

Narrow seams – reliable connections

welding



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Applications of electron beam welding in various businesses, e.g. 1. Medicine 2. Supply of raw materials and energy 3. Track and railroad technology

Welding with an electron beam

Narrow seams

Minimum angular distortion and transverse shrinkage

Economic technique

- Productive due to high welding speed
- Ability to reduce costs due to alternative design options
- No additional material required
- Simple seam preparation

Material optimization

- A wide range of materials can be welded
- Flexibility of materials choice according to local requirement

Automation of processes

All process parameters are of electric nature and therefore can be easily measured, controlled and monitored.

The electron beam technique is very reliable in producing deep yet narrow and parallel welding seams. Angular distortion and transverse shrinkage and other unwanted effects are minimal particularly when welding sensitive parts.

The potential application ranges from welding ultrafine films to joining work pieces more than 200 mm thick in a single pass. The design of mechanical parts profits from the freedoms made possible by the electron beam technique. This principle applies just as well to processing parts for aerospace and space exploration, boat construction or large-quantity mass production in electrical and automotive industry.

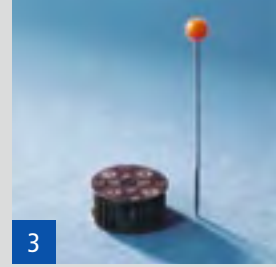
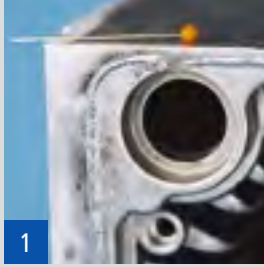
Technique ■ As an elementary particle of matter, the electron is an excellent medium for transferring energy. When electrons are decelerated, they release their energy in form of heat precisely at the point of impact. The surrounding material remains basically cold. Due to the deep welding effect, narrow, deep seams can be produced. Electron beams are easily deflected, so they can be controlled precisely.

Vacuum ■ Working in a vacuum makes it possible to focus the beam to a small spot. When reactive materials are joined, such as titanium, zirconium or niobium, the best metallurgical values are achieved in a high vacuum at a pressure of 5×10^{-4} mbar. From a cost perspective, creating a vacuum is usually less expensive than working in an inert gas atmosphere and harmful emissions are avoided.

Production planning ■ Electron beam welding releases new potential for design and product planning. The joining technique tolerates relatively rough joint faces and can be placed in any stage of the production line. It can even be at its end, because it does not interfere with the finishing of machined parts, the surface finish or the assembly of part groups prior to welding or hardening of components.



1. Heat exchanger made of die cast aluminum
2. Large piston for commercial vehicles (ø 175 mm)
3. Planetary drive for hand prosthesis



Deep welding with a focused electron beam



Typical deep welding in bronze/steel (30 mm, upper photograph) and aluminum (150 mm, lower photograph)

Electrons are elementary particles of matter; they usually adhere to atoms. They can be removed from their shell by imparting energy to them. A cathode is heated, to emit and form a cloud of free electrons. With voltages 30 to 200 kV, they are accelerated towards the anode. Suitably arranged control grids and electromagnetic lenses focus the free electrons, creating a narrow beam of electrically charged particles. In an electron gun, the electrons attain speeds of between one- and two-thirds of the speed of light.

The deep welding effect

When electrons penetrate material, they decelerate and release their kinetic energy (mostly as heat). The deep welding effect is produced as follows. One electron after another blasts the surface of the work piece and heats a spot. At energy densities greater than 10^6 W/cm², the melted material at the center of the so-called focal point evaporates. This produces a vapor capillary surrounded by molten material. This allows the beam to penetrate deeper and to melt more solid material. If the work piece is moved relative to the beam, then the material in front of the beam will melt, flow around the vapor capillary and solidify behind it. The deep welding effect makes it possible to create narrow welding seams with depths of greater than 100 mm.

Rapid welding ■ Very high process speeds compared with other techniques:

For thin foils up to 60 m/minute (1,000 mm/s) at power densities of up to 10^7 Watt/cm². Welding speeds typically range between 10 and 100 mm/s for welding depths between 20 and 2 mm. A steel plate 200 mm thick can be welded in one pass at a feed rate of 1.25 mm/s, equivalent to 13.3 minutes for one meter of seam length. By comparison, submerged arc welding with a tandem arc requires 10 hours per meter and manual shielded metal arc welding takes 130 hours per meter (values taken from the U.S. standard for steel or boiler plate). The filler material required for conventional welding techniques alone often costs as much as producing the entire seam with the electron beam technique.

Energy density in the focal point ■ 10^5 to 10^9 W/cm², spot diameter 0.1 to 2 mm

Aspect ratio (ratio of depth to seam width) ■ up to 50:1

Permissible joint gap ■ The maximum permissible gap width is one to five percent of the welding depth, but at most 0.3 mm. Deviations from these values must be checked for each specific application.

Sensitive sensors, stable connection

Precision in mass production



Components with sensitive inner parts, such as sensors, profit from the advantages of electron beam welding. Little heat is transferred to the surrounding material or inner circuitry. For the manufacture of pressure sensors, this is a decisive advantage.

Welding at the end of the process line

A pressure sensor contains a strain gauge manufactured by thin film technology. It reacts sensitively not only to pressure but also to temperature changes during the manufacturing process. For this reason, when the sensor area is welded into the housing as a final operation, thermal stress must be avoided. Also, welding should only contribute to very minor contraction strain and any such strain must be symmetrical. Otherwise, this final production step will distort the measurement characteristics of the sensor. With sensors used for pressures up to 2,000 bar, the strength of the welding seam is important. Seam depths of 4 millimeters ensure the sensors will withstand considerable stress. Such sensors, for example, are in use on drilling platforms.

In the automotive field, the advantages of the electron beam welding technique like low distortion or precise control of the process parameters come to bear. With automatic transmissions, the overall tolerance of the assembled parts and part groups permits a smooth operation. Audi uses this capability, for instance, with its innovative Multitronic transmission. Welding a drive gear must be very precise. A gear wheel made of case hardening steel is welded onto an assembled transmission part, a planetary carrier.

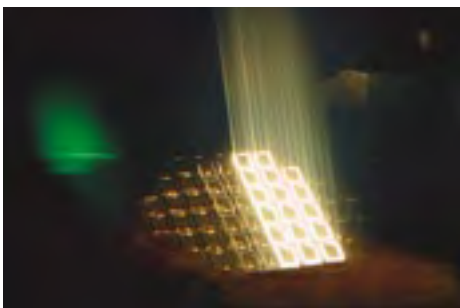
Reliability with minimum tolerances

When the planetary carrier is manufactured, the sheet metal of a clutch housing must be welded to a forged web. This web is 5 mm thick; however, the weld seam must not penetrate through. Because of the complicated geometry of the clutch housing, other techniques do not perform this task with the required reliability.



1. Pressure sensor
2. Transmission shaft for a 750 Nm transmission e.g. in VW Touareg and Porsche Cayenne

Constructive solutions from the electron beam laboratory



Multi-beam technique

The electron beam technique provides you, the design engineer, unimagined freedom when dealing with joining problems. Optimised material selection can then lead to cost saving production.

Working with an electron beam ensures low distortion and greatest precision. In addition, using an electron beam overcomes the limitations of other welding techniques.

As an example, with the electron beam technique pro-beam can reliably join pressure cast aluminum parts. Separating agent residue, trapped in the material as a gas, can escape slowly so as not to cause an explosion. In an innovative twin-beam welding process, iron and aluminum can be joined, thanks to a thin intermediate layer of copper. With high-strength nickel alloys, in many cases the formation of hot cracking can be avoided by offset focused heating. These are three examples of innovative thinking expanding the realm of technical potential, step by step.

Reliability in mass production – parts crucial for safety are welded with the electron beam technique



Connections made of separate parts – better than parts made in one casting

Process parameters for welding

Welding speed:
approx. 1,000 mm/s in light-gauge sheet metal and 1.25 mm/s for steel 200 mm thick

Energy density in the focal spot:
 10^5 to 10^9 W/cm²

Diameter of the focal spot:
adjustable from less than 0.1 mm to more than 2 mm

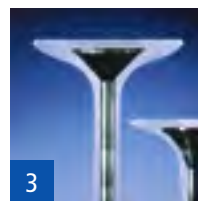
Ratio of depth to width of seam:
up to 50:1

Maximum permissible gap width:
5 to 10% of metal thickness,
maximum 0.3 mm

Train carriages couplings are subject to very high stress. An innovative design from pro-beam makes it possible to manufacture these couplings from separate standardized and various individual parts, in different configurations. Previously, the couplings were made from one-piece steel that was subsequently tempered.

However, the part can be broken down into individual components - a spring housing and a coupling lug made of heat-treated steel, which is subject to high loads. Thanks to the welding technique, the housing can be manufactured from standard pipe and flanges made of fine-grain construction steel. With an electron beam, these two elements can be welded together reliably and very precisely. For each variation, the required processing steps are performed in advance, upon the easy to handle, single components. Welding is the last operation in the process line. As these couplings are crucial for safety, they have to be certified by quality assurance representatives of the railroad company.

By optimizing the material for the couplings and reducing logistics and storage expenses, it is possible to reduce production costs significantly. The same lugs are used for the ICE high-speed train, trams in cities like Munich, for the Öresundsbahn as well as in Singapore and Shanghai. – A clear demonstration of how flexible this technique is.



1. Special spark plugs for gas engines
2. Coupling for the Shanghai subway
3. Sodium-cooled cavity valve

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