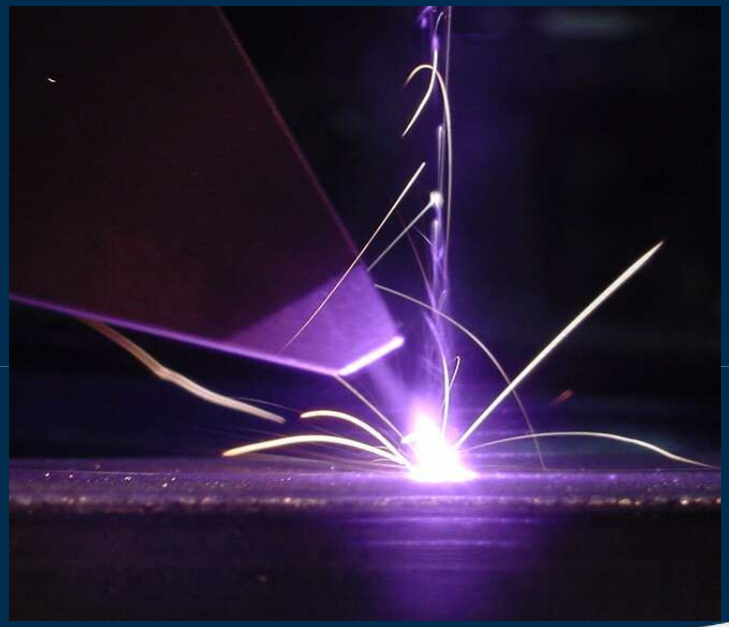
Laser Enabled Refurbishment and Performance Enhancement of Industrial Components



C van Rooyen, M Theron, HP Burger
Afrimold
29 September 2011

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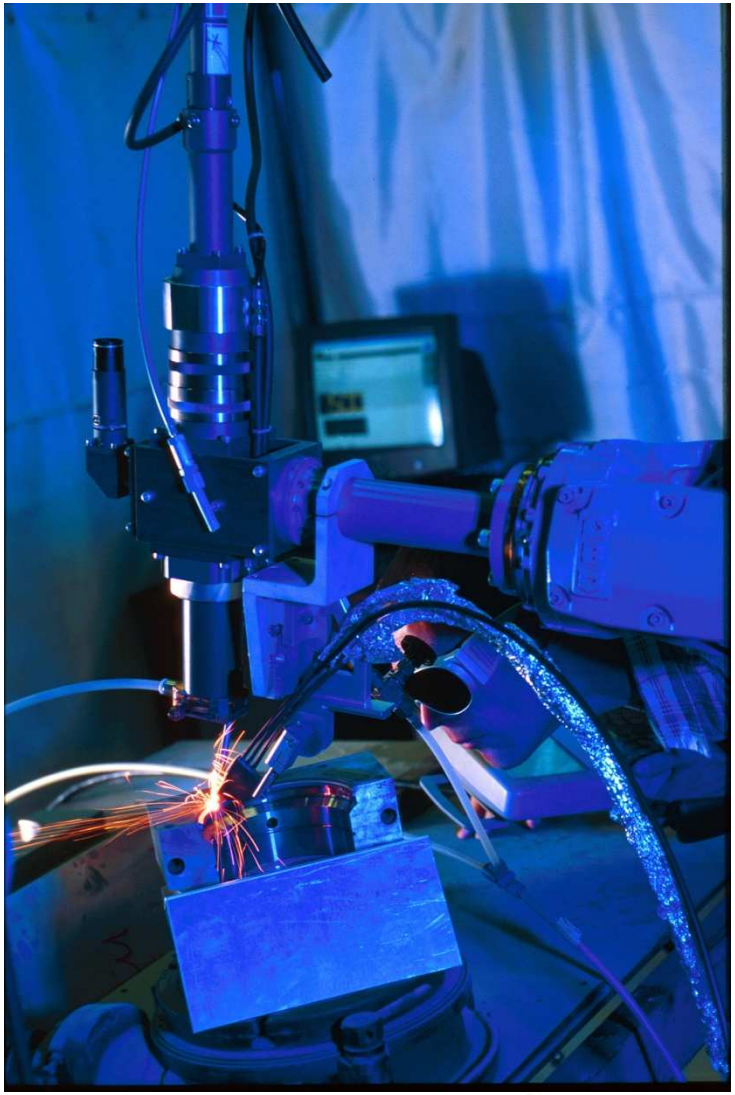

Introduction

- **Refurbishment**

  Reconditioning of a component, no longer fit for service, to original specifications

- **Performance Enhancement**

  Reengineering of components during refurbishment to obtain longer service life than achievable with original design.

  Ideally also included in the manufacturing process if possible.

The Case for Refurbishment/Performance enhancement of Industrial Components in South Africa

The potential to improve operational efficiency and reduce operating cost

- Manufacturing Industry largely dependent on imported equipment
- Expensive to import replacement parts
- Long lead times – loss of production
- Expensive inventories of critical spare parts
- Volatile exchange rate – complicates financial planning

The potential to reduce environmental impact

Provided that:

Techno-economically viable refurbishment processes and service providers are available

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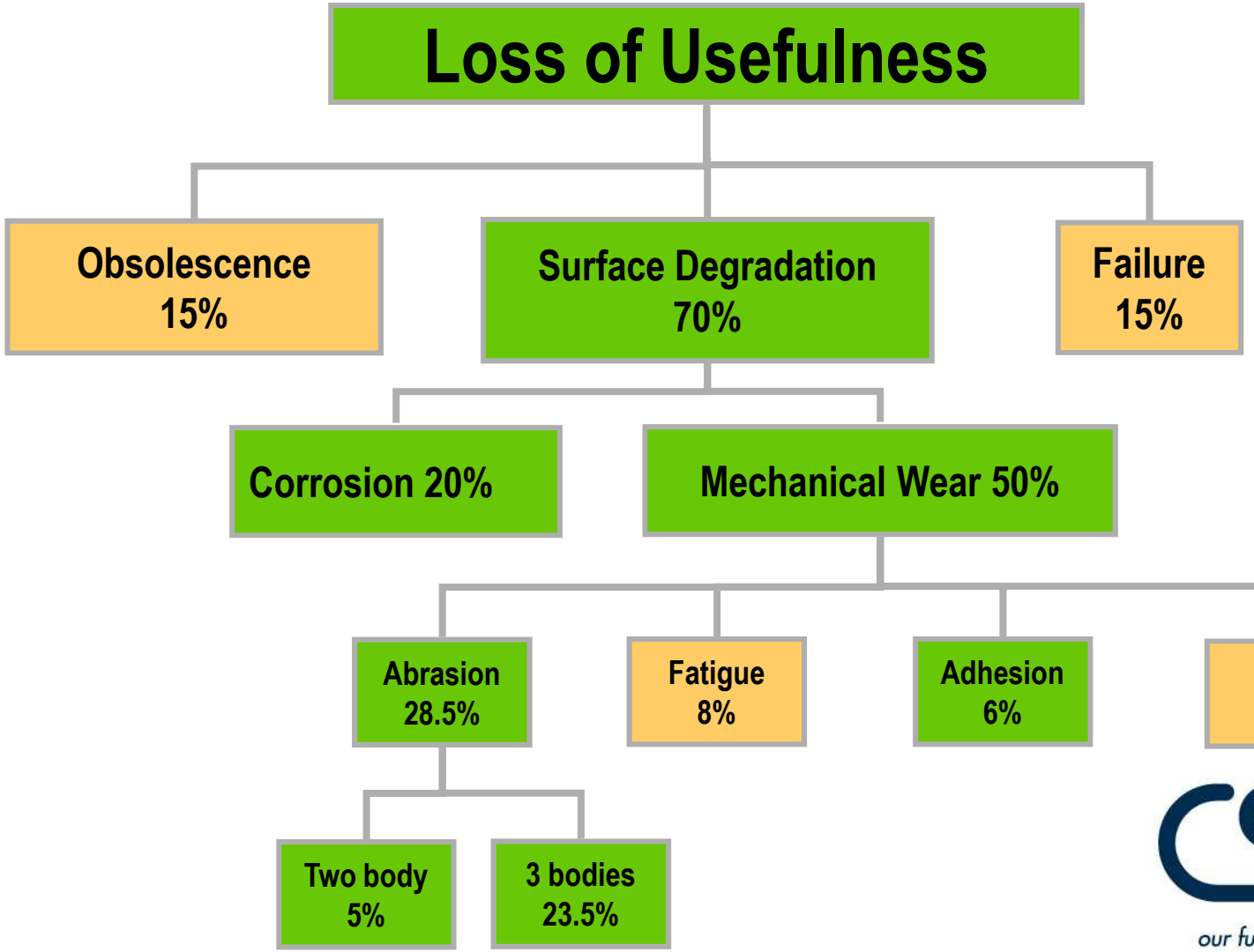
Root causes of degradation of machinery



http://www.maintenanceworld.com/Articles/reliabilityplant/Machines-Wear-Out.htm

Current state-of-the-art of surface refurbishment/performance enhancement

Predominantly

- **Weld overlay process based on arc welding**

Pro's

- Thick layers (metallurgically bonded)
- High deposition rates
- Inexpensive

Con's

- High heat input
- High dilution
- Distortion

- **Thermal spray processes**

Pro's

- Versatility
- Low heat input
- Minimal distortion
- Layer thickness range

Con's

- Low impact and fatigue resistance (mechanical bonding)

Niche for process which provides

- Minimal distortion (Low heat input)
- High impact and fatigue resistance (Metallurgically bonded layer)
- Thin layers (low dilution)

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Laser Enabled Refurbishment/Performance Enhancement Process

Laser Metal Deposition (Laser cladding)

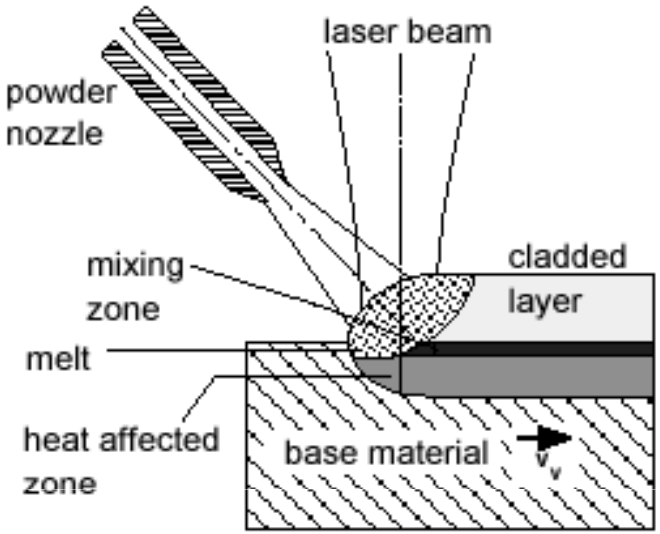
Laser Cladding is essentially a weld overlay process where

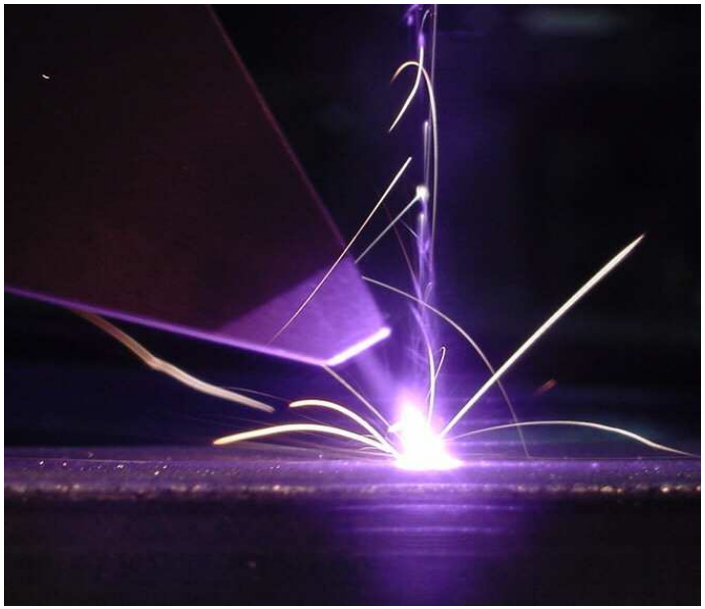
- The heat source is a laser beam and
- The welding consumable is a metallic powder or wire

Background:

- High power lasers produce power output in the multi kilowatt range.
- Laser beams can be focused to spot diameters of well below 1 mm
- A focused laser beam can produce power density on a work piece surface that is both very high and highly localized.
- This feature enables the relatively low heat input that is characteristic of all laser based manufacturing processes.

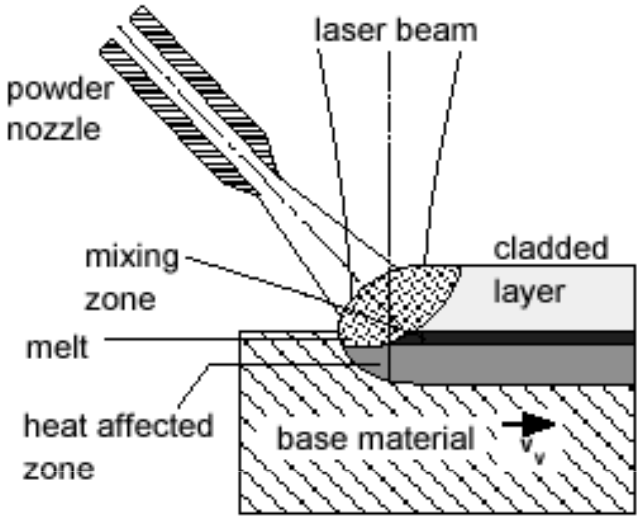
Process Fundamentals.

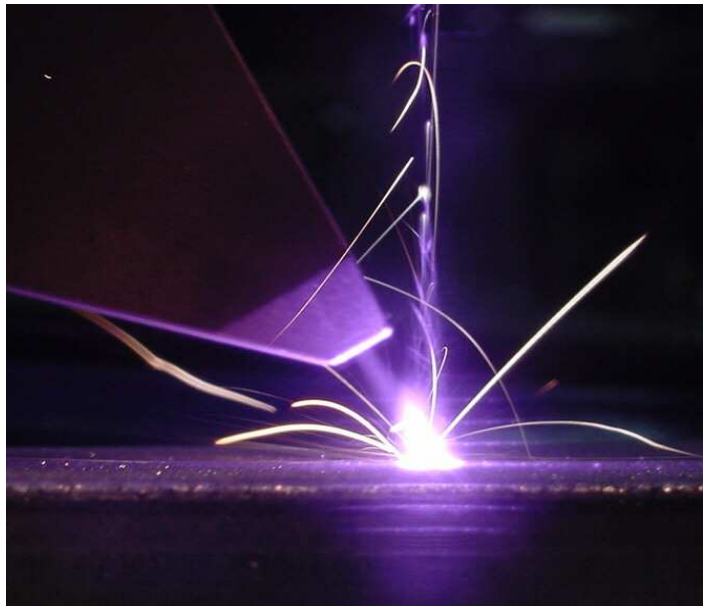




- Laser beam creates shallow melt pool on substrate surface.
- Consumable is fed into melt pool.
- Deposition of weld bead results from relative movement between laser beam and substrate.
- Successive weld beads with appropriate overlap results in clad layer.
- Process parameters:
  - Laser power
  - Laser spot diameter
  - Powder feed rate
  - Weld speed
- Simultaneous optimization to ensure fusion, minimize dilution and optimize deposition rate.

Laser Metal Deposition (LMD)





•Laser beam creates shallow melt pool on substrate surface.
•Consumable is fed into melt pool.
•Deposition of weld bead results from relative movement between laser beam and substrate.
•Successive weld beads with appropriate overlap result in clad layer.

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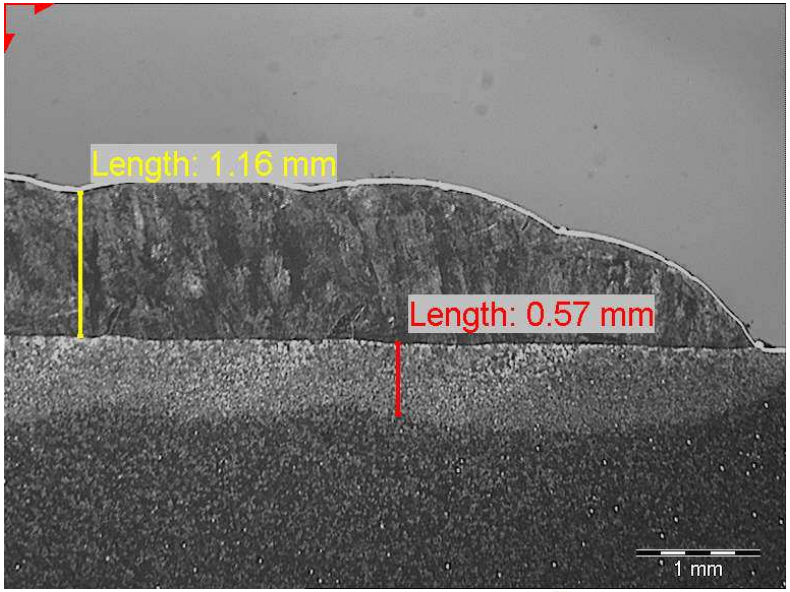
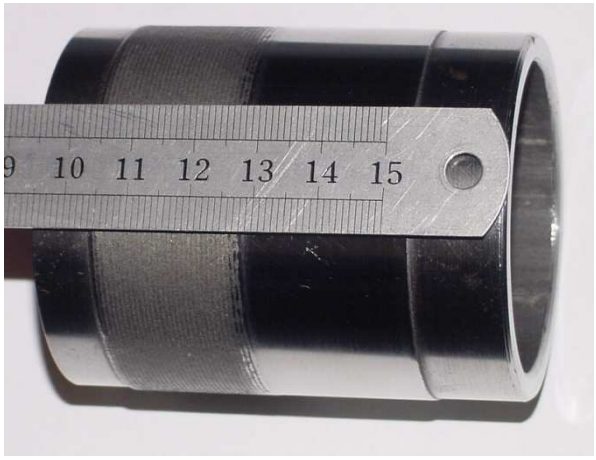
Process Characteristics

- **Low Heat Input** (Typically 0.02-0.2 kJ/mm)
  - Small HAZ
  - Low dilution (<5%)
  - Minimized distortion
  - Thin layers possible
  - No undercut
  - Increased hardness (Grain refinement caused by rapid solidification)
  - Combination of thin layers and low dilution allow consumable saving.
- **Metallurgical bonded layer**
  - Good fatigue resistance
  - Good impact resistance
- **Layer thickness**
  - Typically 0.1 – 2 mm
  - Thicker layers possible through multiple passes



Process Characteristics (continued).

- **Reduced machining effort**
  - Capacity for thin layers reduce pre machining.
  - Low layer surface roughness reduce post machining. Machining tolerance 0.2 – 1.0 on dia.
- **High level of quality assurance**
  - Automated process
  - Combination of laser technology and CNC processing ensures excellent process control and reproducibility.
- **Flexibility**
  - Much larger range of commercially available powder consumables than welding wires.
  - Ability to modify consumable chemical composition by mixing of powders.
- **On Site applications becoming possible**
  - Increased mobility of new generation high power laser sources.



Process Characteristics (continued).

- **Flexibility**
  - Much larger range of commercially available powder consumables than welding wires.
  - Ability to modify consumable chemical composition by mixing of powders.
- **Deposition rate**
  - Up to 1.3 kg/hour (316L).
- **Consumable utilization (Powder efficiency)**
  - Up to 95%

Applications of Laser Metal Deposition

- Refurbishment of worn components.
- Performance enhancement of functional surfaces on components.
  - Improved wear resistance
  - Improved corrosion resistance
- Correction of machining errors on high value components.

Laser Metal Deposition in South Africa

- Technology platform established at CSIR-NLC in 2002
- Technology transfer from Fraunhofer ILT
- Ongoing core funded R&D program
- Contract R&D for Industry
- Refurbishment service
- Small number of manual wire feed systems in industry

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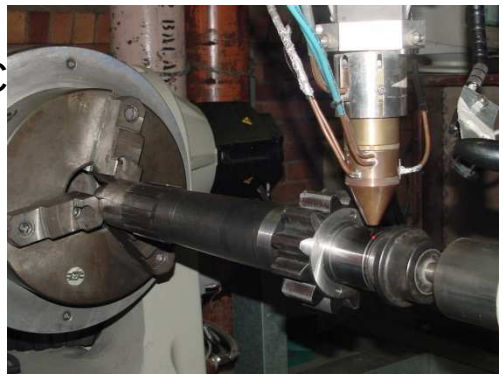
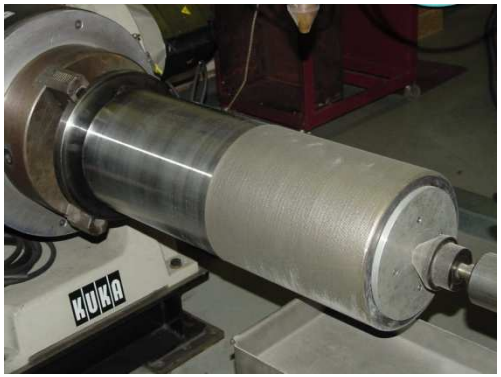
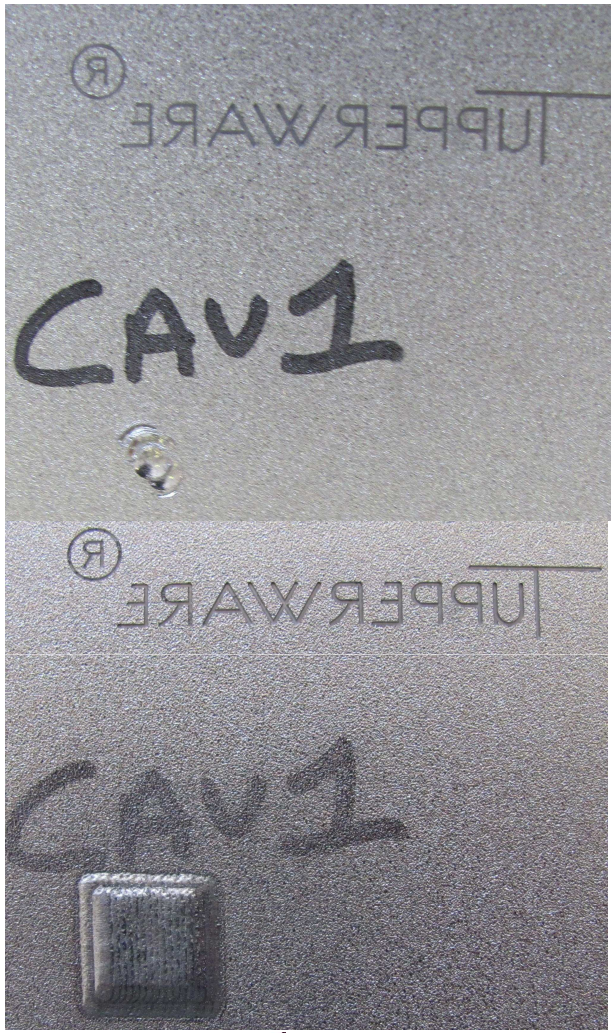
Materials and Applications

- Stainless steel
  - Low-C martensitic (0.02C,12Cr, 5Ni, 1-5Mo) - 38-40 HRC
  - 431 (0.2C, 16Cr, 4Ni) - 52 HRC
  - 316L
- Ni alloys
  - Inconel (625, 718)
  - Nistelle C, D
  - Self fluxing - 40-60 HRC
- Co alloys
  - Stellite 6 – 52 HRC
  - Stellite 12 – 55 HRC
- Ti alloys
  - Ti6Al4V





Also Al-Si, Al-Si-Mg, Al-Zn-Mg-Cu



Tupperware®

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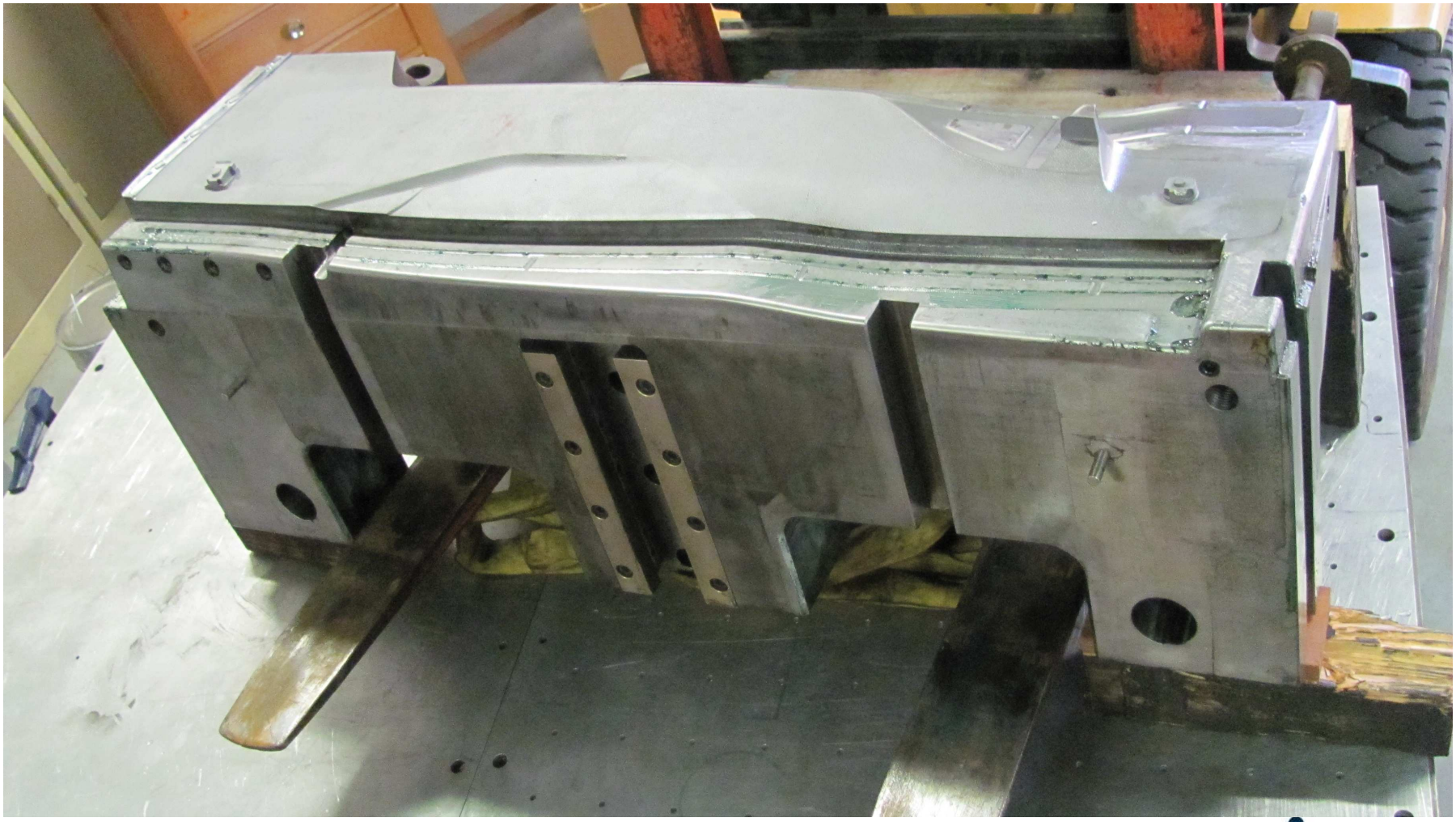
Injection Mould Repair



Werma Patterns & Moulds

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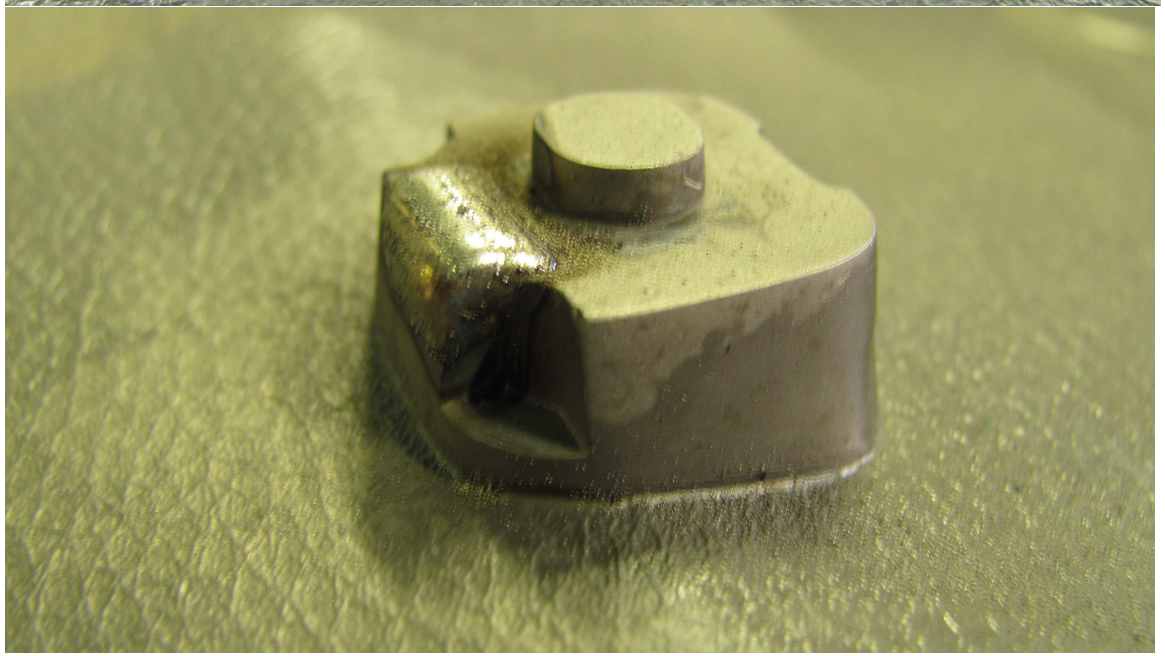

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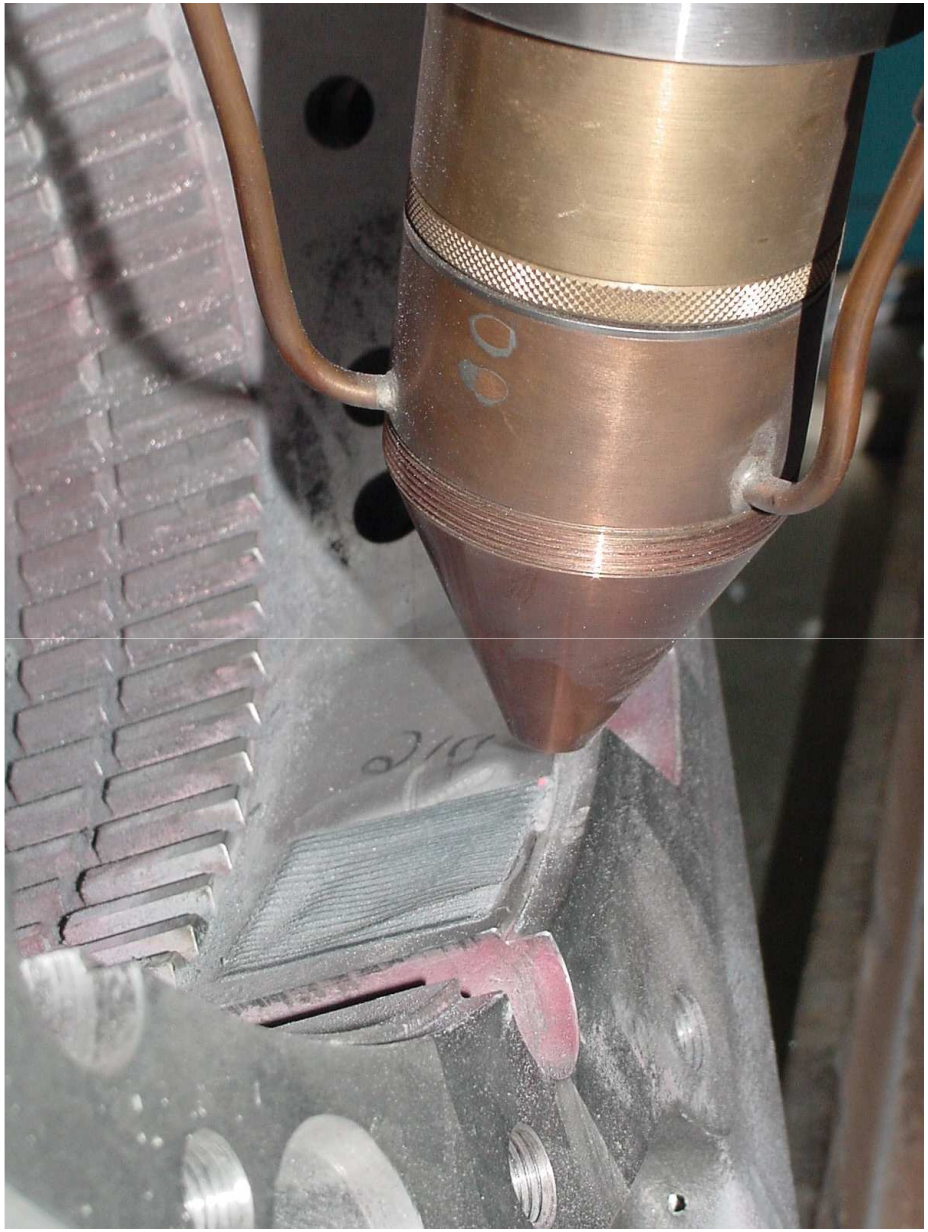
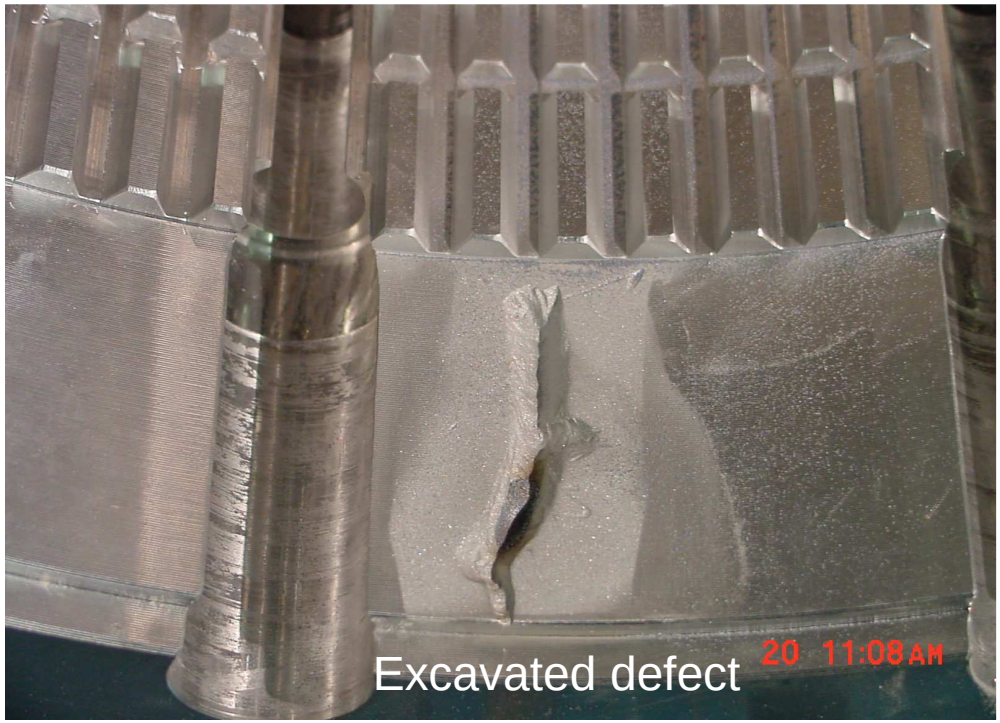
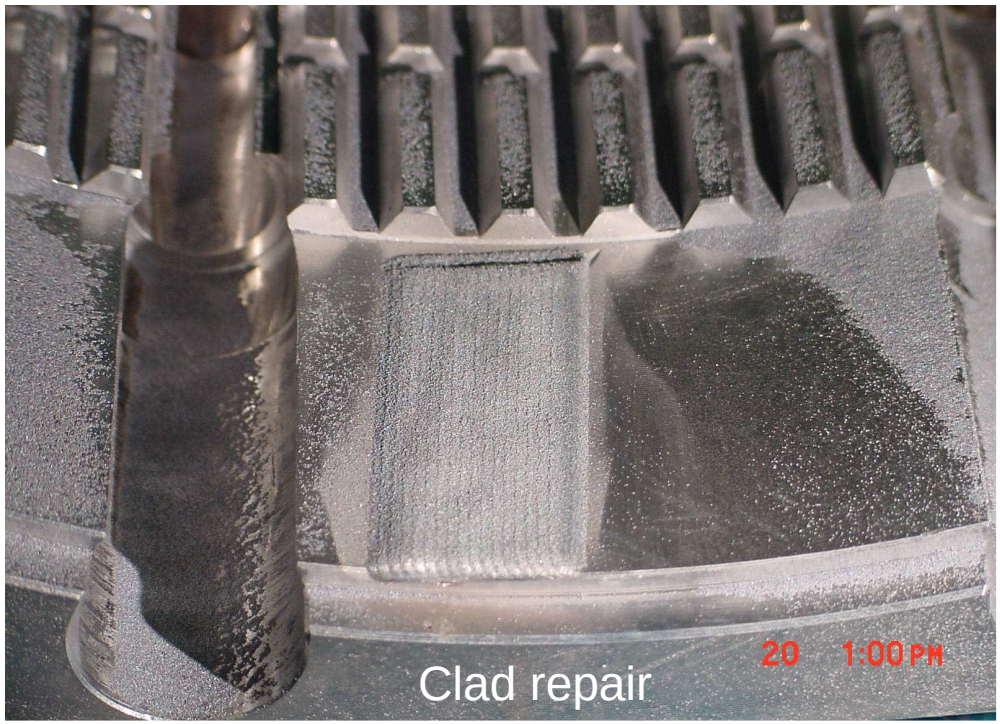
BAE SYSTEMS

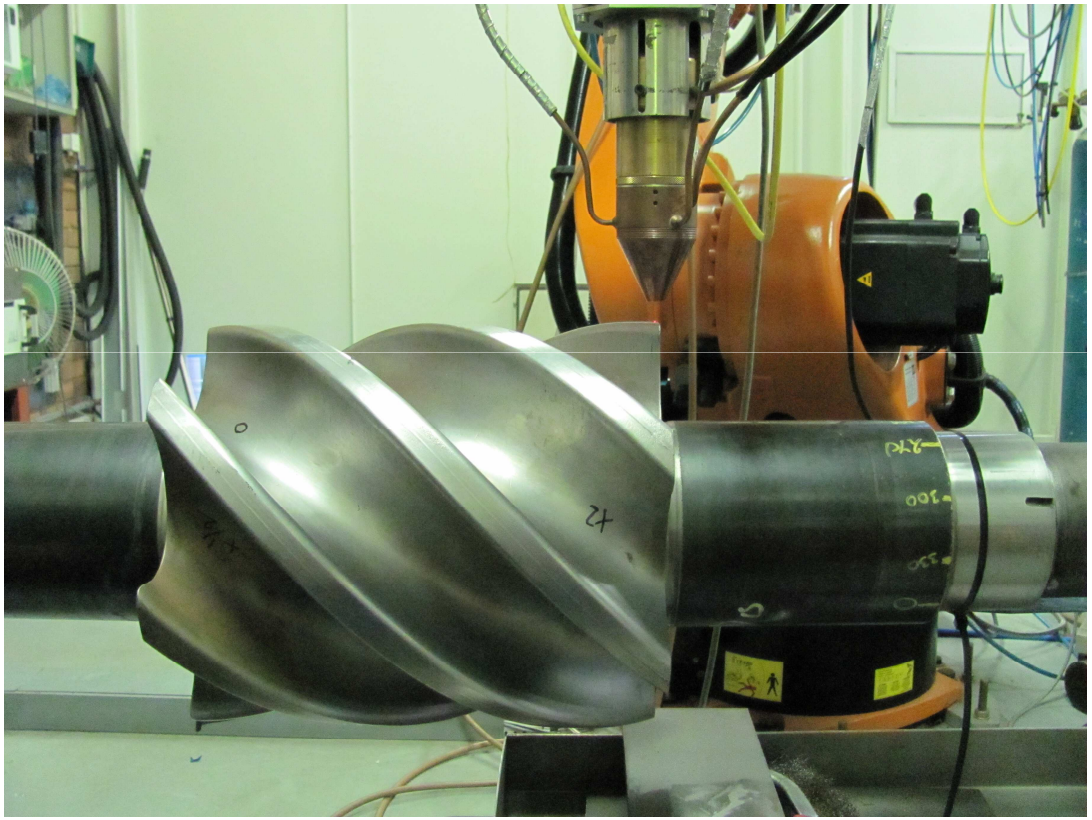


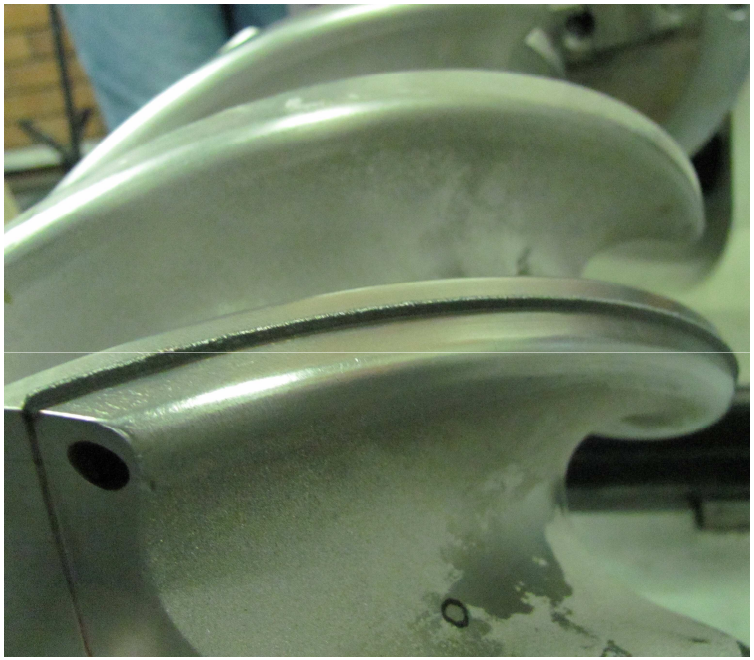




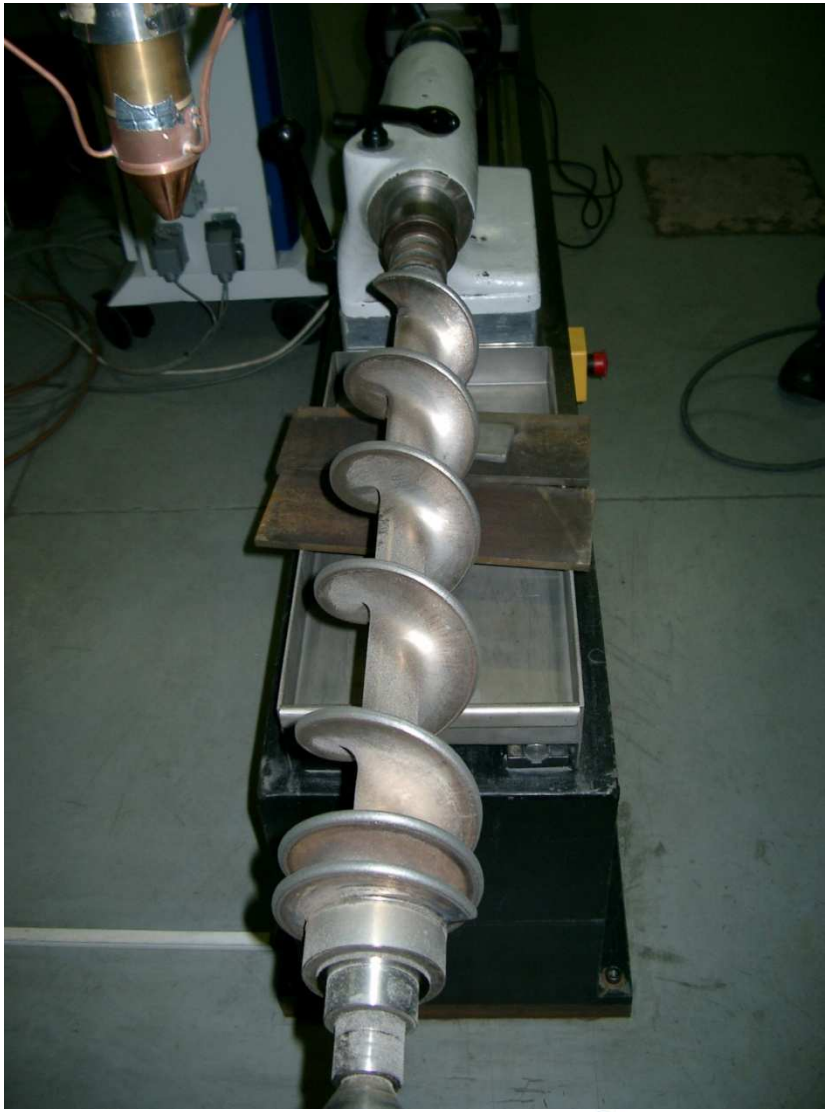
Repair of casting defect in gearbox housing

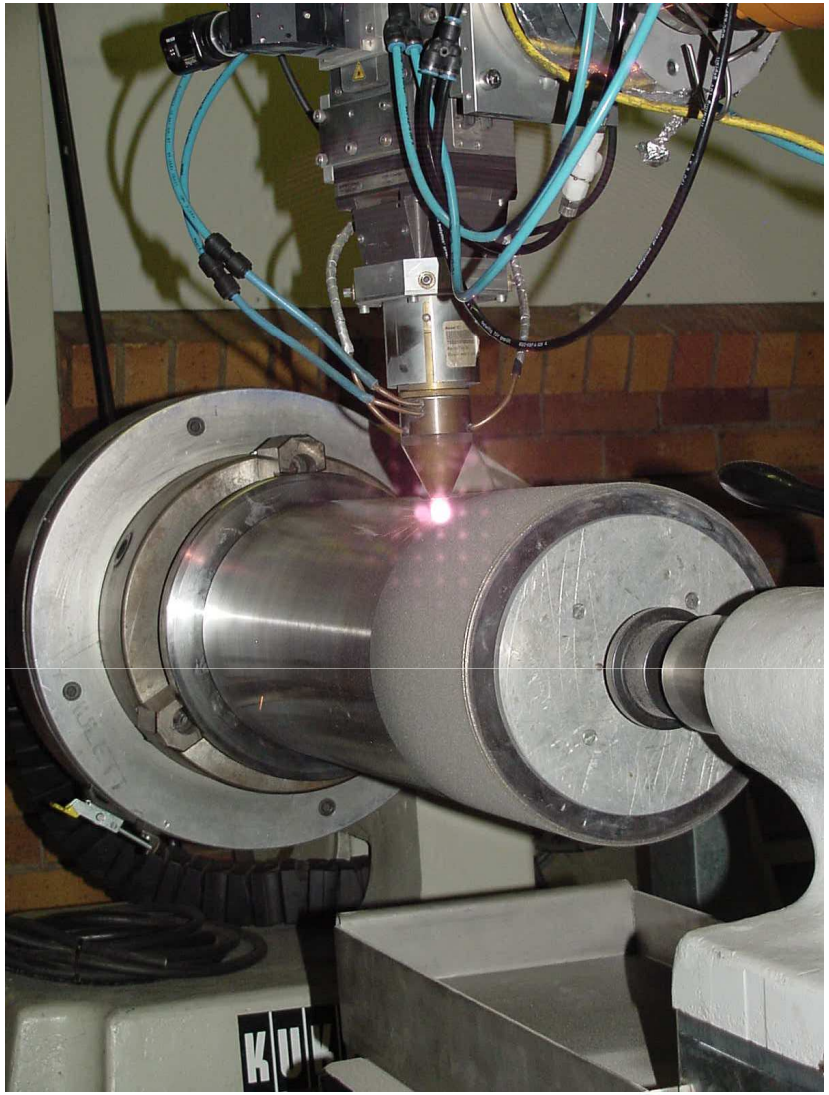
Refurbishing of compressor screw





Rebuilt mechanical seal





Refurbishment and performance enhancement of concast rolls

ArcelorMittal

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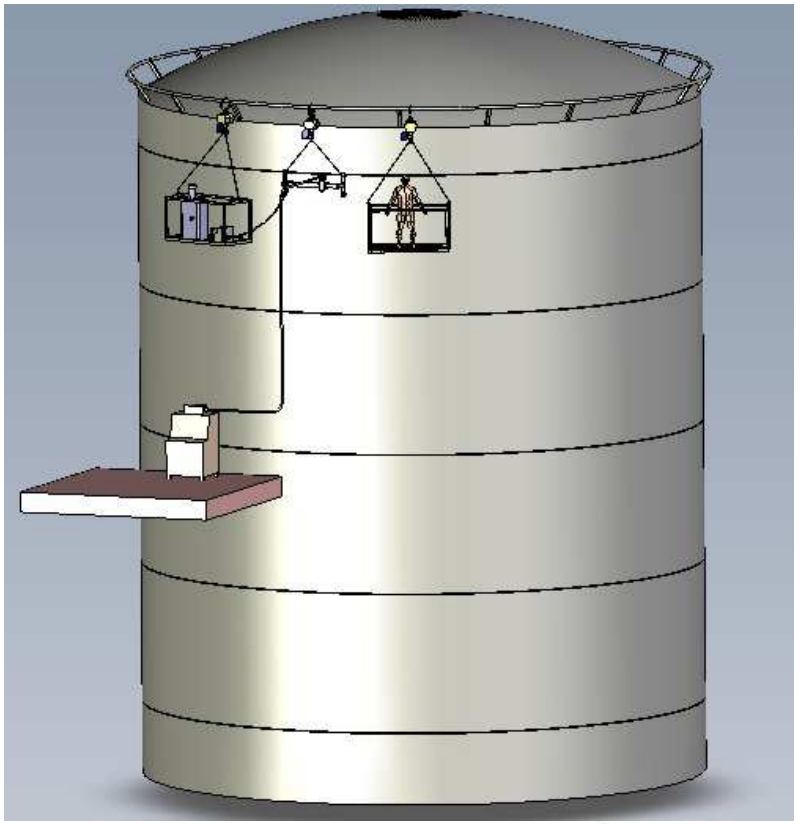
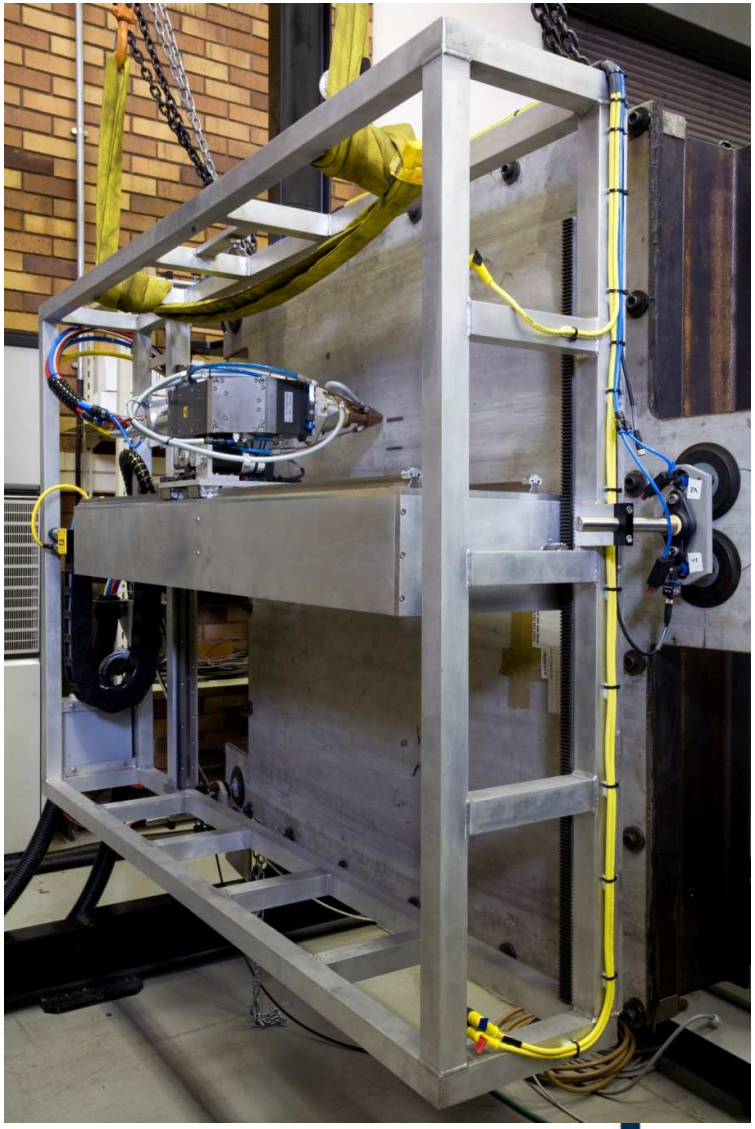
Refurbishment of Water Storage Tanks

- Combination of high residual stress and marine environment induced stress corrosion cracks in SS 304L MIG weldments.
- Process required to seal leaking cracks.



Lab demonstration – January 2010



Eskom

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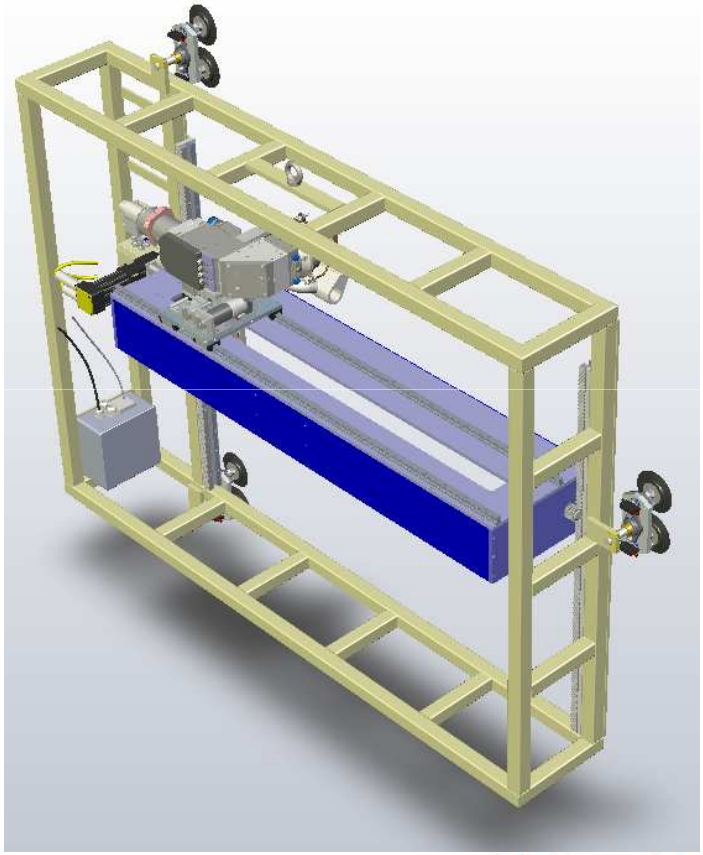
Mobile Laser Cladding System

- 3 Axis space frame
- Pneumatic suction pads
- Laser cladding head
- Fiber laser
- Chiller
- Powder feeder
- Control system



On Site Application: April 2011

Service life of R1bn asset extended till at least 2015

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Conclusion

- **Refurbishment is underutilized in South Africa**
  - OEM requirements for original parts and approved processes.
  - Subcontracting of maintenance requirements
  - Lack of technological awareness
  - Lack of confidence
  - Change of mindset required

- **Laser metal deposition has potential to increase refurbishment significantly**
  - Excellent process control
  - Low dilution, low HI, high repeatability, high precision

  - Address application niche
    - Thermal spray – PTA
    - Maximum benefit - Thin layers, metallurgical bond, expensive consumables

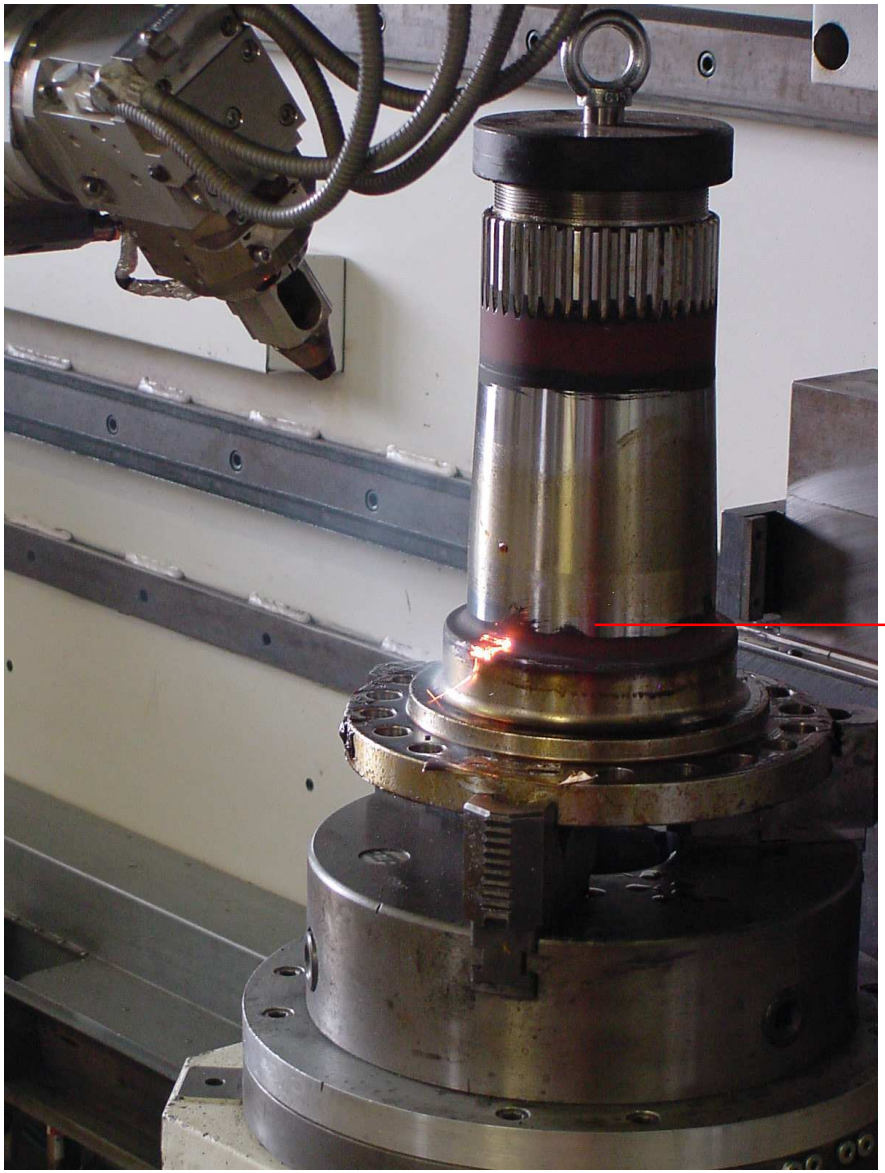
Laser Transformation Hardening

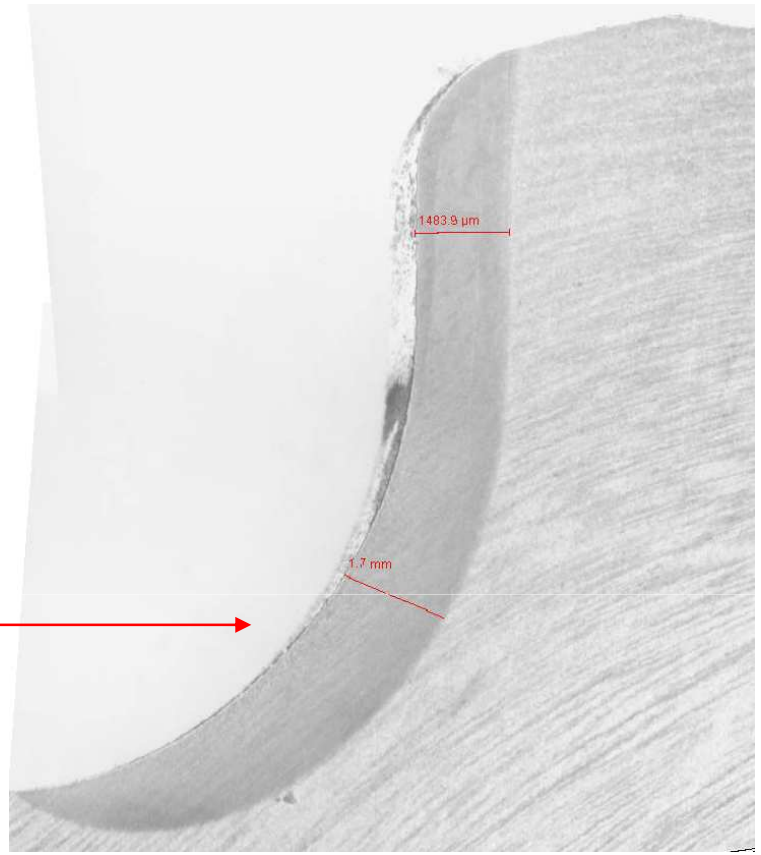
Alternative processes

- furnace hardening (electric or gas)
- thermo-chemical methods
  - carburizing
  - nitriding (0.1 – 0.5 mm, 55-70 HRC)
  - Carbo-nitriding
  - Cyaniding
- electric induction
- flame hardening

Laser hardening indicated when application requires:

- Selective case hardening
- Minimum distortion
- Quenching is impractical





Laser hardening of stub axle

BELL EQUIPMENT

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Laser Hardening of Punch Die

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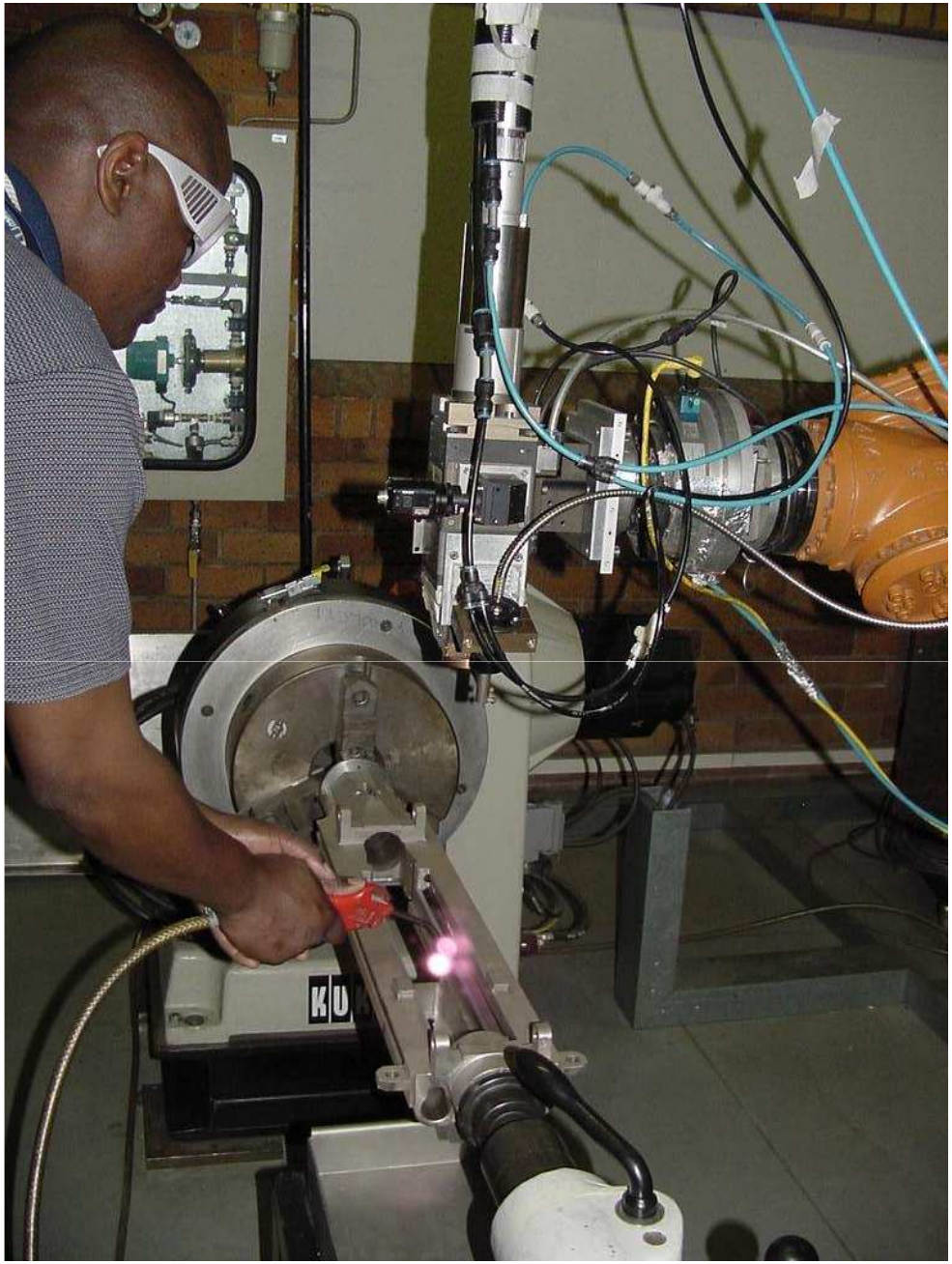

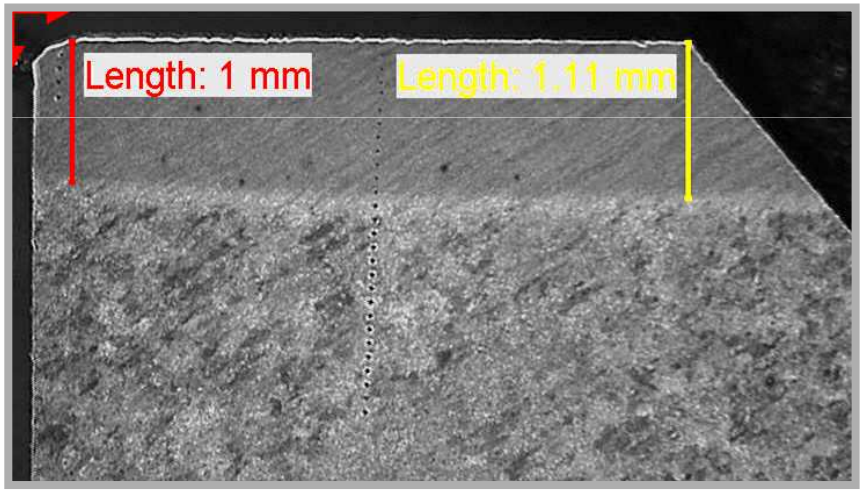

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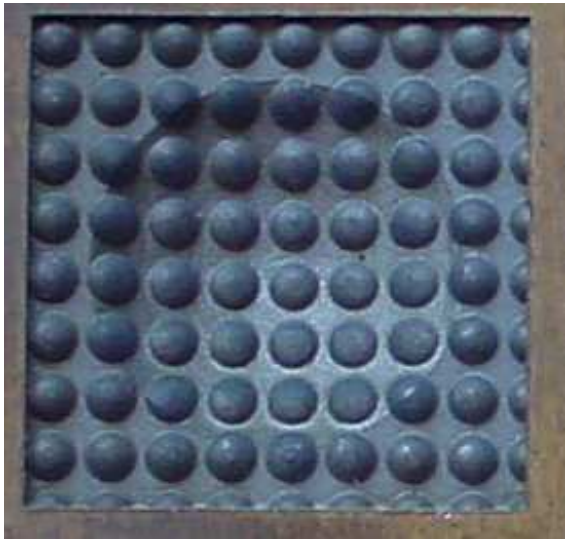

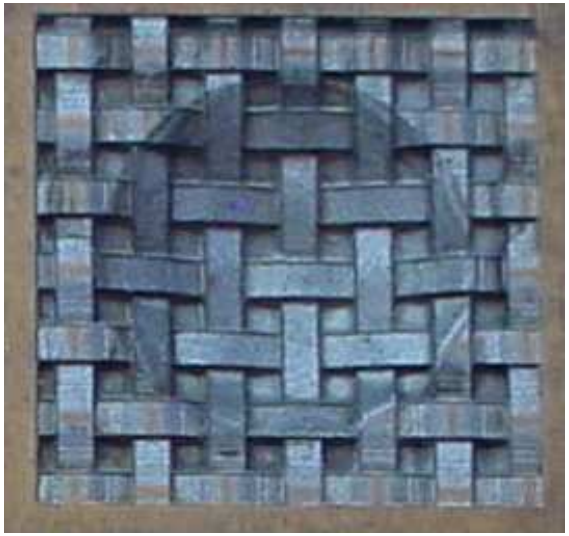

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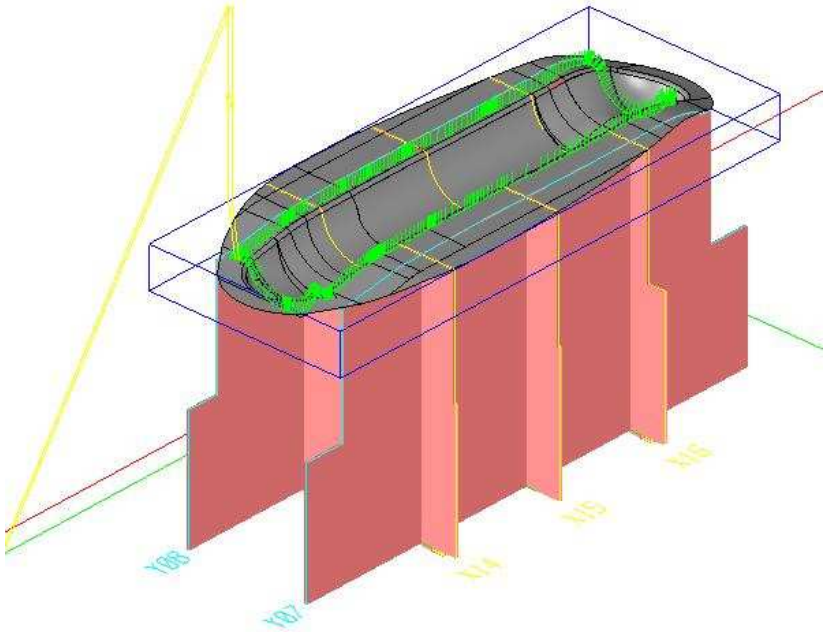

“Soft Tooling” – Laser trimming of sheet metal pressings

- Reconfigurable
- Trim tool development
- Small batch production
- Handy alternative when trim tool is unavailable

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Thank you for your attention!

The Laser Materials Processing Competence area wishes to express their gratitude to:

• DST
• CSIR
•Fraunhofer ILT

For enabling us to make LIGHT work of industry challenges!

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