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Project No. 601217-EPP-1-2018-1-BE-EPPKA2-SSA-B

SECTOR SKILLS STRATEGY IN ADDITIVE MANUFACTURING

CU 01: DED-ARC

Session 5.1 –Shielding for DED

Prepared by: David Wimpenny

FOR SAM PILOT ATTENDEES AND TRAINERS ONLY

Contents

- Shielding requirements for DED
- DED with titanium
- Rigid gas tight enclosures
- Flexible enclosures
- Local shields

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Shielding for DED

- For deposition of material using a WAAM (DED-arc + wire feed stock) it may not be necessary to provide additional inert gas shielding .

- Welding of aluminium and steel parts can be undertaken using the local shield gas provided with the conventional welding head

Wire+arc additive manufacturing vs. traditional machining from solid: a cost comparison

April 2015
Affiliation: Cranfield University
Authors:
Filomeno Martina
WAAM3D Limited
Stewart W. Williams

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DED-arc of titanium

"AM or welding titanium, the component needs to be shielded where the temperature exceeds 427 °C to avoid oxidation of the surface.."

Babish, F., 2007. Guide for the Fusion Welding of Titanium and Titanium Alloys, AWS. G2.4-G2.4M-2007

Need to achieve less than 2000 ppm of oxygen

Compared to standards welding in DED;

- Large parts which remain hotter for longer
- Surface oxidation affects subsequent welds beads

For DED of titanium (whether from wire or powder) an enhanced shielding environment is required

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Enhanced shielding options

- Rigid gas tight enclosures
- Flexible enclosures
- Local shields

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Rigid gas tight enclosures

Courtesy Norsk Titanium

- Commonly used in DED –LB systems and laser cladding systems using reactive powders
- Chamber is typically partially evacuated and then back- filled with inert gas
- Enables low oxygen levels to be achieved

But

- Slow to pump down
- Can require a large quantity of inert gas
- Restrictive in terms of part size and automation solutions compared to open systems

Note: Some systems are being fitted with interlocks to enable parts to be removed without venting the inert gas

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Flexible enclosures

- Enclosed “tent” usually constructed from a flexible mylar (form of polyester resin) material
- Effective solution for specialist welding
- Inert gas contained around the part
- Some of the welding/ automation system can sit outside of the tent

But

- Difficult to apply to large DED parts
- Easy punctured by spatter and sharp edges

Flexible enclosure used for manual welding

Flexible enclosure used for semi-automated welding

https://www.huntingdonfusion.com/index.php/en_gb/

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Enclosures ..another issue

- Arc welding generates significant quantity of fumes and this need to be considered in the context of a sealed enclosure

- As with PBF-LB we need to enable some filtering and removal of these fumes to maintain the cleanliness of the atmosphere in the enclosure

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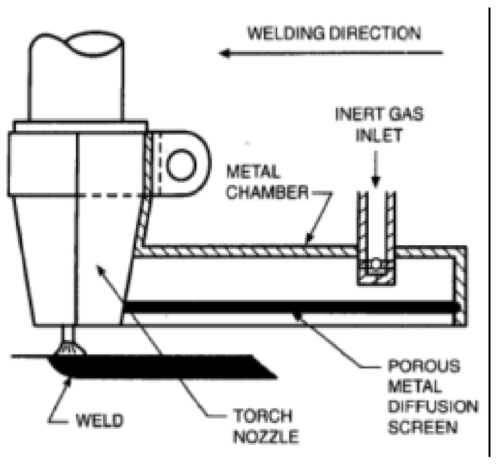
Localise inert gas shields

- Localised shields have been used in arc welding for many years
- Shield tend to be very simple
- Sometimes shaped to match the work piece
- Small stand-off distance
- Close fitting with workpiece at edges



trailing shield set up for arc welding application
http://www.ja-online.de/index.php/en/tig-burner-accesories/gas-nozzles/trailing-shields

https://www.huntingdonfusion.com/index.php/en/newsletters/3128-weld-purging-best-practices-2

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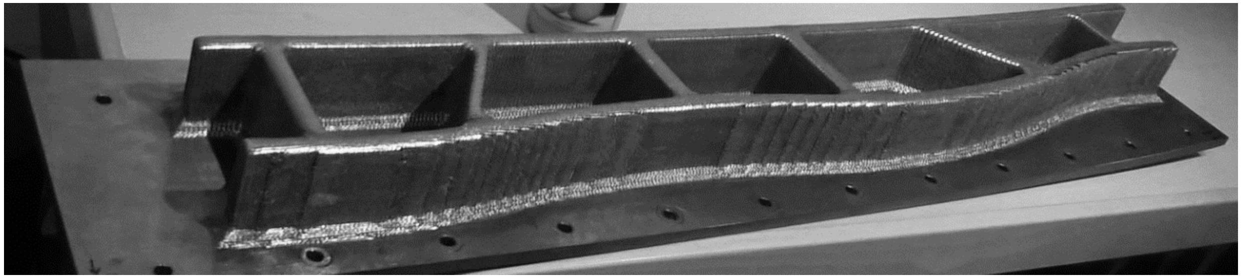
Localised shielding for DED is more difficult

- Possible to use localised shielding to generate flat coupons or simple shapes
- Much more difficult to shield large complex DED parts;
  - Large stand off distance
  - Changing geometry
  - Difficult to seal edges of shield
  - Walls which create turbulence and draw in air



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Background to work

- Applying local shielding can increase flexibility of WAAM process
- Conventional welding devices do not provide adequate protection due to entrainment of the surrounding air
- Improved trailing shield device show promise
- In this study, a new local shielding device based on laminar flow was developed and compared with a conventional device.

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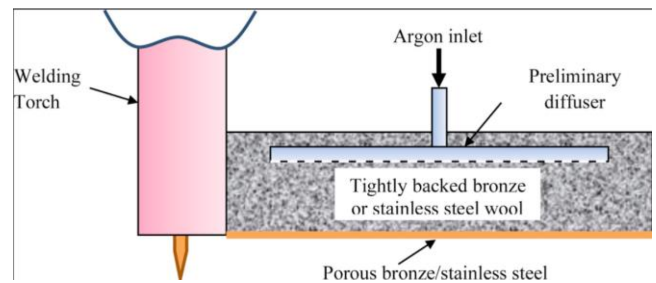
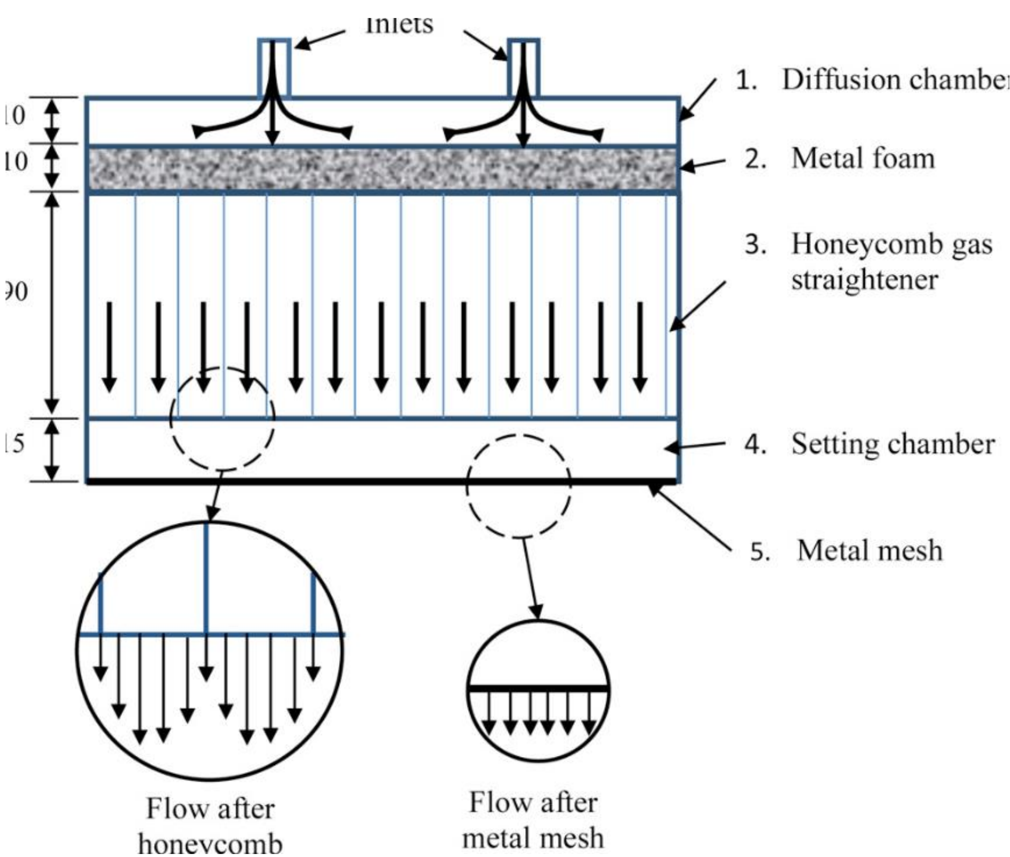
Development of a laminar flow local shielding device for wire+arc additive manufacture

J. Ding [a], P. Colegrove [a], F. Martina [a], S. Williams [a], R. Wiktorowicz [b], M.R. Palt [c]



Proposed design



1.Diffusion chamber : uniformly distribute inlet gas.

2. Metal foam: based of diffusion chamber, 2x5mm thick layer of metal foam, average hole size 0.5 mm

3. Honeycomb gas straightener: length-to-diameter ratio has to >8:1 to reduce turbulence. In this case regular hexagonal cells 6mm across flats and height of 90 mm giving a length-to-diameter ratio of 15.

4. Setting chamber: equalises flow exiting the honeycomb straightener. Needs to be 3x honeycomb so height was 15 mm.

5. Metal mesh: 0.2mmmesh size and an aperture 0.647 mm giving 0.42 mesh porosity

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Trail 1 – Flat plate

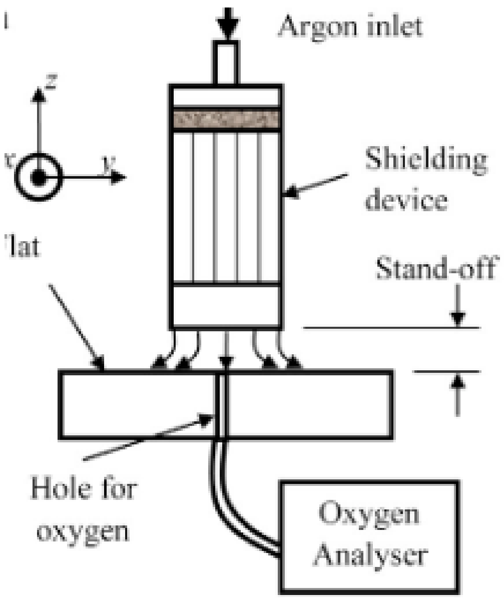

Table 2. Parameters for the plasma deposition process.

Wire feed speed	2.4m/min
Travel speed	4.5mm/s
Current	160A
Plasma gas flow-rate	1l/min
Shielding gas flow-rate (through the torch)	10l/min
Torch stand-off	8mm

Table 3. Summary of the experiments performed for Trial 1.

Shielding device	**Stand-off distance (mm)**	**Argon flow-rates (l/min)**	**Oxygen sampling location (s)**
Laminar and conventional	10, 15, 20 and 30	10, 15, 20 and 25	Centre of shielding device
Laminar and conventional	15	15	Map under device with a spacing of
Laminar	25	25	10mm in the *x* and *y* directions

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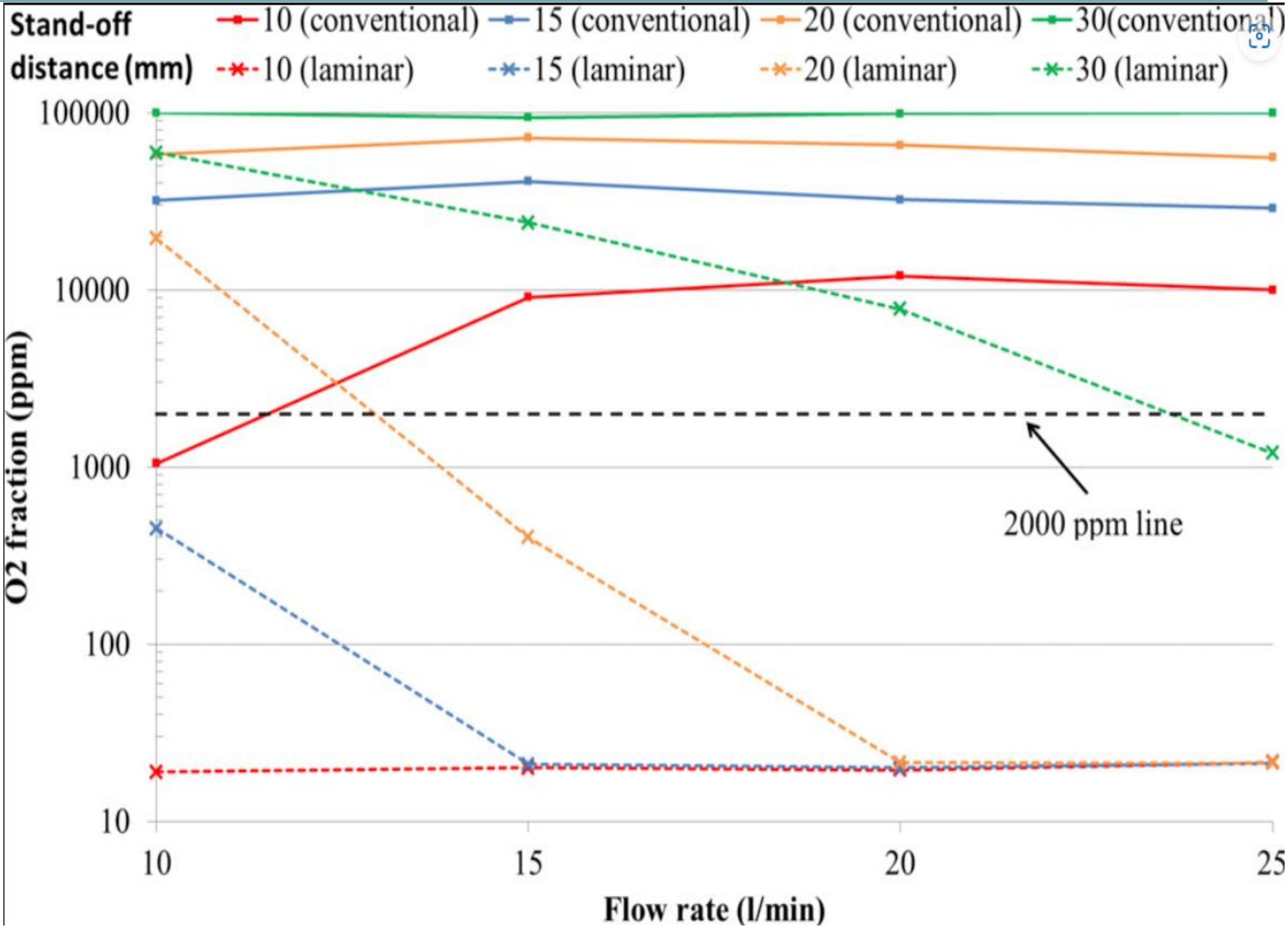
Results Trial 1



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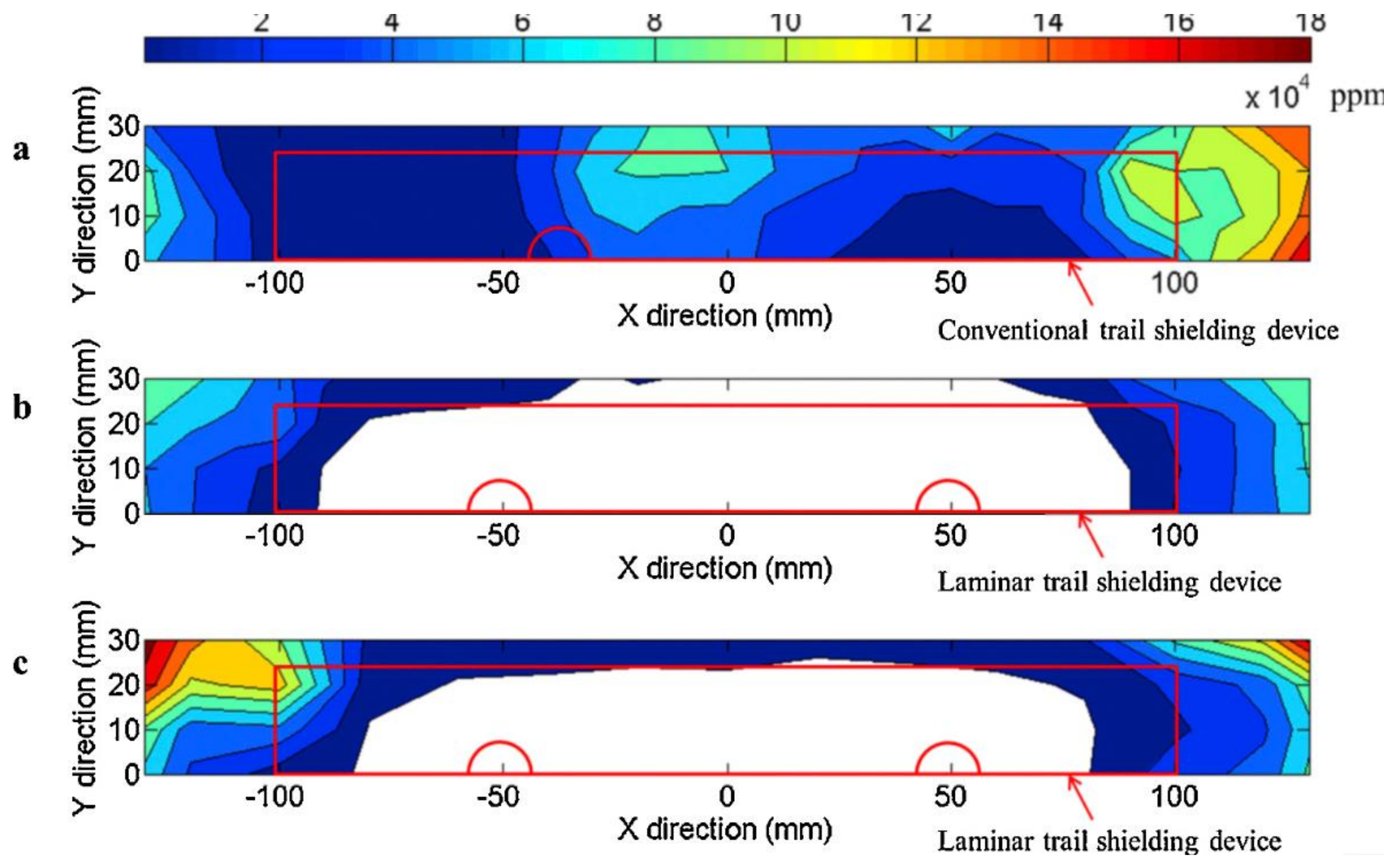
Results
Trial 1

Map of oxygen level under the shielding devices.

Conventional shield: **O**xygen >2000 ppm at all locations

Laminar shield: improved shielding at all locations under the device white area indicates the region that is below 2000 ppm

At higher stand-off distance it was necessary to use higher flow-rate to provide adequate coverage



(a) Conventional shield @ stand-off 15 mm and flow-rate of 15 l/min
(b) Laminar shield @ stand-off 15 mm and flow-rate of 15 l/min
(c) Laminar shield @ stand-off distance of 25 mm and a flow rate of 25 l/min.

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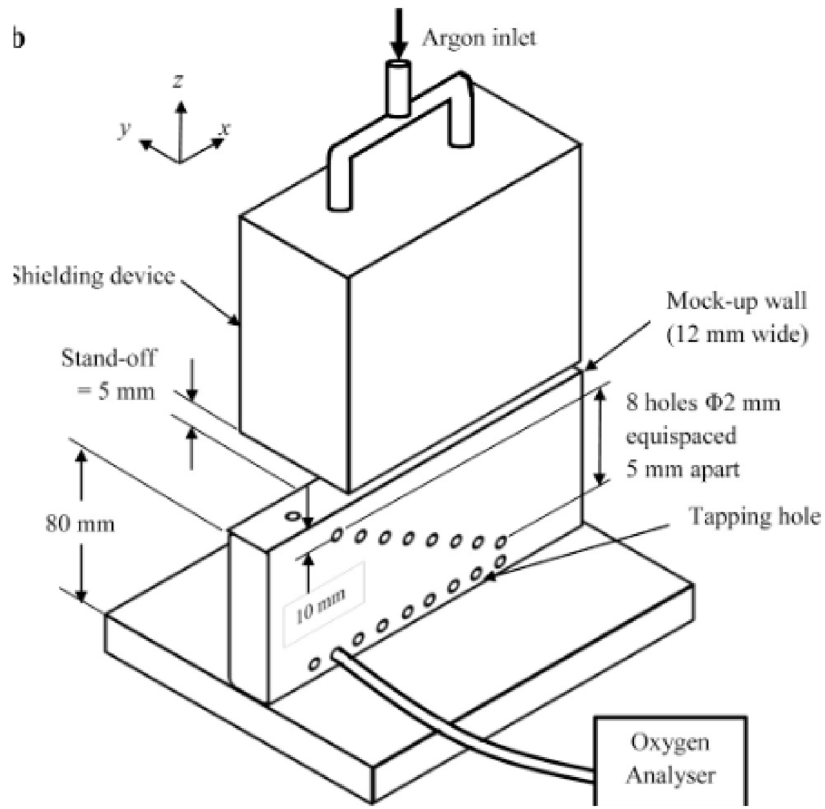
Trial 2 -Wall

Evaluation of shielding device performance using a mock-up wall

Stand-off distance above the wall was increased



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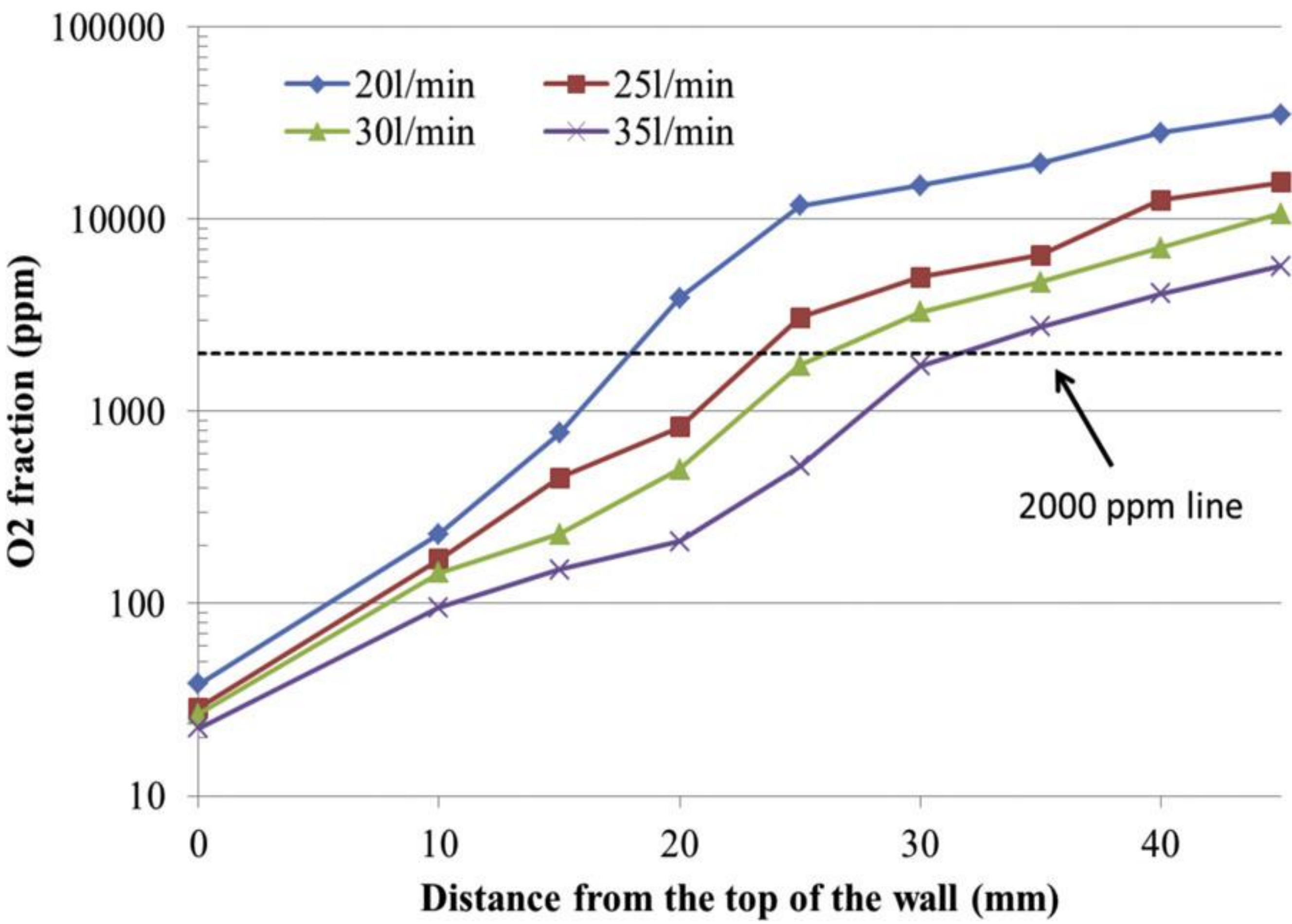
Results – Trial 2

oxygen level increased with stand-off distance

Flow-rate of 35 l/min enabled wall to be protected with stand-off of 30mm



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Results

- Laminar shielding device was able to ensure oxygen levels <2000 ppm for both the flat plate and wall even at stand-off distances of up to 30mm

- Experimental comparison of the laminar shielding device with a conventional device which showed three orders of magnitude improvement in the contamination levels.
- Evaluation of laminar shielding device performance with a mock-up AM wall which showed that it could be protected up to 30mm from the top.

Overview of the OpenHybrid project

David Wimpenny

Project Overview

Start date: 1st October 2016

Duration: 3 years

Total value: €6.6437m

EU: €5.133m

Switzerland: €1.643

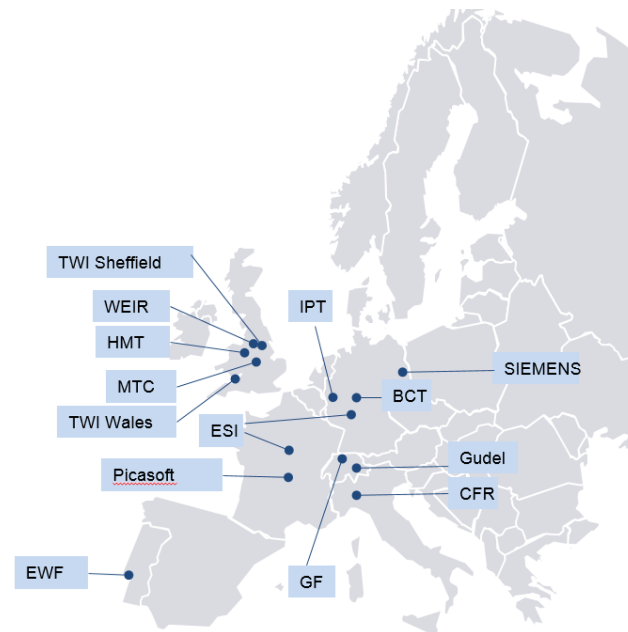
Participants: 14

Horizon 2020
FoF1 – 2016
Novel hybrid approaches for additive and subtractive manufacturing machines

Project: 723917

This project has received funding from the European Unions HORIZON 2020 research and innovation programme under grant agreement No 723917 – OpenHybrid.

Project consortium

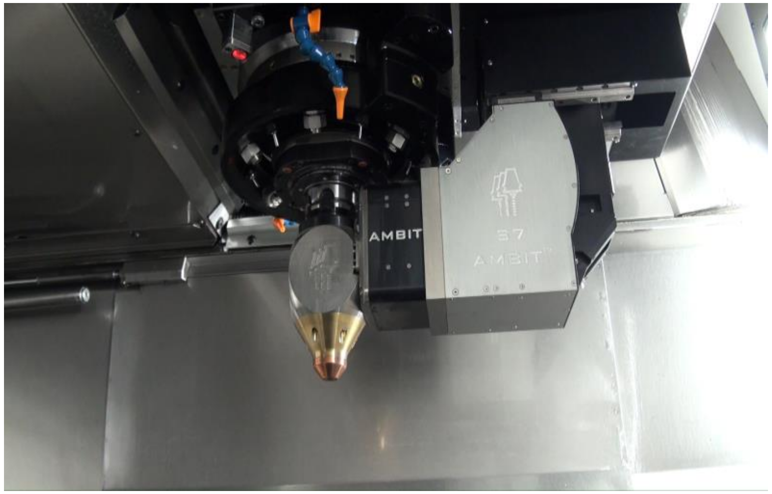


This project has received funding from the European Unions HORIZON 2020 research and innovation programme under grant agreement No 723917 – OpenHybrid.

Project Aim

Develop hybrid additive and subtractive system based on laser cladding using both wire and powder feed and 5 axes milling;

- New interchangeable process tools
- New easy to use CAM software
- Process simulation tools



Integrate the technology in two new platforms;

- 5 -axes milling machine (GF)
- and gantry platform (Gudel)

Demonstrate the benefits of the approach for the <u>repair</u> of industrial demonstrators

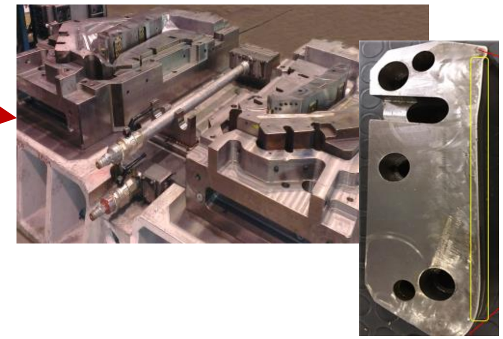
This project has received funding from the European Unions HORIZON 2020 research and innovation programme under grant agreement No 723917 – OpenHybrid.

Repair of high value components

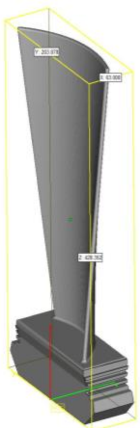
CRF – Automotive press tooling

Weir – Mining equipment

Siemens – Power generation

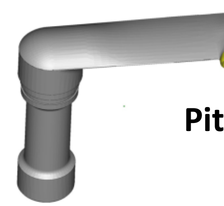


Press tool insert



Blade

Volute



Pitot tube

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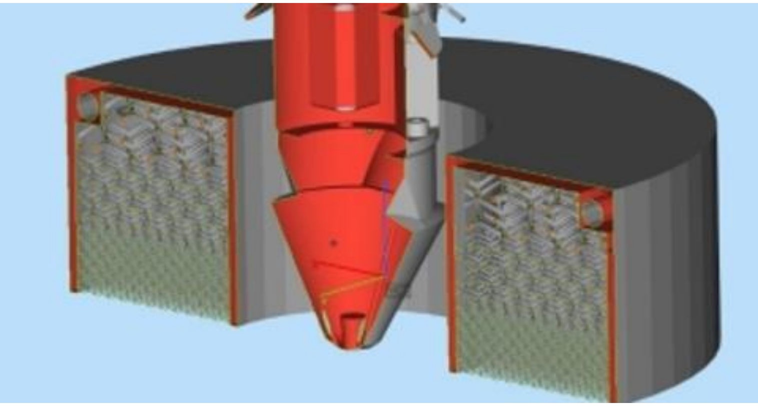
Localised shielding trials

- Hybrid DED-LB process integrated into conventional 5-axes machine tool

- Provide local shielding for DED of titanium (powder feed-stock) without the need to provide sealed enclosure and back full with Argon



Initial test head designed by TWI Ltd

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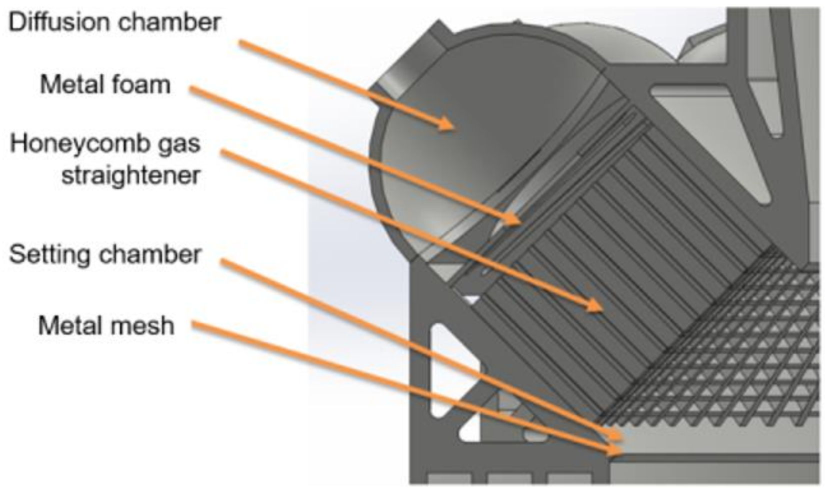

Adapted Flexifinish head (used for laser polishing of Ti64)

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Test results

Encouraging results at different stand-off distances over flat surfaces and wall

BUT these were stationary trials

As soon as head moves across a complex rib intersection turbulence destroys the shielding effect!

Has anyone really solved local shielding ?

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www.skills4am.eu

Thank you & Questions ?

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