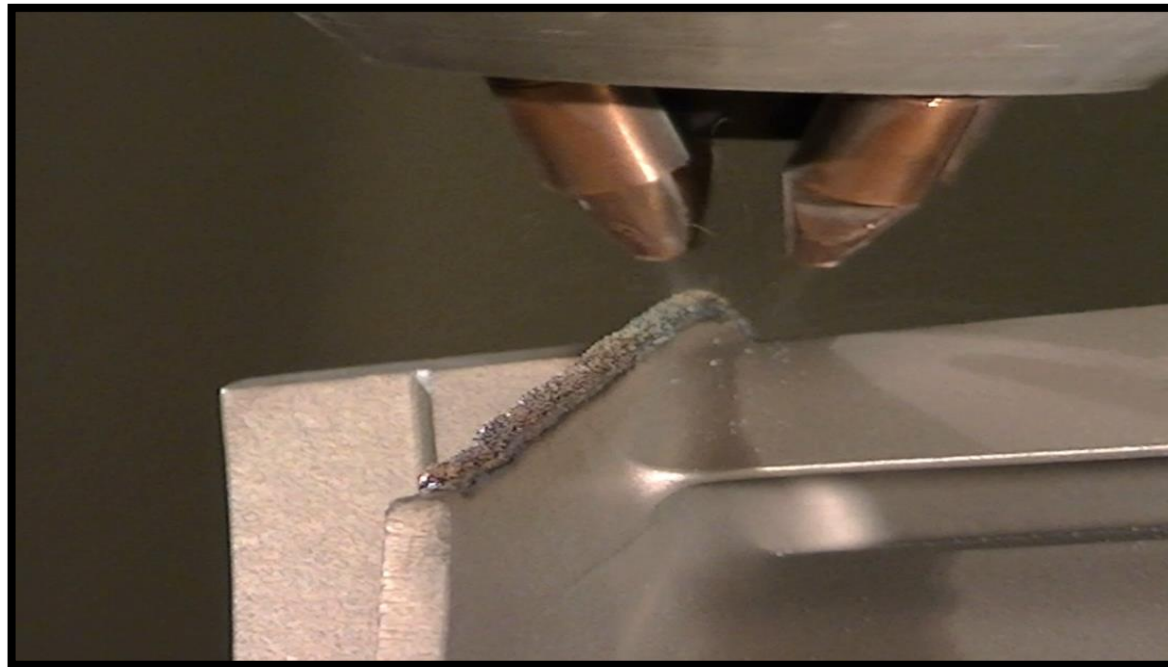


LENS Applications Introduction

REPAIR



LENS Repair: Preview Gallery

ROTATING PARTS

Shaft



Gear Teeth



Impeller

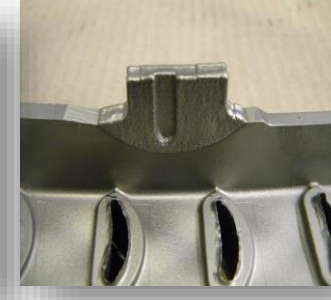


GAS TURBINE

Blade



Vane Wall

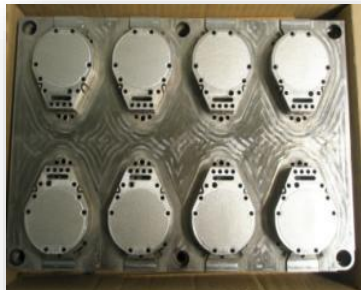


Z Notch



TOOLING

Injection Mold



Deep Draw

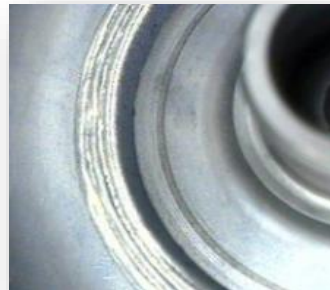


SEALS

Ball Valve



Rotating

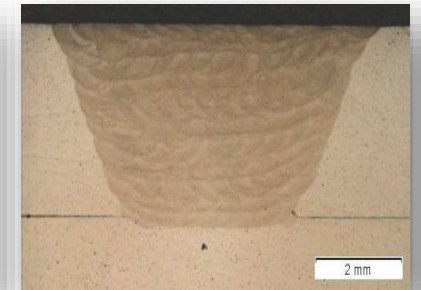


PRODUCTION DEFECTS

Thru Hole

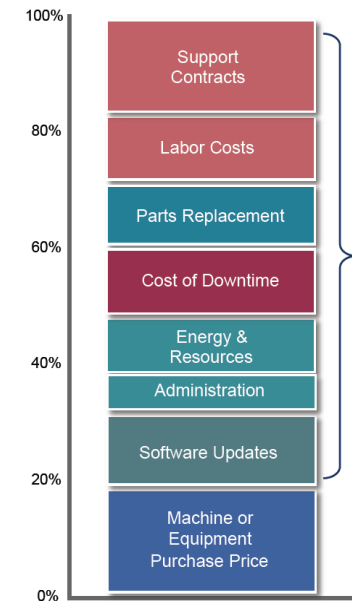
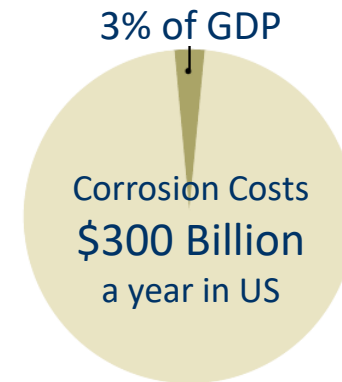


Notch



LENS Repair: The Need

- Corrosion or wear costs- \$300B/yr in US-
- GE's "3 Million Things that Spin" (IIOT)
 - Spinning leads to wear, which requires repair.
 - 200,000+ gas turnbines; ie aircraft, power, etc.
 - Lifecycle costs run 5-15X initial purchase price.
- \$100B's/yr spent on spares and overhaul
 - Commercial aviation spends >\$100B per year.
 - US DOD spends >\$50B per year.
- More cost effective to restore vs. replace
 - DED repairs are often more wear resistant than original.
- Significant ROI for LENS/DED repair solutions



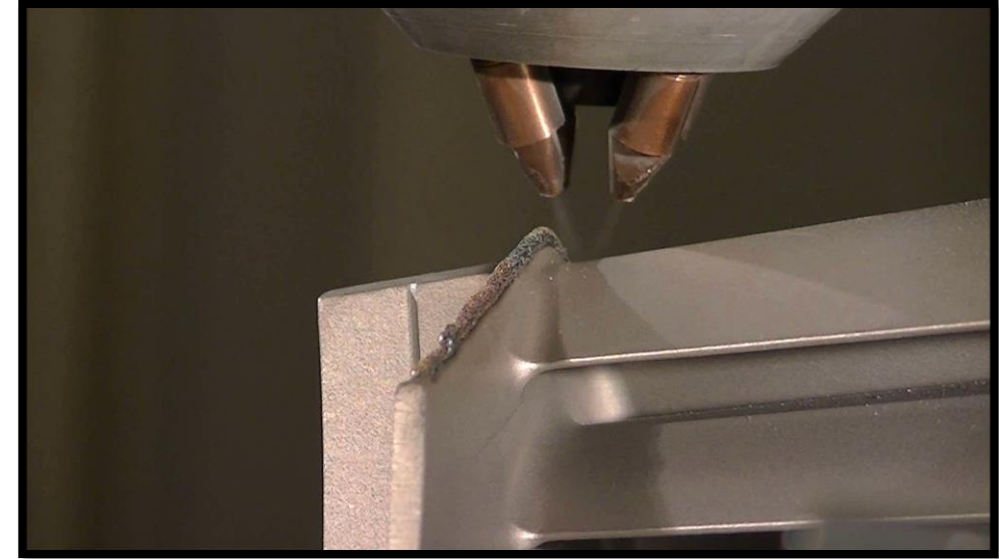
Sector	# of Global Assets & Plants	"Big" things that spin
Transportation		
Rail: Diesel Electric Engines	120,000	2,160,000
Aircraft: Commercial Engines	43,000	129,000
Marine: Bulk Carriers	9,400	84,600
Oil and Gas		
Big Energy Processing Plants (1)	990	36,900
Midstream Systems (2)	16,300	63,000
Drilling Equipment: Drillships, Land Rigs etc.	4,100	29,200
Power Plants		
Thermal Turbines: Steam, CCGT, etc.	17,500	74,000
Other Plants: Hydro, Wind, Engines, etc. (3)	45,000	190,000
Industrial Facilities		
Steel Mills	1,600	47,000
Pulp and Paper Mills	3,900	176,000
Cement Plants	2,000	30,000
Sugar Plants	650	23,000
Ethanol Plants	450	16,000
Ammonia and Methanol Plants	1,300	45,000
Medical Machines		
CT Scanners	52,000	104,000
Total		3M

Ref: GE
Industrial Internet
Vision Paper



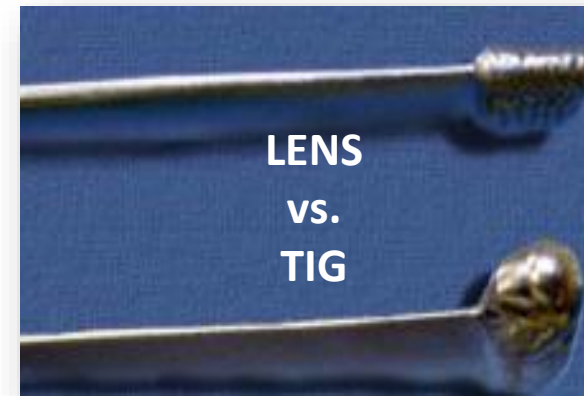
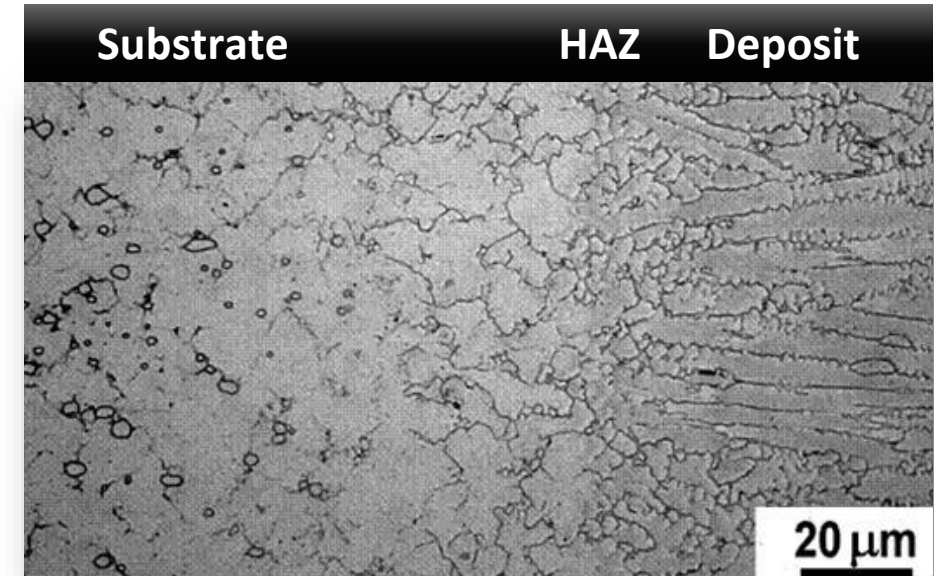
LENS Repair: Application Overview

- LENS repair capabilities include:
 - Restoration of worn components.
 - Repair of damaged components and production defects.
 - Remanufacturing of spare parts.
 - Rework to new design iterations.
 - Locally enhanced material properties
 - corrosion or wear resistance, additional strength, etc.
- LENS can perform repairs on a wide variety of materials-
 - CMn steels- from basic (AISI-304) to high strength steels (4140).
 - Stainless steels- 304L, 316, martensitics, PH stainless steels.
 - Nickel based alloys- Inconels, Monels.
 - Tool steels, Cobalt steels (Stellites), WC steels.
 - Reactive metals- titanium, aluminum, magnesium.



LENS Repair: Benefits – Process Advantages

- Metallurgical bond vs. mechanical/adhesive
- Small heat affected zone (HAZ); ie microns
 - Eliminates cracking and distortion.
 - Minimizes base metal dilution.
- Precision placement; near net shape deposition
 - Reduces finishing time and consumables.
- Rapid solidification
 - Fine grain size= superior properties.
 - Repair often has enhanced material properties.



LENS Repair: Benefits – Cost Savings

Inco / SS

Example: US Army repair of components from Honeywell AGT 1500 gas turbine engine

M1 Abrams Tank



3rd Stage Rotor



4th Stage Rotor



2nd Stage Nozzle



Compressor Stator

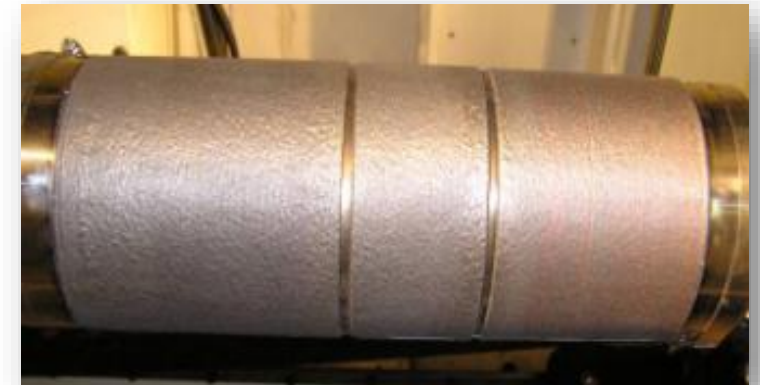
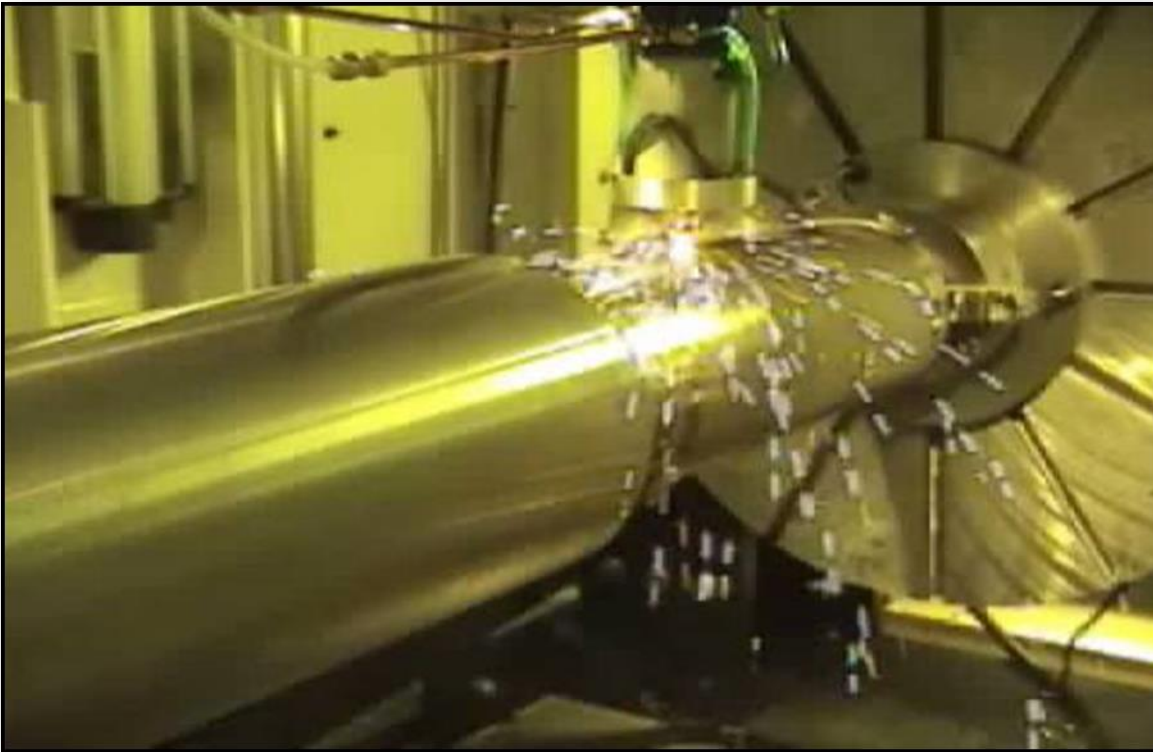


Material	Inconel 713	Inconel 713	Inconel 713	321 Stainless
New Cost	\$ 8297	\$ 5485	\$ 6032	\$ 910
Repair Cost	< \$2,000	< \$2,000	< 2,250	< \$300
Savings/Part	> 75%	> 60%	> 60%	> 60%

LENS Repair: Rotating Parts – Shafts

SS

Bulk Deposition



After Printing; Before Finishing

After Grinding and Polishing



LENS Repair: Rotating Parts – Gears

CMn



- Line down due to broken teeth on a gear at a local NM food processing plant.
- Fully repaired and back in operation in <12 hours vs. 12-week lead time for new gear.

Broken Gear Teeth



After LENS Printed Repair



Machined to Spec

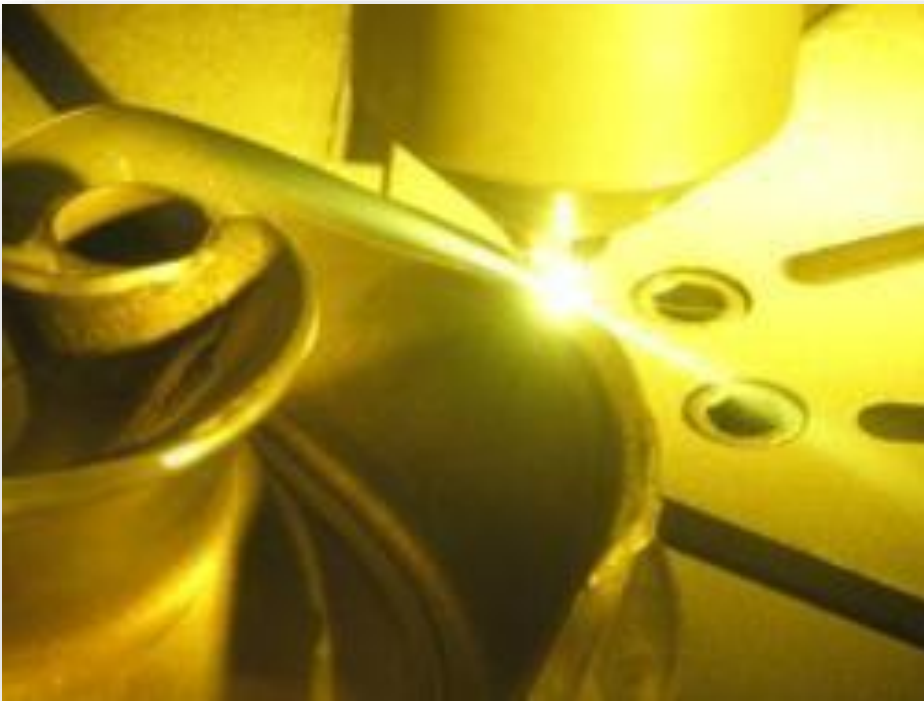


LENS Repair: Rotating Parts – Impeller

SS

- Worn impeller degrades pump performance. Long lead Item.
- Printed stainless steel onto hard iron to improve properties.

Using LENS to Restore Wear Areas



After Finish Machining



LENS Repair: Rotating Parts – Seal

Inco 718

- Second stage rotor disc seal repair for AGT 1500 M1 A1 Abrams Tank engine
- Process: Machine back worn seal, LENS deposit Inco718, heat treat, machine finish.

Surface Preparation (Machining)



After LENS Printed Repair



Machined to Spec



LENS Repair: Rotating Parts – ID Seals

Ti-6-4

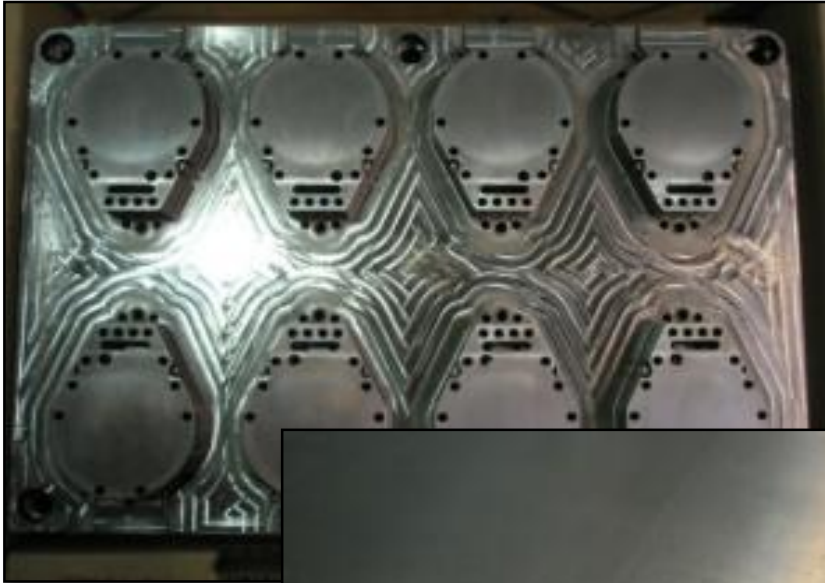
Repair Facts:

- Material: Ti-6-4
- Engine: T55 – Chinook Helicopter
- LENS Advantage:
 - Quality
 - Access to recessed features
- Two repairs qualified by U.S. Army
- Saving >\$10K vs. replace per part

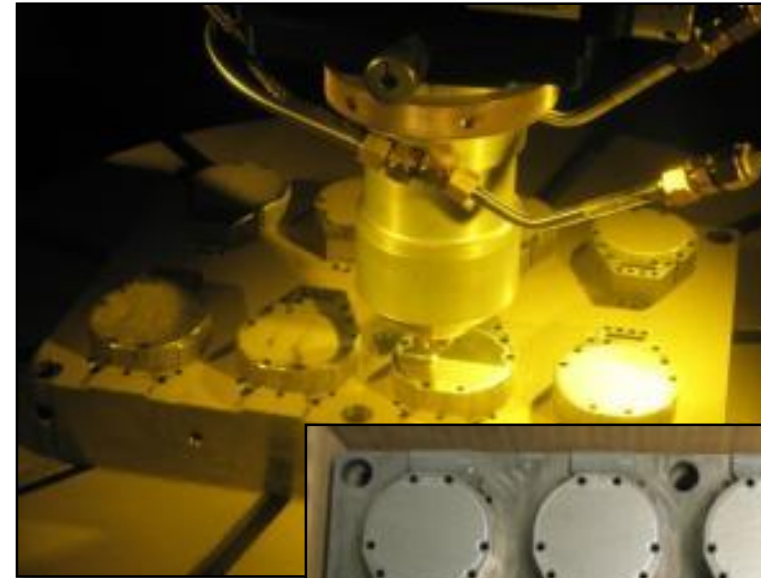


LENS Repair: Tooling – Injection Mold Resurfacing

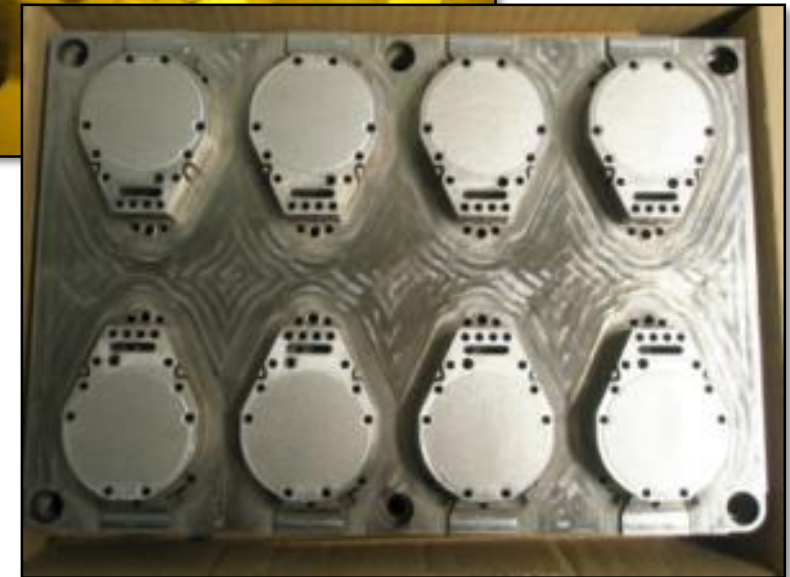
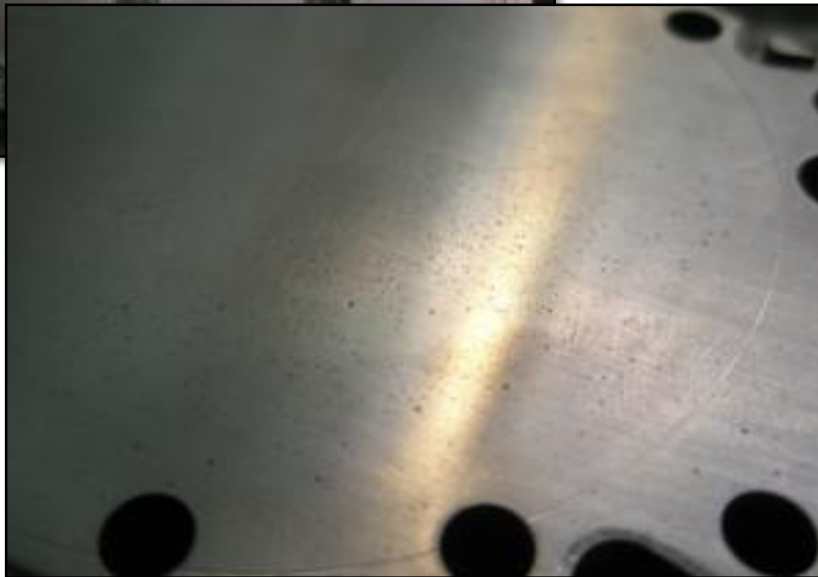
H 13 Tool Steel



Mold prior to repair shows pitting on surface



Resurfacing worn areas with LENS printing

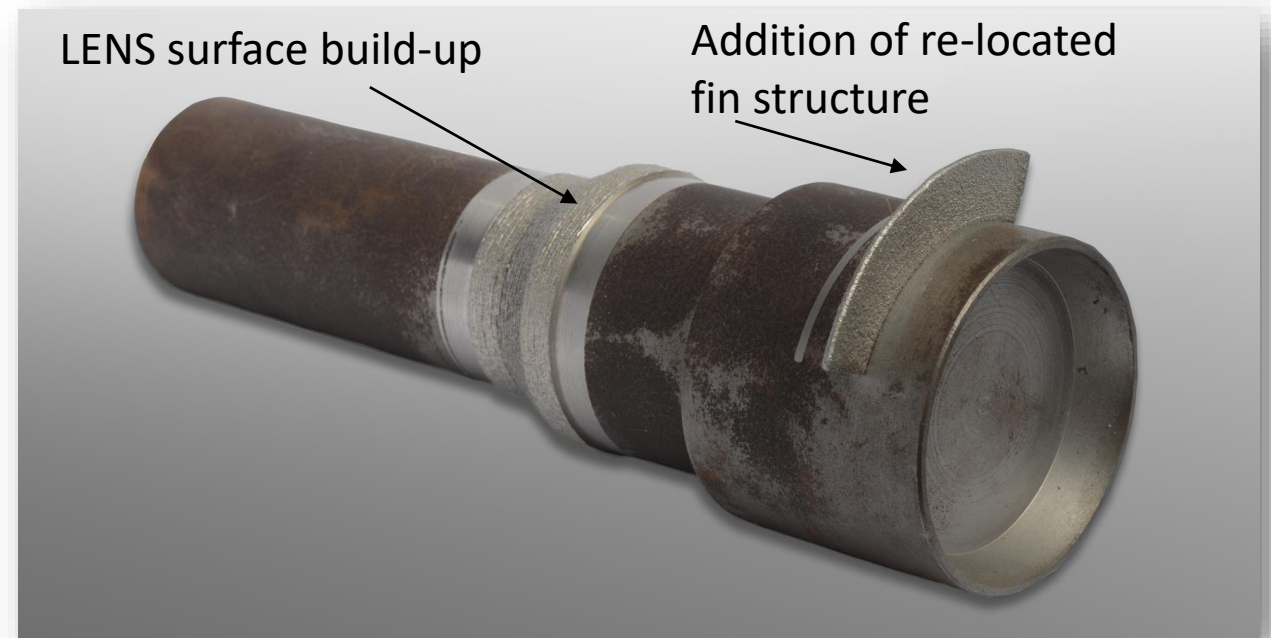


LENS Repair: Tooling – Core Pin

Tool Steel

Repair/Rework

- Build up of worn shaft surface.
- Re-design- the fin structure location was moved.
- Cost savings/lead time reduction vs. new part.

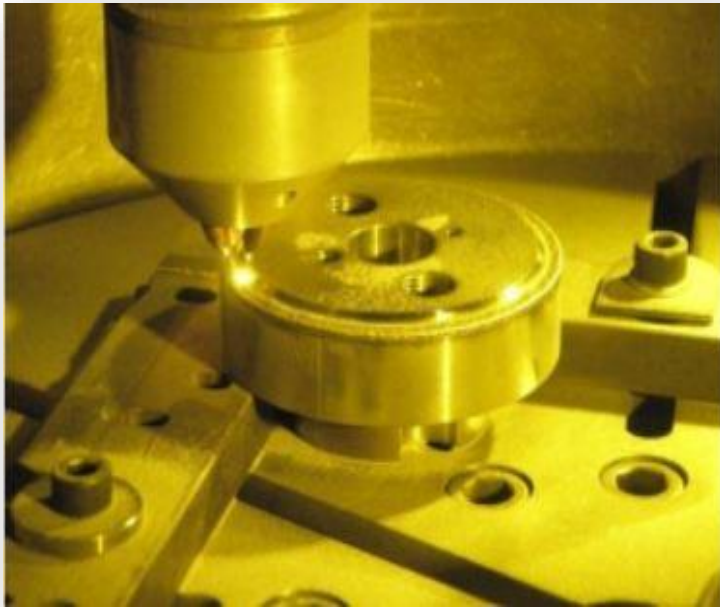


LENS Repair: Tooling – Deep Draw Tools

Co / WC

- Substrate Materials: nodular cast iron and various tool steels.
- LENS deposition of various hard facing steels (Co and WC alloys) and final machining.

Printed Repair Process



After Printing; Before Finishing

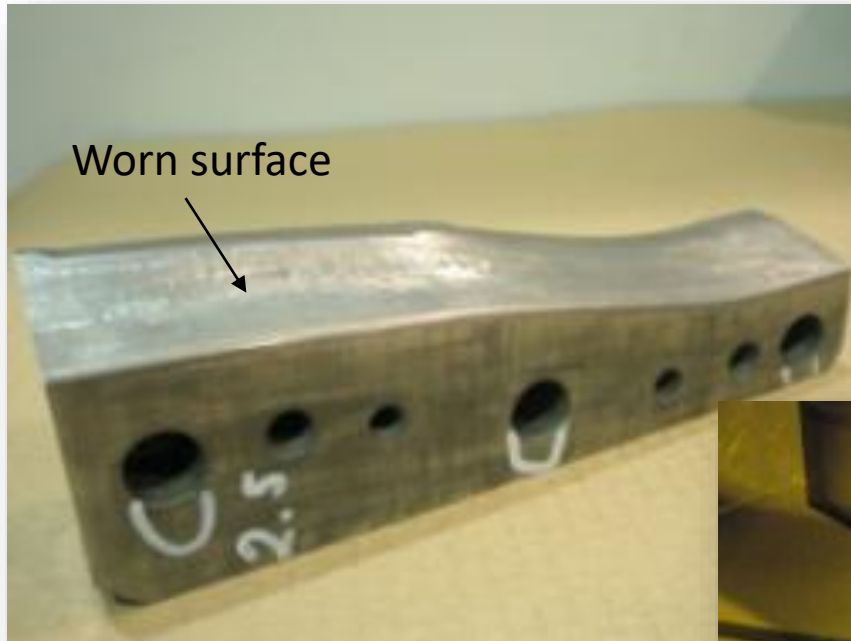


Machined to Spec



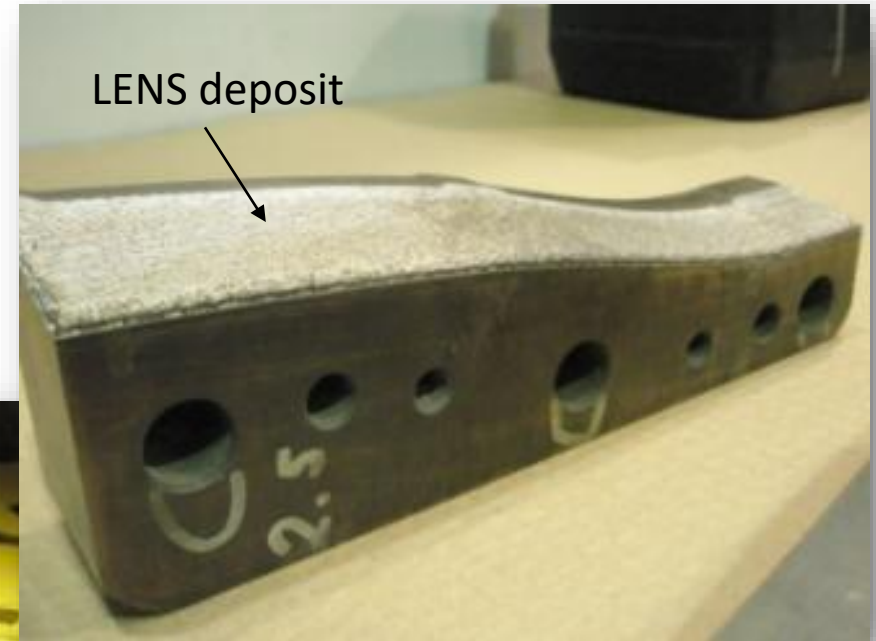
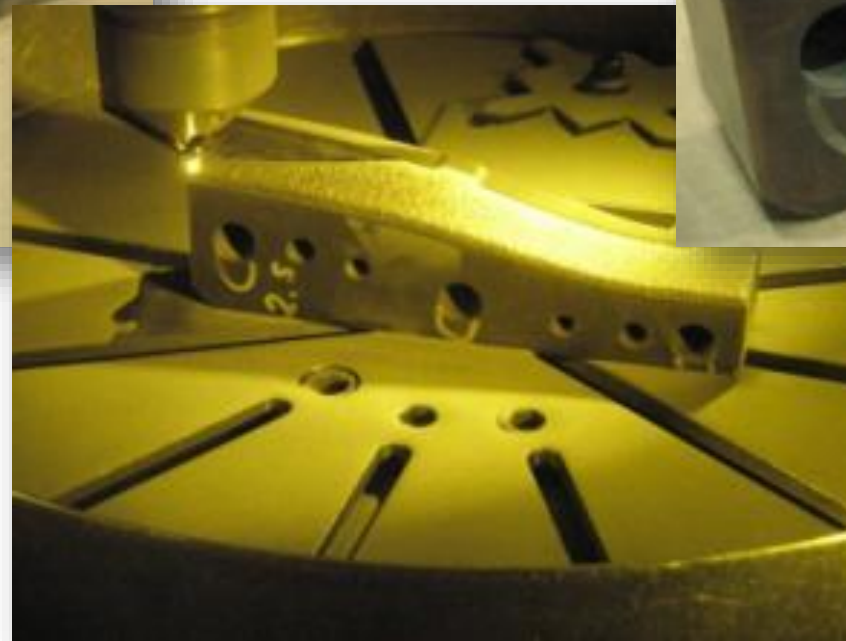
LENS Repair: Tooling – Deep Draw Tools

H 13 tool steel



Worn Tool

LENS Printing



As Printed

LENS Repair: Tooling – Injection Mold Barrels

Stellite 694

- Barrels used to eject hot resin in injection molding.
- High wear surface, especially with glass-filled resins.
- LENS printing of a carbide wear resistant material.
- Uses LENS proprietary “Deep Repair Head”.



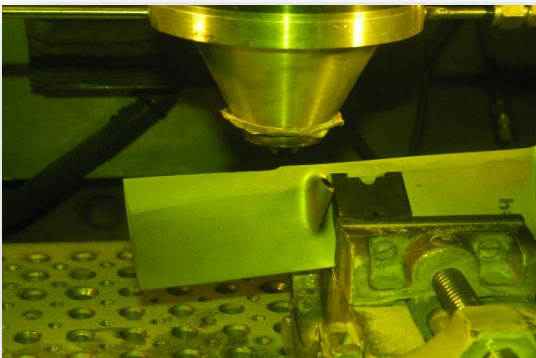
LENS Repair: Gas Turbine – Blade Tips, Edges and FOD

Titanium

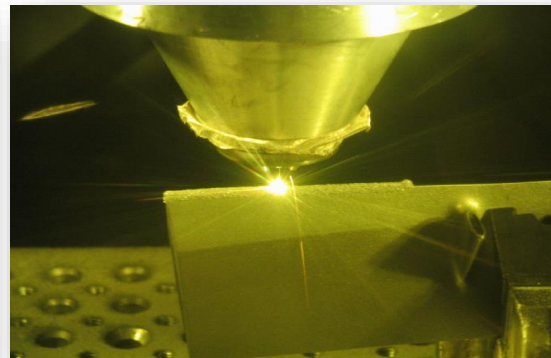
- Turbine blades wear over time and suffer damage from ‘foreign objects damage’ (“FOD”).
- New blades can be very expensive, and very long lead times for older units.
- LENS can be used to cost-effectively restore/resurface blades at a fraction of the cost.

Example: Using LENS to repair tips, leading edges, and scratches on Ti blades

Auto alignment



LENS restoration



As deposited



After finishing



LENS Repair: Gas Turbine Blisk Repair- Material Enhancement

Stellite 21

Example: Repair of leading edges for T-700 blisk (passes spin test requirements)



After printing; before finishing

- Base Material:
AM355 Steel
- Repair Material:
Stellite 21
(cobalt based,
wear resistant)

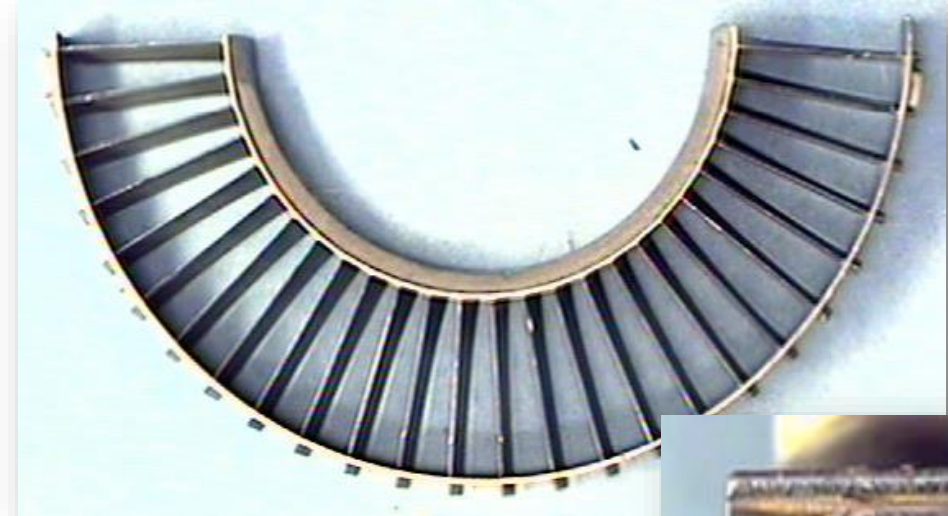
- ✓ 60,000 rpm
Spin Test
- ✓ 50,000 Cycle
LCF Spin Test



After finishing and successful spin tests

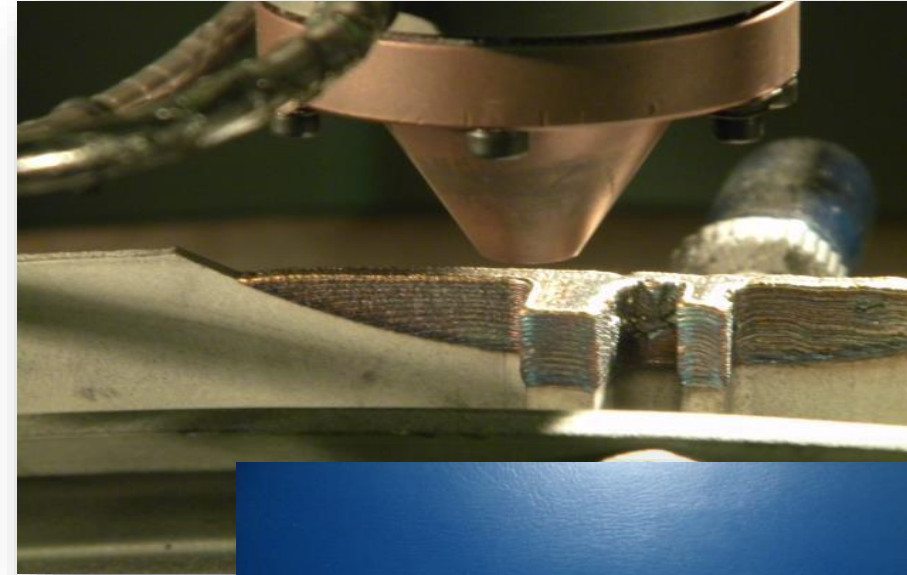
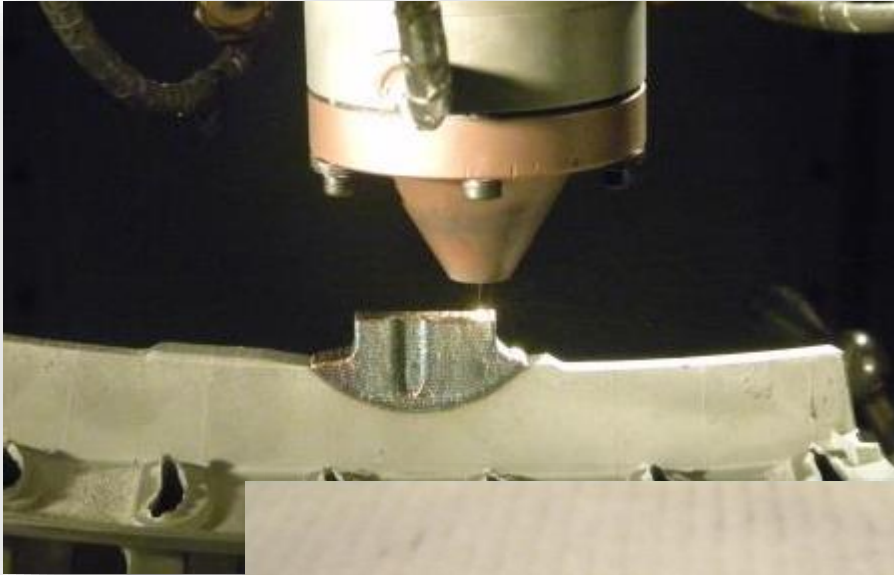
LENS Repair: Gas Turbine – Vane Segments

410 SS



LENS Repair: Gas Turbine – Stator Guide Walls

Nimonic 75



LENS Repair: Seals – Ball Valve

Ti-6-4

- Scratch on Titanium ball valve causes leak; gas tungsten arc welding unsuccessful due to distortion from heat input.
- LENS conformal printing on surface successful, 15 minute repair. Cost/time greatly reduced vs. part replacement.

1" long scratch



After printing; before finishing



machined & polished



LENS Repair: Bearing Surface- Material Property Enhancement

410 SS

- LENS used to resurface a worn bearing surface.
- 4340 high carbon steel resurfaced with 410 stainless steel.
- 410 stainless steel used to build up worn surface and to provide better corrosion and wear resistance over original material.
- Quick turnaround repair of part to place back into service with minimum down time.

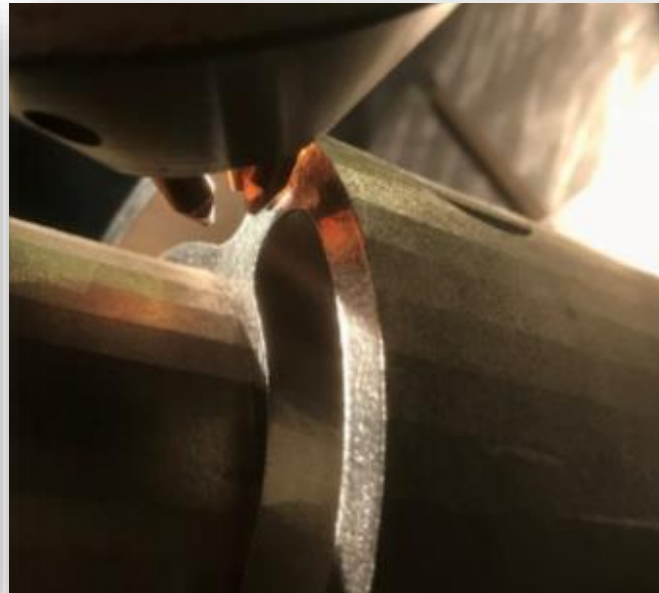
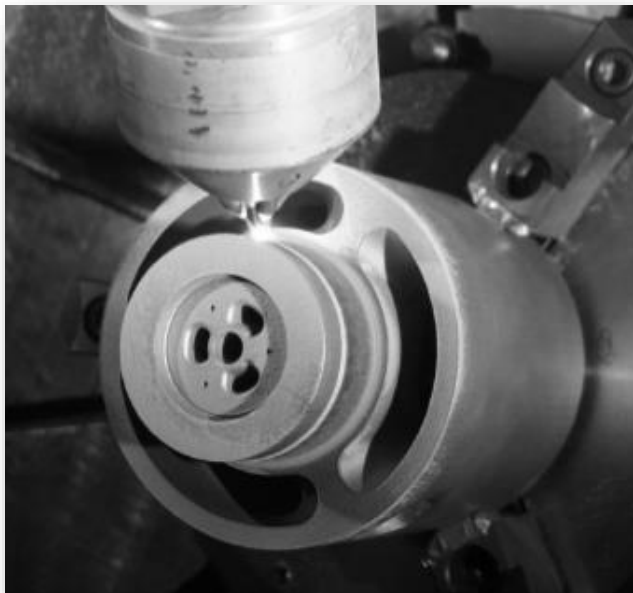


LENS Repair: Powder Bed Fusion Parts

Inconel

- Powder bed fusion parts are very expensive to fabricate, but must be scrapped if underbuilt, if defects are found, or if the process is interrupted prior to completion.
- The LENS process can effectively repair/add metal to powder bed parts to repair/complete the build.

LENS repair of an Inconel PBF part



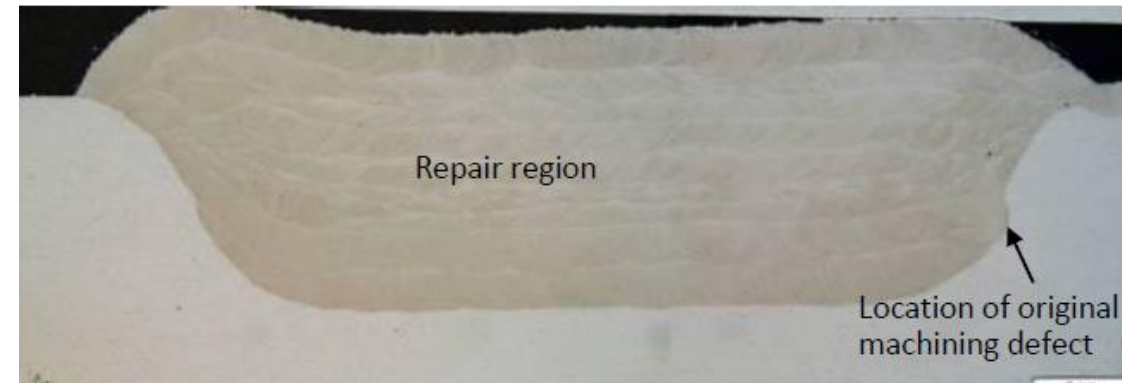
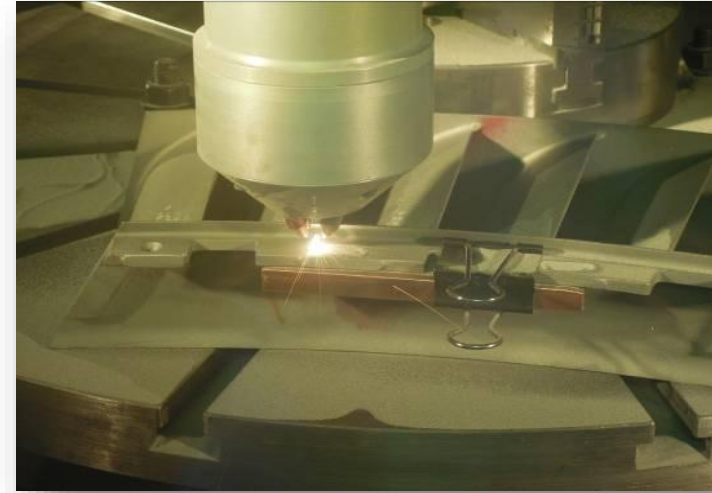
LENS used to extend shaft length on PBF fabricated fork joint



LENS Repair: Defects – Machining Error

Waspalloy

- Tier 1 aircraft engine manufacturer.
- Machining error on high cost part.
- Developed rework procedures for IN718, Waspalloy, Rene 77 and Mar-M-247 parts.
- Machine and qualified processes delivered to Field Repair Center in Taiwan



LENS Repair: Defects – Filling Blind Holes

Waspaloy

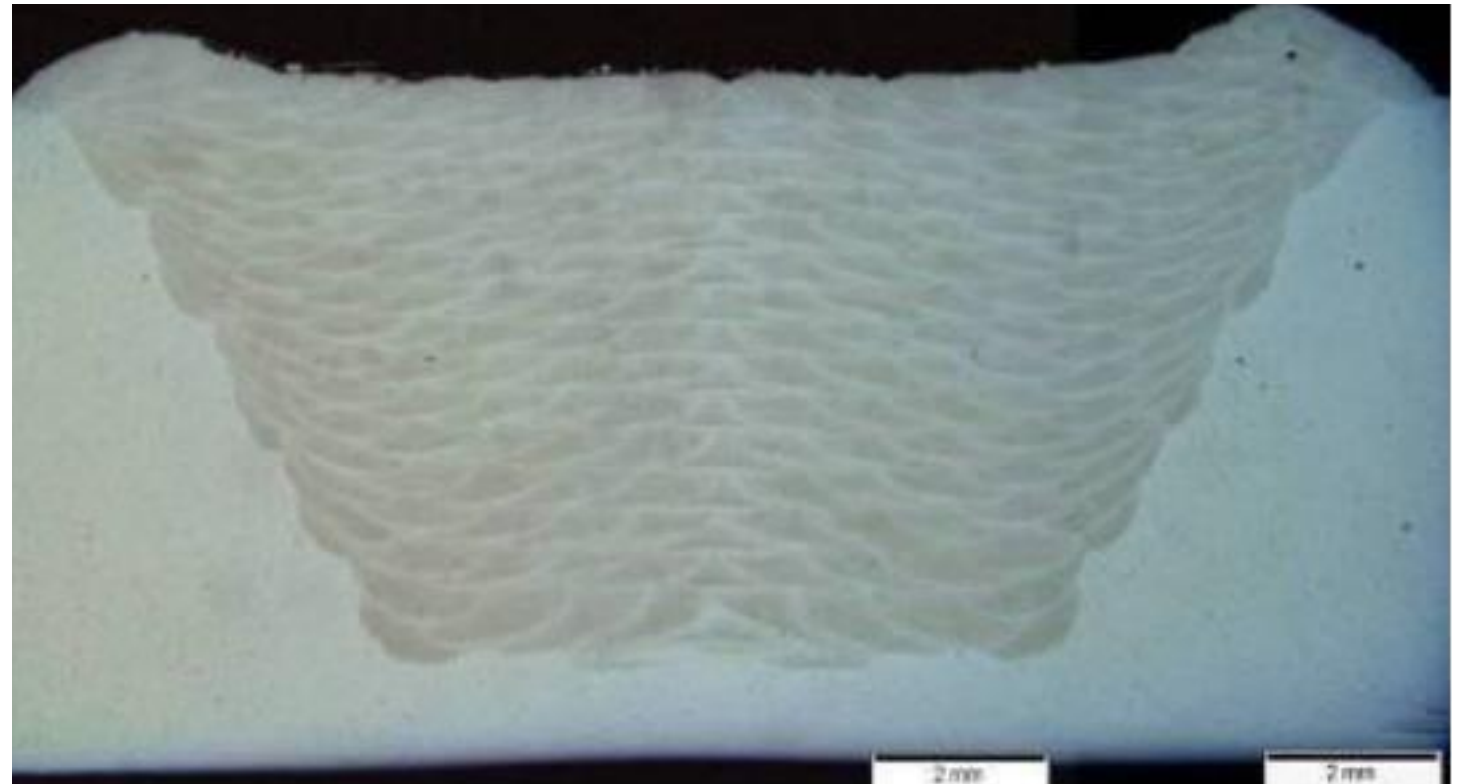
Machined
sample



Surface
remelt



After LENS
deposition



Cross-Section

LENS Repair: Systems – Cost Effective Flexible Machine Options

LENS Machine Tool Series

- Work envelope up to >1m³
- 3/4/5-axis configurations
- Laser power from 500W to 3kW
- Open and controlled atmosphere
- **SIEMENS** controllers

Software and Digital Products

- **MasterCAM** additive/hybrid toolpath software
- Pre-qualified process recipes
- MeltPool Sensor for closed-loop process control

Hybrid enables “Mill and Fill” Repairs

- Integrated spindle and tool changer
- Prep/print/machine without re-fixturing

LENS 500



LENS 860



LENS MTS 500	Item / Option	LENS MTS 860
\$264,500	Base System	\$319,500
\$10,000	System Software	\$25,000
500 x 350 x 500	XYZ (mm)	860 x 600 x 610

Thank You.

David Ramahi/Tom Cobbs
Optomec, Inc.

