NEW ELECTRON BEAM TECHNOLOGY FOR ENHANCED PRODUCTIVITY

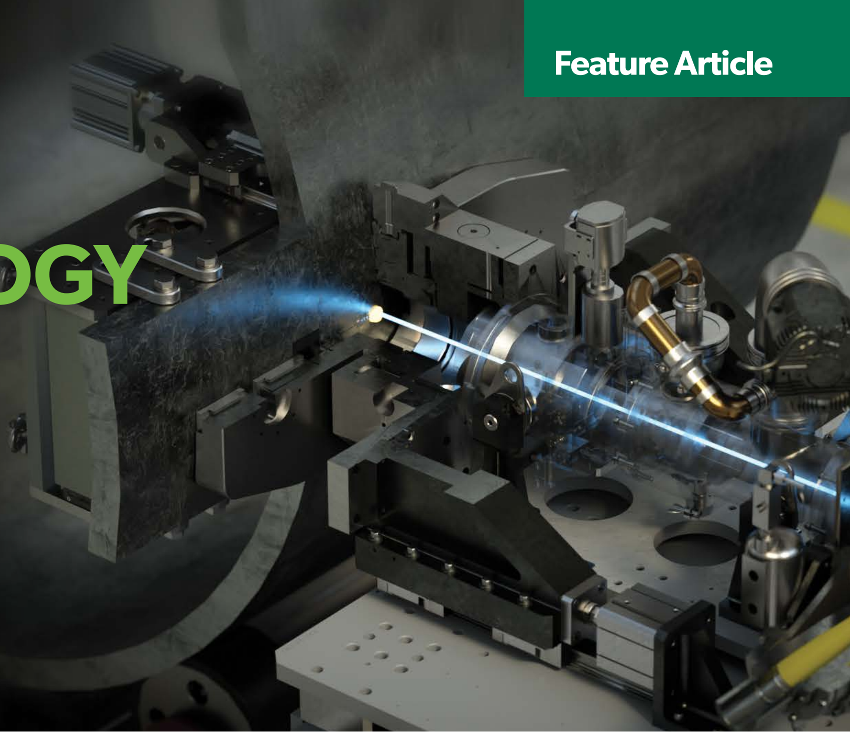

Figure 1: Graphic representation of Ebflow beam generator and local vacuum system. © published courtesy of Cambridge Vacuum Engineering.

Electron Beam Welding

Electron beam (EB) welding is a fusion welding process that uses a high-energy electron beam to join metals, with a wide range of applications in many industries. The process is extremely energy efficient (typically 95%), and the welds produced have excellent quality. Many of the benefits associated with electron beam welding are achievable because the process takes place in a vacuum, and typically in a chamber. Whilst electron beam welding is a long-established welding method within the automotive industry for components such as turbochargers and gears, or the aerospace industry for manufacturing gas turbine components, adoption in heavy fabrication industries is limited due to the process requirement for a vacuum environment. It can be extremely costly to build a vacuum chamber large enough to accommodate large components and structures. It is also very time-consuming and energy consumptive to pump down large chambers for high-productivity manufacture.

Highly Advanced Engineering and Process Development

After years of advanced engineering and process development, CVE has introduced a new technology – called Ebflow – to the market. Ebflow is an electron beam welding system that creates and maintains a local vacuum on the area where it is needed. Therefore, Ebflow brings the advantages of electron beam welding to structures of nominally unlimited size.

A system of sliding seals and precision handling enables fast longitudinal and circumferential welds on large cylindrical workpieces. A coarse vacuum is ideal for thick-section welding – achieving the very rapid thick-section joining rates. There is no filler wire, so the weld is autogenous. As a result, it can be heat-treated, and the weld rendered metallurgically almost indistinguishable from the parent materials.

Figure 2: Fully penetrating linear weld in 60mm thickness 304H grade austenitic stainless steel – completed in 8 minutes of welding time. © published courtesy of the EBManPower Project.

Ebflow is thus a versatile system with applications in a wide range of industries, for pressure plant and renewable energy generation, steel construction, shipbuilding and more.

Pressure Vessel Manufacture

Figure 3: Ebflow system installed in Cammell Laird shipyard for fabrication of demonstration nuclear pressure vessel in support of the EBManpower project. © published courtesy of the EBManPower Project.

CVE completed an Innovate UK supported project, EBManPower, in collaboration with TWI and Cammell Laird, to produce a welded vessel representing a full-size MMR pressure vessel. The project deployed an Ebflow system at Cammell Laird's shipyard in Birkenhead to demonstrate a low-cost and rapid manufacturing solution for thick-section vessels.

Typically, vessels like this would be welded using a multi-pass arc welding process. This can be a lengthy process that involves extensive pre-work, including fixtures, tooling, pre-heating of the components, and multiple weld passes. Furthermore, most arc welding processes can achieve a limited depth of penetration per pass. Therefore, a 140mm section could need up to 100 weld passes. Ebflow can weld material thickness of up to 250mm in a single pass – making it potentially 20-30 times faster than conventional submerged arc welding. It is also possible to perform the post-weld inspection immediately, with minimal weld prep/bevel required, and increased weld quality and reliability due to the inherent low distortion characteristics of the process.

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Figure 4: Completed demonstration pressure vessel with two longitudinal and three circumferential weld seams produced using Ebflow. © published courtesy of the EBManPower Project.

CVE then welded a second nuclear pressure vessel test assembly in a project supported by IUK in collaboration with Sheffield Forgemasters, TWI, and others. The project saw the installation of a local vacuum Ebflow system capable of welding 3m diameter cylinders to manufacture a full-sized (4.3m high x 3.0m diameter) vessel section typical of small modular reactor pressure vessel component. Ebflow achieved a continuous, fully penetrating 200mm thick weld on the demonstrator vessel in just 140 minutes.

Notably, the weld was performed in a low alloy steel without pre-heat or consumables and with an overall energy consumption of less than 100kWh. This represents a considerable saving in CO_2 emissions, in comparison with more conventional arc welding practices that require ~1,000kWh arc energy, and a pre-heat of ~180^{O}C before welding can begin.

The welded assembly was examined using several ultrasonic test methods, including conventional pulse-echo ultrasonic testing (UT) and time of flight diffraction (TOFD). TOFD is particularly well suited to the vertical EB weld joint preparation, resulting in a high level of accuracy in the size and position of weld imperfections. The tests confirmed that the weld zone was free from any reportable indications, as defined by the ASME acceptance criteria.

All electrical data is monitored continuously and captured so that it can be stored and uniquely linked to the welded part, providing a through life record of the welded component. The resulting weld is inspected in real-time with a temperature-resistant ultrasonic test method to provide immediate information on weld quality indication where detailed examination may be needed on completion of welding. The outcome is in line with the industry 4.0 data management approach.

Enabling Clean Energy Growth in Offshore Wind

The developers of the world's largest offshore wind farm will carry out the first large-scale pilot of Ebflow for welding in the fabrication of monopile foundation structures, which could reduce welding times by as much as 80%. Ebflow can streamline the fabrication process for offshore wind farms, further increasing the efficiency of large-scale projects and demonstrating increased cost- effectiveness of renewable energy for consumers. Ebflow can also reduce the carbon emissions associated with traditional welding methods by 90%. This is a collaborative project between SSE Renewables (a leading developer, owner, and operator of renewable energy across the UK and Ireland), Sif (a leading manufacturer of offshore foundations), TWI (the UK's foremost welding research establishment), and CVE (the designer and manufacturer of Ebflow).

The project is now reaching its first production phase, and Ebflow will be used to produce welds in the fabrication of offshore wind foundation monopiles and transition pieces for the Dogger Bank Wind Farm. When complete, Dogger Bank will be the largest offshore wind farm in the world. The consortium looks forward to sharing the results of the project upon completion.

Chris Punshon, Head of New Energy Applications, Cambridge Vacuum Engineering (CVE)

QUICK LINKS: WELDING BASICS

Terminology of the different welding processes, (with the process numbers in BS EN ISO 4063:2010)
https://www.twi-global.com/technical-knowledge/job-knowledge/welding-and-joining-process- classification-001

What is manual, semi-automatic, mechanised, and automatic welding
https://www.materialwelding.com/what-is-manual-semi-automatic-mechanised-and-automatic- welding/

Welding processes primer: MMA, TIG, MIG/MAG and Plasma welding
https://www.ewm-group.com/downloads/262194

The ESAB University
https://training.esabna.com/

QUICK LINKS: WELDING MECHANISATION, AUTOMATION AND ROBOTICS

Where machines could replace humans—and where they can't (yet).
https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/where-machines-could- replace-humans-and-where-they-cant-yet

What is automation and when should I consider its use in welding?
https://www.twi-global.com/technical-knowledge/faqs/faq-what-is-automation-and-when-should-i- consider-its-use-in-welding

Difference between mechanised, automated, and robotic welding
https://www.twi-global.com/technical-knowledge/faqs/faq-what-are-the-differences-between- mechanised-automated-and-robotic-welding

Welding automation https://www.millerwelds.com/products/automation-solutions

Robotic system integration

https://www.cyberweld.co.uk/?gclid=Cj0KCQjwviWBhD8ARIsAH1mCd5frgJqhH9uprFxkqPNjR3RBd_ KcbmyQGyIWYv8RJeniePy-4Mw4soaAsAKEALw_wcB

Automation for arc welding
https://www.kuka.com/en-us/industries/metal-industry/arc-welding

Collaborative robots
https://www.jakarobotics.com/products/jaka-pro/

State of the art of robotic welding
https://www.metalworkingworldmagazine.com/state-of-the-art-of-robotic-welding/

Welding and cutting carriages
https://www.gullco.com/products/welding-cutting-carriages/