Electron Beam Welding

Process Summary

Electron beam welding (EBW) is a joining process where a beam of high-velocity electrons is utilised for welding materials together. Upon impact, the high kinetic energy of the electrons is transformed into heat, melting the material and fusing two parts together. In order to prevent dissipation of the electron beam EBW usually requires vacuum which is beneficial for the weld quality too by avoiding oxidation or contamination. Commonly the required vacuum chamber is also used as a radiation protection enclosure against X-rays produced by the process. The electro-magnetic nature of the electron beam allows easy control and fast deflection of the beam facilitating automated CNC driven manufacturing.

Process Advantages

Due to the high energy density of the electron beam the process generally has a very localised heat input leading to a very narrow fusion and heat affected zone, high depth to width ratio welds and low distortion. Single pass butt welds may be made without costly filler material and interstage non-destructive testing. Single pass welding is also possible for thick joints, generally to thicknesses of 100 mm but significantly higher thickness are also achievable with specialised set-ups. EBW is a very rapid joining process and welding velocities of several metres per minutes can be realised, depending on the quality required and the part thickness. High quality welds with low levels of contamination can be achieved due to welding in vacuum. Another advantage of this process is the capability to accomplish the joining of dissimilar metals for certain material combinations. An alternative application for EBW is the production of hermetic sealings of components whilst retaining an internal vacuum which may be applied for example for hot isostatic pressing as a follow-up non-fusion joining process. By including wire feeding systems it is possible to modify the chemical composition of the fusion zone in order to control certain material properties, to repair worn parts such as titanium aero blades, or to build up new three dimensional parts (additive manufacturing).

HVM capability

The HVM Catapult EBW capability is located at the Nuclear AMRC which operates two EBW facilities. Details of the set-up are given in the table below. The K25 is a medium sized unit where the EB gun is attached externally either vertically or horizontally. The K2000 consists of a mobile EBW gun mounted inside of the vacuum chamber on a gantry system allowing linear CNC movements of the gun in three directions and rotations around two axes. The vacuum chamber has a volume of 208 cubic metres and is the largest in the UK and possibly the largest operated by an academic institution in the world. The powerful mechanical and diffusion pumps can achieve a vacuum of 10-4 mbar within 45 minutes.

Capability details of the K25 and K2000

	Units	K25	K2000
Chamber size	[m^3]	1.6x1.2x 1.2	8.7 x 5.2 x 4.6
Chamber volume	[m^3]	2.5	208
Max. work piece size	[m^3]	Task dependent	6.4 x 4.0 x 3.2
Max. work piece load	[tonne]	0.5	100
Max. x-y working envelope	[m^2]	0.7 x 0.3	6.2 x 3.4
Max. z working envelope	[m]	0.2	3.1
Max. rotational axis diameter	[m]	0.6	3.0
Max. beam power	[kW]	40	30
Max. acceleration voltage	[kV]	80	60
Max. beam current	[mA]	500	500
Wire feeder	#	n/a	2 off (Ø 0.8-1.2 mm)
Pump down time	[min]	10	45

Typical applications

EBW is widely used in industry where high value, high quality welds are required. The extremely stable and high repeatability of the process makes it ideal for automated mass production. EBW is for example extensively utilised in the manufacturing of automotive and aeronautic components. One goal driven within the HVM Catapult is to develop EBW manufacturing routes for large scale, thick walled components such as those required in small modular nuclear reactor plants.