ELLIOTT GROUP
EBARA CORPORATION

Elliott Repair Capabilities in Asia Pacific

Elliott Repair Services

Elliott Group's global network of full-service repair centers offers single-source, comprehensive repair services for Elliott and non-Elliott rotating equipment throughout the Asia Pacific region, and around the world. We provide global expertise, regional response, and 24/7 emergency service and support. Elliott service centers are registered to ISO 9001 or have structured quality management systems. They feature the latest technology and are staffed with skilled personnel to quickly repair, restore, or upgrade your critical rotating machinery to meet or exceed operational requirements. We are here when you need us with the right tools, technologies, and expertise.

Full Range of Repair Solutions for Elliott and Non-Elliott Equipment

Our capabilities include rapid response, genuine original equipment manufacturer (OEM) parts, service, repair, replacement, and remanufacture of all rotating and stationary components including:

- Blades
- Impellers
- Diaphragms
- Shafts
- Seals
- Bearings
- Nozzles

Diagnostic Tools

Elliott service centers are equipped with the diagnostic tools required to evaluate your rotating equipment and determine what is required to repair, restore, or rerate the unit and return it to service. Our analytic capabilities include:

- Coordinate measuring machine (CMM)
- 3-D modeling
- Concentricity and vibration probe track testing

Repair Technologies

Elliott service centers use a full range of advanced repair techniques and technologies to get your critical rotating equipment back in service as quickly as possible. Key technologies include:

Inspections and Measurements

In accordance with American Petroleum Institute (API) standard API 687, Elliott conducts both Phase I and Phase II inspections and provides corresponding documentation and reports. We perform all measurements using calibrated gauges to the measurement accuracy stipulated by API 687.

Phase I – Initial Inspection

- Visual inspection of equipment documented with photographs and sketches showing size, location, and orientation of erosion, corrosion, or any other damage that results in deposits, buildup, or loss or displacement of material.
- Dimensional measurements of distinct rotor features including journal and shaft-end seal area diameters and location of axial and radial probe areas.
- Residual magnetism, concentricity, and electrical runout.
- Non-destructive testing such as fluorescent dye penetrant and magnetic particle inspection.

Phase II – Final Inspection

If Elliott receives a contract for repairs based on our initial inspection, we will conduct a post-work inspection and provide a final report documenting the results.

Automatic Micro TIG Welding

Automatic tungsten inert gas (TIG) welding, also known as gas tungsten arc welding (GTAW), is a high-quality, precision welding process. In TIG welding, an arc is formed between a tungsten electrode and the pieces being welded. This creates significant heat, fusing the two parts. An argon and/or helium cover gas is often used to allow the arc to form, and to shield the welding area from contaminants. Micro TIG welders typically supply a current from 5 to 300 amperes with pulse durations up to four seconds. Sometimes the current is rapidly turned off and on to create multiple mini-pulses. This feature, known as pulsation, reduces the porosity of the completed weld nugget.

Submerged Arc Welding

Submerged arc welding (SAW) is a common and versatile process ideally suited to the longitudinal and circumferential butt welds required for the manufacture of pressure vessels. The molten weld and the arc zone are protected from atmospheric contamination by being submerged under a blanket of granular, fusible flux consisting of lime, silica, manganese oxide, calcium fluoride, and other compounds. When molten, the flux becomes conductive and provides a current path between the electrode and the work. This thick layer of flux prevents spatter and sparks and suppresses the intense ultraviolet radiation and fumes that are a part of the shielded metal arc welding (SMAW) process.

Metco Spray Coating

Thermal spray coating is a cost-effective method of enhancing surface properties or repairing surface defects. Spray coatings have a wide variety of uses including protection against corrosion and erosion, enhancement of sliding wear properties, restoration of dimensions to drawing tolerances, and manufacture of abradable / rub-tolerant seals. They also can be used to repair critical areas under certain conditions.

During the thermal spray process, melted or heated materials are sprayed onto a surface. The resulting coating (20 micrometers to several millimeters) is made by the accumulation of sprayed particles. The technique provides thick coatings over a large area at a high deposition rate, as compared to other coating processes such as electroplating, or physical and chemical vapor deposition. Coating quality is assessed by measuring its porosity, oxide content, macro- and micro-hardness, bond strength, and surface roughness.

Post-Weld Heat Treatment

Post-weld heat treatment (PWHT), also known as stress relief, reduces and redistributes the residual stresses introduced through welding, and restores the macro structure of the material. The extent of relaxation of the residual stresses depends on the material type and composition, temperature of PWHT, and soaking time at that temperature. At higher temperatures, PWHT also permits some tempering, precipitation, or aging effects. These metallurgical changes can reduce the hardness of the as-welded structure, improving ductility and reducing the risks of brittle fracture.

Machining and Parts Fabrication

Machining is a three-step process that restores all dimensions, concentricity, and runout results to meet the design criteria. First, we machine away the damaged areas to prepare these areas for repair. After the repair processes such as coating and welding are completed, the unit is rough machined, followed by non-destructive testing, and then final machining.

When critical parts are damaged and there are no spare parts available, Elliott reverse engineers and fabricates the parts. We use CMMs to prepare the drawings. We identify the appropriate material and pre-machine the part. The part is then quenched and tempered, checked for hardness, finish machined, and its dimensions are inspected and verified. Parts fabrication shortens the lead time in emergency situations as compared to ordering new parts.

Non-Destructive Testing

Non-destructive testing is the process of inspecting, testing, or evaluating materials, components, or assemblies for discontinuities or differences in characteristics without destroying the serviceability of the part or system. Elliott's non-destructive testing methods include: dye penetrants, magnetic particle inspection (MPI), ultrasonic inspection (UT), hardness check, and alloy analysis.

Magnetic particle inspection.

Ultrasonic inspection..

Hardness check.

Spin Testing

Spin testing (overspeed testing) is an API requirement for all impellers that have undergone repair. Each impeller must be tested at not less than 115 percent of its maximum continuous speed for a minimum duration of one minute. Impeller dimensions identified by the manufacturer as critical (e.g., bore, eye seal, outside diameter) must be measured both before and after each overspeed test. All measurements and test speeds must be recorded and submitted for the customer's review following the test. Any permanent deformation of the bore or other critical dimensions outside the drawing tolerances is cause for rejection.

Dynamic Rotor Balance


Rotor in balance machine.

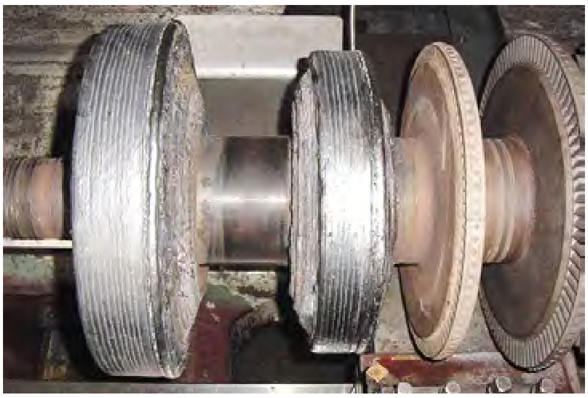
When the mass center axis of a rotor is different than its running center axis, the rotor is unbalanced. During operation, centrifugal force causes an unbalanced rotor to vibrate. Vibration causes wear to the bearings, rubbing with stationary parts, and in extreme cases, disintegration of the rotor itself. All repaired or re-bladed rotors should be balanced before returning to service. Elliott's dynamic balancing capabilities minimize vibration in any manufacturer's rotor throughout its speed range.

Repair Specialties and Examples

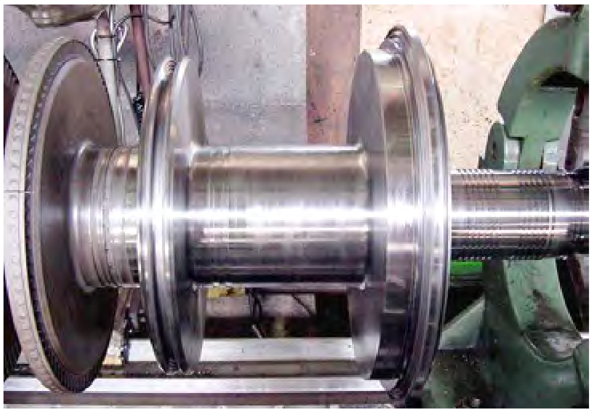
Turbine Disk Buildup

Caustic operating environments and elevated temperatures can cause carbon-steel turbine disks to develop cracks from stress corrosion cracking and corrosion fatigue. If they are not repaired, the cracks may cause disk failure in continued service. The impact of ingested foreign objects or contact with stationary parts because of rotor bending can also cause disk damage.

The photos illustrate before and after repairs to an Elliott SBPG-5 turbine rotor.


Disk buildup.


After rough machining.


Repaired disk with machined slots.

Repairing the disk rather than replacing it offers the dual advantages of lower costs and a shorter lead time. Elliott repaired the disk buildup on two stages, re-bladed and balanced the rotor.

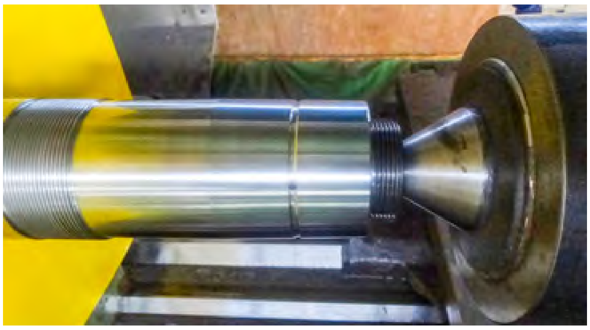
During the disk repair process, we machine away the damaged areas and then weld layer by layer to build them back up to the required thickness and height. After heat treatment to relieve the residual welding-related stress, we machine the welded areas to design dimensions including the grooves and Christmas trees.

Shaft Weld Repair

The taper end of a rotor shaft can sustain damage from heavy pitting caused by contaminated oil use during installation, and scratches caused by incorrect installation / removal procedures, or coupling hub slippage because of over-torque. Damage to the journal bearing areas commonly occurs from oil contamination or deprivation, electrostatic discharge, or bearing failure because of high vibration.

The photos illustrate before and after repairs to the taper end of the rotor coupling and the journal bearing areas of the rotor shaft. Using weld repair techniques and PWHT, Elliott repaired the damaged shaft and restored the rotor to its original condition.

Severe hitting marks.



Completed repair.

Depending on the extent of the damage, Elliott can restore a rotor to its original condition within two to four weeks. The repaired weld area has the same properties as the original steel, and does not suffer from issues such as poor bond strength, porosity, or the inappropriate hardness that comes with high-velocity oxygen fuel (HVOF) or other sprayed coating processes. In addition, welding does not have the thickness limitations of HVOF, which is only suitable for a maximum thickness of 0.3 mm.

Impeller Repair

Impellers are subject to erosion caused by condensates in the gas. Scrubbers and separators remove liquids from the gas before it enters the compressor, but liquid carryover always occurs, especially in wet gas compressors. The first-stage impeller is the most likely to suffer erosion damage caused by liquid droplet impact.

Severe erosion.

Completed repair.

The photos illustrate before and after repairs to an impeller vane that was severely eroded by condensates.

Welding repair of impeller vanes requires a high level of skill and experience. Usually the impeller vane can be repaired if the discharge measures a minimum of 12.7 mm x 250 mm. To access the damaged area, the impeller must first be disassembled from the rotor. Because of the tight space constraints, the welding must be done manually. Specially designed fixtures prevent heat distortion during welding.

After welding, the impeller must undergo stress relief and spin testing per API 617. Each impeller will be subjected to an overspeed test at not less than 115 percent of maximum continuous speed for a minimum duration of one minute. Impeller dimensions (such as bore, eye seal, and outside diameter) will be measured before and after each overspeed test to make sure that they are within the acceptance criteria before the impeller is reassembled onto the rotor. The rotor is then balanced before being returned to operation. Elliott has successfully repaired eroded vanes measuring 0.5 to 2.0 mm in thickness.

Besides weld repair, a spin test can be used to confirm the integrity of the impeller when there is an increase in the operating speed during a rerate, or to relieve residual stresses when an impeller is impacted by foreign objects.

Spin pit for spin testing.

Bucket and Blade Repair / Replacement

Steam turbine bucket and blade failures are usually related to excessive stress caused by impact, low-cycle or thermal fatigue, or creep; resonance caused by vibration or nozzle passing frequency; or conditions related to the operating environment such as stress corrosion, corrosion fatigue, or erosion.

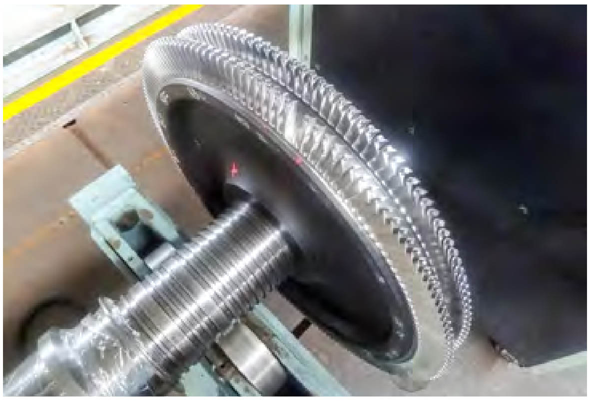
Elliott chooses a repair strategy based on the extent of the damage. Minor cracks or pitting on the aerodynamic portion of a bucket or blade might be repaired by simple grinding and dressing.

However, major cracks or cracks at the roots require blade replacement. Replacing the blades involves removing the locking mechanism and the blades, followed by installing the new blades and reinstalling the locking mechanism. If the blades have linking and attachment features such as shrouds, lashing wires, or zig-zag pins, they also must be replaced. Once the blades have been replaced, the rotor must be balanced before returning to service. Elliott also offers removal / installation of erosion shields (stellite) for the blades in the last stages.

The photos illustrate before and after repairs using different repair strategies.

Broken blades / buckets.

Severe hitting marks.



Reblading with new bucket.

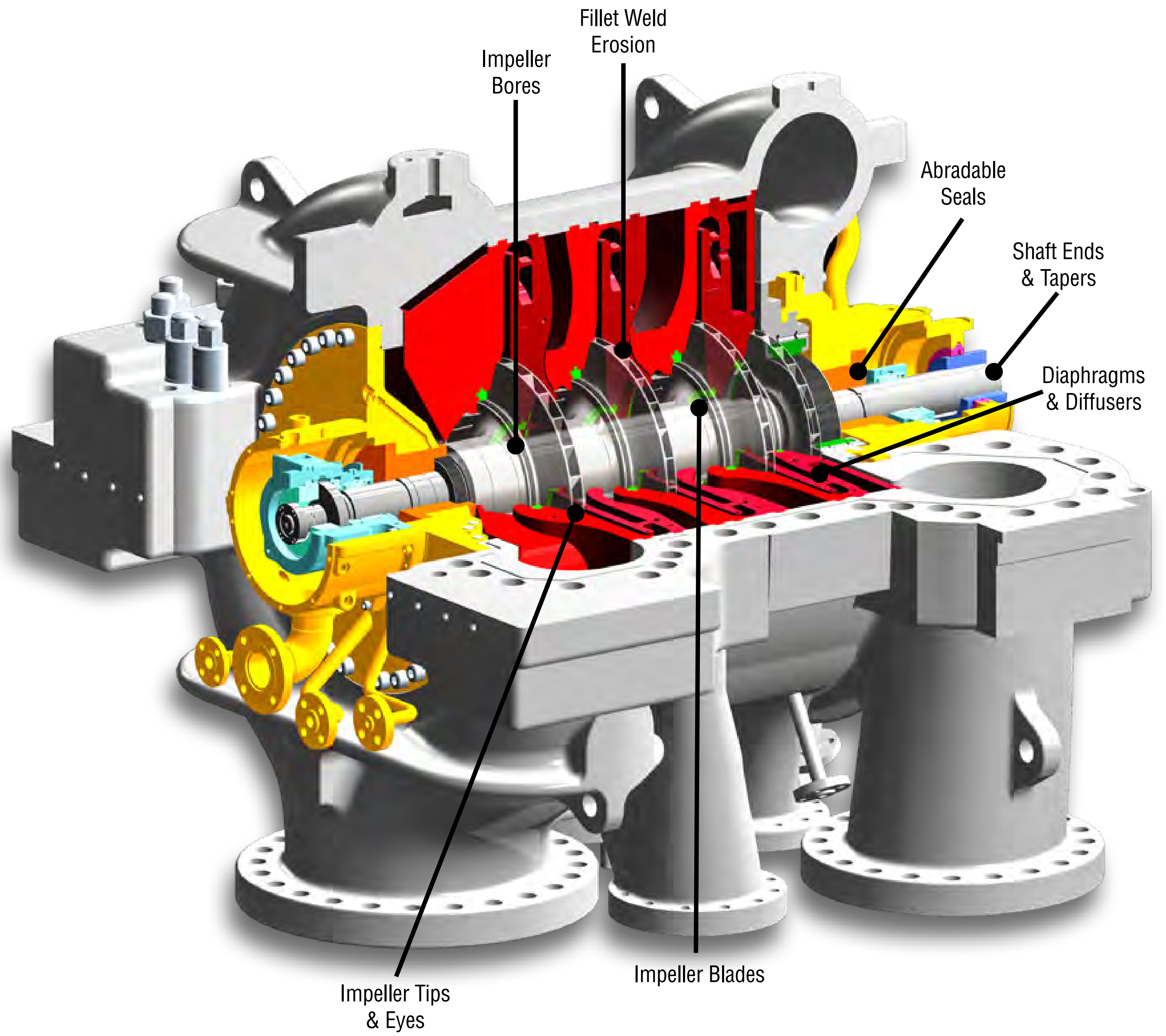
Installing shroud rings.

Peening.

Completed repair.

Common Repairs & Upgrades for Compressors

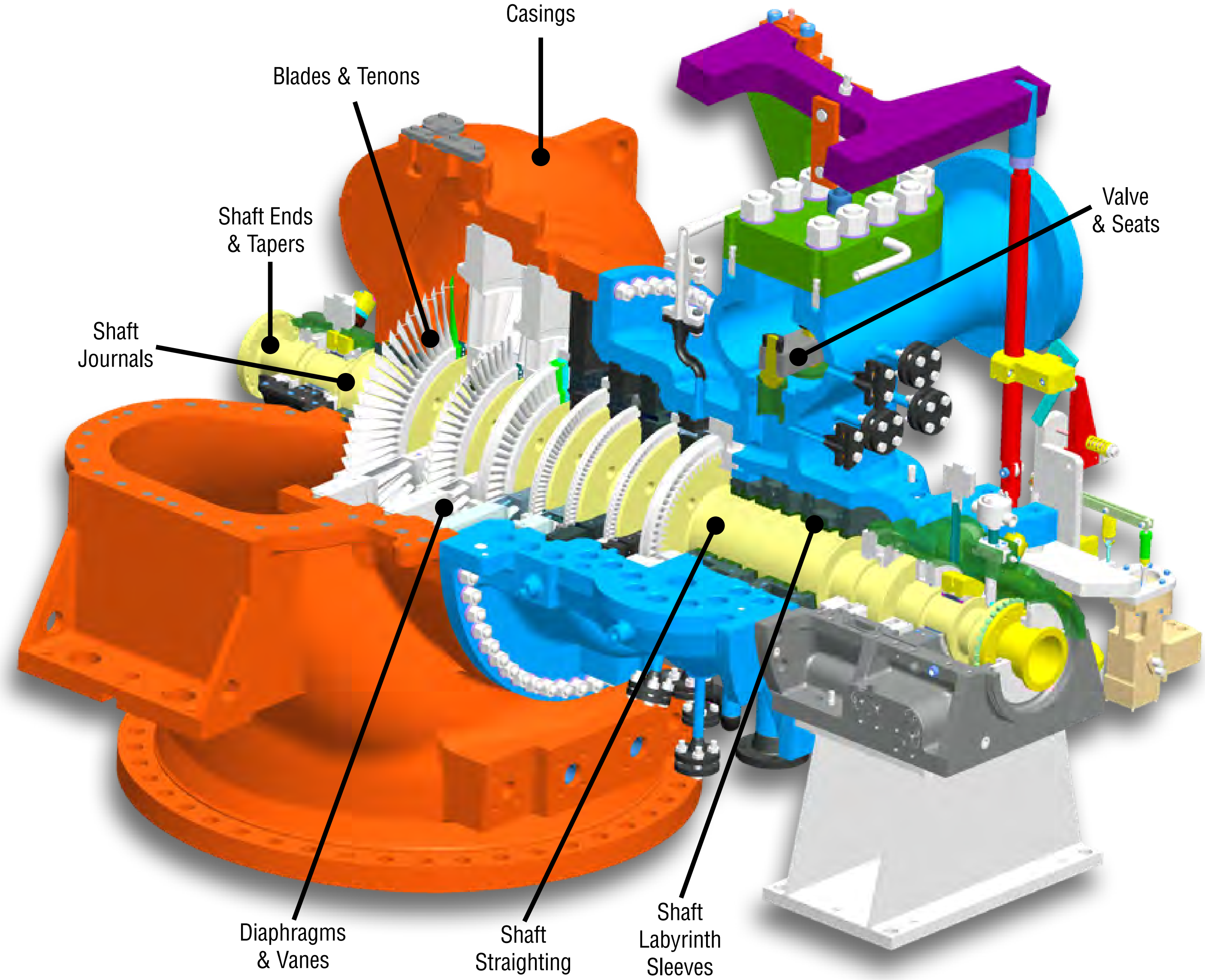
Full Range of Repair Solutions for Elliott and Non-Elliott Equipment



Enhance performance to meet process changes, environmental regulations, or increased capacity requirements. Elliott can help you maximize the value of your equipment investment with cost-effective repairs, upgrades, and modifications.

■ Common Repairs & Upgrades for Steam Turbines

Full Range of Repair Solutions for Elliott and Non-Elliott Equipment



As installed turbomachinery ages, efficiency and reliability can decline. Repairs, upgrades, and modifications will keep equipment performance high and maintenance costs low.

Stationary Blade Repair

Stator blades are typically damaged due to the impact of ingested foreign objects and/or poor steam quality.

The damaged stator blades shown in the photos cannot be replaced with new ones. Because of the risk of decreased performance efficiency and damage to the rotor if a part breaks off during operation due to propagation of the cracks, the stator blades are repaired for temporary use. The photos illustrate before and after repairs to stator blades as a temporary solution until a new diaphragm can be manufactured and installed.


Damaged stator blade.


Weld repair.


Nondestructive testing after repair.

Lead time for a new diaphragm is six months or more. Restoration of the damaged blades took three months. Elliott provided a one-year warranty for the repairs that allowed the customer enough time to order a new diaphragm for change-out during the next scheduled overhaul. If the inspection result is acceptable during the next overhaul, the customer can continue to use the repaired diaphragm, or replace it with the new spare diaphragm and keep the repaired one as an emergency spare.

Casing and Blade Carrier Repair

Steam turbines are exposed to wider temperature variations during steady-state operation between high-pressure and low-pressure sections, and more transient thermal stresses during start / stop cycles than compressors. For this reason, damage to steam turbine casings is more common than damage to compressor casings. Damage to steam turbine casings is usually caused by cracking, distortion, or erosion.

Cracking can occur on the interior surfaces of steam chests, valve seats, nozzle chambers, diaphragm fits, and bolt holes if the turbine is exposed to rapid quenching due to exposure to condensates, especially in the case of repeated start / stop cycles. Cracking is less common in newer units due to advanced design technology and alloys. Repair methods depend on the severity and location of the cracks and the thickness of the surrounding material. Minor cracks can be removed by grinding or by drilling stop holes to arrest further cracking, while more serious cracks are weld repaired. In certain cases, mechanical repairs such as metal stitching might apply.


Casing distortion.


Weld repair.

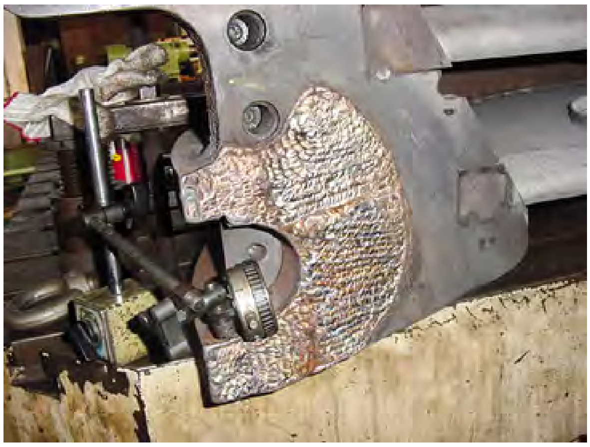
Completed repair.

Casing distortion is caused by exposure to repeated thermal and / or piping stresses over time. Inner casings distort more easily than outer casings because of their thinner cross-section and higher temperature differentials across the casing walls. Distortion causes interferences, gaps at the horizontal split line, and misalignment of seals. In minor cases, leakage reduces efficiency. In major cases, internal rubbing causes high vibration which may trip the equipment, causing a forced outage. Casing distortion is repaired by welding and machining, followed by PWHT for stress relief. Special fixtures are required.

Erosion usually occurs in the low-pressure stages of the turbine where moisture content is high. Moisture can erode the casing, diaphragm, and blades. If there are gaps at the horizontal split line due to casing distortion, the moisture causes further erosion, leading to a larger efficiency drop as the gap increases. Eroded split line areas can be repaired by welding and machining to restore the contact surfaces.

The photos illustrate before and after repairs to a turbine blade carrier that was restored by welding buildup.

Worn blade carrier.



Weld repair.

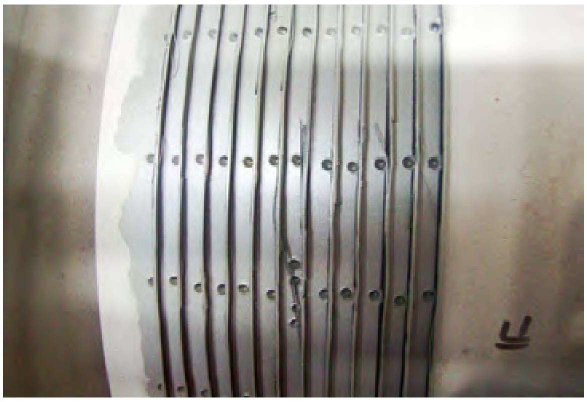
Completed repair.

Elliott identified the base material, selected a suitable filler, and welded the eroded area, followed by PWHT for stress relief. Polishing the split line surface provided good contact between the top and bottom surfaces. After repair, the surface flatness must be within 0.03 mm when the repair area is smaller than 200 mm2 (or smaller than 30 percent of the total split line surface). Typical repair time is 7 to10 days for such damage.

Seal Fin Replacement

Seal fins minimize steam turbine leakage loss. Rubs suffered during rotor excursions can damage seal fins, resulting in larger clearances and higher leakage, and reduced turbine efficiency and performance. Damaged seal fins must be replaced.

The photos illustrate damaged seal fins and a new seal fin replacement by Elliott.



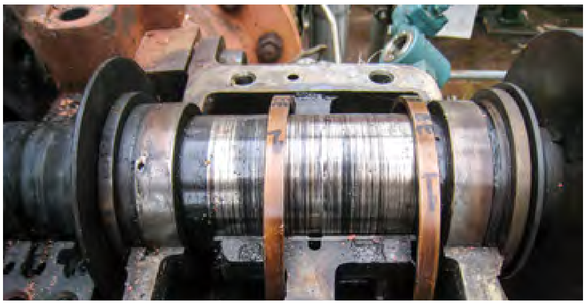
Damaged seal fins.

New sealing strip.

Shaft Replacement

Single-stage steam turbines are commonly used to drive lube oil pumps, condensate pumps, generators, and process pumps. In these types of applications, wet steam often causes erosion and corrosion to the shaft packing area, and wiped bearings caused by lube oil issues can damage the shaft journal bearing area. When the shaft is damaged, Elliott recommends shaft replacement rather than replating it for higher reliability without the risk of delamination due to poor bond strength.

The photos illustrate typical shaft damage, removal, and replacement.



Damaged journal bearing area.

Damaged packing area.

New rotor shaft.

Elliott can complete shaft replacement within a week, subject to parts availability. The rotor is then balanced before resuming operation.

New shaft installation.

Stress Relief and Rotor Straightening

Stress relief is achieved through heat treatment and is required after welding. This kind of PWHT typically takes two days. Besides PWHT, heat treatment also can be used to straighten a bent rotor. Depending on the extent of the bend, rotor straightening takes 5 to 10 days.

Shaft undergoing stress relief for straightening.

When wet steam contacts a hot turbine rotor, it causes partial quenching and bending of the rotor. This usually happens when sealing steam is switched to an external supply during the shutdown process, and condensates are accidentally introduced into the hot rotor at the packing area. The rotor straightening process involves hanging the rotor vertically and applying heat using a programmable heater controller that records heat history. Using this method, Elliott has successfully straightened a rotor with 0.2-mm runout.

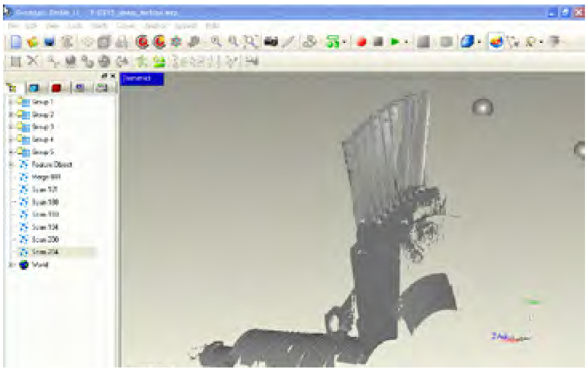
Reverse Engineering and Custom Parts Manufacturing

When original equipment and component drawings are unavailable, Elliott engineers can precisely map the geometry of equipment from any manufacturer using portable CMMs and positive material identification (PMI) tools. This is a timely and cost-effective way to provide spare components for your rotating equipment.

The photos illustrate how we use CMM and PMI tools to get the information needed to redesign, rerate, or upgrade stationary and moving components.

During service outages, Elliott uses CMM tools to record the geometry of internal components, and a PMI gun to conduct a material analysis.

Scanning.



Modeling.

Material analysis.

Material identification.

Non-Elliott Repair Experience

Elliott services all types of turbomachinery. Here are some of the manufacturers whose rotating equipment we have repaired:

- ABB
- AC
- AEG Kanis
- Ansaldo
- Atlas Copco
- Alstom
- Bird
- Broadbent
- Cameron Cooper
- Cameron
- Coppus
- Chicago Blower
- Demag
- Dresser Clark
- Dresser-Rand
- Ebara
- EIC Cryo Dynamic
- Fuji
- Flowserve
- Garden City Fan
- GE
- GHH
- Goulds Pump
- Hitachi
- Ingersoll-Rand
- IHI
- Kansui BFP
- KHI
- KKK
- Kobe
- Kobelco
- KSB
- Man GHH
- MHI
- Mitsui
- Nash
- Nuovo Pignone
- NKG IDF
- NKK
- Piller
- Renk
- Roots
- Shin Nippon
- Siemens
- Sulzer
- Sundyne
- Terry
- Thermodyne
- Thomassen
- Torishima
- York

Elliott Group is a global leader in the design, manufacture, and service of technically advanced centrifugal compressors, steam turbines, power recovery expanders, cryogenic pumps and expanders, and axial compressors used in the petrochemical, refining, oil & gas, liquefied gas, and process industries, as well as in power applications.

Elliott Group is a wholly owned subsidiary of Ebara Corporation, a major industrial conglomerate headquartered in Tokyo, Japan.

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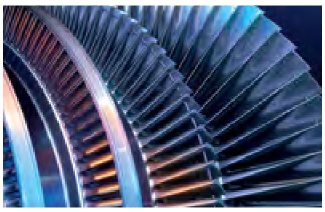
For a list of customer contacts for the Asia Pacific region, go to:
http://www.elliott-turbo.com/contacts

THE WORLD TURNS TO ELLIOTT

COMPRESSORS ■ TURBINES ■ CRYODYNAMICS ■ GLOBAL SERVICE

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