# Maximising Quality and Productivity in Offshore Fabrication

## TWI Technology Centre (North East)
## Riverside Park, Middlesbrough

## 30 January 2014
## 0900-1400

Supported by the Regional Growth Fund

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# *Offshore Wind Technology Transfer Project*

Nick Elbourn
Technology Transfer
TWI

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## Programme

**Offshore Wind (OSW) project** - Nick Elbourn - Project Manager, TWI

**Commercial reality and opportunities in the OSW sector** -
Richard Ousey – GROW:Offshore Wind

**How to achieve high productivity welding** –
Andy Woloszyn - Section Manager Arc Welding, TWI

**Benefits of power beam welding in structural steel fabrication** –
Mike Nunn - Section Manager Electron Beam Welding, TWI

**1100 coffee and demonstrations**

**Case Study: How the OSW project has helped OGN** - Andy Woloszyn

**ISO3834 and EN1090 fabrication standards - the essentials** –
Dave Godfrey – Consultant Welding Engineer, TWI

**Welding and fabrication documentation management** –
Andy Brightmore – Software Business Development, TWI

**1300 lunch and close**

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# TWI

- A world centre of expertise in Manufacturing, Engineering, Materials and Joining
- Dedicated to supporting the needs of our Industrial Membership
- Non-profit distributing

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# TWI

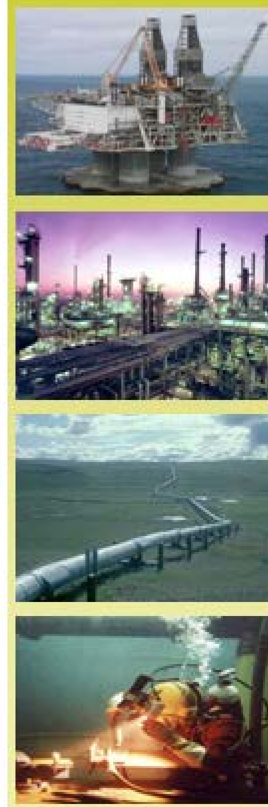
Construction & Engineering

Aerospace & Automotive

Energy & Environment

Electronics, Photonics & Medical

Oil, Gas & Chemical



Equipment, Consumables & Materials

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# RGF Funded OSW Project

4 parts:

1. Development and automated application of 40-year coatings
2. Development of condition monitoring of wind turbine towers and blades
3. Demonstration of a high capacity, innovative, multi-facetted approach for offshore foundation fabrication
4. Supply chain technology transfer

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# Technology transfer in practice

Awareness and making contact

Access to expert know-how *(helpdesk, events, www.twi.co.uk)*

Identify issues

Deliver technical support

Implementation of best practice and innovation

Impact: Jobs created and safeguarded

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# Technology Transfer – Business Impacts

<table>
<tr><th>Region</th><th>jobs created</th><th>jobs safeguarded</th><th>t/o created £M</th><th>t/o safeguarded £M</th></tr>
<tr><td>North East</td><td>355</td><td>1249</td><td>30.3</td><td>74.8</td></tr>
<tr><td>Wales</td><td>190</td><td>1029</td><td colspan="2">83.5</td></tr>
<tr><td>North West</td><td>76</td><td>248</td><td>5.4</td><td>15.3</td></tr>
<tr><td>Scotland</td><td>44</td><td>95</td><td>2.9</td><td>5.1</td></tr>
<tr><td>Yorkshire</td><td colspan="2">1420</td><td colspan="2">62.4</td></tr>
</table>

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# *OSW Technology Transfer*

## For companies which are:

- **already in the OSW supply chain or who are interested in moving into this sector**

- **Growing and able to make use of high quality technical support**

# *OSW-TT project key facts*

- 21 month project, started in Oct 2012
- funded by Regional Growth Fund, managed by Narec
- outreach/technology transfer: assist 100 companies, aiming to create/safeguard 650 jobs
- events programme

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# *OSW-TT project key facts*

- **All TWI technologies covered: fabrication, surfacing, cutting, inspection and NDT, processes, materials, quality**
- **Large and small companies in North East, North West, Yorks & Humber**
- **Technical support – up to 12 FREE days**

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# *OSW-TT technical support*

- **Initial 2 days scoping then**
- **Up to 5 days Feasibility Study**
- **Up to a further 5 days**

**Innovation Support**

## <u>All free of charge</u>

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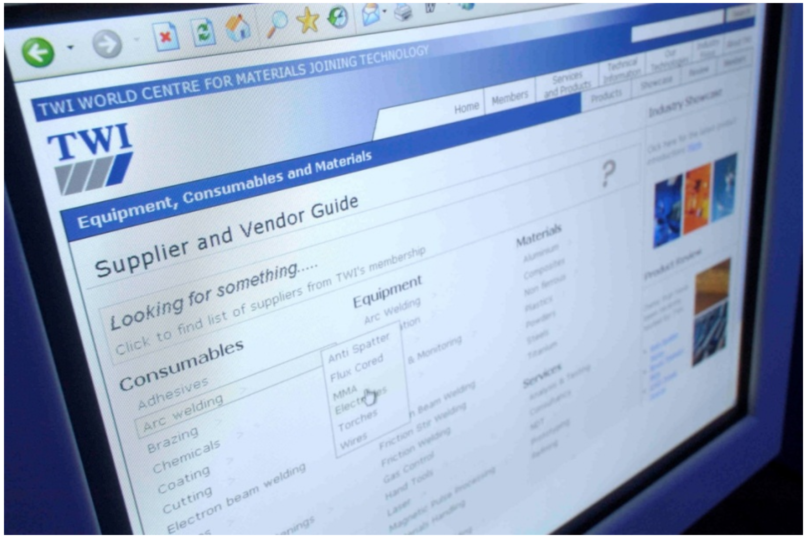
# *Technical Support*

- **Process/material change/innovation**
- **Procedure development**
- **Trouble shooting**
- **Design improvement**
- **Workshop practice**
- **Complying with standards**
- **Materials/consumables selection**
- **Health & safety issues**
- **Carbon footprint**
- **Skills development**
- **Quality systems**
- **Cost reduction**

# *TWI Website Content*

- Best practice guides
- Software toolkits
- Frequently Asked Questions (>1000)
- Knowledge summaries
- Corporate information
- Members reports (since 1995)
- Staff papers
- Technology briefings
- Weldasearch™
- MI-21 Consumables database
- Photographic images



# Knowledge Summary on Hydrogen Cracking

## Visual appearance

Hydrogen cracks can be usually be distinguished due to the following characteristics:

- In C-Mn steels, the crack will normally originate in the heat affected zone (HAZ) but may extend into the weld metal *(Fig 1)*.
- Cracks can also occur in the weld bead, normally transverse to the welding direction at an angle of 45° to the weld surface. They are essentially straight, follow a jagged path but may be non-branching.
- In low alloy steels, the cracks can be transverse to the weld, perpendicular to the weld surface, but are non-branching and essentially planar.

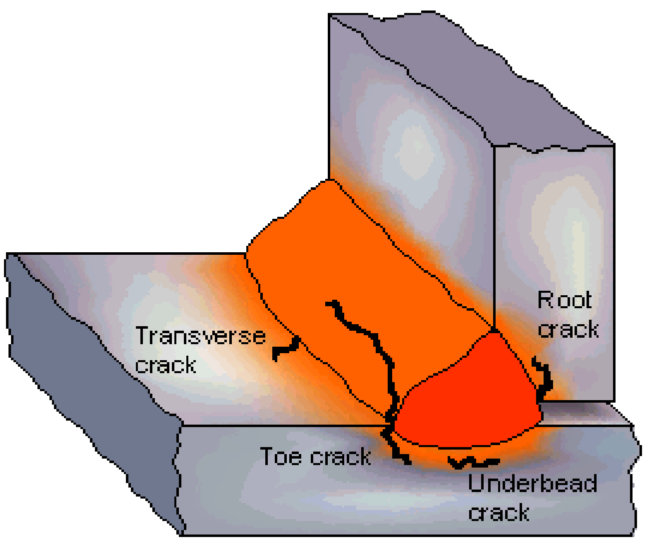



**Fig. 1 Hydrogen cracks originating in the HAZ (note, the type of cracks shown would not be expected to form in the same weldment)**

On breaking open the weld (prior to any heat treatment), the surface of the cracks will normally not be oxidised, even if they are surface breaking, indicating they were formed when the weld was at or near ambient


AARYAN
North Sea Logistics
RESCUE
ZONE

# Case Study: Alnmaritec

- Innovative aluminium boat builder Alnmaritec has supplied operators from the Arctic to the Antarctic
- Customised work boats for oil and gas industries, fire and rescue, fishing, ferries and offshore
- Support vessels for OSW tower maintenance became central
- Boats 10 to 15m long single or twin hull vessels made from 5083 and 6082 grade aluminium alloy plate of between 4-6mm thickness
- Design and fabrication to Lloyds Rules involved MIG butt welding in the flat, horizontal, vertical and overhead
- Success rate was already high, x-ray examination revealed that a 100% pass rate was achievable
- Surface appearance was excellent and advice given on sidewall fusion and porosity, both of which were not perceptible visually
- TWI highlighted importance of operating gas-shielded process in a draught-free environment and emphasis on completing welding within four hours of degreasing

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# *Summary*

- **TWI World Centre for Technology Transfer & Training - meeting the needs of Industry**

- **OSW-TT: free technical assistance and supply chain support, technology demonstration and trials**

- **Practical assistance and support provided to achieve real business benefits**

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# *OSW-TT project support*

## For more information contact:

## Nick Elbourn


## 07765 403 465

## nick.elbourn@twi.co.uk


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# Commercial Reality / Opportunities in the Offshore Sector

## TWI Rapid Fabrication Event

30th January 2014

## FUNDING

The UK offshore wind market, estimated to be worth more than £100bn over the next 20 years, offers manufacturers a significant, sustained growth opportunity.

**+£100BN**

**FUND IT**

**GROW : OFFSHORE WIND**

Opportunities for manufacturers in the offshore wind market

mas
manufacturing advisory service

# 'UK global lead in offshore wind'

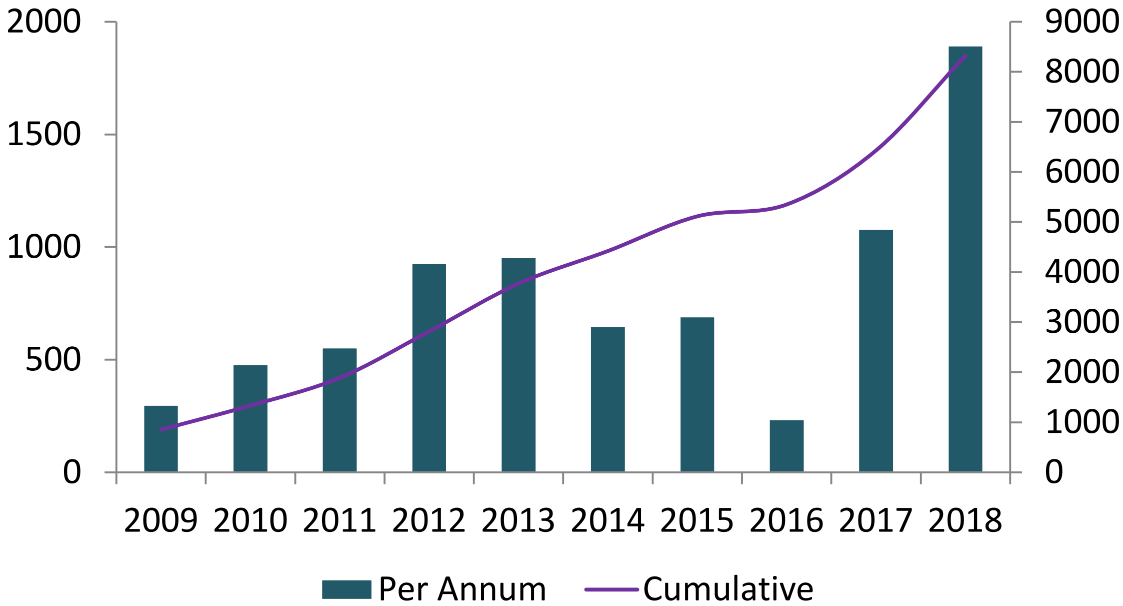
London Array becomes the world's largest offshore wind farm with 175 fully operational wind turbines as of April 2013 *The Guardian . April 13*

“The current state of play, which isn’t actually acceptable, is we’ve got the biggest offshore wind capacity in the world but much of the kit is actually currently made in western Europe" *Vince Cable* , *FT ,August 13*

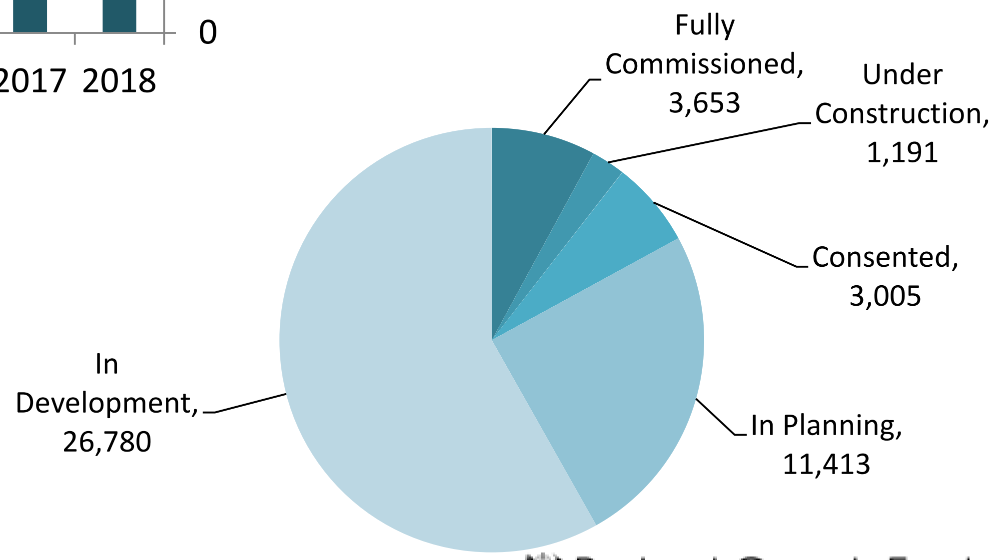
Drivers & Challenges:

- Currently little UK content: Offshore Wind Developers' Forum targeting 50% UK content in offshore wind farm projects
- EU Target – 15% of UK Energy by 2020 from renewables
- Approximately 40 build projects planned to satisfy capacity requirement
- Total investment of £1.5bn last year, a year-on-year increase of 60% Offshore UK market opportunity £15bn and £500bn globally driven by significant growth in both UK and Global capacity (see over).

# 'The UK Opportunity'




**8 GW by 2018 – currently 3.7**




**Total pipeline of over 46GW**

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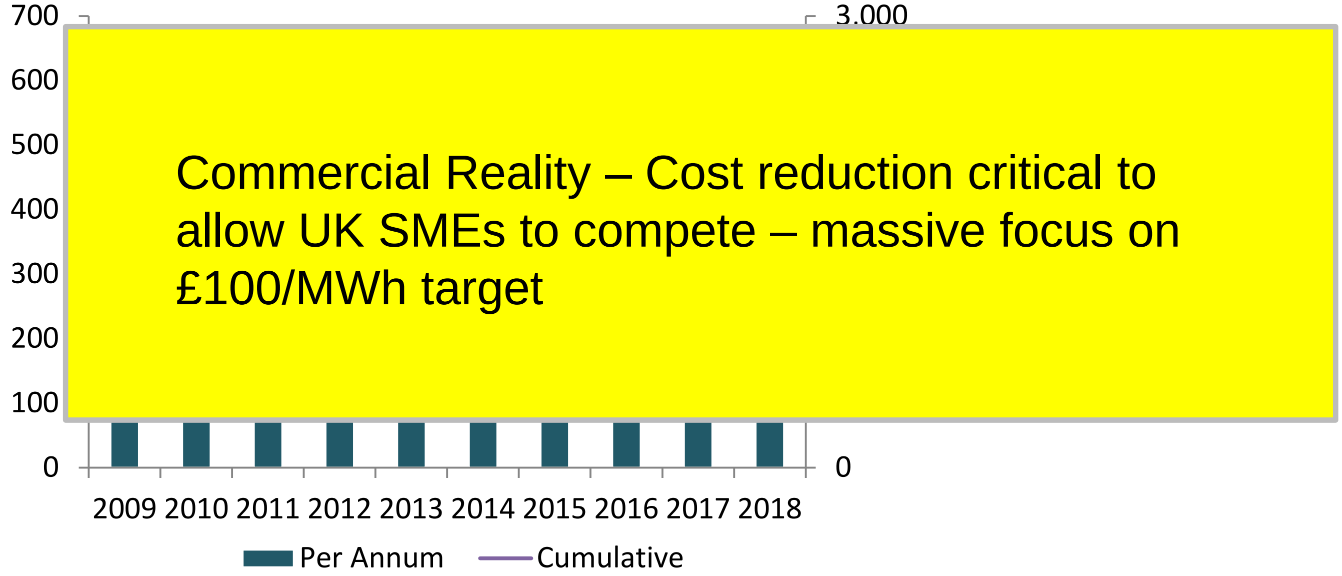
# 'The UK Opportunity cont'

- A minimum of 500 foundation orders could be placed over the next 2 years




Commercial Reality – Cost reduction critical to allow UK SMEs to compete – massive focus on £100/MWh target

- 1,327 foundation units currently installed (Jan 2014)
- 2,800 foundations units possible by the end of 2018 (110% increase)
  - Despite the fact that foundation numbers per MW are decreasing, as turbine size increases, the volume and size of Round 3 projects that will continue to deliver high levels of growth

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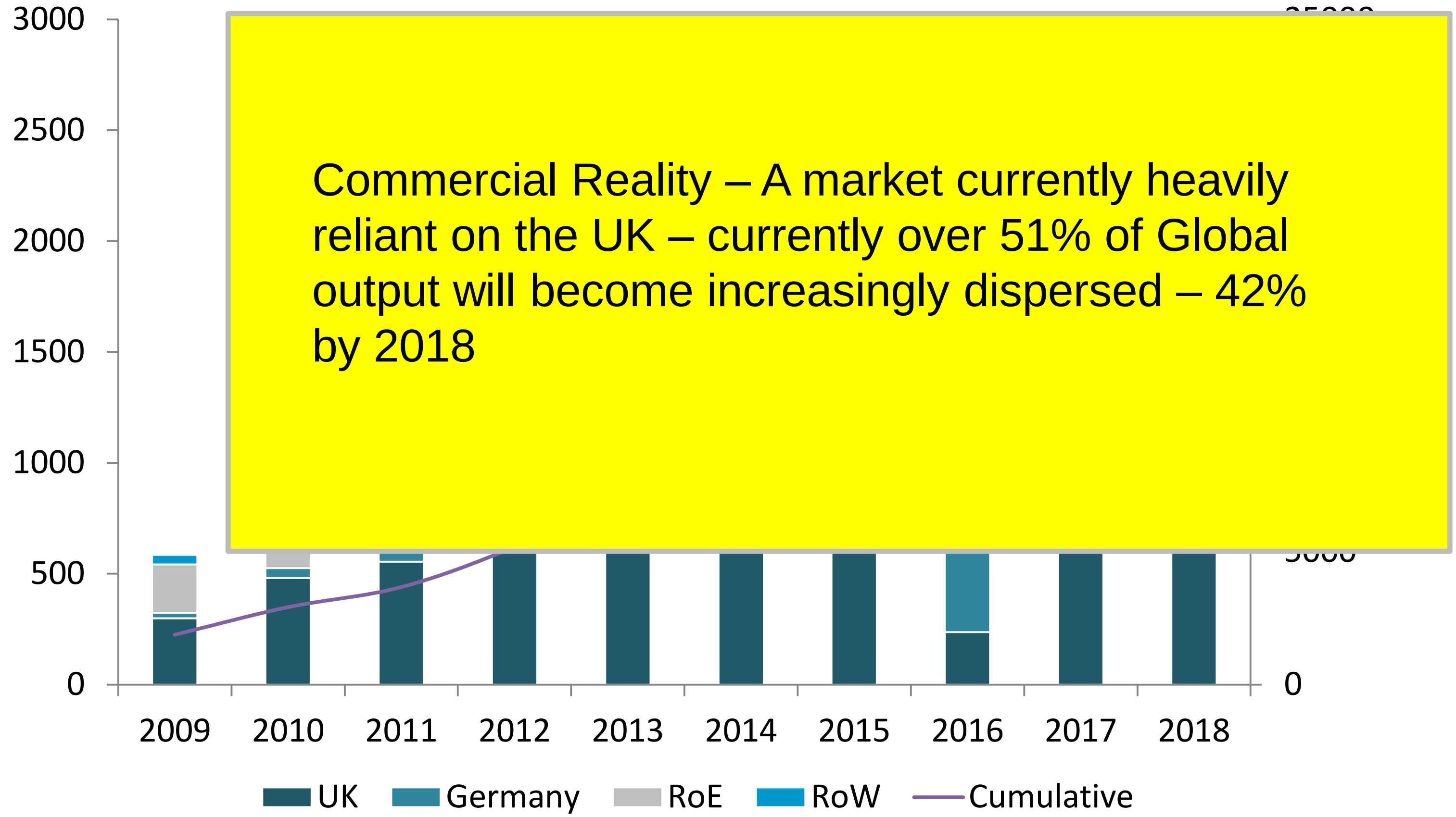
# 'The Global Opportunity – 19 GW by 2018 – currently 7GW'




Commercial Reality – A market currently heavily reliant on the UK – currently over 51% of Global output will become increasingly dispersed – 42% by 2018

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# Challenges to market entry / expansion – feedback from SMEs

**"How do we know what the industry wants and who are the people who want it?"**

- Clarity on timeframes
- Confidence in the market
- What regulations must be complied with
- Clarity on who is procuring at Tier 2/Tier 3 level
- Risks of investing without firm orders
- Skills shortages – skilled staff migrate to larger firms
- Knowing who the correct specialists are to consult
- Understanding the pre-requisites to supply – registering Achilles database etc.
- Inability to access finance due to poor credit rating
- Finding funding to support sudden scale up in required output

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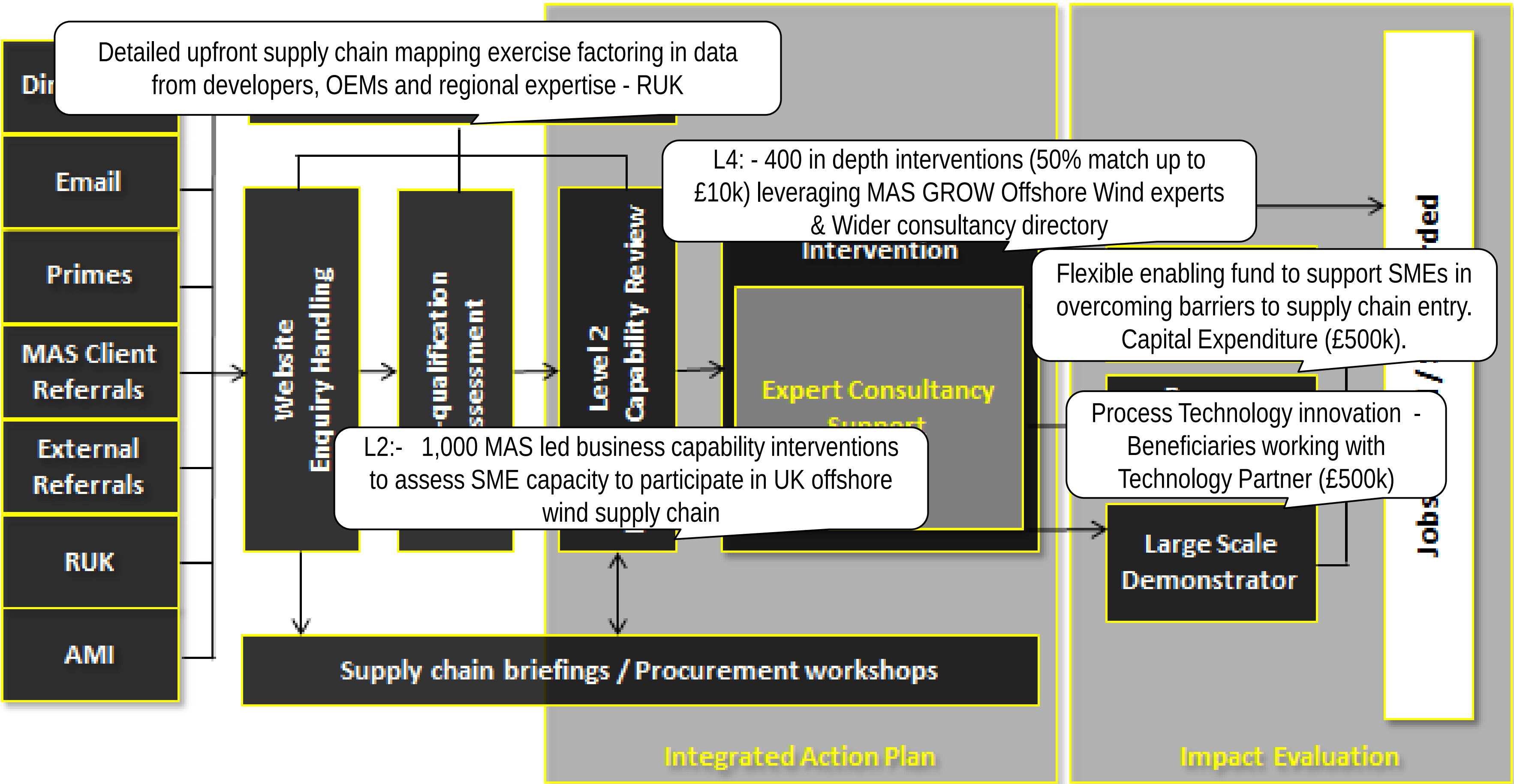
# GROW Offshore - Programme Overview

- £50m programme to stimulate English offshore wind manufacturing supply chain
- Multiple areas of support delivered by core delivery partners encompassing Consultancy, Grant funding and R&D
- Can benefit those already in Offshore Wind or those seeking to enter the market
- Up to **£500k** available for any beneficiary up to 30 June 2015 across the various funding sources available under the programme
- SME focus, though scope to assist Large Enterprises
- Key programme KPI is **Job Creation / Safeguarding**
- Excellent potential alignment with current TWI RGF programme

# Customer Journey

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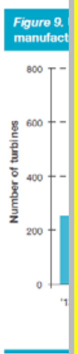
# Market Assessment / Supply Chain Mapping

Commercial Reality – Opportunities for local supply chain linked to Fabrication of Foundations – key areas

- Foundation Fabricator
- Load out
- Cable Protection System
- Anode Supplier
- Secondary Steel Supplier
- Technical appurtenances
- Offshore electrical installation works
- Other components – Fall protection, FRP gratings for Walkways & Platforms, Railings
- Seafastening

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…pply chain

Co… …nglish SMEs.
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RenewableUK's sponsoring members:

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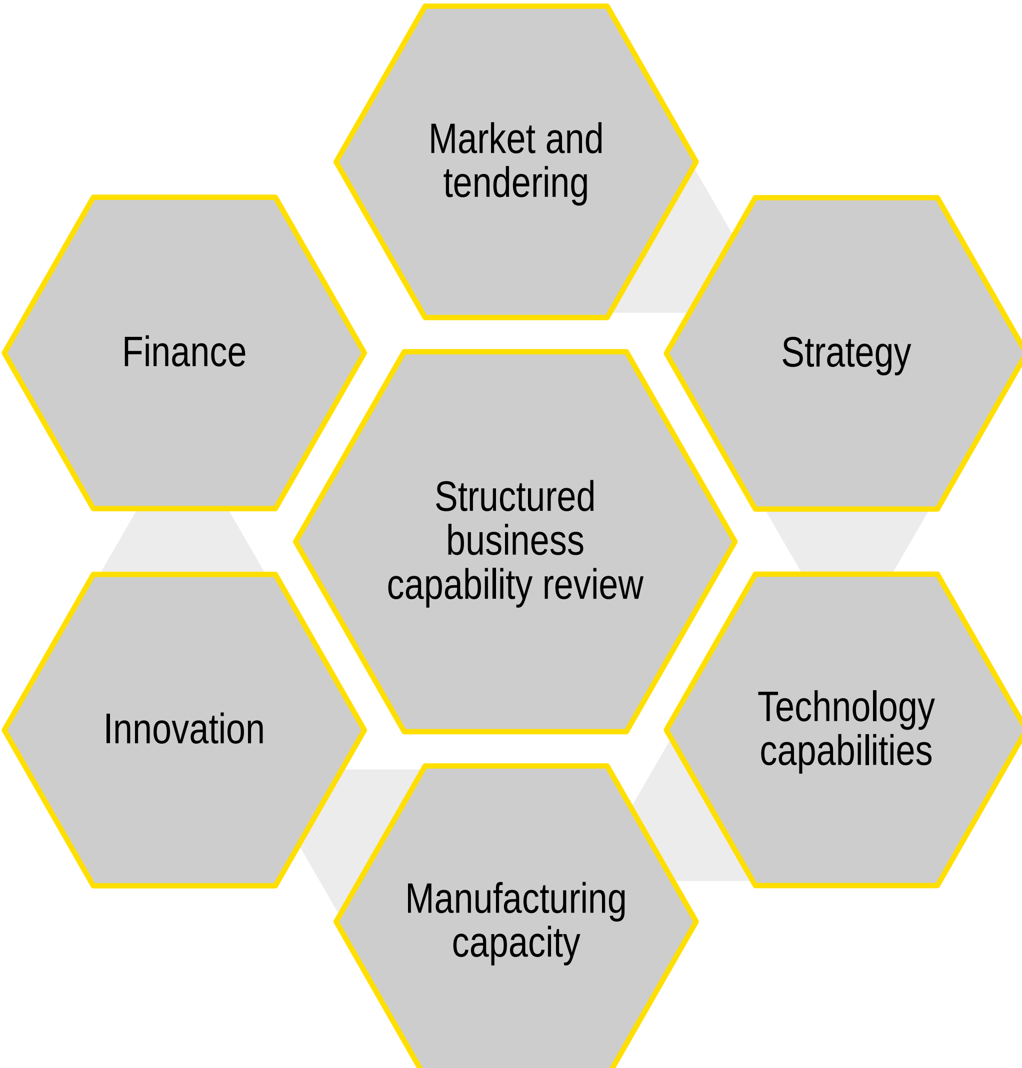
# Business Capability Review




- Identify barriers to entering or growing in the market
- Identify how GROW:Offshore Wind can help unlock these barriers
  - ✓ visibility on contracting opportunities
  - ✓ identifying projects we could support
  - ✓ identify if growth could be supported by FEF or PTI funds

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# Consultancy Funding Support

- GROW:Offshore Wind can provide funding up to **50%** towards the cost of a project, grant value of up t

- The eligible

  ✓ Patent
  ✓ Produc
  ✓ Supply
  ✓ Testing
  ✓ Bid wr
  ✓ Busine
  ✓ Bespoke/product specific tooling (made in UK)
  ✓ Capacity planning and utilisation

Commercial Reality – GROW is all about matching you with the consultant best able to develop your Growth plans. Over half of consultancy interventions to date have been with consultants that SMEs have previously worked with

- You choose consultant, who you may have used previously worked with

- Applications for grants are assessed by **job creation / safeguarding**

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# GROW & TWI – RGF LINKAGES

June 14

June 15

Commercial Reality – GROW can be an excellent fit for companies who have benefited from the TWI RGF programme and now wish to develop further projects / project phases with newly identifiable outputs

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# Flexible Enabling Fund - Overview

**What is it?**
Grant funding to underpin Offshore Wind investment plans and stimulate Job creation

**Who can apply?**
All English SMEs. Large Enterprises but only if located in an EC designated Assisted Areas

**How much funding is available**
Up to 20% of eligible costs of projects for Small Enterprises and 10% for Medium, with higher %s available to companies falling within EC designated Assisted Areas

**What can funding be used for?**
**Tangible Assets** - Land, Buildings ,Plant, Machinery Equipment) – buy or lease
**Intangible Assets** – Acquisition of patent rights, licences/know-how/unpatented tech knowledge
**Wage Costs** – Of jobs directly resulting form investment in assets

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# Process Technology Innovation - PTI

## What is it?

PTI is designed to help English manufacturers demonstrate their capability to manufacture offshore wind components by collaborating with  relevant technology partners on R&D projects

## Who can apply?

English SMEs AND Large Enterprises – no Assisted Area restriction

## How much funding is available?

Between 25% and 50% of eligible costs based on nature of applicant and project (see over)

## Who can be used as a Technology Partner?

Universities, Technology centres,  other business or individuals

Currently speaking to a number of Large Enterprises (UK and abroad) to understand how they can work collaboratively with TWI and other technology partners on Rapid Fabrication/Welding type projects

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# Process Technology Innovation (2)

How much can be funded?

| Aid Intensity caps for Small, Medium and Large Enterprises undertaking Industrial Research of Experimenta | terprise |
|---|---|
| Industrial Re | |
| Experimenta Developmen | |

Commercial Reality – There is no such thing as a 'normal' PTI application.  We would love to talk with you

What can b

- Instruments & Equipment
- Land & Buildings *
- External contractual research, technical knowledge. patents bought
- Additional Direct Overheads
- Other relevant Operating Costs

** To the extent that used in the Project*

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# FEF & PTI – Application Process overview

Define

- L2 / *L4*
- Define Application with GROW Advisor

3-4 weeks

Commercial Reality – A robust case for Jobs + Willingness to devote couple of days to a form can quickly help to transform and catalyse your investment plans

Applicants will complete a standard application form (Bus Plan not required). Assessment will focus on Jobs, Additionality, Funding, Risk, Market Demand, Competitive advantage and confirming eligibility of costs in line with EC guidance

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# Contact Details

- Nik Brown – Head of GROW Offshore Wind – 07920 049 531
  Dominic.C.Brown@uk.gt.com
- Richard Ousey – Investment Panel Lead – 07917 071 784
  Richard.Ousey@uk.gt.com
- Alan Whittaker – GROW Advisor – North East – 07834 307 915
  Alan.Whittaker@mymas.org
- Web site: www.growoffshorewind.com
- Enquiry Number: 0207 728 2738
- Enquiry Email: growoffshorewind@mymas.org

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# Appendix 1 - Flexible Enabling Fund – Snapshot of Applications to date

| Sector / speciality | Proposed Project |
|---|---|
| Protective Coating and Rope Access Engineers. | Purchase of Specialist Spraying System which enables the spraying of protective coatings |
| Rubber and Plastic Products | Machinery enhancement to upgrade production |
| Corosion protection (submerged surfaces) | Purchase of specialist computer simulation IT that simulates the impact of corosion on structures |
| Scaffolding, Access and Encapsulation servics for Offshore Wind industry | Investment in a System Scaffolding system to enhance abiity to compete for R2 and R3 contracts |
| Specialist ballbearings | To support significant investment in equipment to support building of production plant in England |
| Stainless Steel and Aluminium Fabrication for Offshore vessels | Additional Welding Plant and Storage to accommodate expansion |
| Design & production of specialised seats for offshore operators | Investment in moulding tools to help service anticipated step up in demand for seats |
| Specialist signage | Purchase of specialised machinery to help penetraion of offshore market |

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# Appendix 2 - PTI – Snapshot of Applications in process

| Sector / speciality | Proposed Project |
|---|---|
| Provision of monitoring systems for Onshore Wind Turbines | Siginificant 1 year project to develop / prove applicability of current system for Offshore platforms |
| Hardware/safety products for boats | Work with partner to develop more effective and cost-efficient core offshore wind safety product |
| Corrosion protection | Work with University partner to enhance output of core product and thus compete more effectively with foreign competitors |

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# *How to Achieve High productivity Welding*

**Andrew Woloszyn**

**Maximising quality and productivity in offshore fabrication**

30th January 2014

TWI
Technology
Engineering

# *Overview*

- **Introduction**
- **Productivity related to Offshore wind tower fabrication**
  - **Wind tower design**
  - **Processes employed**
- **Productivity – general overview**

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Engineering

# *Introduction*

# *Productivity & Process Choice*

**pro·duc·tiv·i·ty (prō′dŭk-tĭv′ĭ-tē) n.**

1. The quality of being productive.
2. *Economics* :The rate at which goods or services are produced especially output per unit of labour.

- **Maximise rate of weld production**
- **Maximise weld deposition rate**
- **Identify and implement most applicable process.**

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# *What Process?*

**‘The process chosen should provide the required quality at the lowest cost’**

*Principles of Welding Technology*

# Constraints

- **Quality: Skill of those available to do the job, & customer requirements (Processes may be defined by Codes & Standards)**
- **Equipment: Availability, justification of new kit (based on volume)**
- **Determining true cost of a process:**
  - **Fixed / ‘hard’ costs** eg. Labour rate, consumables, raw materials
  - **Operator factor / time based costs** eg. Pre/post welding ops: interaction with other manufacturing ops, arc on time

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# *Technical requirements of operation*

- **Type of material**
- **Type of joint**
- **Production requirements**
  - **Jigs, fixtures & positioners required?**
  - **Integration with other fabrication ops**
  - **Maintenance requirements?**

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# Productivity related to Offshore wind tower fabrication

## *Wind tower design*

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Engineering

# Wind tower construction

- **Constituent parts:**
  - **Nacelle (generator) + blades**
  - **Foundation**
  - **Tower**
- **Modern towers:**
  - **Height: 70-140m**
  - **Diameter: 4-5m**
  - **Material: S355 variants**
  - **Plate thickness:**
    - Onshore: 16-60mm
    - Offshore: 80-140mm (monopile)
  - **Constructed from segments, consisting of butt-welded circular ‘cans’**

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# *Wind tower segments & cans*

- **Cans rolled from plate; followed by longitudinal seam weld.**
- **Typically 3-3.5m in length.**
- **6-10 cans joined by multipass butt-welds to produce section or segment**

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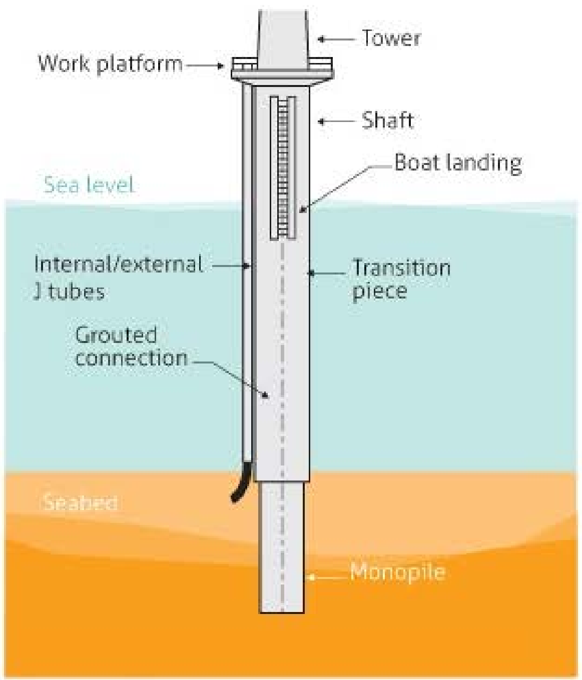
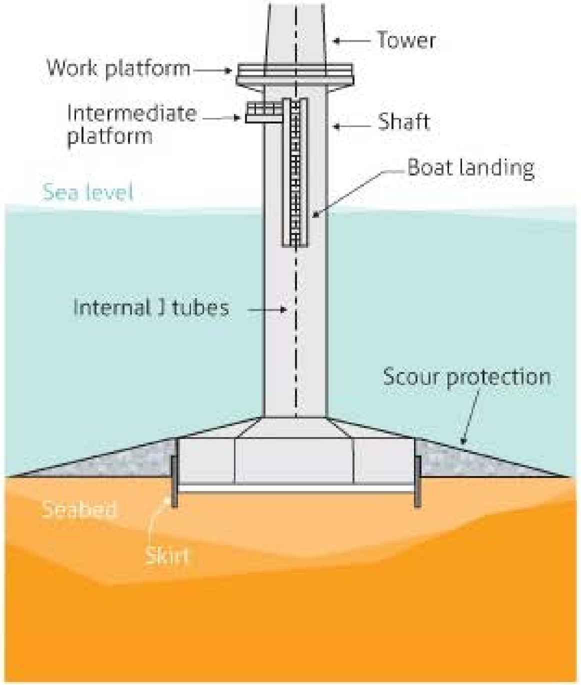
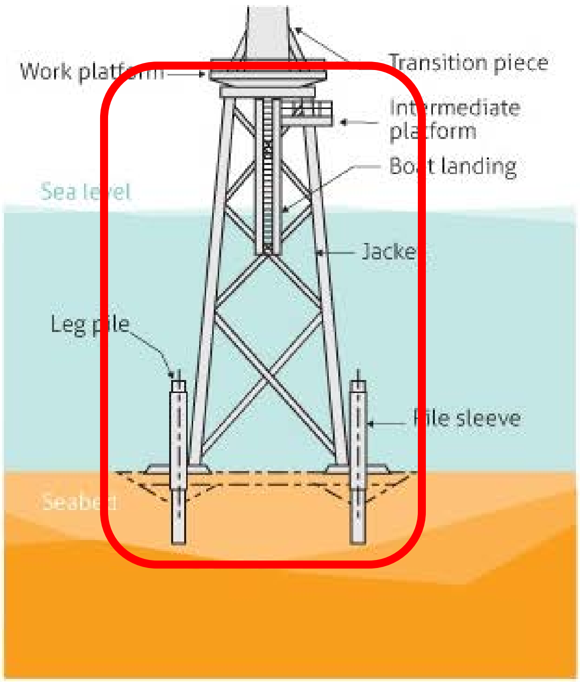
# Support structures




**Monopile**

**Gravity base structure**

**Space frame foundation**

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# *Space frame / Jacket foundation*

- More complex geometry
- ‘Nodes’
- More variation:
  - Diameters
  - Thicknesses
  - Angles

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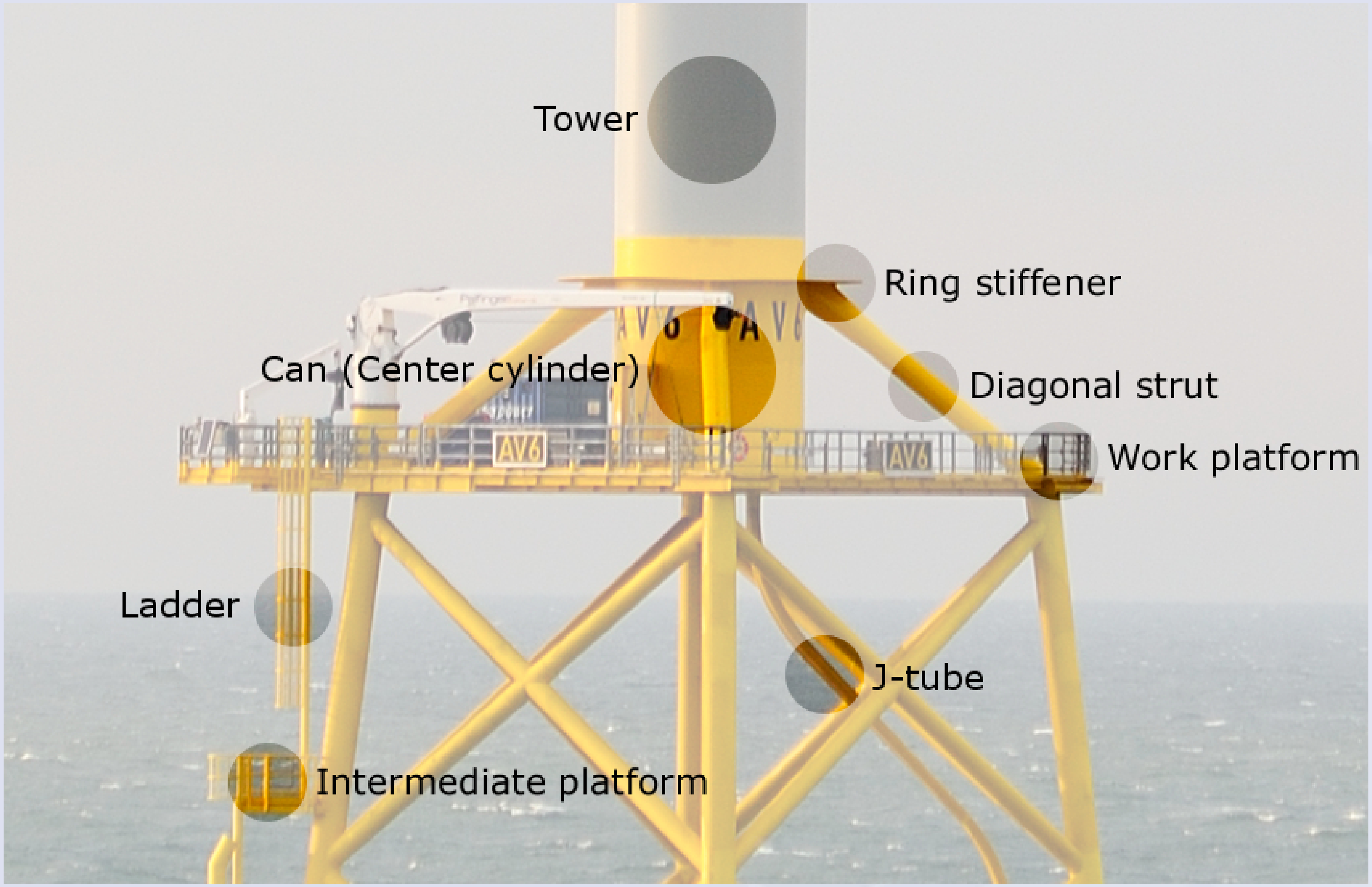
# Secondary steel

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# *Operating conditions*

- Offshore environment
- Specific demands set by local regulatory bodies
- Material toughness requirements:
  - 27J at -40°C (or even -50°C) for Onshore
  - 47J at -60°C for the most severe Offshore
- Plate qualities:
  - S355J2G3 and S355N for Onshore
  - S355G7+M and S355G9+M  TMCP steels

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***Productivity related to Offshore wind tower fabrication***

*Processes Employed*

# *Welding of Cans*

- Code/Standard and design will set material property (toughness) requirements
- Required bead shape, tensile strength and other properties are determined
- Corresponding weld processes and joint geometry selected
- Maximise deposition rate > SAW preferred choice
- Details of joint geometry determined > minimisation of production time >

  Minimise joint volume

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# *Submerged Arc Welding*


- **Column and boom mounted welding head for access.**
- **Associated manipulation system.**
- **Bulk packs of wire and flux.**

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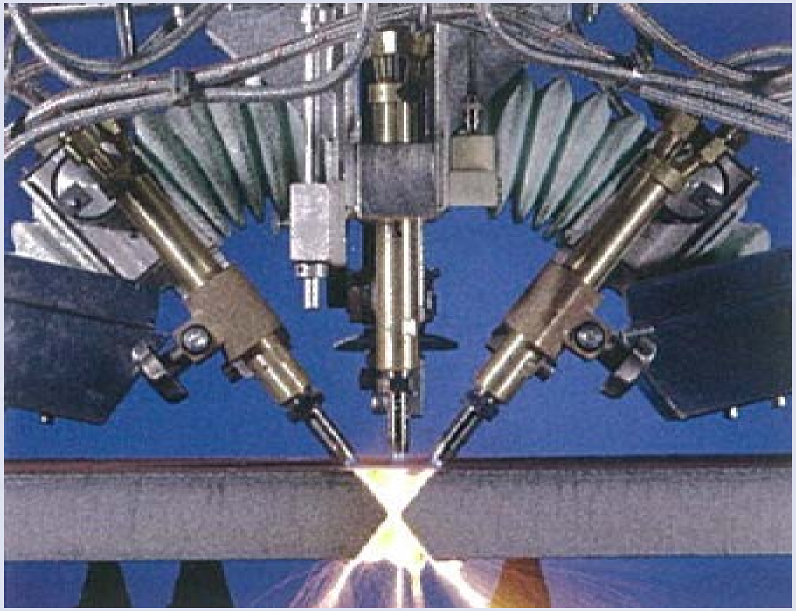
# *Cutting operations*

- **Plates to be rolled / welded – suitable edge prep**
- **Traditionally cutting/grinding operations**
- **Can use one smooth (high accuracy) cutting run** eg. Oxyfuel triple-torch head



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# *Joint Volume*

- **Double V-groove most common (flame cut)**
- **Thicker (offshore) applications – ground U-groove possible BUT high cost**
- **Reduce joint angle > reduce volume**
  - 60º common in wind tower fabrication >> 50º **BUT**
- **Tougher demands on welding consumable performance – slag detachability**
- **<u>Requires consideration of fluxes and wire types</u>**

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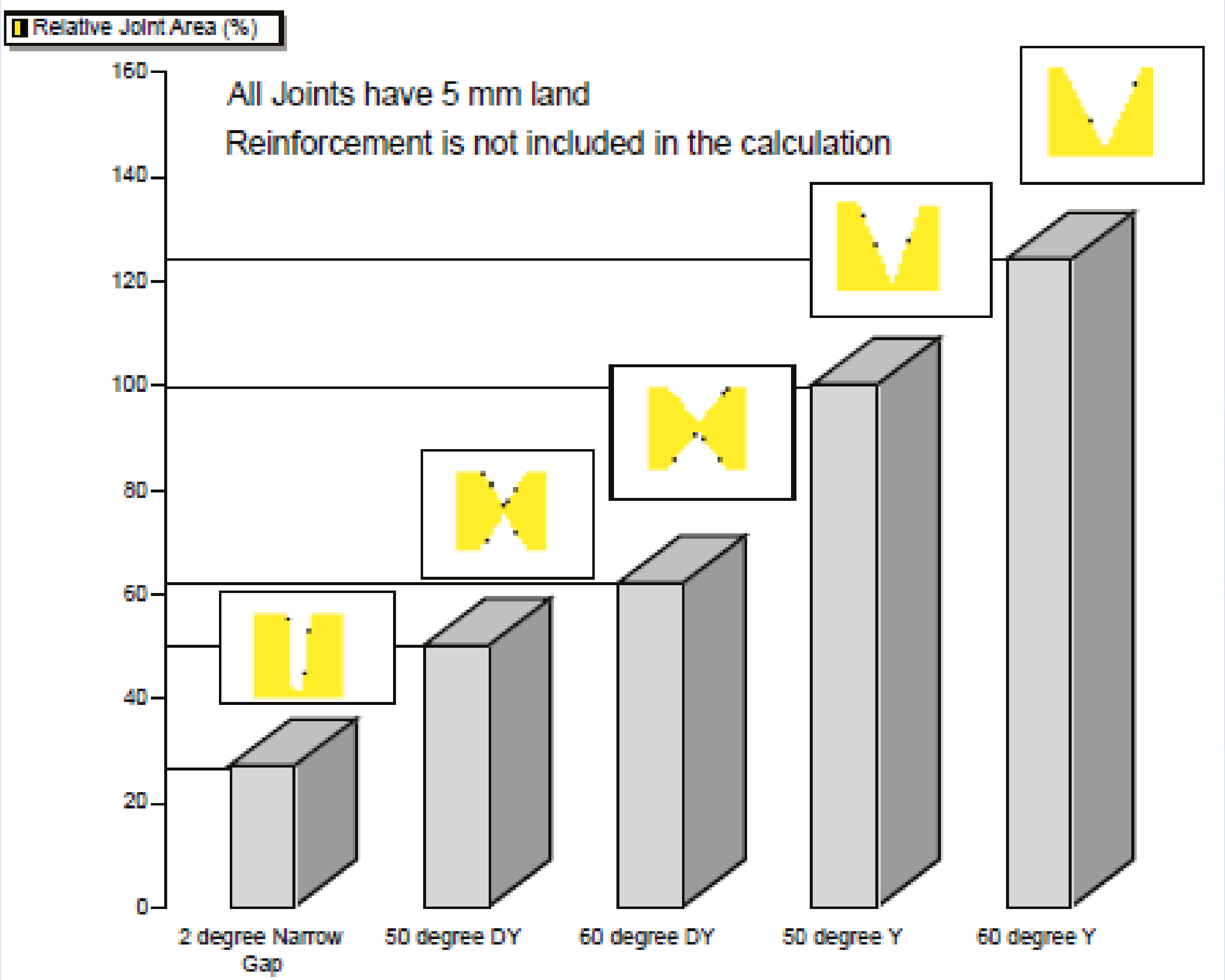
# Effect of Joint Type on Weld Joint Area

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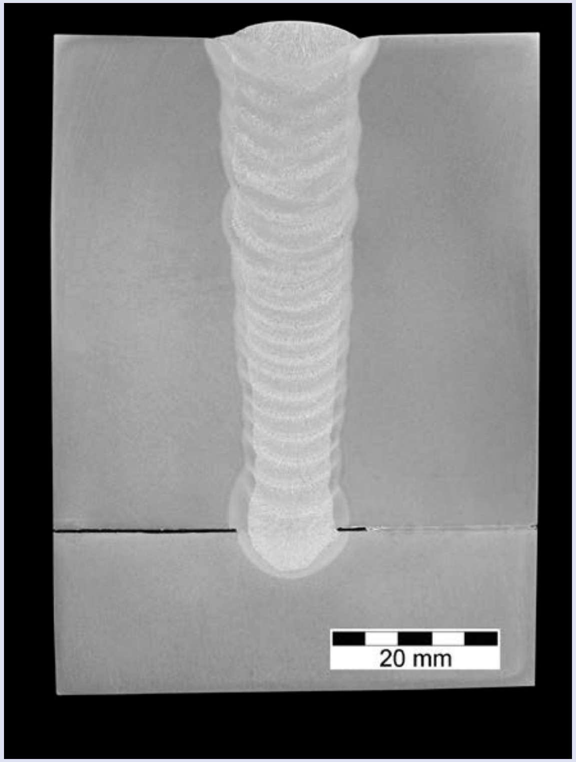
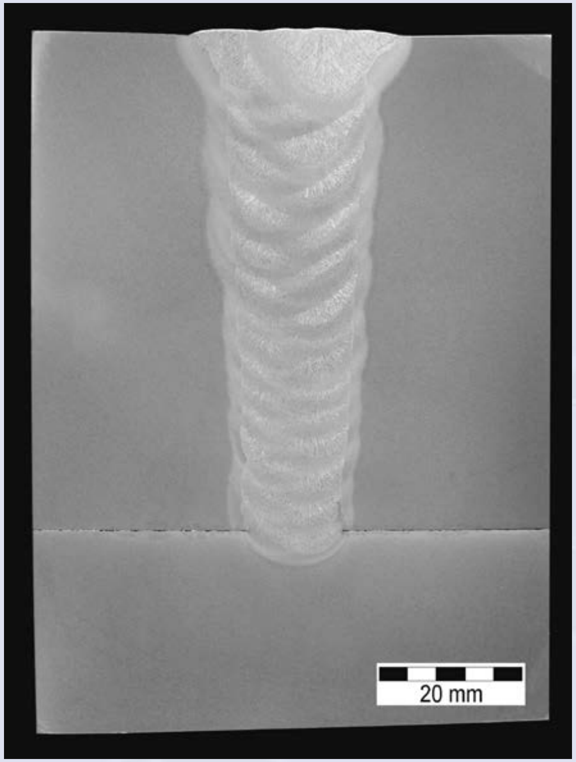
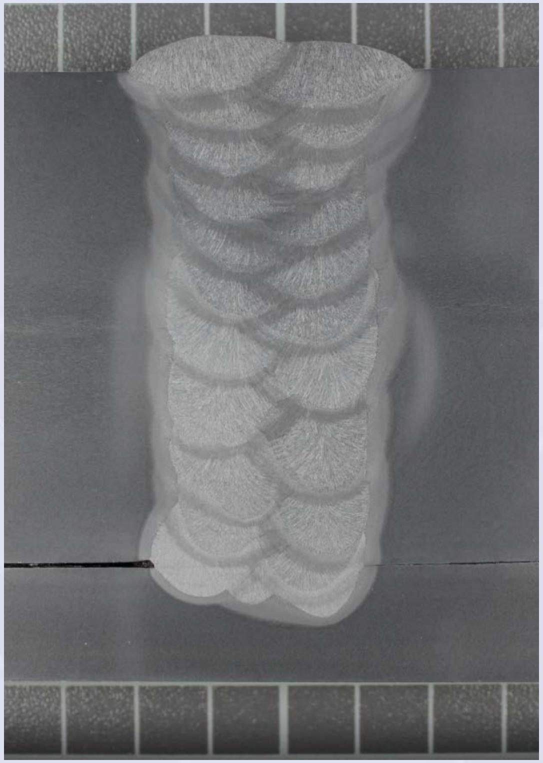
# SAW welding trials




Root gap: 10mm
Angle: 4º
23 passes




Root gap: 15mm
Angle: 4º
29 passes



Root gap: 15mm
Angle: 6º
22 passes

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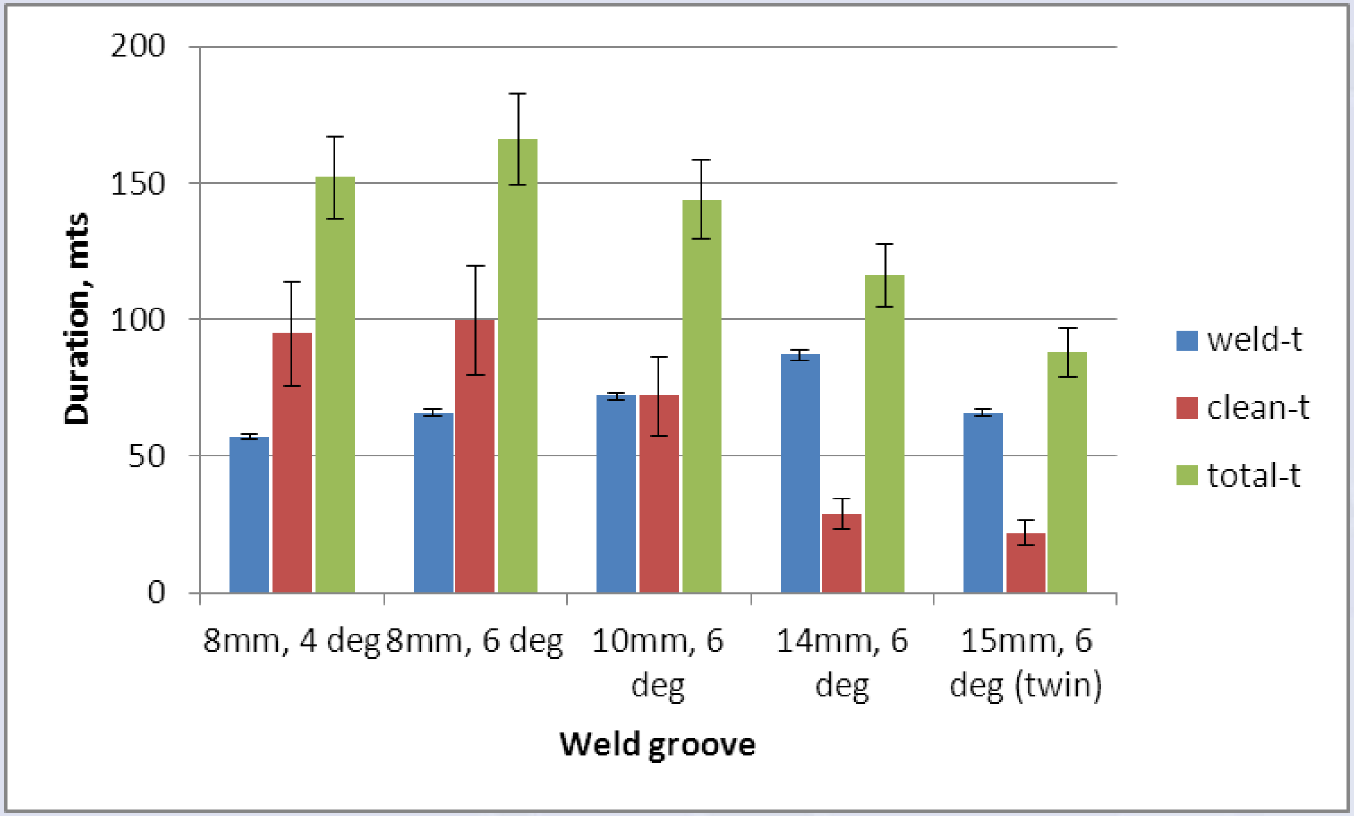
# Corresponding production times

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# *Deposition rate*

- Maximise deposition rate
- Reduce overall welding time
- EVEN if this demands a larger joint opening
- Dramatic increase with:
  - Multiple wires
  - Optimisation of wire diameters
  - Flux cored consumables
- BUT need to consider heat input and effect on properties (inter-run cooling)

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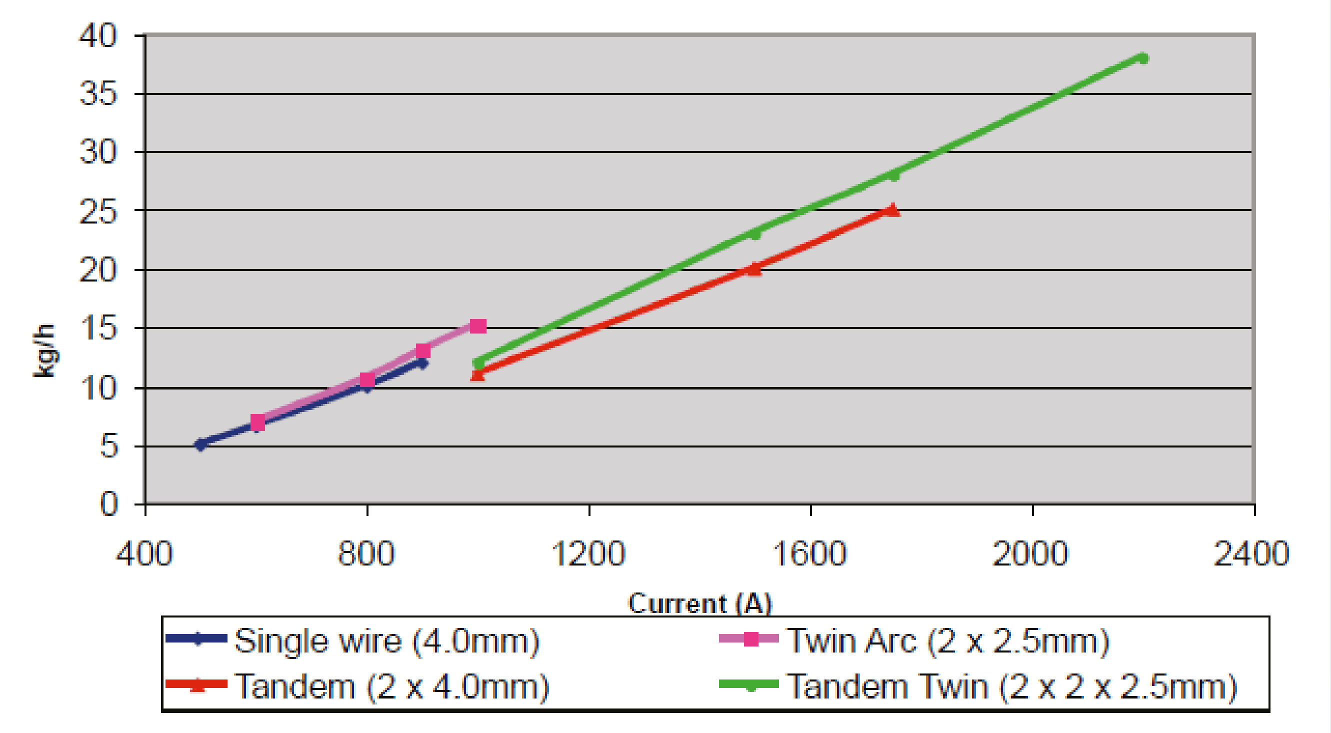
# ***Process control***

- **Wire position and feed critical at lower bevel angles**
- **Wire *close enough to sidewall***
  - **to created desired wetting action**
  - **Giving bead with smooth concave profile**
- **Wire *not too close***
  - **to avoid excess melting/undercut > <u>slag entrapment</u>**
- **<u>Higher travel speeds require close control of travel/wire feed speed and arc behaviour</u>**

# Process variants – Deposition Rates




| SAW Variant | Single Wire | Twin Wire | Tandem | Tandem Twin | Multi Wire |
|---|---|---|---|---|---|
| Number of Wires | 1 | 2 | 2 | 4 | 3 – 6 |
| Max. total deposition rate solid wire (kg/h) | up to 12 | up to 15 | up to 25 | up to 38 | up to 90 |

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# *Tandem –Twin SAW*


Lincoln Electric
tandem-twin AC/DC
1000

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# Polarity

- **Traditional approach in tandem configuration**
  - **DCEP lead, AC trail**
- **Higher deposition with both heads AC**
  - **<u>BUT</u> penetration capabilities of AC moving closer to DCEP**
- **Digital control (eg Lincoln PowerWave AC/DC)**
  - **Square-wave AC to stabilise arc**
  - **Change waveforms between weld passes e.g. DCEP pen / AC fill**
  - **Longer durations in either +ve or –ve side of cycle, allowing move to AC-AC tandem**

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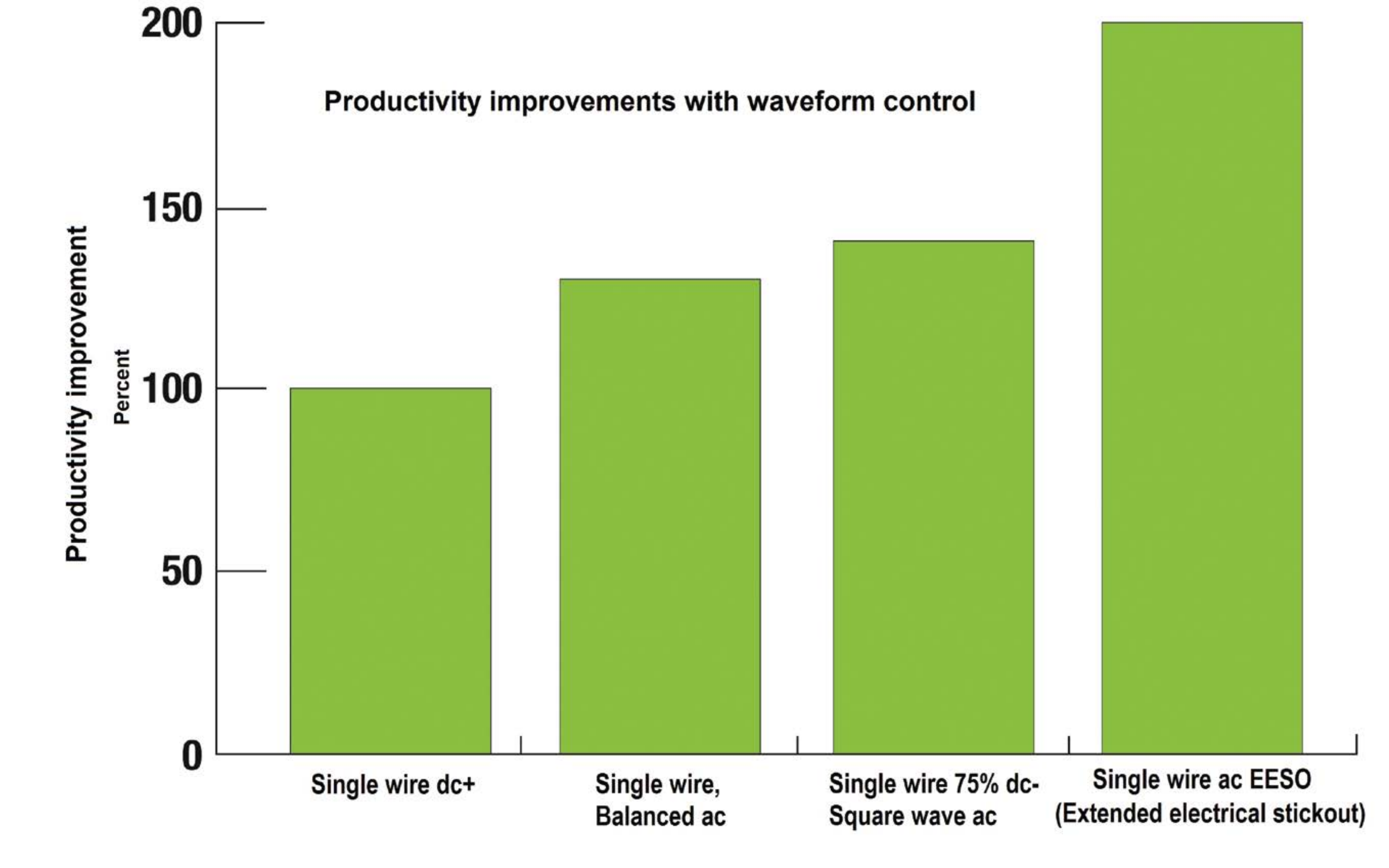
# Influence of waveform control

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# Example

- **480m joint length in a tower, 60° joint angle, 25mm thickness: 490kg of weld metal**

| Process variant | Single wire | Single wire | Tandem wire | Tandem-twin wire |
|---|---|---|---|---|
| Joint angle | 60° | 55° | 55° | 55° |
| Deposition rate | 8kg/hr | 8kg/hr | 20kg/hr | 38kg/hr |
| Total welding time | 61hrs | 55hrs | 22hrs | 12hrs |

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# *SAW consumable considerations*

- **Weld metal properties**
- **Travel speed**
- **Deposition rate**
- **Consider effect on weld bead geometry**
  - **Resulting problems with slag entrapment**
  - **<u>Additional time associated with slag removal</u>**
  - **Reduction in productivity**

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# *Flux type*

## Distinct types and properties

- **ACID (FUSED) – will not change WM chemistry, not affected by fluctuations in welding parameters (e.g. Voltage) >**
  – Faster travel speeds e.g. single passes on thin matls
  – Easily removed slag
- **BASIC (AGGLOMERATED) – consumption rate affected by parameters; must be taken into account, but >**
  – De-oxidants, work well through contaminants (rust/mill scale)
  – Good for heavy, thick sections in low-alloy steels

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# Flux-wire combinations

- For weldability, flux-wire combinations
  - Must accommodate high deposition rate
  - Must allow good slag detachability
- Smaller wire diameter allows greater penetration at a given current
  - Tandem-twin SAW has become standard in Europe for wind tower fabrication
  - e.g. tandem-twin using 4 x 2.5mm-dia. wire > <u>38kg/hr weld deposition rate</u>

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# *(Metal) Cored Wire*

- **High deposition rates**
  - **For given flux, current, stick-out combination**
- **Reduction of number of passes or travel speed increase possible (10-15%)**
- **Cost considerations:**
  - ***Product price* – metal cored wire more expensive**
  - ***Total cost* – takes into account wire cost and all other factors, such as flux and <u>labour (85%)</u>**
    - <u>Product cost offset by labour savings</u>

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# Welding of Jackets

- Different node types
  - Dimensions
  - Angles
- Variation around joint line
  - Joint line orientation
  - Weld gun axis
  - Fit-up / root gap
  - Resulting weld profile
- MMA / MAG/ FCAW

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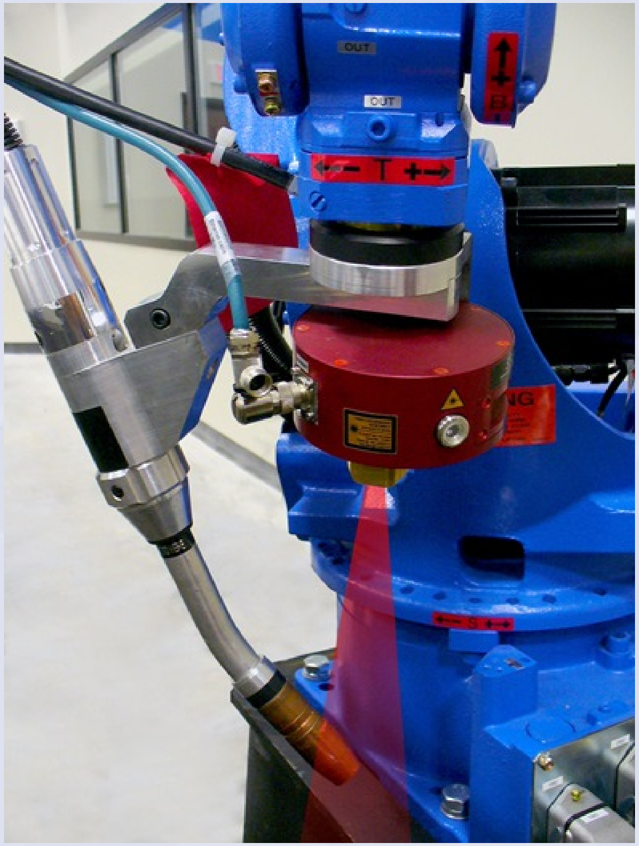
# Metal Active Gas / Flux-cored Arc Welding

- Most adaptable to automation
  - Arc length control via power-supply
  - Tolerance to nozzle-plate distance
- Positioning and access still a key issue:
  - Movement of ancillaries
  - Orientation of gun
  - Manipulation of workpiece



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# *Robotic solutions*

- **Large capital investment**
  - **Just a robot?**
    - Robot system cost can be 2-3x robot cost
- **Change in management & workforce practices**
  - **Design**
  - **Fabrication / Inspection**
  - **Staff retraining: Operator/technicians & Supervisors**
  - **Maintenance & Equipment support**

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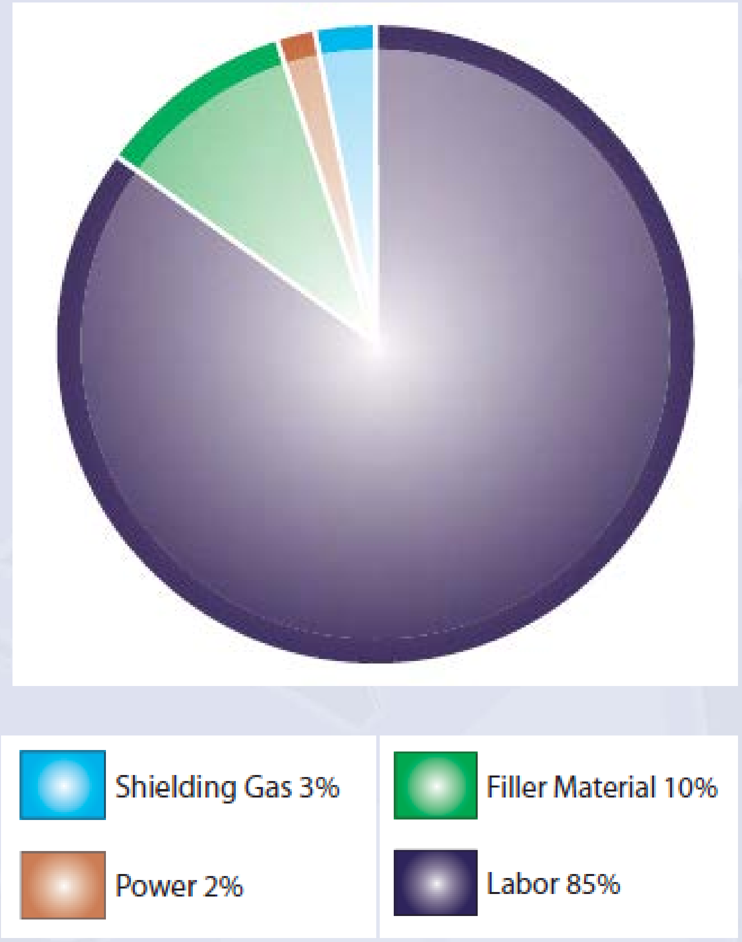
# *Productivity*

*General Overview*

# *Productivity & Welding Costs*

- **Welding labour continues to be the single largest cost variable in any welding operation**
- **Biggest problem in assessing direct labour relates to time spent actually welding ie. Arc-on time**

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# Items and costs to track

## Fixed or 'hard costs'

- Labour rate
- Overhead
- Filler metal
- Shielding gas
- Other consumables (gun components, grinding wheels etc.)
- Electricity
- Raw materials

## Operator factor or time-based costs

- Preparing metal for welding
- Preparing the joint
- Assembling components
- Pre-heating time
- Tack welding
- Positioning weldment
- Arc-on time
- Grinding spatter

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# *Arc-on time*

$$operator\ factor = \frac{arc\ time}{total\ labour\ time}$$

(duty cycle)

- Maximise duty cycle
- Reduce (eliminate) ancillary tasks
- Support with appropriate process choice (eg. MIG/MAG, SAW) BUT
- Little value for short weld runs when joints are far apart

# *Waste*

**Key question:**

***Is Step B in a process***
***true preparation for Step C,***
***or compensation for inefficiency of Step A?***

# *Operator factor or time-based costs*

- Preparing metal for welding (eg cleaning)
- Preparing the joint (eg cut, bevel, grind)
- Assembling components
- Pre-heating time
- Tack welding
- Setting parameters
- Arc-on time
- Interpass cooling time
- Grinding spatter
- Chipping slag
- Ginding/polishing bead to final size
- Welder inspecting weld
- QA/QC inspection
- Rework/repair
- Subsequent inspection
- Changing electrodes
- Process change over (eg MIG root > FCA fill)
- Cylinder swap outs

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# *Common reasons for excessive arc-off time*

- Lack of welder preparation ('just weld that')
- Delayed machine set-up (locked machines?)
- Dirty shop (impede movement, H&S issues)
- Unavailability of material handling equipment
- Out of position welding
- Cylinder change out
- Wire feed issues (recognise/correct issues)
- Repair and rework (determine cause and rectify first)
- Slow QC inspection/acceptance
- Cell phone use

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# *Summary*

- **Optimise and maximise on the performance of a given process variant and associated consumables**
- **Consider all the other factors that influence arc-factor/duty cycle of the welder/process**
- ***The higher the duty cycle, the greater the effects of high deposition processes***

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# Benefits of Power Beam Welding in Structural Steel Fabrication for Offshore Wind


Chris Punshon

Electron Beam

TWI Ltd



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# Scope

- Offshore wind drivers
- Structural steel fabrication requirements
- Local vacuum EB possibilities
- Achievements
- Next steps

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# Offshore Wind Drivers

- UK renewable energy target
  - 20% renewables by 2020
- Offshore wind round 2 and 3 sites
- Bigger Turbines
- Further Offshore
- Difficult weather sea state & ground conditions

# Steel Fabrication

- Tubulars - Jackets and other structures
- Mono-pile Foundations
- Alternative designs
- Flange Manufacture

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# Foundation Cost Drivers

- Steel price
- Plate sizes and accuracy
- Fabrication complexity
- Welding productivity
- Installation cost and weather windows

# EB Welding Advantages

- Large thickness range (>200mm in steel)
- Single pass welding
- Autogenous process (no filler wire)
- Low heat input
- Low distortion
- High speed
- Good accessibility
- Non-contaminating atmosphere (no gas)

http://www.youtube.com/watch?v=hSHWawjpprU

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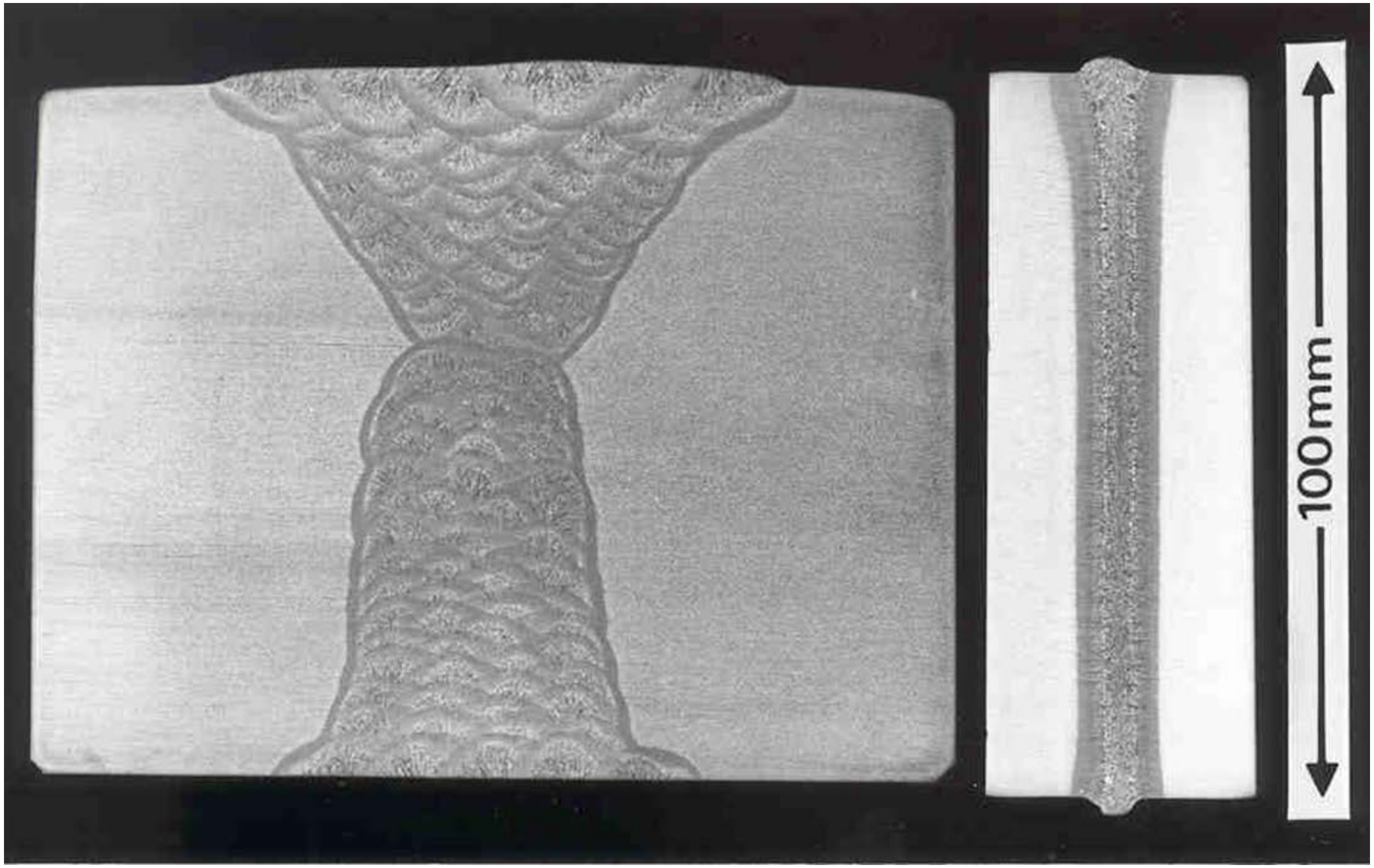
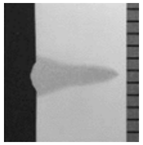
# Power Beam Welding



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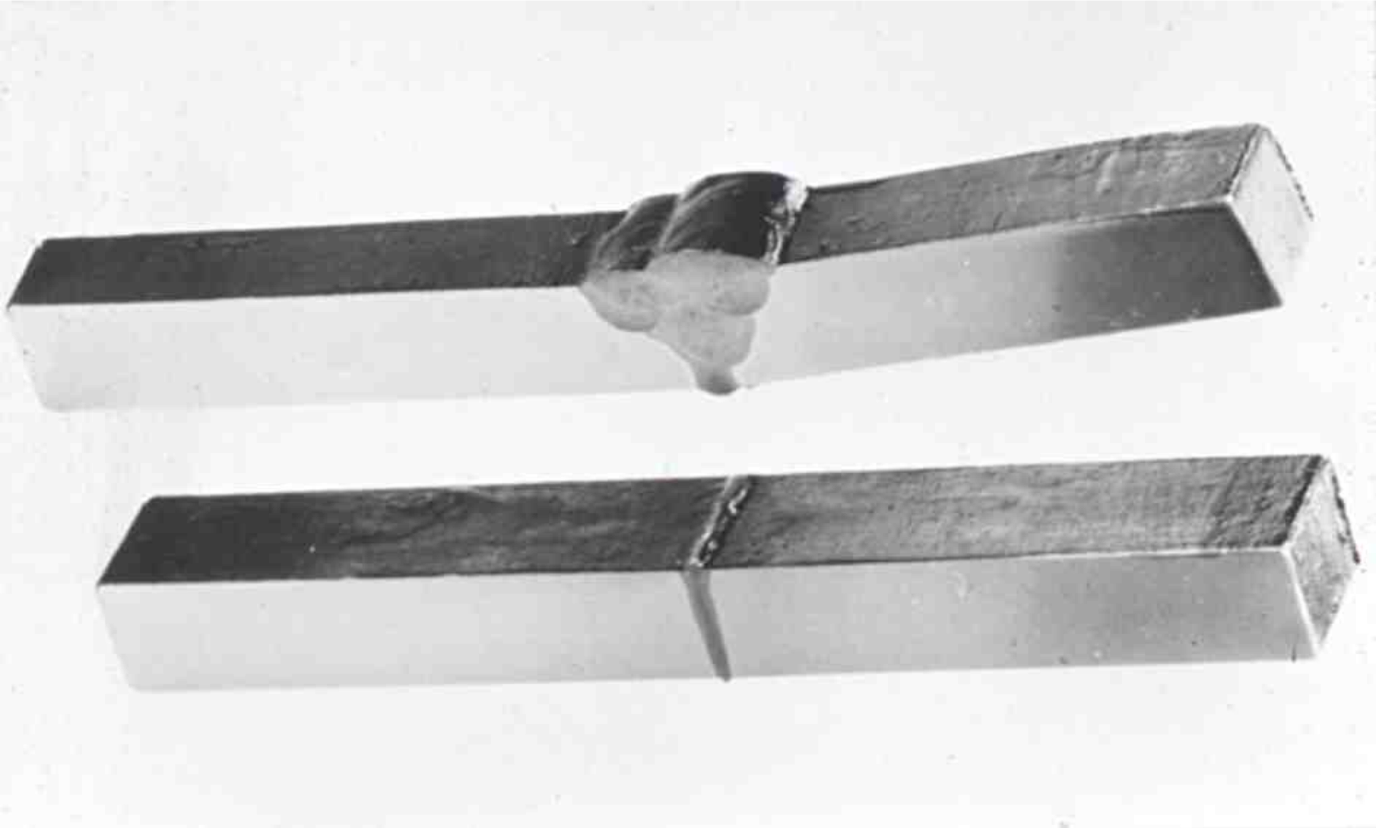
# Power Beam Welding



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# Monopiles - Rolled & Welded

Courtesy Dillinger

Courtesy SIF

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# Serial Manufacture


Courtesy SIF

Courtesy SIF

- Large assembly bay areas
- 800 tonne lifting capacity
- Dock facilities

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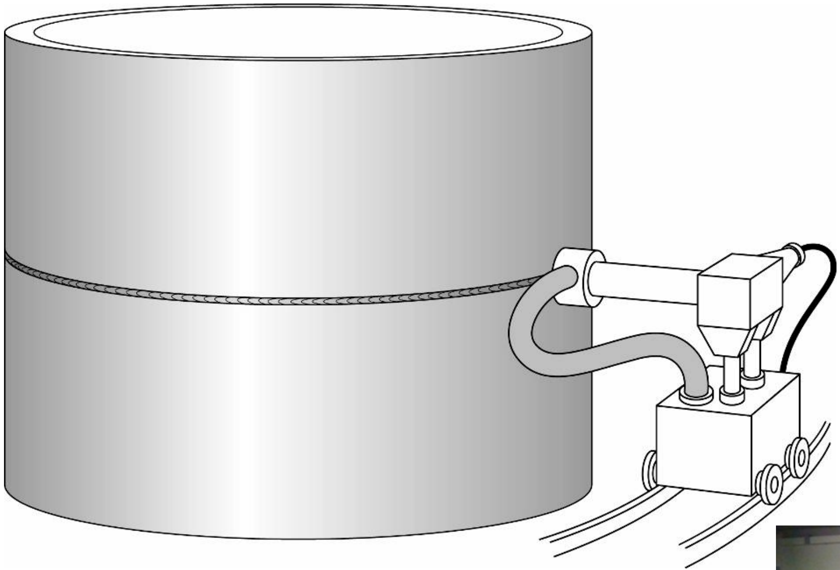
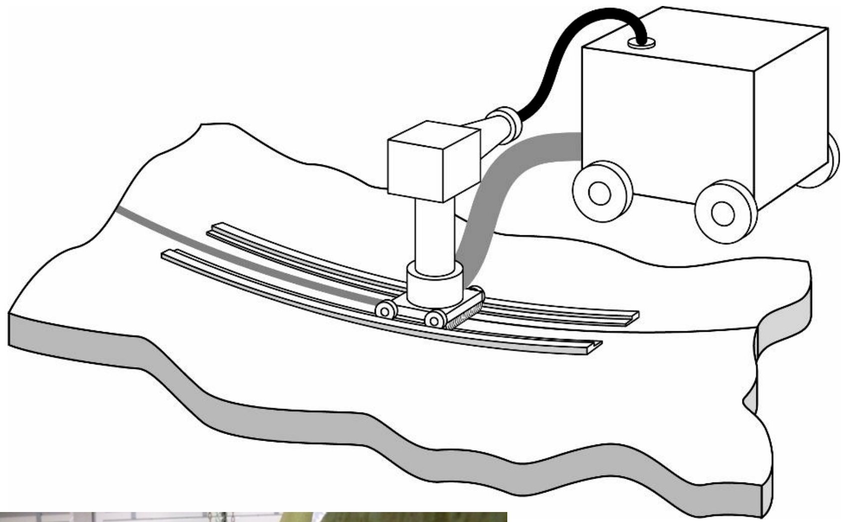
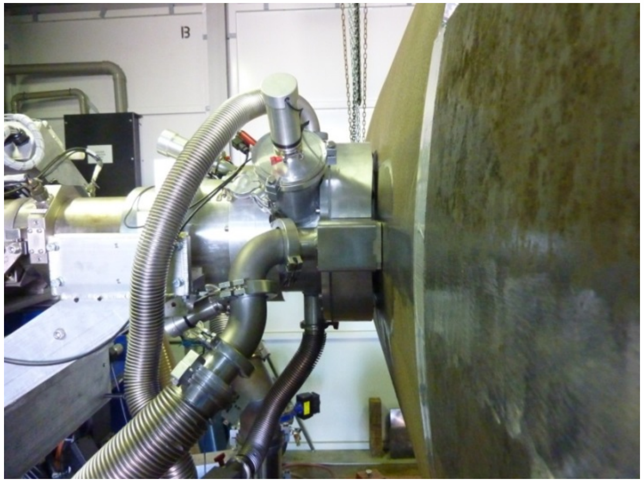
# Local Mobile Vacuum Concept







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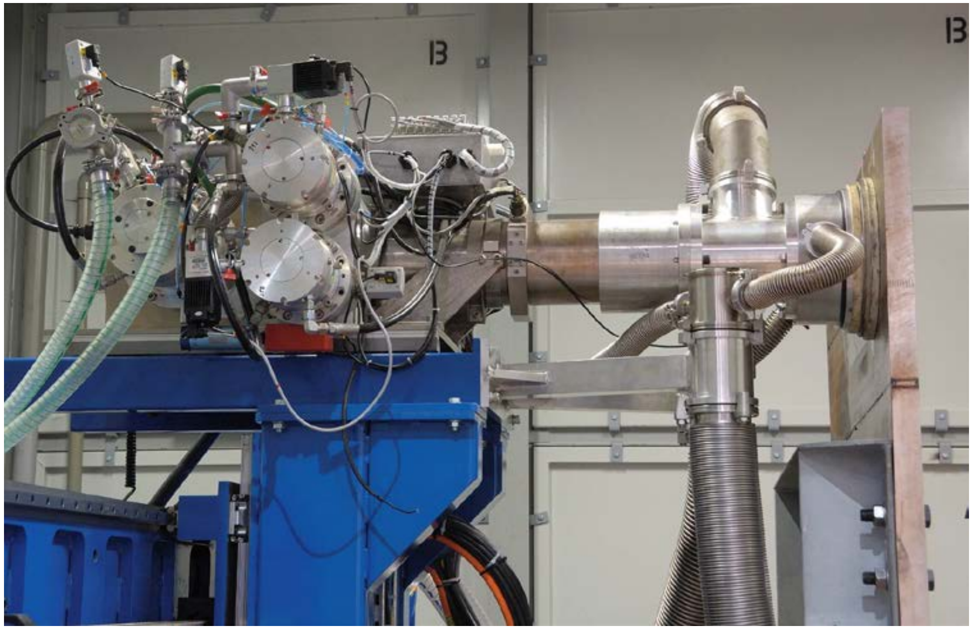
# Local Vacuum EB Facility



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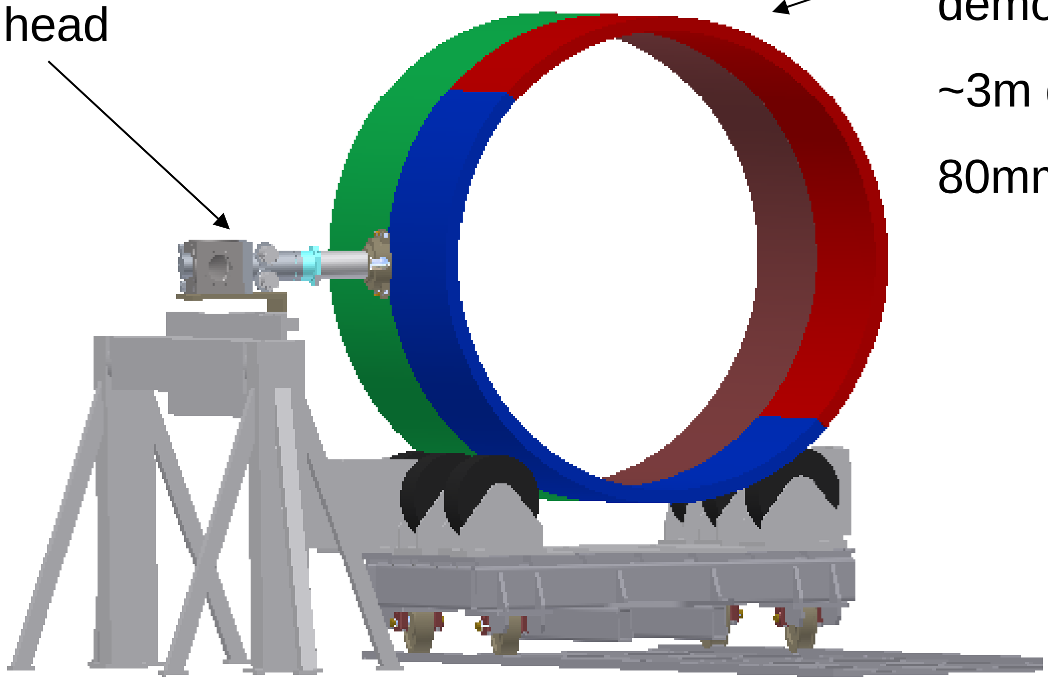
# Proposed Foundation Demonstrator

RPEB Local vacuum head



17.6 tonne tubular steel demo piece

~3m diameter

80mm wall thickness

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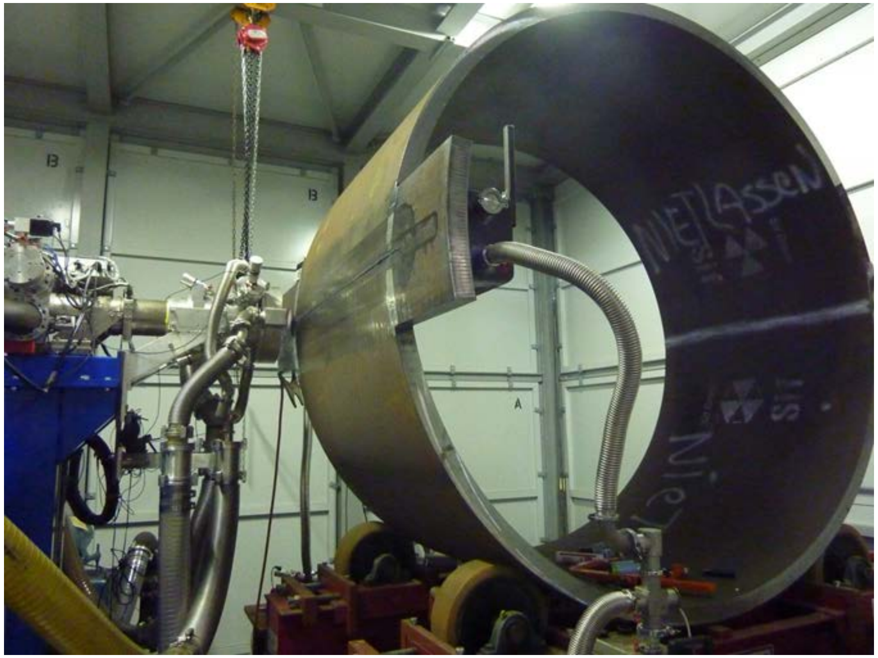
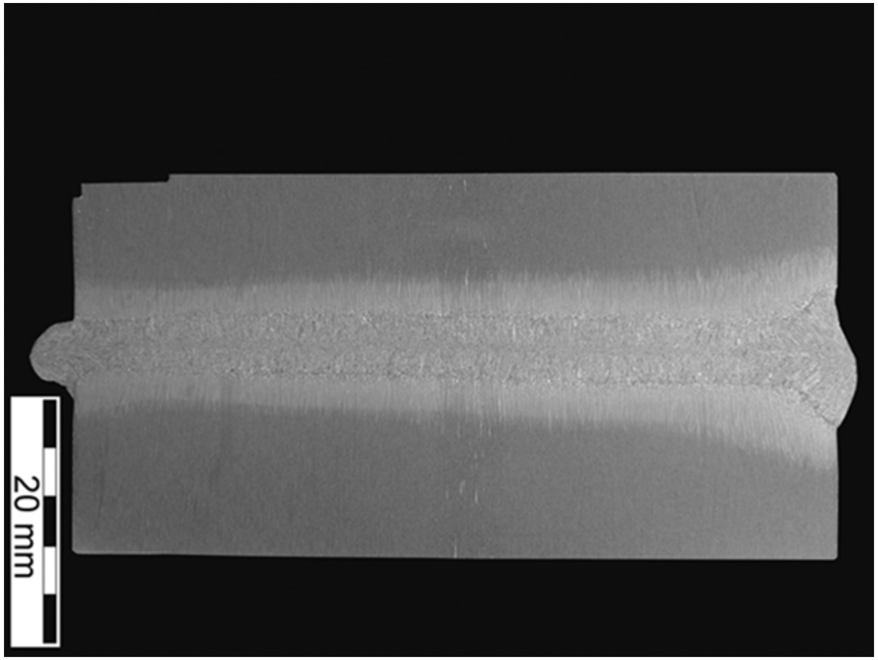
# High Productivity EB Welding




Full penetration welding of 60mm linear seam in 6 minutes – no pre-heat or consumables




Low distortion, high integrity welding

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# High Productivity EB Welding

Video link to:

Cost effective manufacture of offshore wind turbine foundations


# Tubular Foundation Elements


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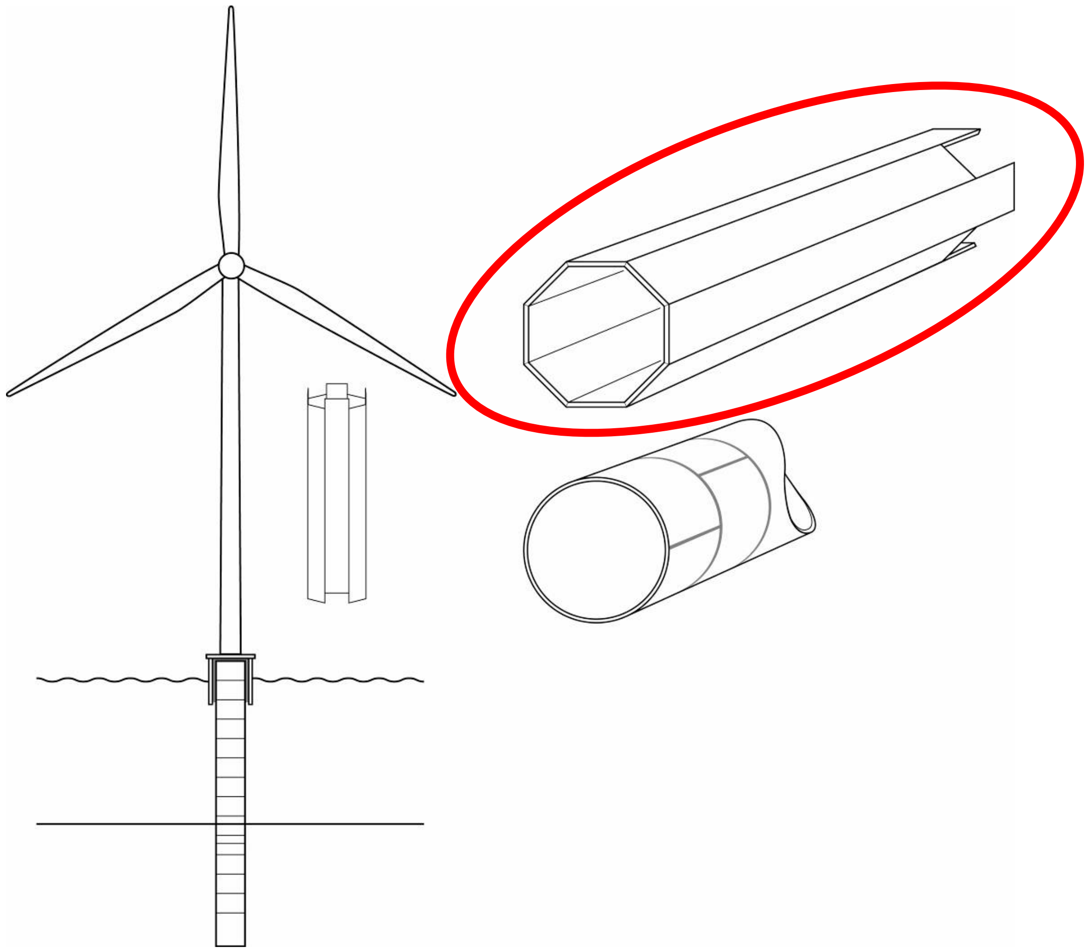
# RGF Facetted Design Concept



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# RGF Novel Fabrication Partnership

- TWI
- University of Newcastle (RCID)
- Gardline
- BSP International
- Scottish Power
- Tata Steel
- OGN

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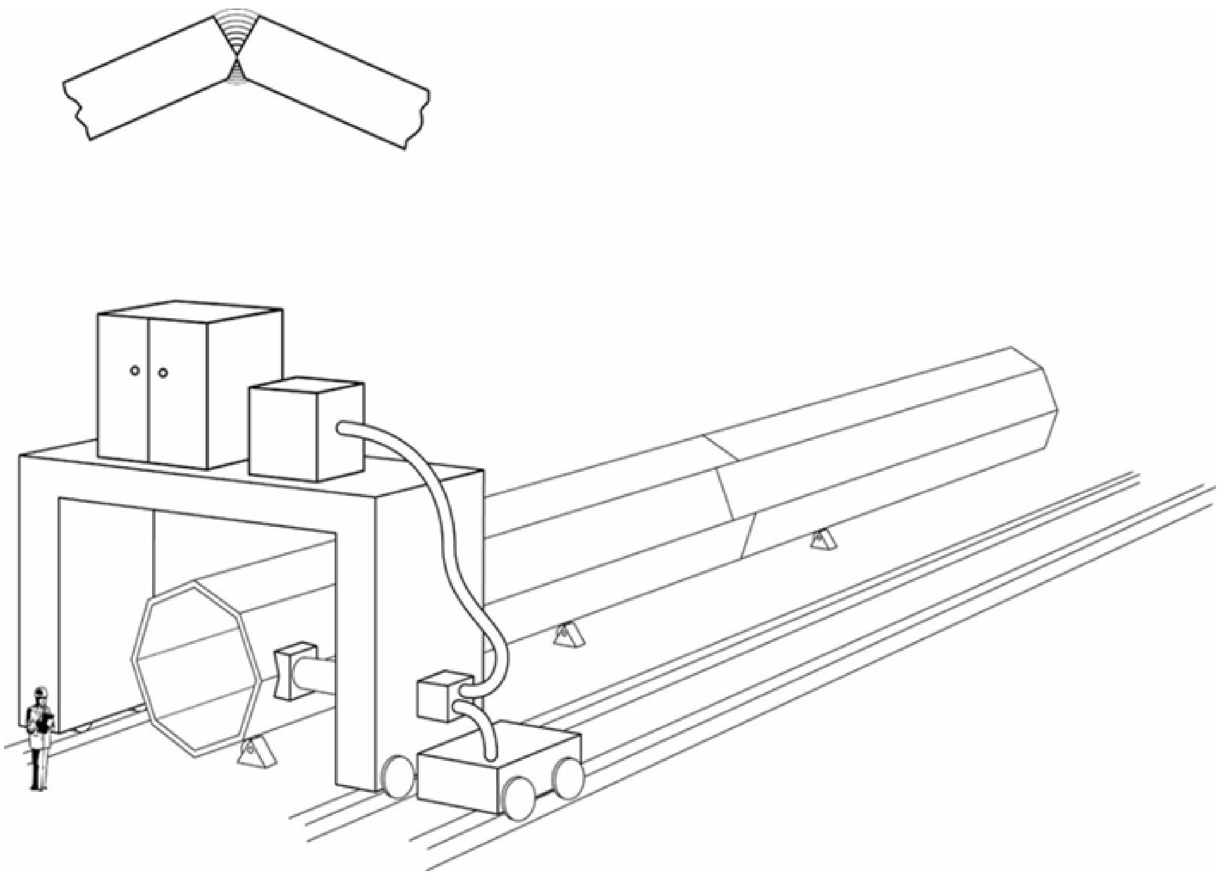
# High Productivity Welding



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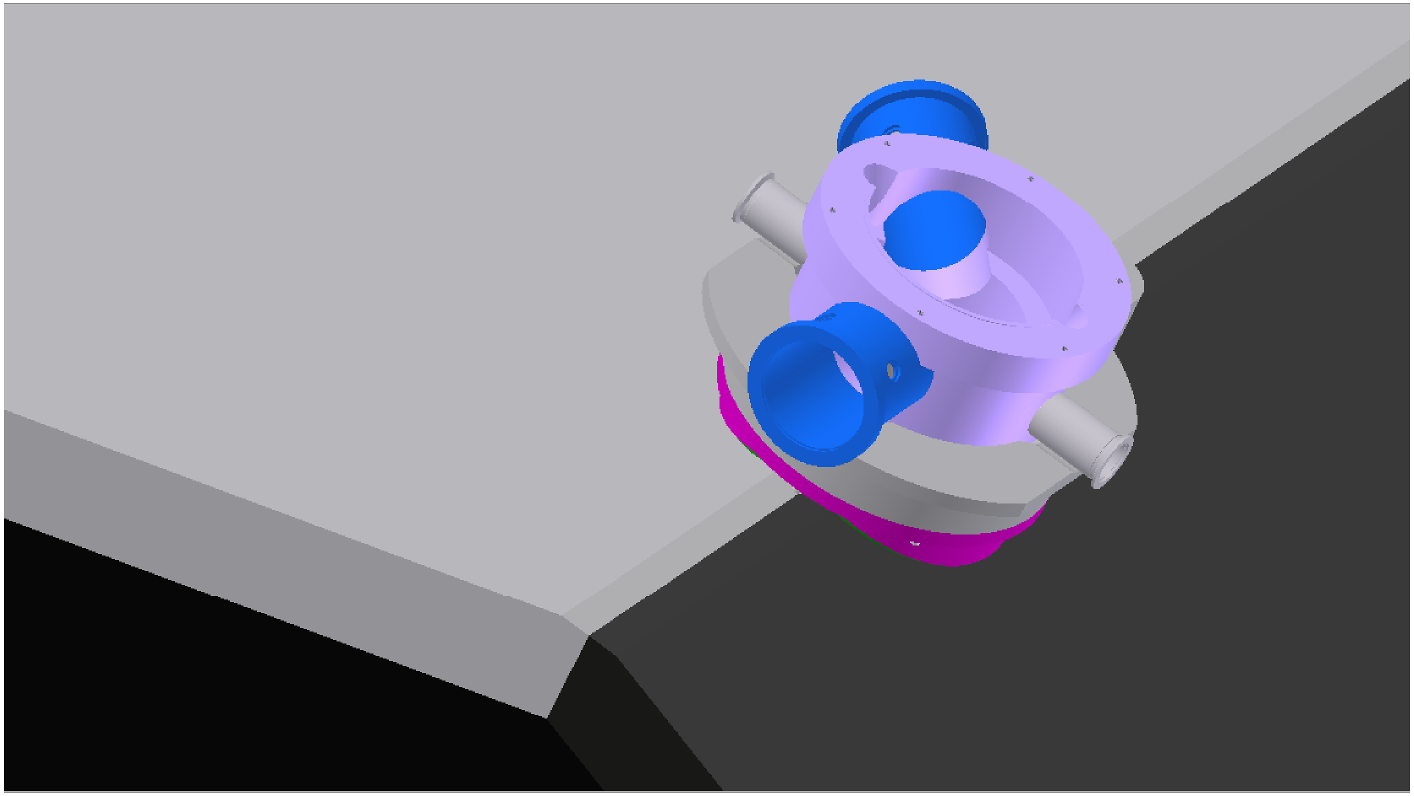
# Local Vacuum Head Design for Facetted Mono-pile



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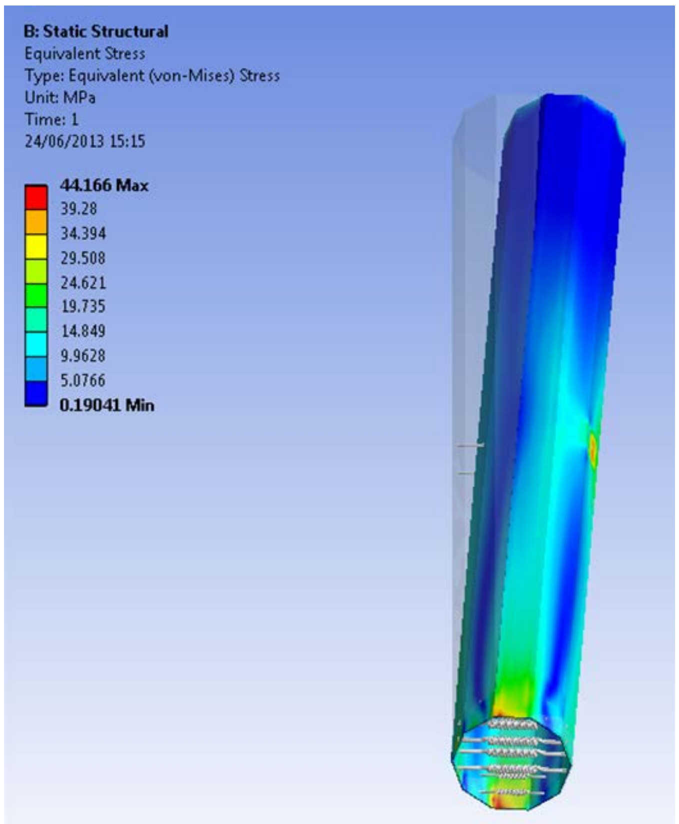
# FE Modelling and Experiment

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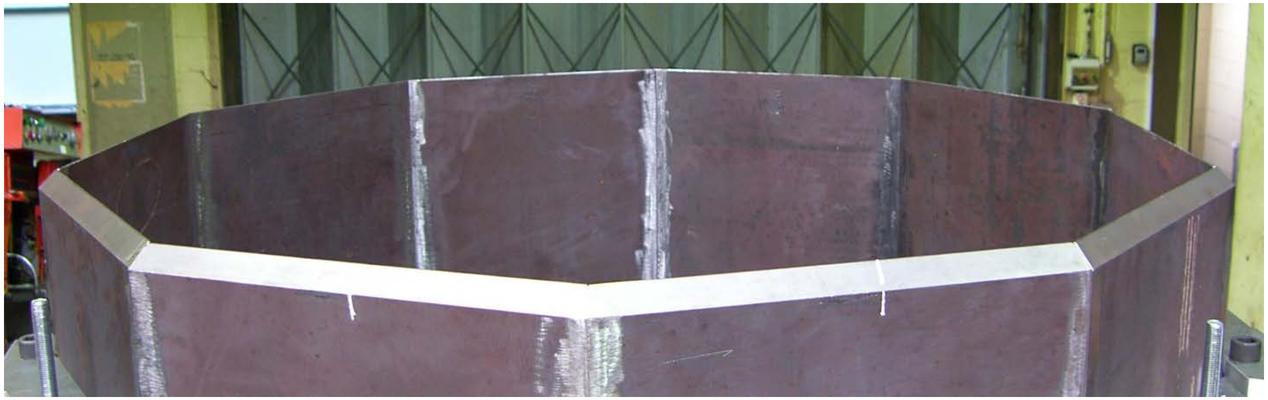
# Instrumented Pile Driving



2.2m long x 1.5m diameter
plate construction

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# Summary & Future

- EB local vacuum welding demonstrated up to 100mm thick in structural steels
- Facetted RGF pile demonstrator to be driven in March 2014 (Ipswich)
- Industrial EB welding demonstrator facility being installed in late 2014 (Scotland)
- Laser-in-vacuum welding developments show early promise for longer term deployment

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Mike Nunn

Section Manager

Electron Beam Processes

TWI Ltd

Cambridge & Middlesbrough, UK

mike.nunn@twi.co.uk

07557 00 23 25

+44 (0)1223 89 90 00

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# *How the OSW project has helped OGN*

**Andrew Woloszyn**

**Maximising quality and productivity in offshore fabrication**

30th January 2014

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# *Summary*

- TWI support as part of the Offshore Wind Project
- OGN requirements
- Approach

# AFWE Team - Key Themes

- **Welding procedure development**
- **Specialist Repair**
- **General Fabrication & Welding Engineering**
- **Arc-welding automation**
- **Arc-welding  quality control**
- **Health & Safety in Welding**

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# OGN

- Offshore Group Newcastle (OGN) currently fabricates large process modules and jackets for the offshore oil and gas industry
- Now drawing on this experience in matters related to design, engineering, fabrication, construction, installation for offshore wind farm developments

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# *Scope of support*

- Product and Process Review
  - Initial discussion of concept and requirements with OGN
  - On-site visit to review current facilities and future requirements

- Feasibility Study
  - Investigation of methods of mechanisation and automation
  - Examine various fabrication options available

# Industrial Process Application

## Technology Push

- Current State-of-the-Art
  - Awareness / Procurement
  - Benchmarking
  - Automation
  - Integration
  - Demonstration

## Industry Pull topics

- Repair by cold temper bead arc welding: austenitic cladding on ferritic base metal in power industry
- Repair of Ni-based super alloys
- Selection of processes for critical / high quality fabrications
- Improving productivity in wind turbine tower fabrication
- Investigation & development of processes for welding (Super) Duplex Stainless Steels

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# *Product and Process Review*

- Key factors:
  - Production volume
  - Automation
  - Design requirements
- Identification of areas for further consideration as part of feasibility study

# Production Volume

Production volume

Candidate processes

Automation

State-of-the-art, and beyond

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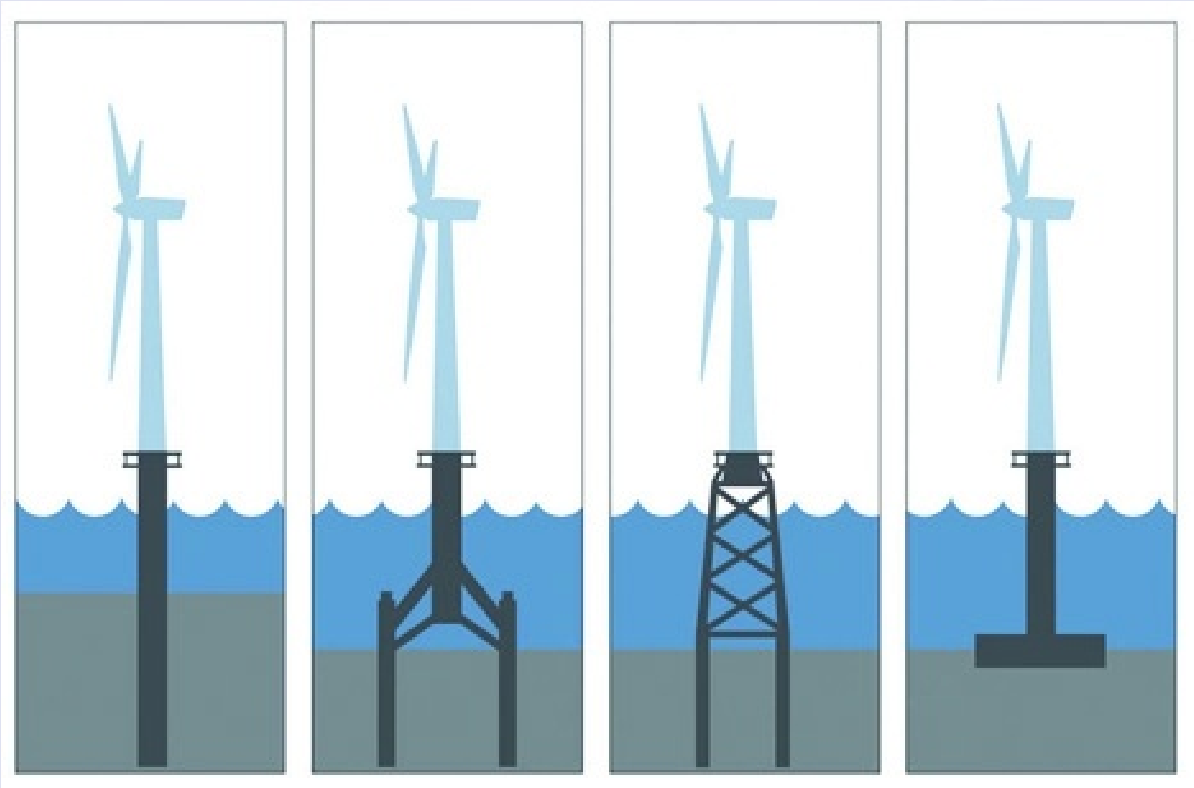
# *Design considerations*

- **Overall design**
- **Variants**
- **Production bottlenecks**



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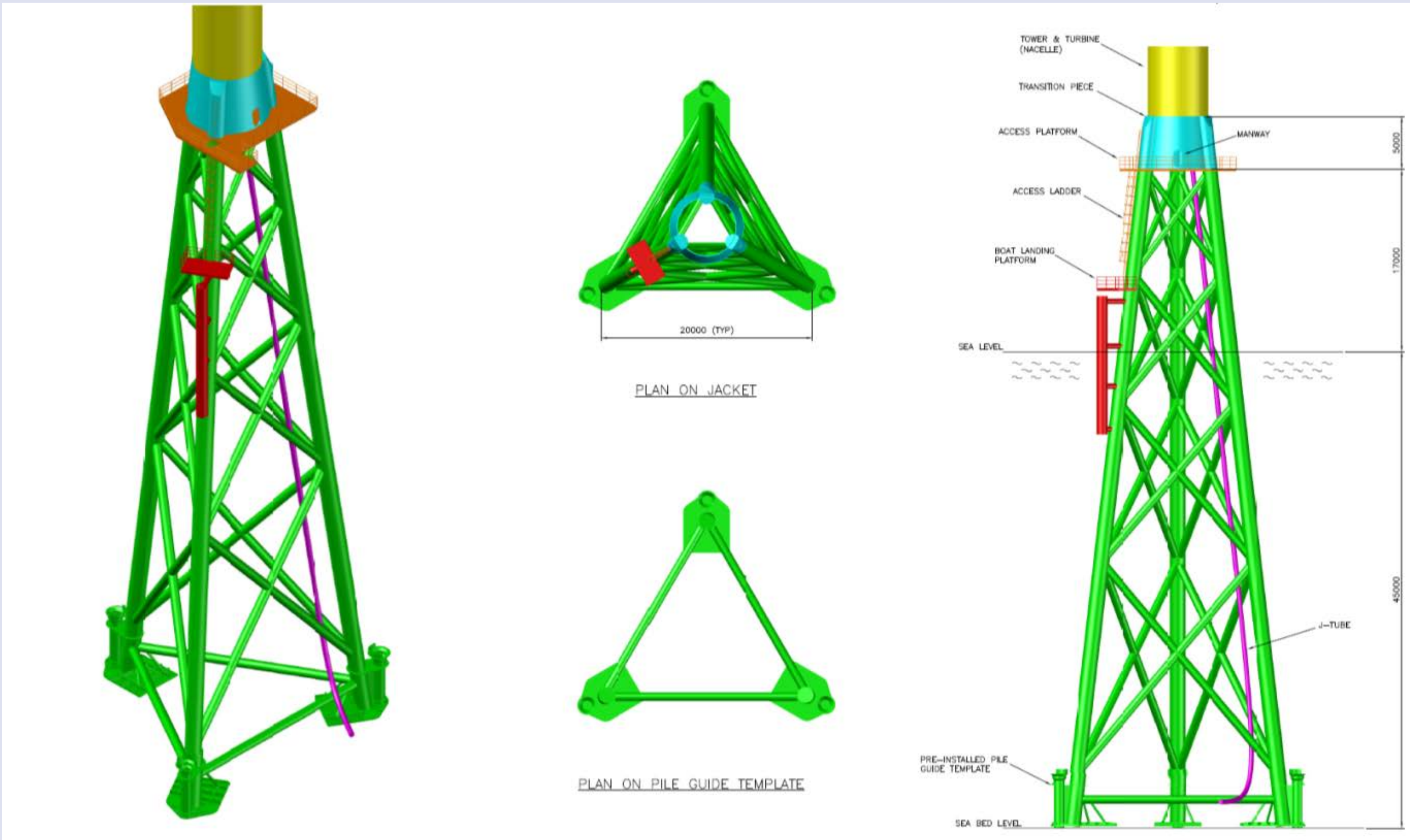
# *OGN Triton® - 3-legged jacket*

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# *Recommendations*

- RGF follow on work – Feasibility Study / Innovation Support
- Examination of specific areas:
  - Methods of automation
  - Assembly sequences
  - Specifics of design and associated fabrication methodology

# Feasibility Study

- Identification of candidate area(s) / structure(s)
- Considerations related to volume and design:
  - Weld metal volume
  - Process deposition rate
  - Welding time / duty cycle
  - Joint completion time
  - Associated level of automation required
- Production of method statement to allow physical trials

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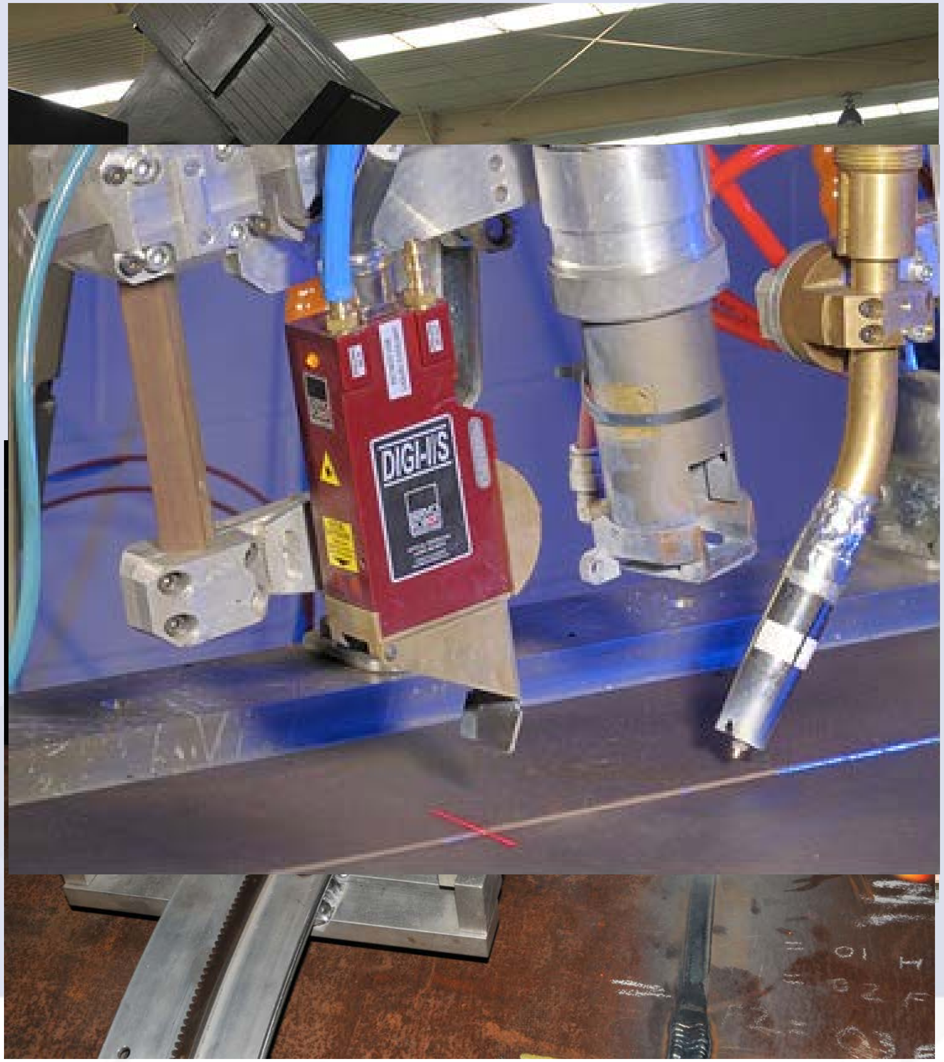
# *Factors considered*

- **Productivity requirements**
- **Fit-up**
- **Welding consumable**
- **Process variant**
- **Equipment specification**
- **Welding procedure**
  - **Position**
  - **Sequence**
- **Joint tracking**



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# Conclusions & Recommendations

- **Technical Challenges to address**
- **Route to developing a prototype**
  - **Specification of system**
  - **Procurement of system**
  - **Demonstration of system feasibility**
    - Full scale part
    - Subsequent testing of joints

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# Joint Industry Project

The overall objective is to provide fabricators with a low risk route to increasing productivity of large, complex structures whilst achieving appropriate integrity through:

- Developing standardised design criteria for OWTSS based upon relevant load data.
- Generating material (weld) data and acceptance criteria for welded joints.
- Developing a concept for low cost/high volume fabrication techniques.
- Developing and validating appropriate automated NDT techniques.
- Demonstrating the capability of the proposed manufacturing solution by setting up a demonstration fabrication cell and producing an example welded structure

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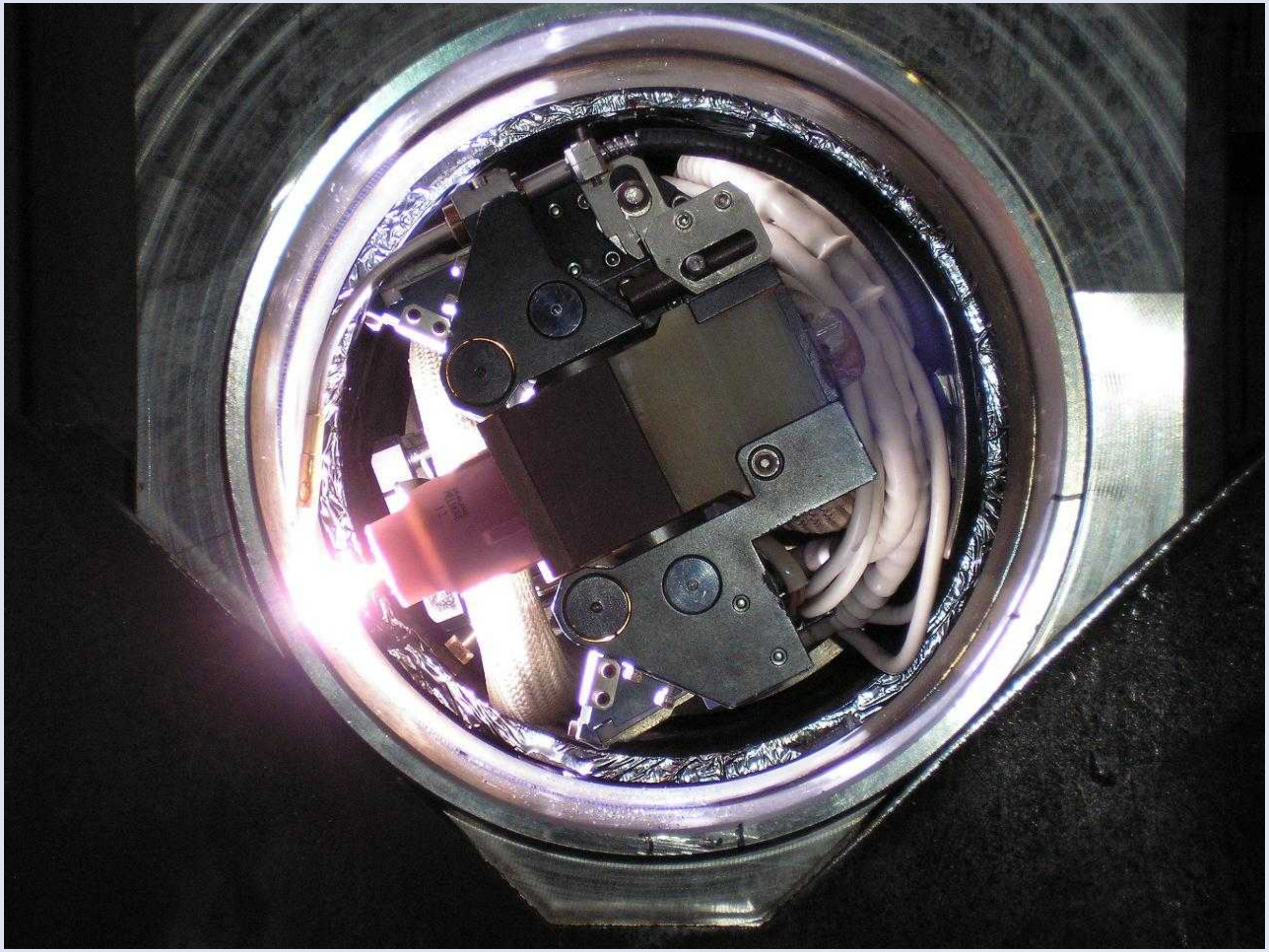
# Thank you

# TWI



# *Gaining ISO 3834*
# *The Assessment Process*

**Eur. Ing. Dave Godfrey C. Eng., C.E.W.E.,**

**Consultant Welding Engineer**

**ISO 3834 Lead Assessor**

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# I will focus on….

- What it is
- Reasons for Certification
- Certifying bodies, Accredited and Non Accredited
- Selection of the appropriate part of ISO 3834
- Stages of the assessment process
- Document review
- Main areas assessed during visit
- Use and control of subcontractors
- Requirements for and interview of RWC
- Surveillance visits and recertification

# Certifying Bodies

- **Authorised National Body**
- **UKAS Accredited**
- **EWF and IIW Approved**
- **TWI Certification Ltd**
- **TuV, DNV, IS**

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# TWI CL Assessors

- All TWI CL Lead Assessors are minimum E.W.T., with audit training, ISO 3834 & 9001
- Detailed knowledge of welding and fabrication
- Preliminary visit carried out by Assessor or Lead Assessor
- Full assessment carried out by Lead Assessor
- Trained in technical interview techniques

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# *Selecting the correct Part*

- **Pt. 2, Comprehensive, ie nuclear, pressure vessels, wind turbine towers, large buildings and bridges**
- **Pt. 3, Specific, ie general industrial equipment**
- **Pt. 4, Basic, ie handrails, balustrades, agricultural equipment**

- **Manufacturer must also define the “Scope of Approval”, and level of technical complexity, or may be specified by application standard**

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# *Stages of Assessment*

- **Initial Enquiry**
- **Preliminary visit**
- **Preliminary visit report**
- **Document Review**
- **Assessment visit and reporting**

# *Initial Enquiry*

- Go to www.iso3834.org and download:
  Preliminary information enquiry, form WFCS/F01

- Gives TWI CL idea of size of company, complexity of assessment, is site welding to be included?

- Quotation issued by TWI CL, order placed, assessment team appointed

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# Preliminary Visit

**Gap analysis, assesses:**

- **What you currently do and how you do it**
- **Reviews processes, procedures, organisation, defines required level**
- **Compares current status to ISO 3834 requirements**
- **Report issued highlighting any shortfalls**

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# Document Review

- Assesses written procedures/work instructions/processes against requirements of ISO 3834 & 14731

- Procedures required to demonstrate control of process in accordance with ISO 3834/14731

- Procedures must be implemented and output recorded

# Assessment visit

- Normally two day
- Interview with Director/Senior Manager
- Generally follows sequence laid out in 3834
- Demonstration of compliance to standard
- Interview with RWC

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# *Quality system aspects*

- Not a full system audit, only welding related aspects
- Responsible person from each relevant department is needed, and should be aware of their input to ISO 3834 requirements
- Records of requirement and technical reviews, production planning and equipment calibration records will be reviewed
- Subcontractor approval system must be demonstrated to comply with ISO 3834
- Welder  and NDT qualifications to be available, WPQR will be examined
- Control of Non Conformances and Corrective Actions must be demonstrated

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# Fabrication shop assessment

- System for identifying weld size and type
- WPS must be available to welders
- If welders inspect own work, must be competent to do so, and have tools available
- Consumable storage, issue and control
- Fabrication facilities and equipment
- Material identification and traceability
- Inspection status
- Control / segregation of non conforming items

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# *Subcontractor Requirements*

- **ISO 3834: Pt.2,3 must be assessed by visit to subcontractor, approved vendors list**
- **Must be able to demonstrate full control of welding and related operations**
- **Responsibility for welding quality remains with the main contractor**
- **May use main contractors procedures, but must also have own qualified procedures**
- **Copies of WPQR/WPS and welder qualifications must be supplied**

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# Duties of RWC

- Review materials and joint designs
- Identify and compile welding procedures
- Input into technical review, production planning, fabrication and inspection
- Responsible for compiling and implementing WQMS
- Assessing subcontractors
- Internal auditing of WQMS

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# *RWC Interview*

- Specific to your company, not transferable
- In line with ISO 14731 requirements but will focus on your company's materials, processes and products
- Depth of knowledge required comparable to C. Eng. / EWE or I. Eng. / EWT but targeted at your company's range of work
- Demonstrate that you know not just what to do, but why you should do it, what to do if things go wrong
- Demonstrate level of authority in the manufacturing organisation

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# *Demonstration of  knowledge*

- **Compile WPS from drawing and specification**
- **Work out preheat from mill cert using relevant standards, fully explain requirement for preheat**
- **Predict weldability problems from mill certificate**
- **Effect of variations in heat input on hardness and toughness**

# *Demonstration of knowledge #2*

- **Avoidance of hot cracking**
- **Marangoni flow in thin section stainless**
- **Sensitization, Σ formation**
- **Aluminium, effect of welding on HAZ**
- **Heat treatments**

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# *Outcome of Assessment*

- Manufacturer verbally informed of outcome on completion of visit
- Report / recommendation issued to WFCS Manager and Committee, copy to manufacturer
- Any NCRs to be cleared within 3 months
- Scheme Manager and Committee approve report, certification issued
- States Scope of Approval and names RWC
- Annual surveilance audit
- Valid for 5 years

TWI Technology Engineering

# *The End,*

## Any Questions?


# Welding and Fabrication Document Management

Andy Brightmore

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# Purposes of documentation

- Welding is a safety-critical activity
- Very easy to get it wrong
- Managing the documentation is an important part of any QA system
- ISO 3834

# Types of Documentation

- Welding Procedures
- Weld Maps/Weld Histories
- Welder Qualifications

# Welding Procedures - Weldspec

- Standards
  - EN 15614 parts 1 and 2
  - ASME IX
  - AWS D1.1
- Documents
  - WPSs
  - PQRs
  - pWPSs (preliminary/prequalified)

# Weldspec Code Rules

- Essential (etc.) variable lists
- Generation of test requirements
- Generation of qualification ranges

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# Welding Coordinator

- Documents
  - Weld Maps
  - Weld Histories
  - Weld Data Sheets
  - Fabrication Inspection Records
  - etc., etc.

# Welding Coordinator

- Reasons
  - Traceability
  - Control
  - Quality Assurance

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# Welding Coordinator

- Ensuring Quality
  - Appropriate WPSs
    - Links to Weldspec
  - Suitably qualified WPQs
    - Links to Welderqual
  - Generating NDT requests

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# Welding Coordinator

- Reporting
  - Progress reports
  - Performance reports
  - End of project reports/Completion reports
  - Many custom reports

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# Welding Coordinator

- Searching
- Monitoring of NDE requirements
- Prolongation of welder qualifications

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# Welder Qualifications - Welderqual

- Standards
  - EN 287/EN ISO 9606
  - ASME IX
  - AWS D1.1
- Documents
  - WPQs
  - Welder history logs

# Welderqual Code Rules

- Essential (etc.) variable lists
- Generation of test requirements
- Generation of qualification ranges
- Prolongation/Expiration

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# Welderqual Code Rules

- BS EN ISO 9606-1:2013
  - New method of prolongation
  - Based on filler materials not base materials
  - New groups of filler materials
  - New combined butt/fillet test
  - New backing details (ss fb, ci, ss gb)

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# Welderqual Code Rules

- Filler Material Groups
- FM1 Non-alloy or fine grain steels
- FM2 High strength steels
- FM3 Creep resisting steels Cr < 3.75%
- FM4 Creep resisting steels 3.75 ≤ Cr ≤ 12%
- FM5 Stainless and heat-resisting steels
- FM6 Nickel and nickel alloys

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# Welderqual Code Rules

- Filler Material Qualification

| Test | Qualifies |
|---|---|
| FM1 | FM1, FM2 |
| FM2 | FM1, FM2 |
| FM3 | FM1, FM2, FM3 |
| FM4 | FM1, FM2, FM3, FM4 |
| FM5 | FM5 |
| FM6 | FM5, FM6 |

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# More information

www.twisoftware.com

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