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Metal Arc Gas Welding vs. Hybrid Laser MAG Welding

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Abstract
The purpose of this paper is to compare two of welding processes, Metal Arc Gas Welding and Hybrid laser-assisted metal arc gas welding that consists of two processes; MAG Welding and laser beam welding. This paper attempts to determine which of these processes works better in industrial applications, and demonstrating the reasons.

Keywords: *MAG welding process, Direct current, Shielding gas, Filler metal, Power, Energy, Laser beam, Laser beam welding, nd:YAG, Hybrid laser MAG welding, System, Process, Advantages, Disadvantages.*

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Abbreviations

MAG:	Metal Arc Gas.
GMAW:	Gas Metal Arc Welding.
DC:	Direct Current
DCEP:	Direct Current and the Electrode is Positive.
LBW:	Laser Beam Welding.
UV:	Ultraviolet.
LBM:	Laser Beam Machining.
nd:YAG:	Neodymium-Doped Yttrium Aluminum Garnet.
CO2:	Carbon Dioxide.

Since the Hybrid laser-assisted metal arc gas welding consists of two processes, MAG Welding and laser beam welding. This paper explains the MAG Welding process, its parts, how does it work, and its advantages and disadvantages. Moreover, explaining Laser beam welding process, its parts and how does it work, its advantages and disadvantages. Furthermore, it clarifies the Hybrid Laser MAG Welding process, its parts and how does it work as well as demonstrates its advantages and disadvantages. Finally, the paper displays which process generally works best in industrial applications, and explains the reason.

MAG Welding

Metal arc gas welding is a very common process used for welding today, it is commonly used welding process for robotic welding. Metal arc gas welding, as shown in figure 1, works on mainly two principles. One of these principles, it has an electrode wire which is continuously fed out of the nozzle, when this electrode wire reaches the electric arc, it melts and drips down into the fusion zone. The second principle of gas metal arc welding is the shielding gas which also comes out of the nozzle, and spreads out to protect the weld.

MAG Welding Process Explanation

MAG stands for metal active gas welding, the American Welding Society calls this process as gas metal arc welding or GMAW, while others call it as wire welding. In MAG welding a thin wire, as shown in figure 2, accesses the electrode that is fed from a spool mounted on a gun or inside the welding machine, through a flexible tube and out of the nozzle on the welding gun or torch.

The MAG welding wire is fed continuously when the trigger on the welding gun is pulled, as shown in figure 3, and it switches-on the welding current and shielding gas. An electric arc forms between this wire electrode in the workpiece and heats both metals above their melting point. These metals mix together or coalesce and solidify to join the workpieces into a single piece. The metal in these parts to be joined is called the base metal, while the metal that comes from the melting wire electrode is called filler metal.

MAG welding always adds filler metal to the joint because the electrode wire melts in the process. Therefore, this process is known as a consumable electrode process. At the MIG nozzle, the wire is fed through a contact tip and comes out at the point of the weld as shown in figure 4. Shielding gas is fed through the welding lead, it goes through a gas diffuser and flows out of the nozzle. This shielding gas is often a mix of Argon, CO2, and oxygen that protects the molten metal from reacting with oxygen, water vapor, and other things in the atmosphere.

The shielding gas also impacts the behavior of the weld pool, with particular regard to the penetration and mechanical properties of the welded joint. The shielding gas is stored in high-pressure cylinders, the pressure of the MAG shielding gas is reduced to a usable level by a device called a regulator, as shown in figure 5.

In MAG welding, all the Machine controls are set on the machine itself, and one of the most important process controls is polarity wire speed and voltage.

The trigger on the MAG gun is used to switch-on the current, the wire and the shielding gas. For most MAG welding processes, the current is direct like the current flowing from a battery; one wire is always negative while the other one is always positive. In DC MAG welding, the electrode is usually positive while the workpiece is negative. As seen in figure 6, the term DCEP is used when the current is direct and the electrode is positive. This is also called reverse polarity, while DCEP is a more descriptive term.

Since the current flows in a loop in an electric circuit, the MAG welding process current has to flow in a complete circle from the machine to the torch into the work and back to the machine. MAG work lead is clamped to the work to complete the circuit from the workpiece back to the machine, as shown in figure 7.

In conclusion, MIG welding is an electric arc welding process. It uses a consumable wire electrode, the filler metal is added automatically, and the shielding gas comes from a high-pressure cylinder.

Benefits of MAG Welding

There are many benefits of metal arc gas welding, as:

- It can be used for a variety of materials.
- It is a very efficient system, this is due to the high deposition rates and the high electrode efficiencies
- It can also create extremely long welds, this is mainly because of the filler electrode that is continuously fed through the nozzle
- It also has very minimal post-weld cleaning, because it has no slag that is created during this process.
- It has an easily automated process, as it is one of the most common ones used for robotic welding in today's industries.

Negatives of MAG Welding

There are many negatives of the metal arc gas welding, as:

- MAG welding can only handle moderate levels of surface contaminants; this is common for most welding processes. If it encounters things such as rust, mill scale dirt, oil or paint, it could potentially incur porosity, or also bad bead appearances or cracking could occur. However, these are the defects that could happen to the weld itself.
- Wind is also problem, which is somewhat unique to this form of welding, this is because of the shielding gases that can get blown away by the wind and that would potentially cause weld defects.
- As with most forms of welding safety is a potential hazard for the user due to the harmful UV rays, which are produced via welding.
- Highly skilled labor is often required to run this process.
- It is only suitable for thin materials, because it has relatively low temperatures that can be achieved by this process. Therefore, the melting of the materials can only penetrate very shallow into the base material. This is one of the major problems associated with this form of welding.

Laser Beam Welding

Laser beam welding process, as shown in figure 8, utilizes a concentrated beam of energy as its energy and location can be precisely controlled. Thus, this technology is ideal for precision welding. Laser beam welding uses amplified light which is delivered and deflected either by glass lenses mirrors, or a fiber optic cable which is often used. The process is an auto genius prop welding process, which means that it has no filler, this is at least to some of its major downfalls. However, it is very efficient system.

Laser Beam Welding Process Explanation

The laser beam machining (LBM) process, as seen in figure 9, is a non-traditional type of machining process which is a thermal machining process that uses the laser beam to produce heat. This produced heat is used to heat the metal from the surface of the workpiece up to the vaporization.

Whenever an atom is exposed to an external energy source, the electrons absorb the energy from and the external energy source, this in electrons which are in their original energy levels jumps to the higher energy level after absorbing the energy, which becomes unstable and it is released back on the absorbed energy in terms of photons. This particular electron comes back to its original state.

If an item that is already at the higher energy level absorbs the energy, it will emit double energy in return to its original status. The energy emitted by the item has the same frequency and wavelength as the stimulating energy, the high amplified light beam produced is known as the laser, see in figure 10.

In general, the basic fundamental of the laser is that the electron absorbs energy and then gives it back, as shown in figure 11, producing a laser which is the light amplification by stimulated emission of radiation. The laser beam, which is produced by emitting the photons is in the form of narrow monochromatic high intense light, that can cut any type of complex metal and nonmetal respective of its hardness as diamond.

Just like the rest of the non-conventional machining, the essential LBM equipment is the power supply as shown in Figure 12, which provides the energy for excitation of the electrons from the low energy level to the higher energy level. The power supply is connected to the flash lamps, the laser material is exposed to the light which is emitted from the flash lamps provided on both sides of the laser material that keeps storing the light energy. The laser discharge tube is filled with the laser material which is located inside it, one side of the tube is partially transparent for emitting out the laser while the other side is 100% reflected.

The laser material is essential factor which plays a key role in this particular process, by using CO_2 as pulsed, or continuous waves. Or by using nd:YAG which can be used as a laser material, as shown in figure 13. If CO_2 used as laser material, basically it images the light in the infrared region, and it can provide up to 25 KW of power in a continuous wave mode, and around 5 KW of power in the normal wave mode, or in discontinuous wave mode. The nd:YAG, which is also called neodymium-doped yttrium aluminum garnet, is a solid-state laser that can deliver the light through optical fiber cables, that can provide 50 KW of power in the form of pulse mode, and 1 KW in the form of continuous mode. These modes are the formation of the laser (continuous or pulse). Moreover, a convex type focusing lens is used to focus the rays at a single point on the work.

In conclusion, the laser material (CO_2 or nd:YAG) atoms electrons get excited by the lights energy of the flashlights powered by a power supply, leading the electron to jump from the lower energy level to higher energy. When the atom absorbs the sufficient energy it starts to emit the energy continuously in the form of laser which is collected by the focus convex shaped lens and directed towards on a point forming the heat on the surface of the workpiece.

Benefits of Laser Beam Welding

Some of the benefits of laser beam welding are:

- It is suitable for welding most ferrous and non-ferrous materials
- It is a deep penetrating welding, so it can penetrate a lot deeper into the material when compared to the gas metal arc welding process.
- It could produce a very good quality and high strength and ductility in the weld, this is mainly because of the minimum shrinkage and distortion due to the very small heat-affected zones that are created by the laser itself, and this also leads to it being relatively free of porosity which is a major component of having a good weld.
- It is very fast speed process that can be achieved when using laser beam welding, it is a very quick system and can be automated to produce welds that are very high rate.
- The process does not need electrode.

Negatives of Laser Beam Welding

There are a lot of negatives associated with laser beam welding:

- There are a variety of safety hazards associated with it, particularly involving the laser itself if it comes in contact with the eyes or skin that could be a major injury risk.
- High costs are associated with this form of welding as the initial cost is extremely high, the maintenance costs are high, the power costs are high. Therefore, it is highly expensive all around.
- Rapid cooling is also something that can be experienced due to this process, this is because it has high heat in a relatively small area, so the heat transfer in the weld zone is relatively quickly compared to the rest of the base material and it cools very rapidly.
- It has a very small spot size. This means that the laser is very focused and can only impact a very small area. This can lead to very poor bridge gapping capabilities and it also has an inadequate inability to provide adequate reinforcement due to a lack of a filler.

Hybrid Laser MAG Welding

Hybrid Laser MAG Welding is a process that combines both of these two processes, the metal arc gas welding and the laser beam loading you get the hybrid laser-assisted gas metal arc welding process.

Hybrid Laser MAG Welding Process Explanation

Combining a regular metal arc gas welding process with a laser beam which is focused into the same fusion zone of the weld, as shown in figure 14, resulting a combination of properties that would normally be mutually exclusive for one of these two processes. On one hand, the extremely high speed of the laser and its excellent thermal input. On the other hand, the good gap bridging ability to make the interplay between these two things stabilizes the welding process and makes spatter-free welding possible all highly cost-effectively.

Benefits of Hybrid Laser MAG welding

Some of Hybrid Laser MAG welding benefits are:

- It has a very narrow heat-affected zone, this is the zone that is traditionally the weakest part of the weld by reducing the size of it will drastically increase the strength.
- It also has a very deep penetration due to the laser beam loading portion which is contributed to the hybrid.
    - It has an increase of ten to twenty percent compared to the laser beam welding.
    - An increase of twenty to fifty percent due to the gas metal arc welding processes.

- The laser beam welding also helps contribute to a lot higher speed for the overall hybrid process.
    - An example of this is that there was a 2 mm thick Aluminum alloy that was tested :

- For the gas metal arc welding, it took a 0.95 m/min.
- For the laser beam welding, it was 3 m/min.
- It was able to increase up to 5 m/min for the hybrid laser gas metal arc welding process.

- One of the negatives of the laser beam welding process alone was the bridge gap in capabilities at 0.3 mm, the gas metal arc loading process was a lot higher at 1.5 mm, but whenever you combine them can get up to 1.9 mm of bridge gapping and this is very useful for bridging large gaps overall.
- It also has much better efficiency than the individual processes that make it up, this is because there is it requires a lot less heat input to melt the same volume of material, and lowering this heat input lowers the amount of distortion which is experienced by the material by the weld itself.
- It also has much better quality this is because the lower heat input considerably increases the metallurgical properties of the weld.

Economics of Hybrid Laser MAG welding

The economics of the hybrid laser gas metal arc welding system is great in terms of being compared to a traditional laser beam welding process, the main savings here occur from the laser itself this is because its consumption is much less whenever it is in the hybrid estate.

- The reduction in power can be between 1KW to 2 KW for the laser itself, thus saving between $130,000 to $260,000.
- It can increase the productivity of the productivity and efficiency of the whole system, thus, the increased welding speeds that can be achieved with the hybrid system can reduce the overall cost per component.
- The higher quality can reduce the amount of scrap necessary, which also has a reduction in the scrap costs, thus the overall cost of the system is lowered.

Negatives of Hybrid Laser MAG welding

The negatives aspects of the hybrid Laser MAG welding are:

- It is more difficult to shield, this is because of the higher temperatures that are experienced due to the combination of the two systems, and that can lead to an increase in hydrogen absorption.
- Poor weld bead appearance can be sometimes noticed is compared to the gas metal arc welding.
- The large amounts of molten liquid compared to the laser beam welding are present, and during certain techniques that require full penetration welding, it can cause significant difficulties.
- The increasing complexity which is due to the number of loading parameters that are encountered whenever combining the two systems.
- Higher skill level is required in terms of operating this type of machinery.

Conclusion

This paper shows the importance of the Hybrid Laser MAG Welding as it is very beneficial system, especially when it is compared to the traditional MAG or laser beam welding. Hybrid Laser MAG Welding is better due to the significant cost reductions compared to the Laser Beam Welding, or to the traditional MAG Welding; because of the deeper welding penetration. Therefore, when the processes are combined together, many advantages of each process are combined, thus getting benefits of both processes resulting a grater advantages welding process. Furthermore, because each process (Laser beam welding and MAG Welding) takes away a few of the negatives of the other, many of the two processes negatives will be eliminated. Hybrid system is for whom have the initial Funds, or for whom already are looking at a laser beam welding system, then they definitely should upgrade it to the hybrid laser-assisted gas metal arc welding system.

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Figures

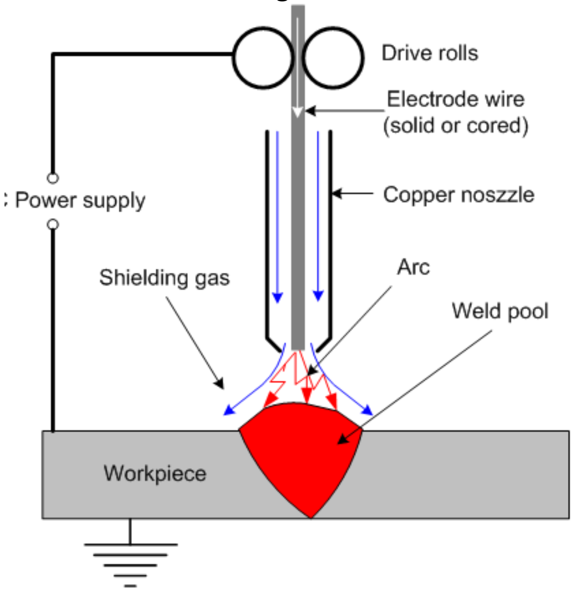

Figure 1. Metal arc gas welding process.

Figure 2. MAG welding wire.

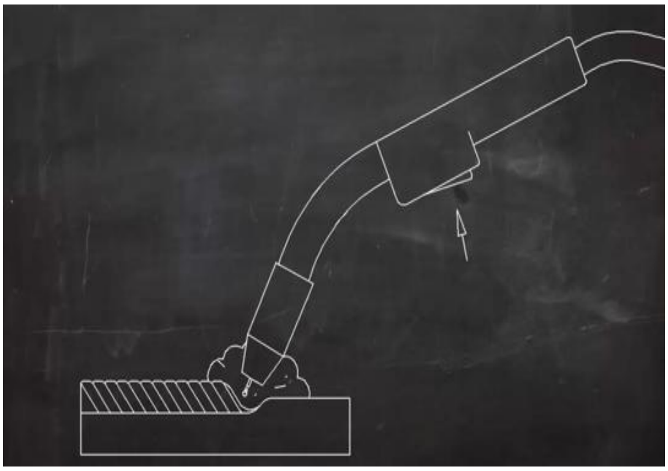

Figure 3. MAG welding trigger.

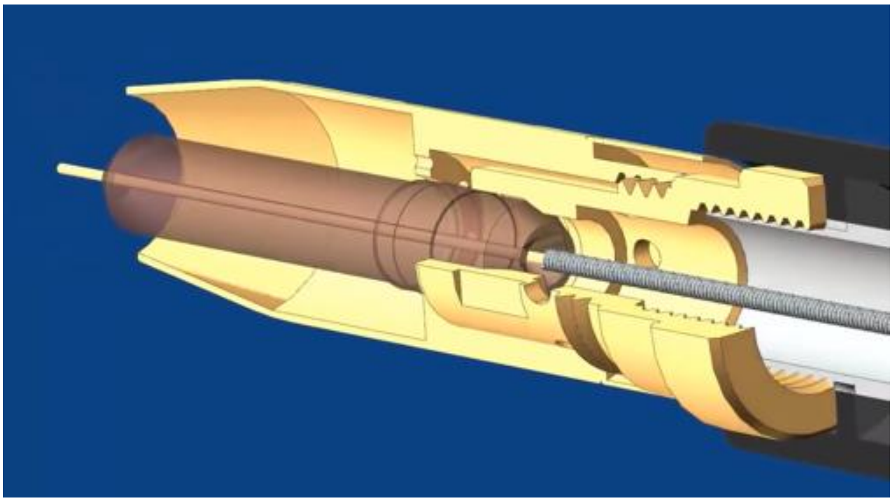

Figure 4. MAG welding nozzle.

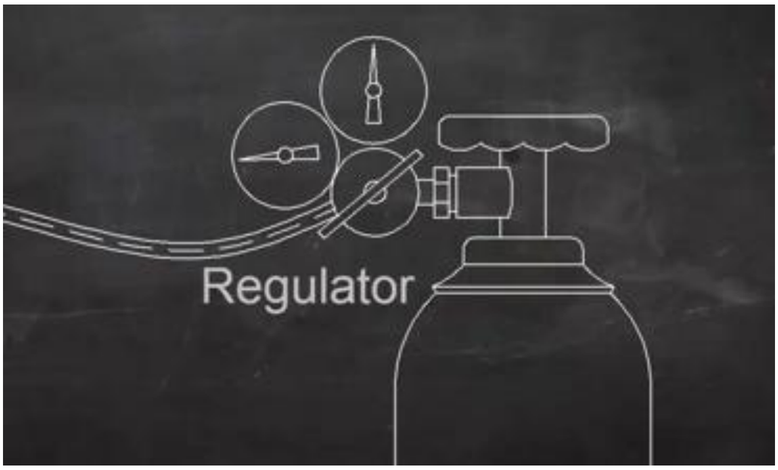

Figure 5. MAG welding shielding gas system.

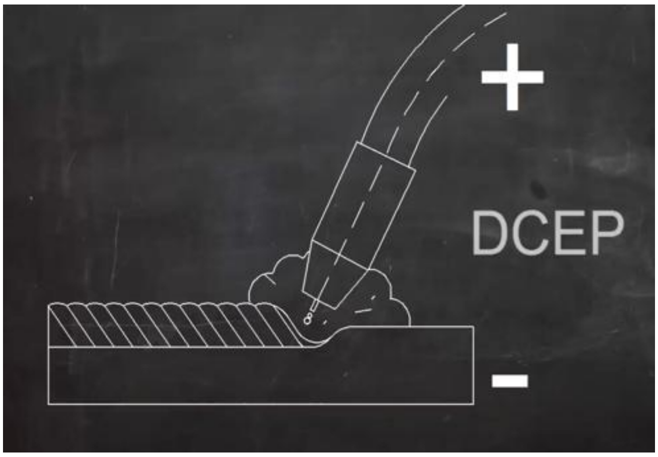

Figure 6. DCEP MAG welding.

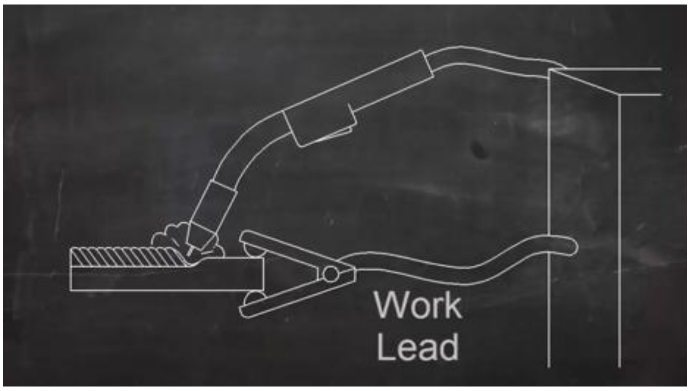

Figure 7. MAG welding work lead clamped.

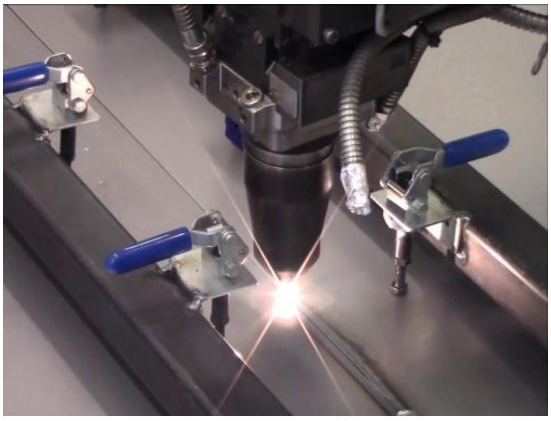
Figure 8. Laser beam welding.

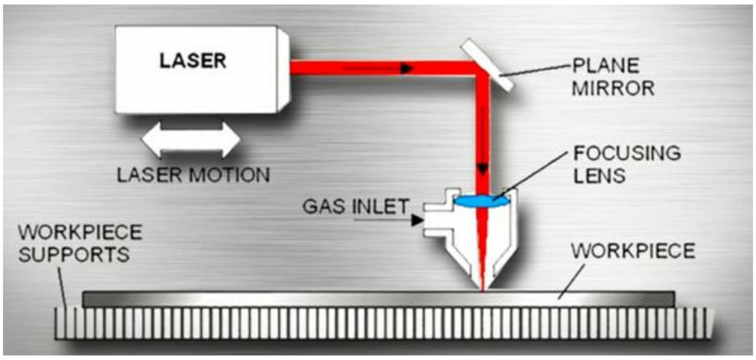

Figure 9. Laser beam machining (LBM) process.

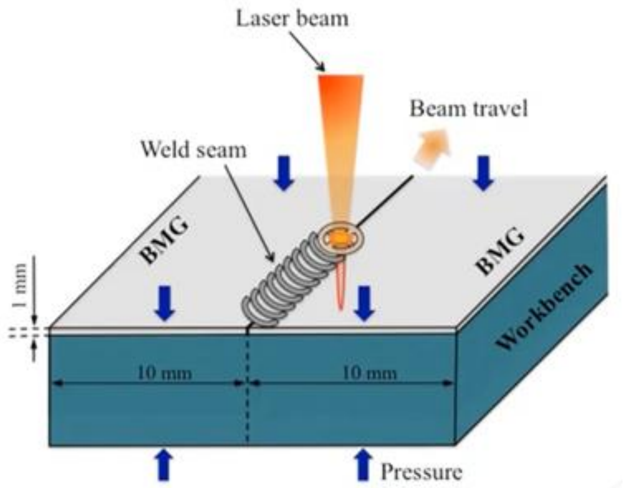

Figure 10. Laser beam welding (LBW).

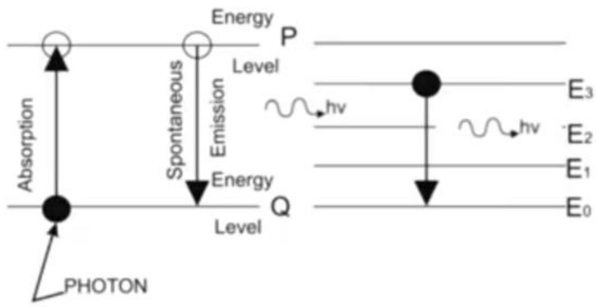

Figure 11. The light amplification by stimulated emission of electron radiation.

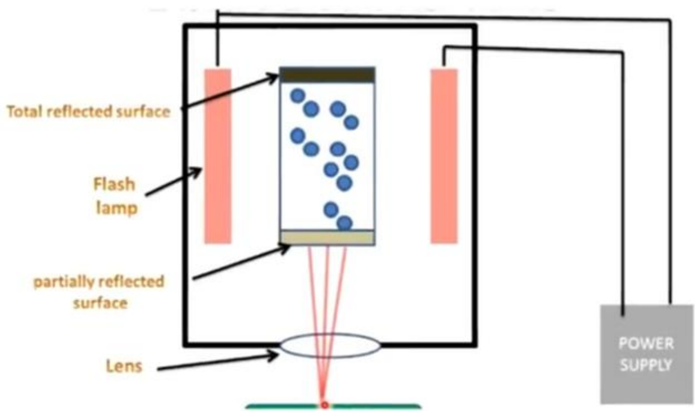

Figure 12. Laser beam welding equipment.

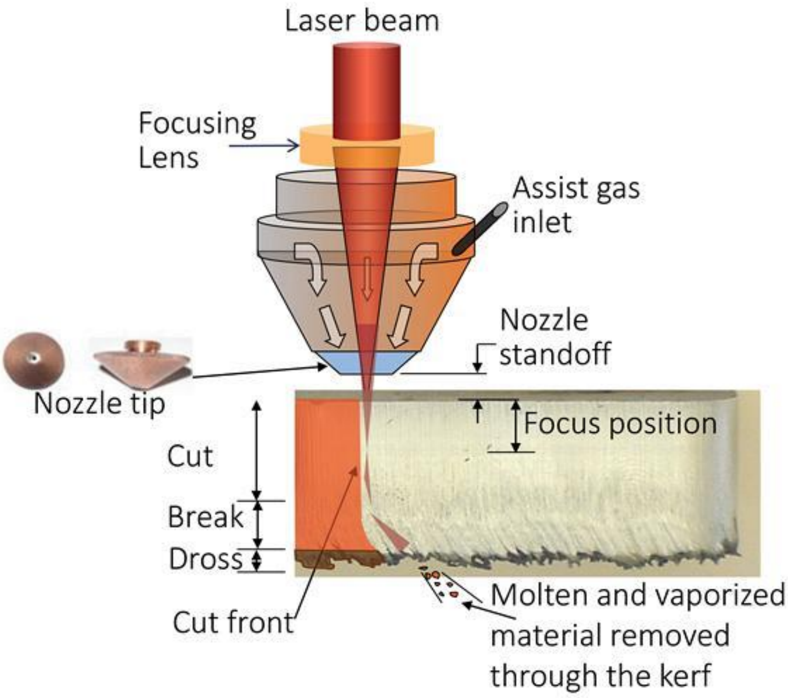

Figure 13. Using CO_2 in Laser beam welding.

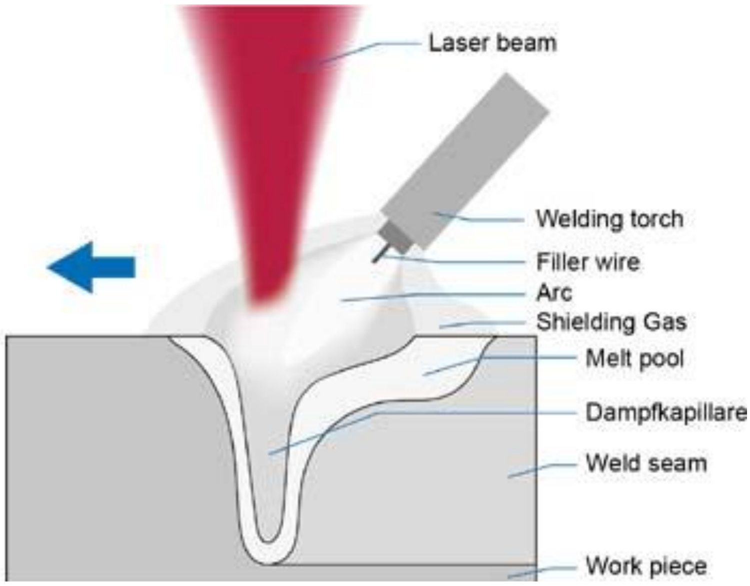

Figure 14. Hybrid Laser Assisted MAG welding

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