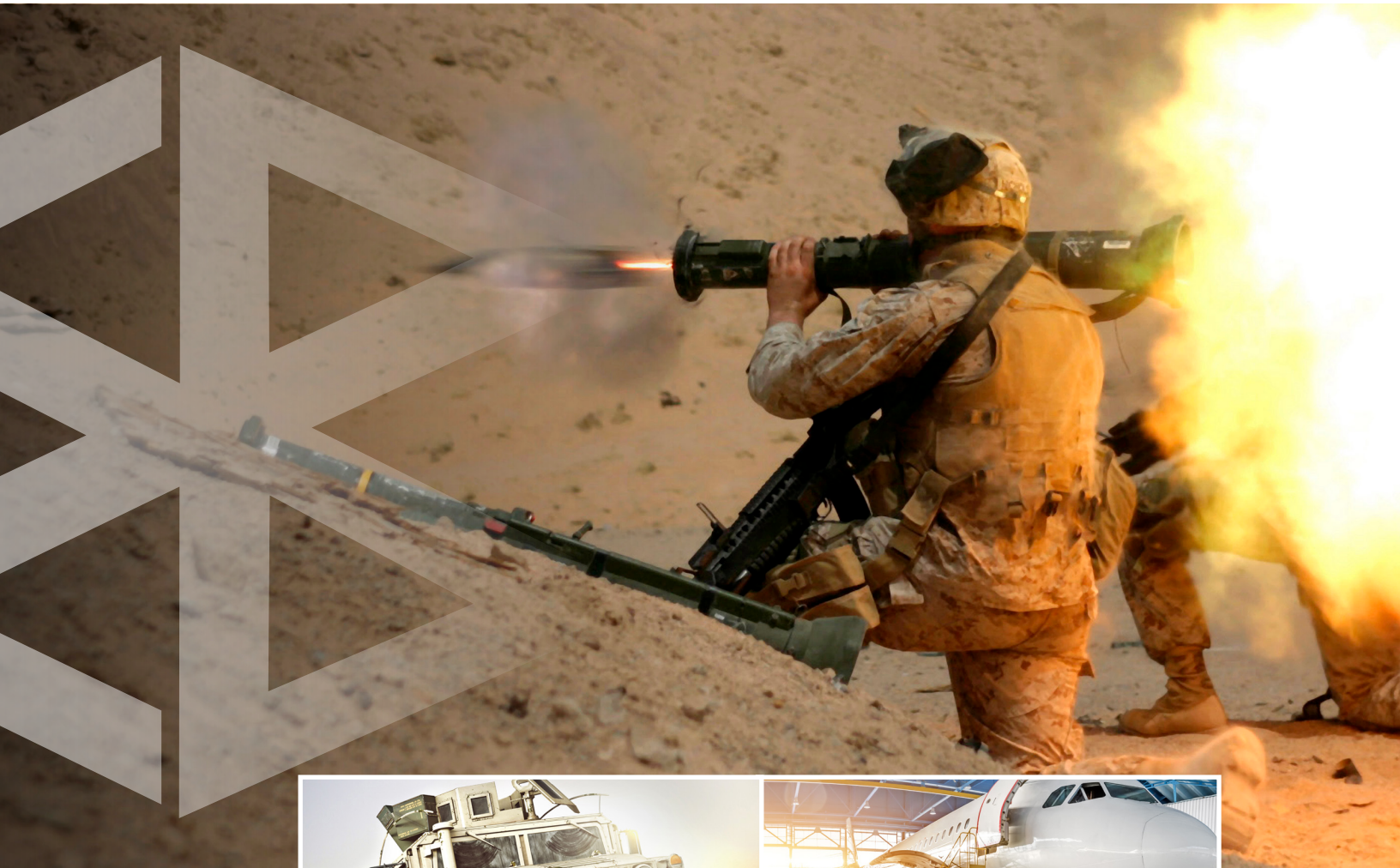




TIG Welding vs. Electron Beam Welding

WHITE PAPER





Welding is a critical technology that the aerospace, defense, medical and many other industries rely on to manufacture the components they need. Choosing a welding technique can make or break your project, so it's important to understand what options are available and when to choose one over the other. This paper compares TIG and electron beam welding, two of the most common ways to weld metals, to help understand the distinctions between them.

When choosing any weld technique, it's important to understand which is best for your specific application, since each has advantages in precision, penetration, energy usage, ability to weld challenging materials and even safety. This paper will discuss those differences in greater detail.

What is TIG Welding

First, let's define the two technologies we're exploring, beginning with Tungsten Inert Gas or TIG welding. Gas Tungsten Arc Welding (GTAW), commonly known as Tungsten Inert Gas (TIG) welding, is an advanced arc welding technique that utilizes a non-consumable tungsten electrode to create precise welds. Initially gaining prominence in the 1940s for its efficacy in joining magnesium and aluminum, TIG welding revolutionized the industry by employing an inert gas shield to safeguard the weld pool, a notable departure from traditional methods reliant on slag. TIG welding transmits electricity through a tungsten electrode to form an arc with the metal at the weld site. TIG welding is traditionally performed using a filler rod, and an inert gas is used to keep the weld free from contamination. Without proper shielding, gases in the air like oxygen (and in the case of titanium, nitrogen) will react with the metal to form oxides and other compounds that can introduce impurities into the weld and weaken it. This innovation quickly positioned TIG welding as a preferred alternative to both gas and manual metal arc welding, particularly renowned for its exceptional suitability in welding aluminum to exacting standards for both structural and high-quality applications.



In contrast, Gas Metal Arc Welding (GMAW), alternatively referred to as Metal Inert Gas (MIG) or Metal Active Gas (MAG) welding, operates through the creation of an electric arc between a consumable MIG wire electrode and the workpiece metal(s). This process effectively heats the workpiece metal(s), inducing fusion wherein they melt and join together. Alongside the wire electrode, a shielding gas is directed through the welding gun to safeguard the welding environment from atmospheric pollutants.

GMAW can be executed in semi-automatic or fully automatic modes, typically powered by a constant voltage direct current source, although constant current systems and even alternating current are also viable. The method of metal transfer in GMAW varies across four primary modes: globular, short-circuiting, spray and pulsed-spray, each distinguished by unique characteristics that offer specific advantages and constraints depending on the application at hand.

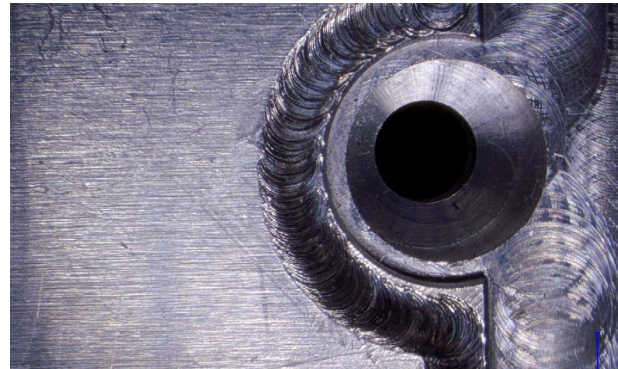
GTAW is used in a wide variety of applications:



- Food and medical equipment where complete fusion and good surface finish are required to prevent contamination
- Tubing for high vacuum systems
- High purity gas systems
- Jet and rocket engines
- Automotive, industrial and aircraft exhaust systems

What Is Electron Beam Welding?

While both electron beam welding and TIG welding use electricity, the way they use it is quite different. Electrons are generated (via an electron gun) and then accelerated to very high speeds using electrical fields. This high speed stream of electrons is then focused using magnetic fields and precisely applied to the materials to be joined. As the electrons impact the materials their kinetic energy is converted to heat, which causes the metals to melt and flow together. Electron beam welding generally occurs in a vacuum as the presence of gas molecules can scatter the beam.



The electron beam has to be contained in a vacuum chamber to prevent it from dispersing due to interactions with gas molecules between it and the target site, among other factors. Because of the high voltages involved in EB welding, and the required vacuum, the entire process is computer controlled and heavily automated. The precise nature of the technology often calls for specialized fixtures to secure parts for joining, and CNC tables are commonly used to move the fixtures and workpieces within the welding chamber.

Comparing the Two

GTAW is used in a wide variety of applications:

- Precision and control/weld quality
- Microwelds
- Penetration/heat input
- Vacuum environment
- Versatility with materials
- Material distortion during the weld
- Throughput
- Safety

be more flexible for working with large pieces, since some welding applications have size restrictions. In addition, TIG welds are excellent for rough-cut parts that have gaps between the surfaces to be welded, since the required filler metal can fill those spaces. However, while many are initially attracted to TIG as a low-cost approach, there are a variety of performance disadvantages to TIG that the engineering and quality teams must take into consideration.

While TIG welds have some areas where they shine, there are several factors that limit their use. The welding process is slower than many other kinds of welds at about 5 inches a minute, which in turn makes the weld less precise and lengthens production time. In addition, the use of a filler metal can sometimes reduce the purity of the weld or potentially weaken it. Furthermore, it can be more challenging to use TIG welding to join dissimilar metals if they have properties that make them less compatible, such as different melting points.

Considerations for TIG Welding

There are several notable advantages to TIG welding for some applications. If TIG welding is an appropriate option for a project, it's often a less expensive choice than something like electron beam (EB) welding. It can

Advantages of Electron Beam Welding

Electron beams can focus a lot of energy in a very small area, as much as 10,000 kW/mm³, which enables them to create welds with extreme precision and strength. The high power and ability to precisely target small areas give these welds several advantages that make them a superior choice for many applications.

1 Higher Quality Welds

Welds made with electron beams can have a very high aspect ratio, or in other words, they have a deep, narrow structure compared to other types of welding. The ratio of width to depth can be as low as 1/10, compared to 1/4 for (true) laser welding. This is because electron beams can be focused more intensely in a smaller area, so they're capable of heating sections of metal a lot faster than TIG welding can.

Since the beam can be applied for a shorter amount of time, there's less time for heat to spread through the material. This means the weld will have less distortion and a smaller heat affected zone. The heat affected zone is the area on the metal that isn't part of the weld, but where the heat dissipating from the weld was enough to change some of the material properties of the metal. Minimizing the heat affected zone creates stronger welds since the material is more consistent throughout the piece.

The vacuum environment required by the electron beam also ensures the weld will have little to no impurities that can affect the material properties of the metals or otherwise weaken the weld.

2 High Repeatability, Precision and Control

Electron beam welding works extremely well with manufacturing many identical pieces repeatedly. This is because the beam's precision and accuracy keep welds consistent across multiple pieces, where a weld done by hand may have variations in the applied heat. As a result, EB welds will have more consistent material properties for multiple components. In general, EB welding provides unparalleled precision and control over the weld, allowing for the welding of parts with minimal heat affected zones, reducing thermal distortion and allowing for the joining of complex and delicate components with remarkable accuracy. Being that the process takes place in a vacuum; the process must be fully automatic or at the very least semi automatic. The parameters and feed rate remain consistent for the length of the job with a much reduced possibility of human error.

In addition, many facilities that provide EB welding services, such as EB Industries, are already equipped with CNC machines that make it straightforward to program repeated actions. Programming the actions needed to perform the welds makes automation not just possible, but fast and reliable. While setting up the machine may require initial time and testing investment, it ultimately saves considerable resources, especially with high volumes of welds.





3 Microwelding

The accuracy and precision electron beams are capable of making them excellent at making welds that are very small, including welding things like tiny syringe needles, or tubing that is less than half a millimeter thick. Additionally, the absence of contamination in the vacuum environment is crucial, as even small impurities can have a significant impact at such a small scale.

4 Deep Penetration with Minimal Heat Input for Faster Production

EB welding can achieve deep penetration in a single pass without the need for filler material, as mentioned earlier, thanks to its high energy density. This is particularly beneficial for thick sections that would require multiple passes with TIG welding, saving time and reducing material stress.

5 Vacuum Environment Advantages

While the requirement for a vacuum may seem like a limitation or complexity for your plant, it actually offers several benefits. Welding in a vacuum environment eliminates the possibility of oxidation and contamination, resulting in cleaner, stronger welds. This is especially important for materials that are sensitive to atmospheric gases.

6 Dissimilar and Complicated Metals

One of electron beam welding's major strong suits is the ability to easily weld dissimilar metals, making it ideal for applications where advanced materials are common, such as aerospace, nuclear and defense.

Welding metals with different properties can get complicated quickly due to differences in melting points, coefficients of thermal expansion, heat transfer rates and other variables. Most types of welding require both of the dissimilar metals to melt in order to form the weld, but electron beam welding can be used to melt one metal directly onto the other if there's enough of a difference in melting point.

EB welding can also be used to weld copper to other metals, such as several alloys of Stainless Steel, which is difficult to weld due to its high thermal conductivity. The fast weld speed and high aspect ratio make welding copper much more manageable than it would be with some other methods for welding.

7 Throughput

The ability to automate EB welds reduces the amount of time needed to process a large quantity of the same piece, but it isn't the only reason EB welding is a good choice for this type of work. The welding process itself is much faster than most other kinds of welding, with feed rates up to 200 inches per minute. This is about 40 times faster than an average TIG weld. For high-volume production environments, especially those involving small-to medium-sized components that can be easily loaded into a vacuum chamber, EB welding can offer higher throughput rates in ways that can reduce labor costs and enhance consistency across welds.

8 Safety

Never an afterthought, electron beam welding, as a fully automated process that takes place in a vacuum chamber, minimizes operator exposure to welding fumes and intense light, providing a safer working environment.

Limitations of Electron Beam Welding

Electron beam welding can do a lot, but it can't do everything. The biggest drawback to EB welding is the amount of specialized equipment, facilities and personnel required. Vacuum chambers are expensive, complicated pieces of equipment that require maintenance and trained personnel to operate them. The electron beams need high voltage electronics, which have their own expenses and requirements. The beams also generate radioactivity while they are running, so the vacuum chambers have to be lead-lined and other safety measures put into place to protect personnel during operation.



What To Consider When Choosing TIG vs EB Welding?

There are some occasions when TIG welding is likely a better choice: if the joints to be welded don't fit together well, if the weld will need to be grinded flat or when the pieces to be welded can't fit inside a vacuum chamber. In other cases, EB welding is usually the best option: when precision and quality are a top priority, when working with difficult materials and bimetals and when automation would be beneficial, among others.

Electron beam welding's unique capabilities make it a crucial technology for critical applications. While it carries higher initial set-up and operation costs compared to TIG, its advantages often justify the investment, offering unparalleled weld quality and performance that TIG welding cannot match.

If electron beam welding is something you're considering for your project, the limitations mentioned above mean you'll probably need to work with experts, like EB Industries, that have the right tools and experience to perform high quality welds safely and reliably. Working with the right welding service provider mitigates risk and ensures welds are up to standards you can trust. EB Industries is certified to ISO 9001:2015, ISO 13485:2016, AS9100D and is also NADCAP certified for electron beam welding.

EB Industries has more than fifty years of expertise in electron beam and laser welding, extensive facilities, knowledgeable experts and a reputation for fast delivery and great customer relationships. EBI specializes in welding for the stringent requirements of the aerospace, defense and medical device industries, as well as the energy sector, electronics, semiconductors and batteries. If you aren't sure what kind of welding is the best choice or you have other welding questions, talking to industry experts can help. **For more information on what type of welding would be the right choice for a project, please reach out to us!**

About EB Industries

EB Industries is a full-service provider of electron beam welding, laser welding and laser hermetic sealing services as well as a contract manufacturing company with a large network for value added processes. We have been a pioneer in precision welding for more than five decades and today are known for precision, service and reliability by OEM, Tier 1 and Tier 2 manufacturers in aerospace, medical, semiconductor, electronics and other critical industries.

EB Industries has continually met the unique requirements of component fabrication companies by helping customers design, develop and produce welded components. EB Industries also provides and manages additional services to produce complete assemblies. We are certified to AS9100D, ISO 9001:2015, OSI 13485:2016 as well as NADCAP certified for welding. Our reputation for fast delivery, low weld failure rates and informed, straightforward customer relationships is unmatched in the welding services industry. In 2019 we were awarded a perfect 100 NPS (Net Promoter Score) for customer experience.