GT component repairs: Why value matters

Nagy

Doug Nagy's (Liburdi Turbine Services Inc, LTS) presentation was particularly valuable for managers charged with making repair/replace decisions on hot-gas-path (HGP) components and with selecting an appropriate shop when repair is the route selected. It also was an eye-opener for newcomers. The meticulous Nagy indoctrinated them on the importance of rigorous due diligence in evaluating repair shops, of proper coating selection and application, and of uncompromising quality.

Many attendees had to return home convinced that formal training in basic metallurgy, HGP repair technologies, and quality control was a prerequisite for advancement in the plant O&M hierarchy. To that end, a popular introductory course on GT component metallurgy and refurbishment is offered periodically by the ASME's International Gas Turbine Institute, Atlanta. It typically is co-located with a major industry meeting, such as the society's annual Turbo-Expo.

"Quality" is a word you hear from virtually every salesperson when evaluating a product or service. But what does it really mean? Nagy offered a simplistic, meaningful definition: Meets all requirements. "High quality" is a common term, he continued, but the modifier "high" is irrelevant: The product or service is either "quality," and meets all requirements, or it is not quality because it does not meet all requirements.

Quality typically is controlled in component repair by the use of specifications for materials, repair processes and limits, dimensions, future serviceability, delivery schedule, and cost. The primary goal of your spec should be to ensure that the repair is reliable, with minimum risk of service problems, and that it will behave similar to the original new part during the next service interval.

Examples of poor quality, he continued, include the following:

- Welding in inappropriate areas—that is, repair limits are exceeded.
- Welding with an inferior alloy—for example, one that does not meet strength and/or hardness specs.
- Coating material is inappropriate for preventing oxidation/corrosion under the specified service conditions.
- Coating application process is out of spec—for example, coating is too thick or too thin.
- Critical dimensions are not fully restored.
- All defects are not identified and/or corrected.

An obvious question: Why does poor quality happen and where should users focus their attention when evaluating suppliers and work in progress? Nagy offered these comments after cautioning "caveat emptor":

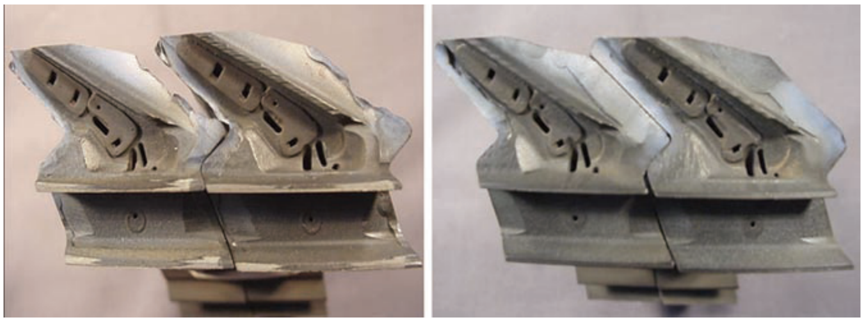
- Power generation is an unregulated industry. Hence, no industry standards for repairs to land-based engines exist as they do for flight engines. Each vendor, in effect, has its own standards.
- Shop backlog and final negotiated price can adversely impact vendor decisions regarding the use of cost- and/or time-saving methods/procedures that may not benefit the GT owner. Similarly, not allowing sufficient lead time for repairs before outage dates encourages poor vendor decisions.
- Depth of knowledge and experience can vary widely among alternative vendors and over time in a given vendor's shop. This includes both professional (metallurgists, engineers, etc) and skilled craft (welders, machinists, etc) positions. Personnel turnover is something every owner should evaluate in the due diligence process.
- Careful review of vendor documentation regarding quality assurance is particularly important. An owner also should conduct a facility walk-through to confirm that written procedures are indeed part of the shop culture.
- Audits to assure that best-available technologies are integrated into repair processes and that shop personnel are qualified to those technologies are at least equal in importance to the preceding points.

The penalty a user pays for poor quality can be significant if engine availability is adversely impacted when power demand is high. Early removal of repaired parts that did not meet expectations is bad enough, but if the parts fail in service and there is collateral damage, a machine could be out of service for weeks.

Sometimes off-spec repairs may prevent parts from being repaired again, at the end of the next service run. This means new parts will have to be purchased sooner than planned and component life-cycle cost will increase. Likewise, a vendor lacking in knowledge, experience, and the latest equipment may have a lower yield of repaired parts than a top shop. Purchase of new parts to complete a set can increase the cost of the total project beyond that expected.

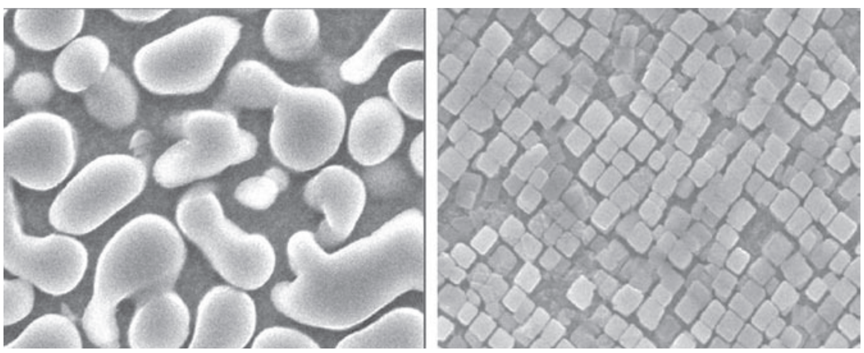
Once "quality" is under control, users should consider component repair "value" instead of "cost," said Nagy. Value, in his view, includes the following:

- A high yield of repaired parts.
- Repairs that permit future repairability—multiple service intervals—of parts.



26. Conventional weld repair of HPT blade shrouds (left) looked like this after 13,000 hours of operation; upgraded extended-life repairs (right) remained "like new" after 24,000 hours

27. First-stage bucket for 7EA will be rejuvenated after 92,000 hours of service with the expectation of completing another cycle and retiring at around 116,000 hours—thereby confirming the value of extended-service-life repairs



28. Service-exposed material from a directionally solidified first-stage bucket (left) must undergo "full-solution" heat treatment (right) to rejuvenate the gamma-prime phase of the D111 alloy

29. Nozzles after 48,000 hours of service (left) exhibit areas with large cracks. These were repaired with Liburdi's proprietary high-strength LPM material. After 92,000 hours, areas where cracks were repaired show little recracking and sometimes none. LPM material can be re-repaired to further extend service life

- Operational risk reduction by the "resetting" of design safety margins.
- "Upgrade" repairs that make components "better than new" by correcting weaknesses in the original design.

Some examples offered as "value" repairs are these:

- Shrouded-blade weld repair, an upgrade that extends component life (Fig 26). To illustrate: Conventional weld repair of shroud edges for RB211 (Rolls-Royce) high-pressure turbine (HPT) blades after 13,000 hours of operation are at left; upgraded extended-life repairs using advanced filler metals (right) seem almost new after 24,000 hours. Blades at the right cost only about 20% more to repair than those at the left.
- First-stage bucket rejuvenation and internal coating to promote life extension (Fig 27). The 7EA first-stage bucket pictured has 92,000 hours of service and will be repaired for yet another service cycle. After this third cycle, the bucket will have doubled its expected service life. Nagy calculated the cost saving attributed to "value" repairs on buckets for this customer's four-unit fleet at more than $5 million over six years.
- Nozzle repairs using Liburdi's patented high-strength powder-metallurgy (LPM) repair process results in repair joints that are stronger than the original cobalt castings, thereby promoting longer life.
- Second- and third-stage repairs, upgrades that extend component life.

Nagy then ran through some "back-of-the-envelope" calculations for Frame 6B bucket "value" rejuvenation compared to conventional repairs. Rejuvenation typically ranges from 15% to 25% of the price of new parts. Three repairs would get a user two full service intervals for—at most—75% of the cost of replacement buckets. Keep in mind that the two service intervals also would include two conventional "strip and recoat" repairs at 10% to 15% of the "new" price. Lastly, there is the cost of new-bucket purchase after one or two recoat repairs.

The bottom line: The "effective" cost of achieving 100,000 service hours with "value" rejuvenations would be about half the cost of conventional repairs and associated parts replacement.

Heat treatment, like quality, means different things to different people and must be clearly defined in specifications. Nagy said that a conventional repair may be heat treated with a "partial solution"—that is, only a fraction of the alloy's creep strength is restored. Usually the upper limit of such restoration is around 50% of the original creep strength. Thus partial-solution heat treatments are of questionable benefit and even the best processes may not recover sufficient strength on a second repair to assure problem-free operation through the next cycle.

By contrast, a "full-solution" heat treatment using a hot isostatic process (HIP) fully rejuvenates alloy creep strength. You pay a premium for this procedure because furnace time is longer than for a partial treatment and there is the added HIP cost. Metallurgically speaking, proper full-solution rejuvenation would "reset" component microstructure to a virtually as-new condition (Fig 28).

A significant requirement of rejuvenation is the shop's ability to remove the internal coatings to allow full-solution heat treatment, then to replace the coatings. Note that internal coatings are sensitive to damage if excessively heat-treated. Nagy claimed that Liburdi was one of very few companies in the industry with long-term success in removing and reapplying internal coatings.

In rare cases, he continued, an alloy may not respond to heat treatment and components must be scrapped. This typically is associated with old alloys manufactured to marginal quality standards. Users can avoid such surprises through proper qualification testing of representative alloy samples before and after heat treatment. Your repair specifications should be written around final alloy creep strength and proper precipitate microstructure as opposed to simple certification of times and temperatures.

Regarding internal coatings, Nagy had this to say: Use of internal coatings depends on the manufacturer's capabilities and design requirements. Frame 6B first-stage buckets are coated internally, but second-stage buckets are not. Originally, he continued, nozzles were uncoated to facilitate weld repair. But today many users are coating R1 nozzles and the latest nickel-alloy R2 nozzles also are coated with a simple aluminide system (Fig 29). Finally, Nagy reflected, internal coatings are expensive; if the designer specified one, respect its value.