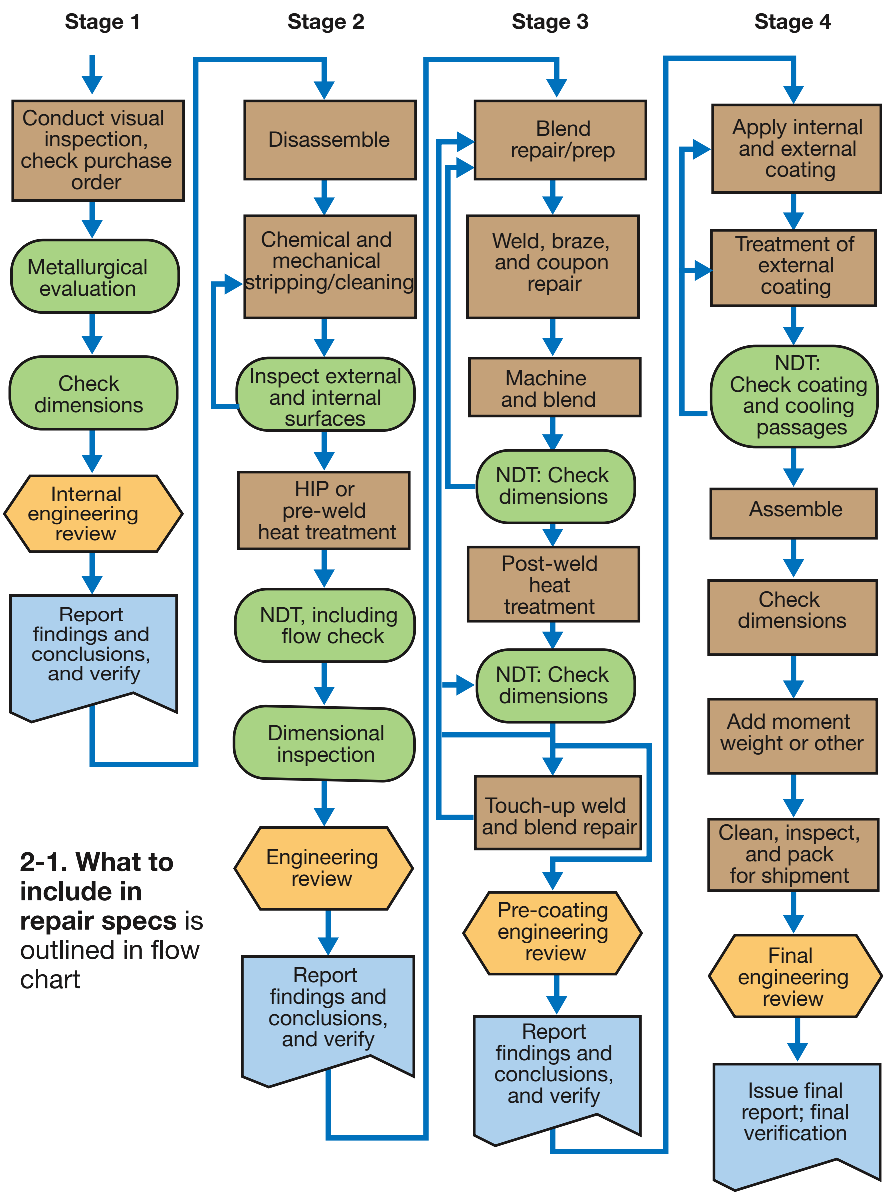
However, absent an LTSA, a better method might be to base overhauls on the actual condition of critical components. Plot your assessment of component condition (based on dimensional check, examination of coating and base material, etc) against operating conditions (fired temperature and hours, starts, etc) and identify the component that is driving the need to initiate an overhaul. Develop a plan to extend the operating life of this part through better coating selection, etc, thereby extending the time between planned outages.

Key to this approach is the development of a meaningful database. Carefully track and record the operating history of all critical parts, making sure to include such information as parts coatings and base materials, hours at temperature, use of water or steam for emissions control and power augmentation, etc. Access to such an information resource facilitates decision-making on outage scheduling, identification of components to repair and those to replace, etc, based on your plant's actual needs.

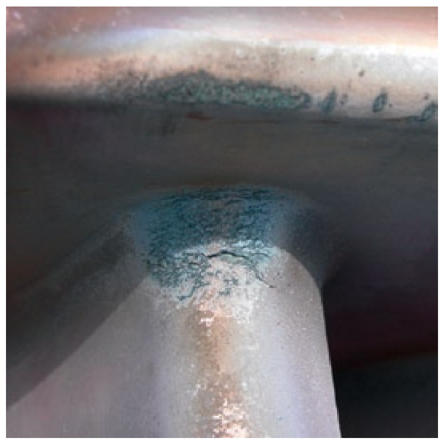
2. Preparing meaningful component repair specs

Preparation of component repair specifications is the first step in vendor selection and these specs should be part of your bid package. The specs also provide a framework for evaluation of work in progress and for conduct and verification of critical inspections from receipt of parts by the contractor through project completion.

Existing specifications from previous repairs or end-user organizations are a good starting point for developing the specific component repair specs you need for the next overhaul. If you have no experience in writing specifications and have no good examples available for reference, call a knowledgeable colleague or a consultant specializing in this



2-1. What to include in repair specs is outlined in flow chart



2-2. Onsite inspection identified the need to repair this Model 7FA second-stage nozzle (above)

2-3. Dimensional checks pinpoint deformation and other problems that should be addressed in your repair spec (below)

work. Avoid "help" from repair facilities that might be on your bidders' list. The flow chart (Fig 2-1) lists some of the items you'll want to include.

Key to your specification development is information compiled during visual inspection (Fig 2-2) and checking of clearances (Fig 2-3) discussed in the first part of this article (above). Also, factor in previous repair experience with the same components and the experience of others on similar parts—things you might have learned at a user-group meeting, for example.

To ensure quality work, divide the repair process—and your spec—into logical stages. You want the repair facility to report its findings and recommendations after each stage and not proceed with the work before you or your representative approves. In most cases, dividing the repair process into the four stages illustrated in the flow chart will produce positive results. The four stages are:

- Receive and conduct the initial inspection.
- Disassemble components, clean/strip, heat treat, and inspect.
- Repair, heat treat, and inspect.
- Coat, reassemble, and make a final inspection.

Stage 1: Receive, inspect

Start your repair specification with receiving, where the parts are visually inspected to ensure that no handling and transport damage have occurred. Individual parts should be identified and marked, and match the shipping and purchase documentation. Dimensional and visual inspections are next, followed by removal of metallurgical samples and disassembly.

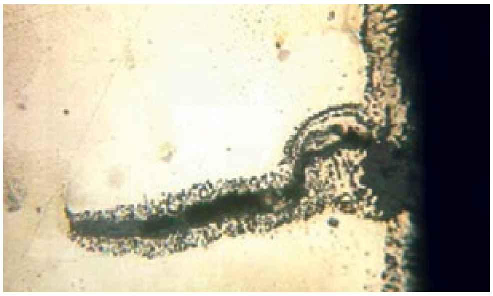
Flow testing of internal cooling circuits with rod, water, or air should be performed at the beginning of the repair process to protect against plugging during cleaning and other operations. Visual inspection during early work can confirm the repairability of a component (Fig 2-4) before more cost is incurred. This also assists in selecting sacrificial parts—those from which representative metallurgical samples will be removed.

Metallurgical evaluation is vital for characterizing the base material to ensure that standard heat treatment will be successful in regaining desired properties post repair. Sometimes special heat treatment—such as hot isostatic pressure (HIP)—is required to make parts serviceable.

External and internal (cooling cavities) surfaces also require evaluation. Consider these possibilities: The internal coating can be in such good condition that stripping and recoating may not be necessary. By contrast, uncoated internal surfaces can be so heavily attacked by oxidation that oxidation products penetrate the grain boundaries (Fig 2-5) and ultimately form cracks that reach the external surface.

Evaluation of the external surface can reveal if the coating system provided the required protection for the component or if another coating is required. In the case of uncoated external surfaces, the amount of degradation can be determined; it must be removed before repairs are made or the coating is applied.

Following incoming inspection and metallurgical evaluation, an engineering review should be conducted with the owner or its representative present. Both parties must come away from that meeting confident that the original scope of work still will result in the desired outcome. Adjustments in cleaning, stripping, repair, and the coating process can be made, if necessary; worst case is that components must be scrapped.



2-4. Visual inspection alone sometimes can identify parts that cannot be repaired—like this Frame 7 bucket (left)

2-5. Metallurgical evaluation helps pinpoint problems such as this internal oxidation attack to IN 738 material (above)

Stage 2: Disassemble, clean and strip, heat treat, inspect

A more thorough inspection of parts received for repairs requires disassembly and removal of hardware—such as core plugs, impingement sleeves, etc. This work makes the surface accessible for cleaning, stripping, and heat treatment without risking damage to other areas of the component.

Most of the coating generally is removed by chemical stripping. Then the external surface can be inspected by heat tinting or macro-etching, so any remaining coating and oxidation/corrosion products can be identified and eliminated by blending.

Important: Specify tight control stripping/cleaning processes to avoid unnecessary thinning of the component.

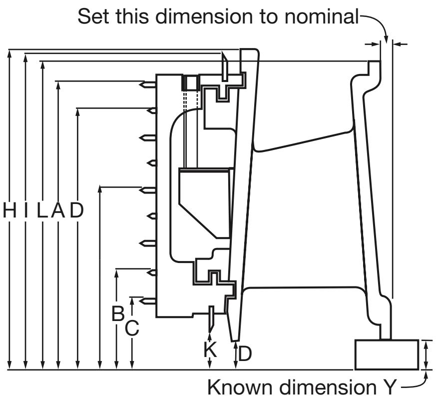
Nondestructive examination. Preparation of components should include standard pre-weld solution for nickel precipitation and cobalt-based superalloys. Occasionally, metallurgical evaluation also suggests the need for specialized heat treatment. Note: In most cases, there are no standard heat treatments.

When specifying the type of NDE for your components, keep in mind that ultrasonic and eddy-current testing can detect sub-surface indications and, therefore, may have advantages over visual and liquid-penetrant inspection. Also, these technologies can determine wall thicknesses at critical locations. Once again, the inspection team should verify that cooling passages are open.

More detailed dimensional checks are required at this stage—such as determining the downstream deflection of nozzle or vane segments (Fig 2-6). This step completes the so-called "incoming" inspection and another engineering review with owner participation is recommended to ensure that the scope of work still will provide the desired outcome.

Stage 3: Repair, heat treat, inspect

The repair process can start after a component is cleaned/stripped, solution heat-treated, and inspected. In most cases, TIG (tungsten inert gas) welding is used for repair, although several facilities also use brazing for component restoration. Keep in mind that while weld methods and filler materials are comparable throughout the industry, braze repairs are proprietary processes. This makes it especially important for you to define in your spec if brazing is allowed and where and under what circumstances it can be used.

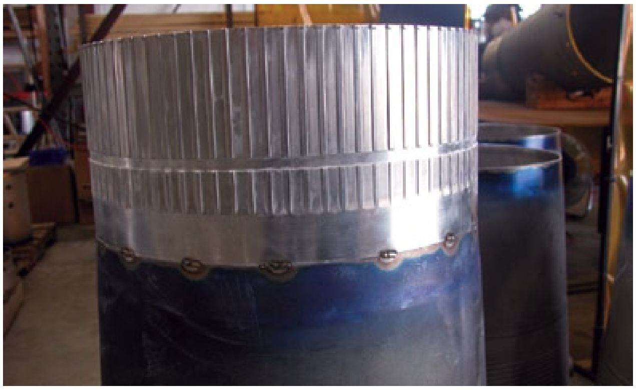


2-6. Dimensional checks conducted by the repair shop are necessary to determine such things as downstream deflection of nozzle or vane segments

Replacement of sections of your components—so-called "coupon repair"—sometimes is required to make the parts serviceable (Fig 2-7). The replacement material should have metallurgical properties the same or better than the original.

Post-weld heat treatments that follow the repairs should be combined with the heat treatments required for coating application and diffusion. Important variables in the heat-treatment process include time on temperature, furnace atmosphere, and heating/cooling rates.

Be aware that vendors sometimes subcontract heat treatment and other critical process steps. When preparing repair specs, ensure that your company has access to its components at both the contracted repair facility and all of its subcontractors until the reconditioned parts are returned after project completion.



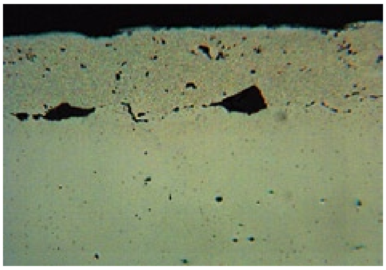
2-7. Replacement of sections of components sometimes is necessary to make parts serviceable

Before coating and reassembly is permitted, yet another inspection is necessary. This is especially critical for items that cannot be inspected or corrected later in the repair process because of heat-treatment, coating, or assembly issues. As for the preceding steps, another engineering review is suggested here to decide if coating and assembly should proceed.

Stage 4: Coat, assemble, inspect

The application process is as critical to coating performance as the selection of the proper coating system. Your spec should address so-called "first-article" qualification, process repeatability, and final inspection. Coating quality should meet specification requirements and be as good or better than that demonstrated on the same or comparable component during the qualification trial. Metallurgical evaluation of the qualification sample should be part of the verification process (Fig 2-8).

The application procedure must lend confidence that this result can be repeated as many times as necessary without question. Quality checks should be conducted to verify process repeatability.



2-8. Metallurgical evaluation of coating quality is a necessary part of the repair process

After coating and inspection are complete, component reassembly can proceed. During reassembly, dimensional checks are necessary to ensure proper installation of core plugs, wear strips, etc. Final inspection should include dimensional verification, like area and harmonics checks of nozzles, moment weight and sequencing for blades, unrestricted internal cooling passages, and visual confirmation of a job well done.

The repair process can be considered complete after the repair vendor's final report is received and accepted. It should include all certifications, inspections, and engineering recommendations. This information is important should problems arise. Also, it provides valuable input to repair specification development for the next overhaul. CCJ