FSR® Full Solution Rejuvenation®
- Bringing New Life to Aged Hot Section Components

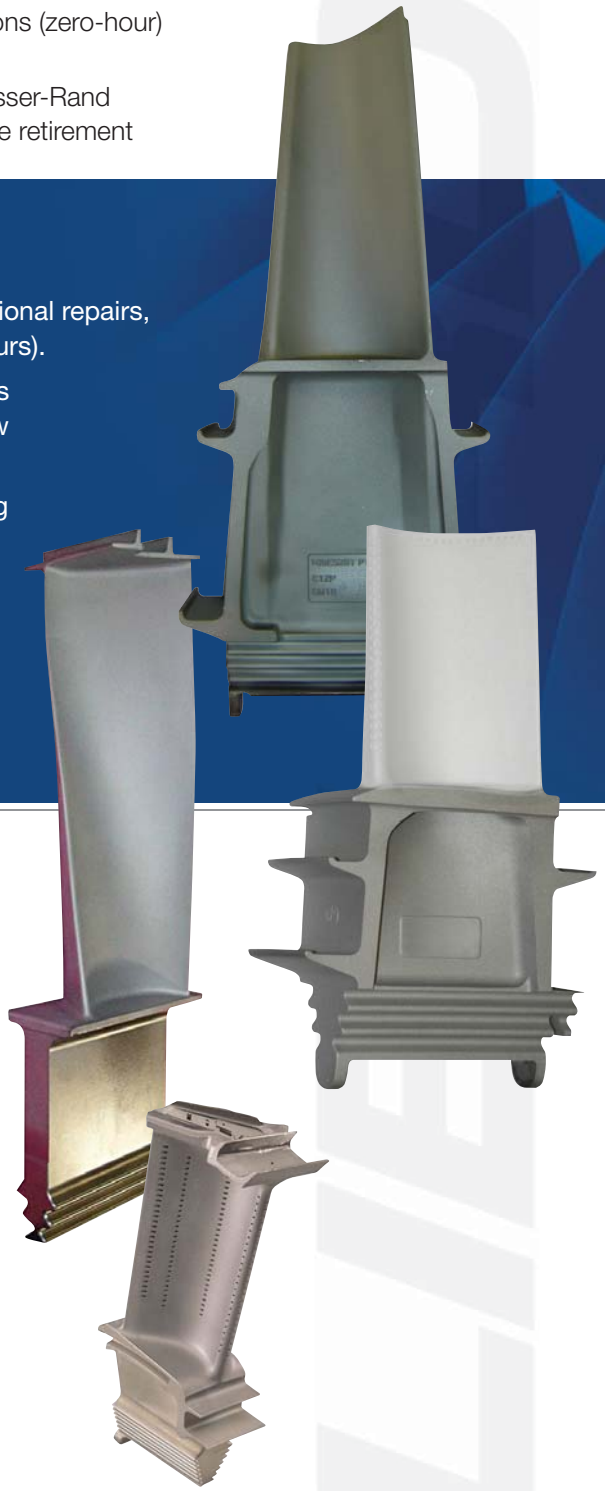
"Zero-Hour" Technology Available only from Liburdi Turbine Services

- 30 Year Track Record - Over 800 sets of turbine blades returned to new life
- Process returns components to OEM New Material Specifications (zero-hour) to extend life, and avoid new replacement parts expense
- Used extensively for GE, Siemens, Westinghouse, Alstom, Dresser-Rand turbine blades to reliably extend service life - 2 or 3 times before retirement

The FSR® Advantage

- OEM's and other component repair sources employ conventional repairs, typically after the first hot section service interval (24,000 hours).

  After the next service interval (at 48,000 hours) the blade sets may be retired as time limited due to service hours - and new components purchased.
- New capital parts are the most significant cost of maintaining the engines – but these cost can be avoided
- Liburdi's proprietary FSR® process returns each part to meet the original OEM new part properties.
- Blade sets are reliably operated for two or three additional service intervals



Turbine Blade Life Limits – Extended by FSR®

Turbine blade life is limited by microstructural aging of the alloy. Aging is metallurgical degradation resulting from exposure to high service temperatures. Aging in nickel-based superalloys is typified by coarsening of the strengthening gamma prime precipitates, carbide degeneration, and grain boundary coarsening.

High temperature FSR® processing of the material dissolves the gamma prime precipitates. This is followed by special aging heat treatment cycles which reform these precipitates into the desired shapes and configuration thereby returning the microstructure back to its optimal condition and restoring the alloy strength.

The FSR® Process

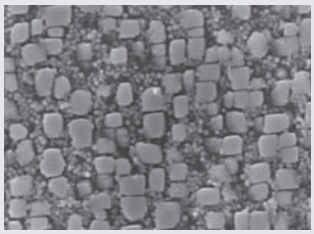
Full Solution Rejuvenation® heat treatments are not the same as the heat treatments applied to new components. Newly manufactured components are heat treated with a focus on casting homogenization and initial strengthening. Rejuvenation heat treatments erase and reform the microstructure of a component after service. The specific parameters used for rejuvenation will differ from those used on new parts and are proprietary to Liburdi.

The manufacturing method of the components plays a critical role in determining the parameters incorporated into the proven FSR® heat treatments. Grain size is an important consideration for castings and also for forgings where the fine grains impart desirable toughness. Maintaining optimum grain size is taken into account in establishing the proven Rejuvenation process.

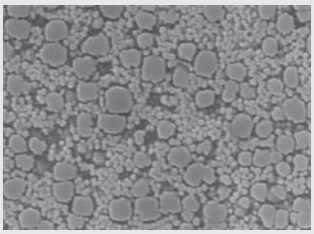
FSR® heat treatments have been developed specifically for all cast blade alloys (including GTD111, MM247, MM002, IN738, R80, IN939, and 20 other alloys). Similarly FSR® heat treatments are developed for most forged blade alloys (including U500, N80, N115, N105, A286, and others)

To process at the high temperatures needed, all coatings must first be removed, internal as well as external. Liburdi has developed a unique proprietary stripping process to remove internal coatings. All coatings are then replaced with equivalent or better protective surface treatments depending on the operating environment.

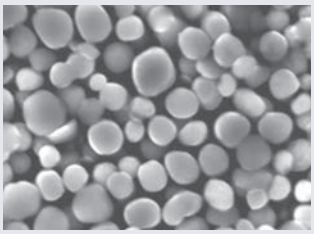
Electron microsope comparing new alloy microstructure, service exposed alloy, and Rejuvenated alloy with full recovery of original microstructure.



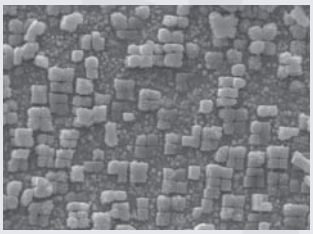
As-New Microstructure
10,000x magnification



Aged Microstructure
At 24,000 hours of service
10,000x magnification



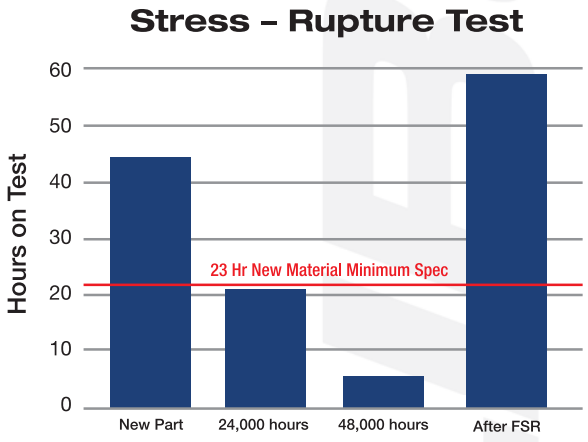
Aged Microstructure
At 48,000 hours of service
10,000x magnification



FSR Rejuvenated
Microstructure
Ready for extended service
10,000x magnification

Re-certification of Blades

As a final qualification of FSR® processed parts, the standard new-part Stress-Rupture Test is applied – the FSR® process must meet or exceed the OEM new-part test specification. The accompanying diagram shows the deterioration in test results due to service hours, and the full recovery of test properties with FSR®.



Proven Results for Operators for over 25 years

Full Solution Rejuvenation® processing of turbine blades has a long history of success since its introduction by Liburdi in 1979, and is now being used for the newer high performance blades alloys such as MM247, GTD111, Rene 80. Blade sets can be successfully processed through more than one FSR® rejuvenation - sets have achieved two and three additional service intervals and accumulated over 100,000 hours of service.

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