Description

Image

 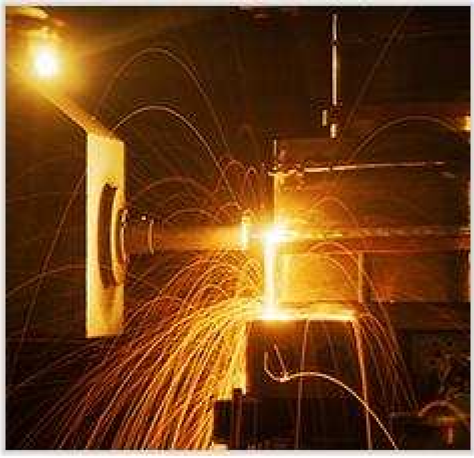 

Image caption

(1) Power beam © Granta Design at TU Delft University (2) Electron beam welding © TWI Ltd at flickr (3) Surface modification of a piston to aid oil retention using electron beam processing © TWI Ltd at flickr

The process

In ELECTRON BEAM WELDING, melting is produced by the heat of a focused beam high velocity electrons. The kinetic energy of the electrons is converted into heat when it hits the work piece, which has to be contained in a vacuum chamber, and it must be a conductor. No filler metal is used. The process is more energy-efficient than laser-beam welding, allowing higher power densities and the ability to weld thicker plates. In LASER BEAM WELDING, the heat source is a narrow beam of coherent monochromatic light. The process is more precise than e-beam welding and takes place in air, allowing greater design freedom, but the penetration depth is less (maximum 20mm in metals). Shielding gas is blown though a surrounding nozzle to protect the weld. Again, no filler metal is used. It is possible to laser weld thin, semi-transparent or opaque polymer films by simply scanning the beam across them, melting them right through, but this is not the best way to use lasers. The trick in welding polymers is to arrange that the beam is absorbed where it is most useful - at the joint interface. For transparent polymers this can be achieved by spraying a thin film of IR or UV-absorbing dye, invisible to the human eye, onto the surface where the weld is wanted; the laser beam passes through the transparent upper sheet (which can be thick - up to 10mm) without much energy loss. But when it hits the dye of the interface it is strongly absorbed, melting the polymer there and creating a weld whilst leaving most of the rest of the material cold. Scanning the beam or tracking the work piece gives a line weld up to 10mm wide.

Process schematic

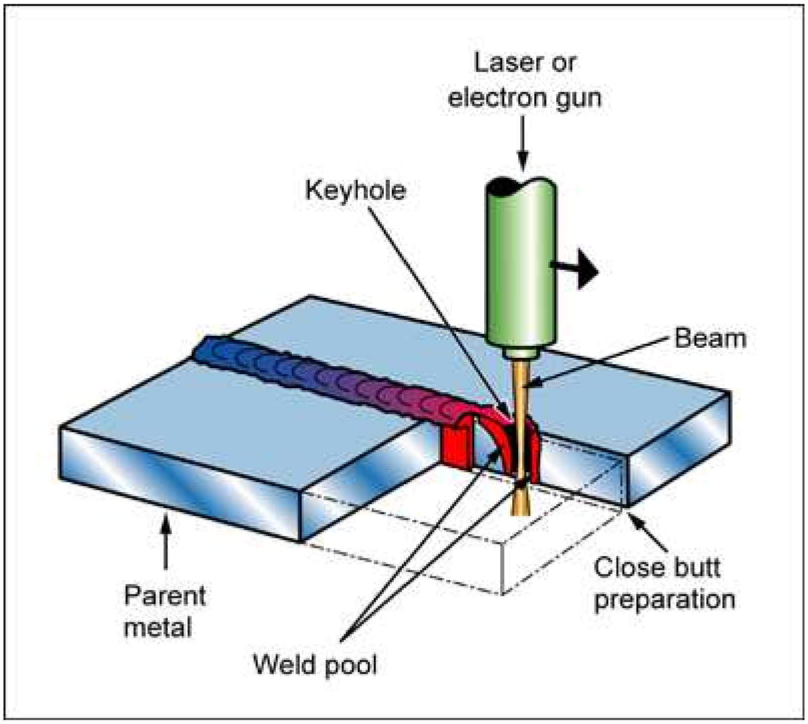

Figure caption

Laser and electron beam welding of metals and polymers

Material compatibility

Metals - ferrous	✓
Metals - non-ferrous	✓

Function compatibility

Electrically conductive	✓
Thermally conductive	✓
Watertight/airtight	✓
Demountable	✗

Joint geometry compatibility

Lap	✓
Butt	✓
Sleeve	✓
Scarf	✓
Tee	✓

Load compatibility

Tension	✓
Compression	✓
Shear	✓
Bending	✓

Torsion	✔
Peeling	✔

Economic compatibility

Relative tooling cost	high
Relative equipment cost	very
Labor intensity	medium

Physical and quality attributes

Range of section thickness	0.3	-	50	mm
Unequal thicknesses	✔			
Processing temperature	207	-	1.93e3	°C

Process characteristics

Discrete	✔
Continuous	✔

Supporting information

Design guidelines

The high power-density in the focused beam gives narrow welds with minimal penetration of heat into the work piece, allowing high weld speeds with low distortion. Accurate machining of mating components is needed, since no filler metal is used. The processes allow products to be made that could not be fabricated in any other way. Welding polymers (particularly transparent polymers) without an interfacial dye is limited to the joining of thin thermoplastic film and sheet. Welding with a dye give more control and allows thicker sections. Dissimilar materials can be joined, although their melting temperatures must be comparable. The main feature of the process is that it is non-contact, and exceptionally clean and fast.

Technical notes

Electron beams have a power of 1 - 100kW, allowing welding of plate from 1 - 200mm thick, but the process requires a vacuum chamber, limiting the size of the assembly. Laser beam equipment has lower beam power - typically 500W - 5kW, although lasers up to 25kW exist. Laser beam welding is preferred in the microelectronics industry because it is clean and requires no vacuum chamber. E-beam welding - because of the vacuum - is particularly suited for refractory metals such tantalum, niobium, molybdenum and tungsten. Laser welding can be used for these too, but it is essential that the metal should not have a shiny surface since this reflects the beam. Coatings are available to increase absorption. The strength of a well-designed laser-welded lap joint in polymers often exceeds that of the parent film or plate. For thin films the weld speed can be up to 30m/min, but for films as thick as 1mm the speed is less: about 1m/min. Control of the laser profile allows simultaneous welding and cutting (the 'cut-seal process'). The use of an interfacial dye deposits the heat at the interface, and allows much faster joining. If one of the two sheets being joined is color, and the other is transparent, the color sheet should be placed furthest from the beam.

Typical uses

Electron beam welding is used extensively to assemble gears and transmissions for automobiles, aircraft engines and aerospace products. High capacity electron beam equipment is used for pressure vessels, nuclear and process plant and chemical plant. Laser beam welding is used where precise control is important: joining of microelectronic components and thin-gauged parts like bellows and watch springs. Increasingly, the process has been adapted for automobile components - gears, transmission assemblies, aerospace and domestic products. Laser welding of polymers: food packaging and the sealing of biomedical materials and equipment. There is growing interest in its use for welding of PET and other polymers for structural use.

The economics

The cost of power beam equipment is high, and - for e-beam welding - cycle times are long because of the need to evacuate the vacuum chamber. The equipment and tooling are both expensive, but the speed and controllability compensate for this in large-scale manufacturing. When production volumes are large as in the automotive industry and the microelectronics field, the high investment can be amortized; and the high welding speed, single pass welding and freedom from the need for secondary operations make the process economic.

The environment

Electron beams generate rays, infra red and ultra violet radiation. Laser beams are damaging - particularly to the eyes. Proper protection is essential for both, so high powered lasers require strict safety procedures. But apart from this, the process is attractive from an environmental standpoint: it is clean, involves no chemicals, and produces no waste.

Links

MaterialUniverse

Reference