Laser Enabled Refurbishment and Performance Enhancement of Industrial Components

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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
Root causes of degradation of machinery

Loss of Usefulness

- Obsolescence 15%
- Surface Degradation 70%
- Failure 15%

Surface Degradation

- Corrosion 20%
- Mechanical Wear 50%

Mechanical Wear 50%

- Abrasion 28.5%
- Fatigue 8%
- Adhesion 6%
- Other 7.5%

Corrosion 20%

- Two body 5%
- 3 bodies 23.5%

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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)
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.
• 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.
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
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
Injection Mould Repair

Werma Patterns & Moulds
Repair of casting defect in gearbox housing
Refurbishing of compressor screw

Rebuilt mechanical seal
Refurbishment and performance enhancement of concast rolls
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
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
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
“Soft Tooling” – Laser trimming of sheet metal pressings
- Reconfigurable
- Trim tool development
- Small batch production
- Handy alternative when trim tool is unavailable
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!