Rolls-Royce

Strategy & Developments in AM

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  • Manual Globe Valve
  • Pipework Tee Fitting

• Justification Strategy

• Future plant materials

• R&T Enabling/key technology strands
AM Equipment & Product Introduction

- First Laser Powder Bed Fusion (L-PBF) capability installed in Rolls-Royce Nuclear in 2008 - 200W, 250x250x250mm system
  - Manufacture of rig components and Material / Parameter development

- 2013 - Second L-PBF capability installed to meet increasing development work volume – 400W, 250x250x320mm system

- 2015 - Third L-PBF capability installed to establish pre-production cell to go from development into production – 400W, 250x250x320mm system

- 2017 - 4th, 5th and 6th systems installed to meet further increase in R-R programme demands

- 2018 - 7th system planned

- No AM components in service in pressure boundary applications

- Current focus on material testing and the manufacture of demonstrator units to support Design Report/Safety Justification
AM Product Introduction

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Lead Applications - General

- Pressure boundary components – various Nuclear systems
- Manual Globe Valves and Piping Tee Fittings
- Stainless Steel
- Direct ‘Substitution’ – no change to engineering definition
- No ‘as-built’ surface texture (100% machined or polished)
- Laser Powder Bed Fusion (L-PBF)
- First application (MGV) to be HIPed post AM
- Solution Annealed condition also being developed
Manual Globe Valve

• Manually operated to open and close to initiate/isolate flow

• Designed to the ASME Code Section III

• Class 1 valve Sizes range from 1” to 2”

• Fitted in numerous types of nuclear systems, e.g. coolant make-up, pressure relief

• A high number of valves fitted in each system

• Striving to reduce cost and delivery time in order to satisfy build programmes/customer needs:
  • Convoluted supply chain - raw material, HIPing, machining. Striving for cell manufacture in one facility.
  • Reduce, ideally eliminate HIP cycles – hard facing powder consolidation/HIP bonding of hard facing to main body
  • Reduce, ideally eliminate subtraction machining
  • Reduce amount of raw material usage and waste

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Manual Globe Valve

As-built MGV

Finish-machined MGV
Pipework Tee Fittings

• Welded into pipework to provide junctions, e.g. for instrumentation line off-takes

• Designed to ASME Code Section III

• Class 1 fittings; Sizes range up to 2”

• Fitted in numerous types of nuclear systems, e.g. coolant make-up, pressure relief

• Eliminating potential for variation and the costs associated in ensuring variation is acceptable:
  • Eliminating hand dressing of the crotch corner - an artisan operation with inherent variability.
  • Must eliminate structural discontinuity, the sharp corners, can't totally eliminate by subtraction machining
  • Reducing the amount of inspection to provide assurance that the crotch corner has been created as required.
Pipework Tee Fittings

Support structure of Tee

Finished Tee
Justification Strategy

Stage 1
Design & Manufacture

- Mechanical Properties
  - Destructive Examination
  - Non-Destructive Examination
  - Component Performance

- Manufacture of Components
  - Quality Assurance
  - Process Robustness
  - Experience of L-PBF

Stage 2
Functional Testing

- Production Requirements
  - Machinability
  - Weldability

Materials & Manufacturing
Justification – L-PBF 316L/1VN
valve/tee meeting a standard suitable for use in the NSRP

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Justification Strategy

Materials & Manufacturing Justification – L-PBF 316L/LN valve/tee meeting a standard suitable for use in the NSKP

Stage 2 Functional Testing

- DU1 Residual Stress Measurement
- DU2 Hydrostatic Pressure Testing
- DU3 Hot and Cold Endurance Testing
- DU4 Ultimate Pressure Testing (Burst Test)
- DU5 Thermal Fatigue Testing
R&T Strategy – Enabling Technology Themes

2 YEAR VISION
- AM alloy design & development
- International standards development
- AM surface texture – use, improvement & justification
- Residual Stress / Process modelling – development & verification + reduction & management

5 YEAR VISION
- New AM technology – AM+HIP Hybrid, Metal jetting, Ultrasonic
- In-process monitoring and NDT
- L-PBF > bigger & faster

10 YEAR VISION
International Standards

2 YEAR VISION
- JR with Lloyds Registry
- Define 316L submission strategy
- EPRI/Westinghouse/ONRL Project – in-process + ex-process route to code case
- Produce materials database and 3x part manufacturing data

5 YEAR VISION
- R-R Submission for 316L code case

10 YEAR VISION
L-PBF – Bigger & Faster

2 YEAR VISION

- Scoping of future programme requirements – build size & rate

5 YEAR VISION

- Multi-laser Package
- Parameter Optimisation Package
  Variation of layer thicknesses within part
- Hybrid AM Package
  AM+CNC, AM+HT, AM+powder recycling (or not?)

10 YEAR VISION

- Acquire and test larger & faster AM capability targeted at MUFC production

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Key Takeaways

• Material Substitution only results in more complicated shapes to inspect – Transitioning to enhanced substitution provides greater benefits

HOWEVER

• Material Substitution only for Pressure Boundary components in a Nuclear application requires extensive effort in inspection and testing to be compliant with ASME requirements