Oil & Gas Remanufacturing Demonstrator through Laser Metal Deposition

Stephen Fitzpatrick
Machining & Additive Manufacturing Team Lead
Advanced Forming Research Centre
1. Introduce the AFRC and the Remanufacturing Theme

2. Overview of LMD and benefits

3. How those technologies can be applied to the benefit of:
   - Oil and Gas applications

4. Demonstrator Project and the steering group
AFRC
Scotland’s only High Value Manufacturing Catapult Centre

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Stephen Fitzpatrick
Machining & Additive Manufacturing Team Lead
Advanced Forming Research Centre
Key Manufacturing Technologies
AFRC Current Capabilities - Remanufacture Technologies / Processes

**Laser Metal Deposition**
- New Hybrid Machine Installed in July 2018
- Multiple Projects Undertaken
- EngDs & PhDs Researching Process
- Process Optimisation via Commercial Project

**Advanced Machining**
- Core Capability
- DMG Partner of AFRC
- EngDs & PhDs Researching Process

**Automated Surface Cleaning**
- Newly Developed Capability for Hot Forming Dies
- Developed Through Commercial Project
- Company Planning Further R&D
Key Manufacturing Technologies
AFRC Current Capabilities – Remanufacture Technologies / Processes

Non-Destructive Evaluation
- Core Capability (Supported by Electrical Engineering)
- Robotic Automation Developed Via Commercial Project
- Automation: Kuka Member of AFRC
- Ultrasonic Measurement is a Key Focus of the AFRC

Non Contact Measurement
- Advanced Capability
- Robotic Automation Developed Via Commercial Project
- Hexagon Manufacturing Intelligence T1 Partner of AFRC

Touch Probe & CMM
- Core Capability
- Ability to Inform Adaptive Machining
- Renishaw Member of AFRC
Key Manufacturing Technologies
AFRC Current Capabilities – Remanufacture Technologies / Processes

Advanced Forming Research Centre

Manufacturing Process Modelling
- Advanced Capability
- Multiple Projects Undertaken
- EngDs & PhDs Researching Process

FEA Modelling – Residual Stress
- Core Capability
- Multiple Projects Undertaken
- EngDs & PhDs Researching Process

Material & Micro-Structural Analysis
- Core Capability
- Multiple Projects Undertaken
- EngDs & PhDs Researching Process
Current Business Model
Linear Economic Model

EXTRACT  MANUFACTURE  DISTRIBUTE  USE  DISPOSE

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Future Business Model
Circular Economy Model
Proposition
Advanced ReManufacturing Cell (AReC)

AReC would be digitally enabled & Reconfigurable ReManufacturing Cell

AReC can be partitioned off or opened up
Large scale components can be worked on, or smaller assemblies
NDE & Metrology Techniques by robots using multiple technologies to increase efficiency
will capture real time data
Laser Metal Deposition
Introduction to the technology
Directed Energy Deposition
Powder & Wire Based DED Technologies

LMD-p (Laser Metal Deposition)

WAAM (Wire Arc AM)
Laser Metal Deposition

Process Benefits

- High precision process
- Low heat input means low dilution levels
- Low residual stress profile and resulting distortion
- High cooling rates: fine microstructure
- Functional Materials
- Large build size
- Experience with the Technology (completed projects + EngDs & PhDs)
- Developing Technology theme at AFRC
Laser Metal Deposition
Applications, Benefits & Limitations

**Repair / Rework / ReManufacture**

- Feature Addition
- Full Component Manufacture

**Coatings & High Integrity Layers**

(1-2mm) onto Lesser Material Substrates
Recent AFRC Funded Work
ReManufacture of BX150 Ring Groove

BX150 Ring Groove (API 6A Compliant) Standard Commercial Oil & Gas Component

The BX150 Ring Groove (API 6A Compliant) was selected for the project as it is a standard commercial Oil & Gas component that was identified as a candidate for ReManufacturing using LMD-p.

It was deemed that the component and geometry provided sufficient technical challenges that would appeal to industry and academia.
Recent AFRC Funded Work
ReManufacture of BX150 Ring Groove

Hardness Contour Mapping
Laser Metal Deposition
What are the Key Opportunities in the Oil & Gas Industry?

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The industry is facing huge challenges in a high operating cost environment where assets are reaching the end of their life.

In some cases assets have exceeded their life.

This has a huge cost impact on maintenance and downtime.

To remain profitable, operators need to reduce operating costs.

Govt. targets set to halve imports & double exports, achieved through +30-50% cost reduction in Manufacturing.

363 discovered fields between 3 and 50 million barrels of oil equivalent (mmboe) distributed across the UKCS.

Large opportunity to exploit these fields.

However, these fields currently are not economical, due to costs associated with Design & Manufacture infrastructure.

There is an opportunity to address this through new technology and innovative approaches.

‘Tie-back of the Future’ initiative aims to both half the cost and half the time to develop small pools.
Challenge - Difficult to Weld Oil & Gas
ReManufacturing using LMD-p

• High value components are being replaced when life is exceeded
• High cost and lead time associated with this
• Some typical oil and gas alloys – corrosion resistant steels and HRSA are difficult to weld
• No remanufacturing procedures exist for high value components
Laser Metal Deposition
Repair & ReManufacture - Potential Benefits

- Cost reduction opportunities
  – increase life

- Lead time reduction opportunities- use existing part

- Functional performance increase- dissimilar materials

- Options to extend maintenance schedule cycles

- Feed back into the design phase
Challenge – Existing/ Old Assets
R emanufacture of Existing / Old Assets

• High value infrastructures are being replaced when life is exceeded

• Small Pools are not economically viable
  ▪ System re-design
  ▪ Complete manufacture

• Designs have to be adapted to suit a small pools location
Laser Metal Deposition
Feature Addition & Design Upgrades - Benefits

Potential Benefits

• Building Features onto existing components/ forgings/castings

• Novel designs can be realised

• Old assets can be re-purposed to suit alternative designs
Phase 1 - Oil & Gas Remanufacturing Demonstrator

Phase 1
LMD Oil & Gas Remanufacturing Demonstrator Project
Aim

To create remanufacturing methodologies for Oil and Gas relevant material combinations using Laser Metal Deposition

This will be validated based on industry standard testing requirements and by standards body (Lloyds Register)

The industry consortium members will guide the project, to ensure that it is addressing industry requirements
Objective

To develop a remanufacturing process which can be applied into Oil and Gas relevant components and systems.

This will unlock additional value by reinstating end of life components.
Process Validation
Develop Industry Accepted Process

AFRC Funded Industry Accepted Process Validation
- Encompassing the Full Value Chain

Demonstrator Process → LMD Processing → Process Modelling

Metrology & NDE → Materials & Residual Stress → Certification & Qualification

AFRC Proprietary Information. © 2018 AFRC
AFRC Equipment-Hybrid Manufacturing
Laser Metal Deposition (LMD-p)

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Newly Commissioned Retro-fitted CNC Mill Capable of Deposition & Rotational Cladding
Work Package 1
Develop Industry/Academic Consortium

Consortium Partners: Operators, T1s and certification body
Work Package 2
Identify Component Material Combination

Material Combination Matrix

<table>
<thead>
<tr>
<th>Substrate</th>
<th>INCO 625</th>
<th>INCO 628</th>
<th>INCO 686</th>
<th>INCO 718</th>
<th>INCO 825</th>
<th>INCO 925</th>
<th>Super Alloy Pyromet 680</th>
<th>STELLITE 1 / METCO CLAD 1</th>
<th>STELLITE 6 / METCO CLAD 6</th>
<th>STELLITE 21 / METCO CLAD 21</th>
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Points System

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Weighting

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Final Score = Points x Weighting

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<th>LMD-p Capability</th>
<th>Exploitation for Route to Market</th>
<th>Interest to your Company and or Supply Chain</th>
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Results

- Depositing INCO 718 on an INCO 718 Substrate scored as the material combination with the greatest industry interest.
- Material combination will be taken forward into WP3 for a detailed literature review prior to trials and industrial/mechanical testing.
WP3 - Process & Material Optimisation
Weld Bead Geometry Analysis and parameter – Methodology

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Optimisation Strategy

- Understanding Influencing Factors of WB Geometry through Factorial Design of Experiment Methodology
- Optical Analysis of Dilution & HAZ
- Microstructural Analysis of Deposition
- Chemical Composition Analysis
- Micro-Hardness Analysis
- Generation of Tool Path Geometry (Z-Level Step & Overlap Fraction)
WP3 - Process & Material Optimisation

Process Layup

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WP4 - Process & Material Optimisation
Process Layup
# Work Package 5
## Industrial & Mechanical Testing

![Image of test samples](image1)

### Test Table

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<th>Type</th>
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<th>In of Scope Phase II</th>
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Experimental Procedure
Heat Treatment Processes, Parameters & Chemical Composition

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Proposed Phase 2
Process to Product

Consortium Partners:
Summary

1. AFRC/ UoS developing remanufacturing theme

2. Overview of LMD and benefits

3. How this could be applied to Oil and Gas

4. Demonstrator Project Stage 1 - with industry steering group
   - develop a process
   - test and validate it

5. Demonstrator project Stage 2 - will focus on a product