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Special Hybrid Laser Welding Processes

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Outline



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– Hybrid Laser Welding Process

- Introduction
- Different processes
- Advantages
- Limitations
- Applications

– Hybrid Laser Welding Process

- History
- Also, termed as Hybrid Laser Arc Welding (HLAW)
- Was announced by Prof. W. M. Steen in the late 1970s
- Two heat inputs for welding
- Typically, primary heat source is laser, secondary heat source is the arc

– Hybrid Laser Welding Process

- Briefly, individual processes...
- In laser welding technology, a powerful laser beam spot is focused on a small area of the workpiece. A small welding spot diameter with less heat input makes this process suitable for welding thin plates that have narrow grooves. The welding method involves a faster processing time. However, in the case of wider grooves, countermeasures like slower processing time are required.
- Arc welding is suitable for welding thick plates. The process uses a large welding spot diameter resulting in shallow penetration. Unlike laser welding, arc welding involves a slower processing time. Electrode / wire itself can be the filler material

– Hybrid Laser Welding Process

- Combines the advantages of two proven welding processes
- Laser welding + GMAW welding (Gas Metal Arc Welding = _____ process)
- LW+GMAW
- Hybrid laser arc welding processes represent a special combination that brings together laser welding with GMAW (gas metal arc welding).
- Here, either MIG or MAG welding (metal inert gas and metal active gas welding), PAW (plasma arc welding) and TIG welding (tungsten inert gas welding) are used.
- Primarily MIG/MAG is used

Hybrid LW

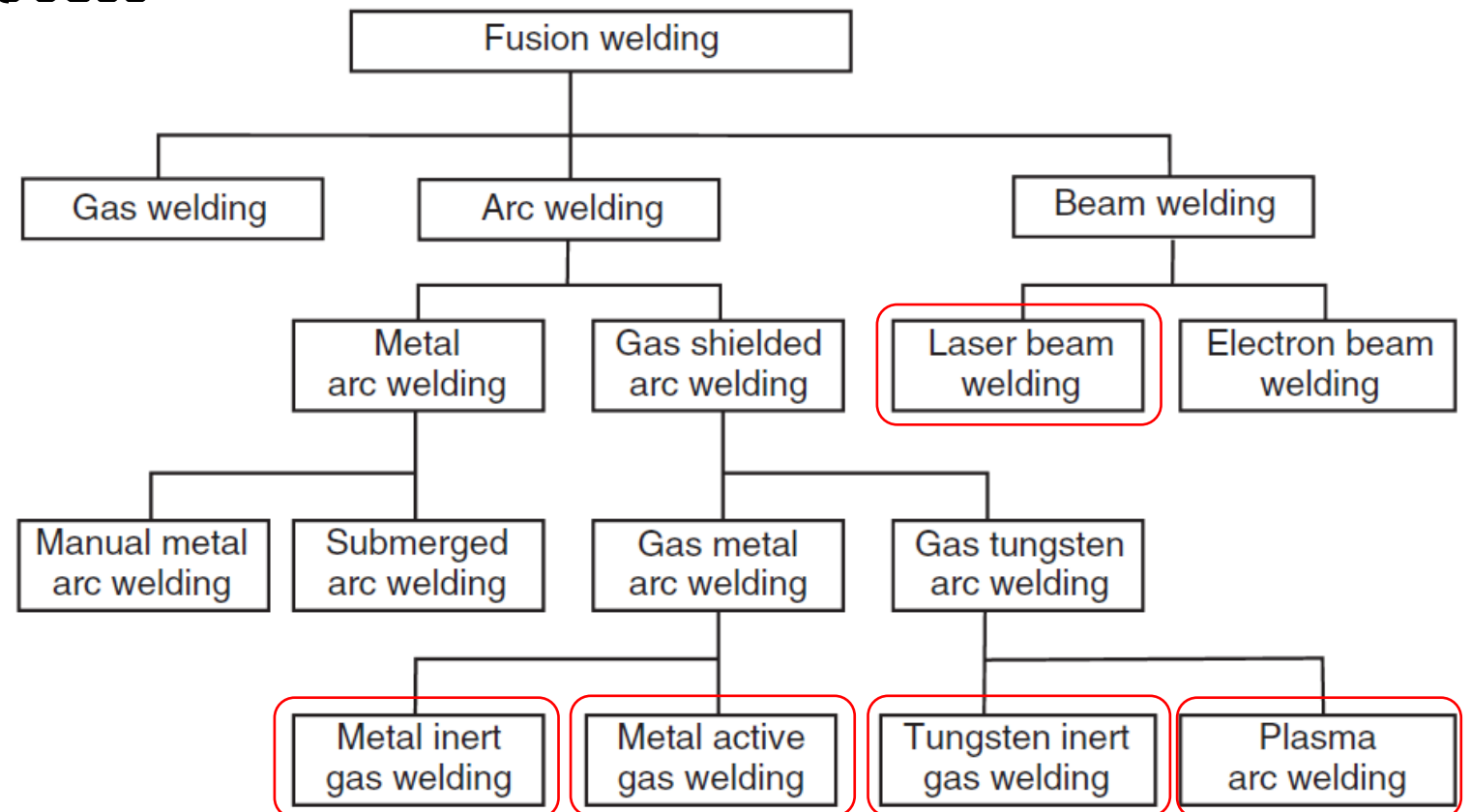
– Hybrid Laser Welding Process

- From family of fusion welding process

- LW

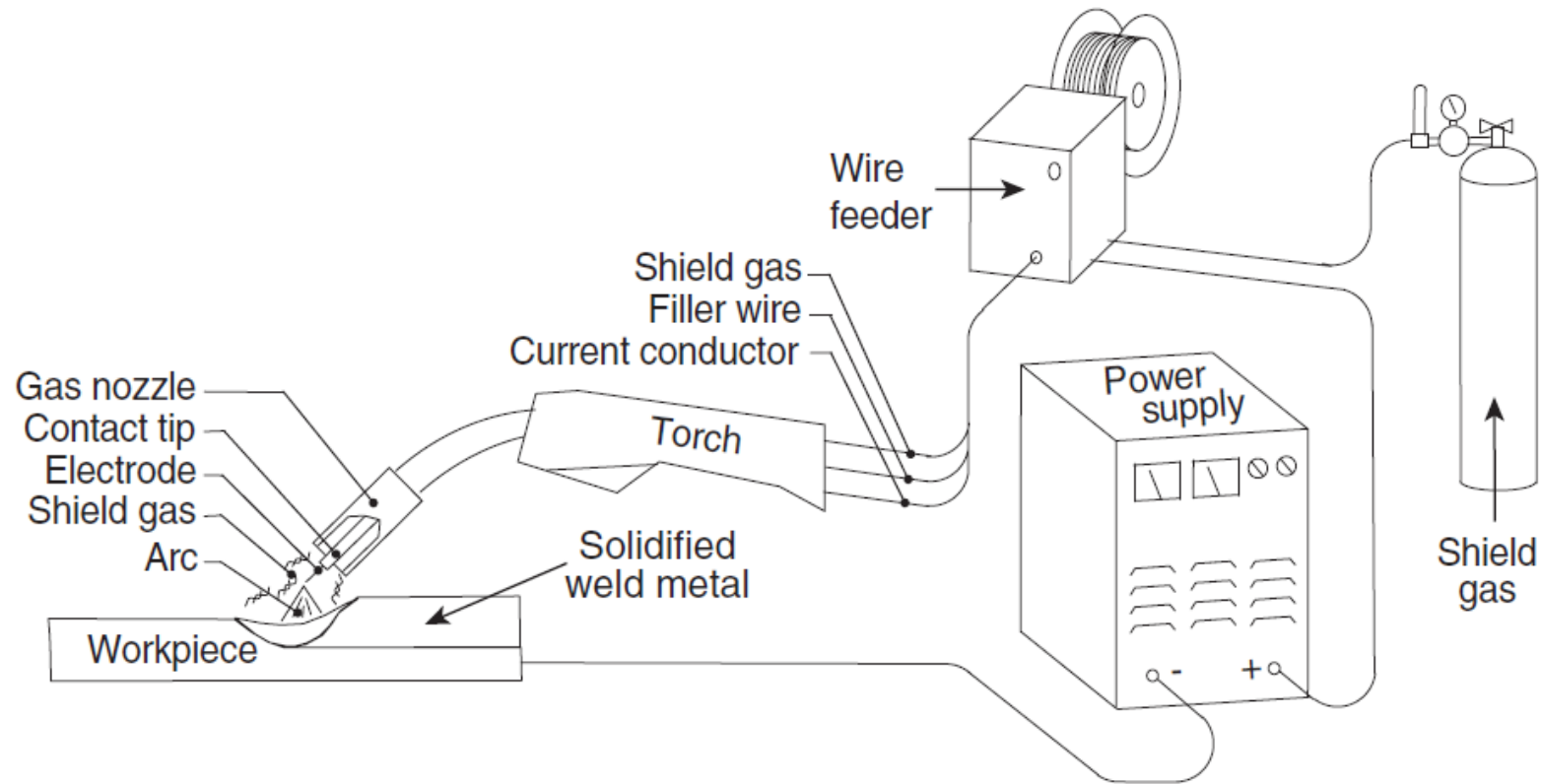
+

- MIG
- MAG
- TIG
- PAW



Hybrid LW

– Schematic of GMAW setup



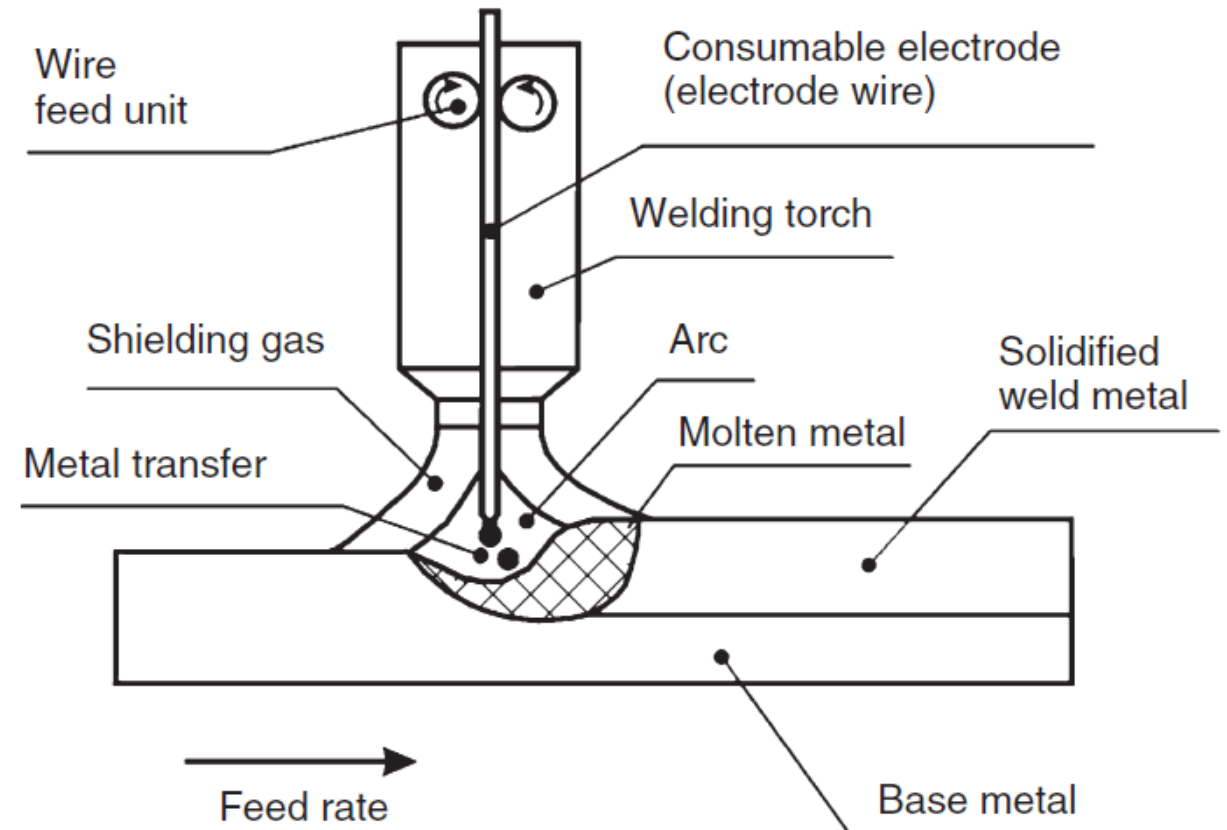
Hybrid LW



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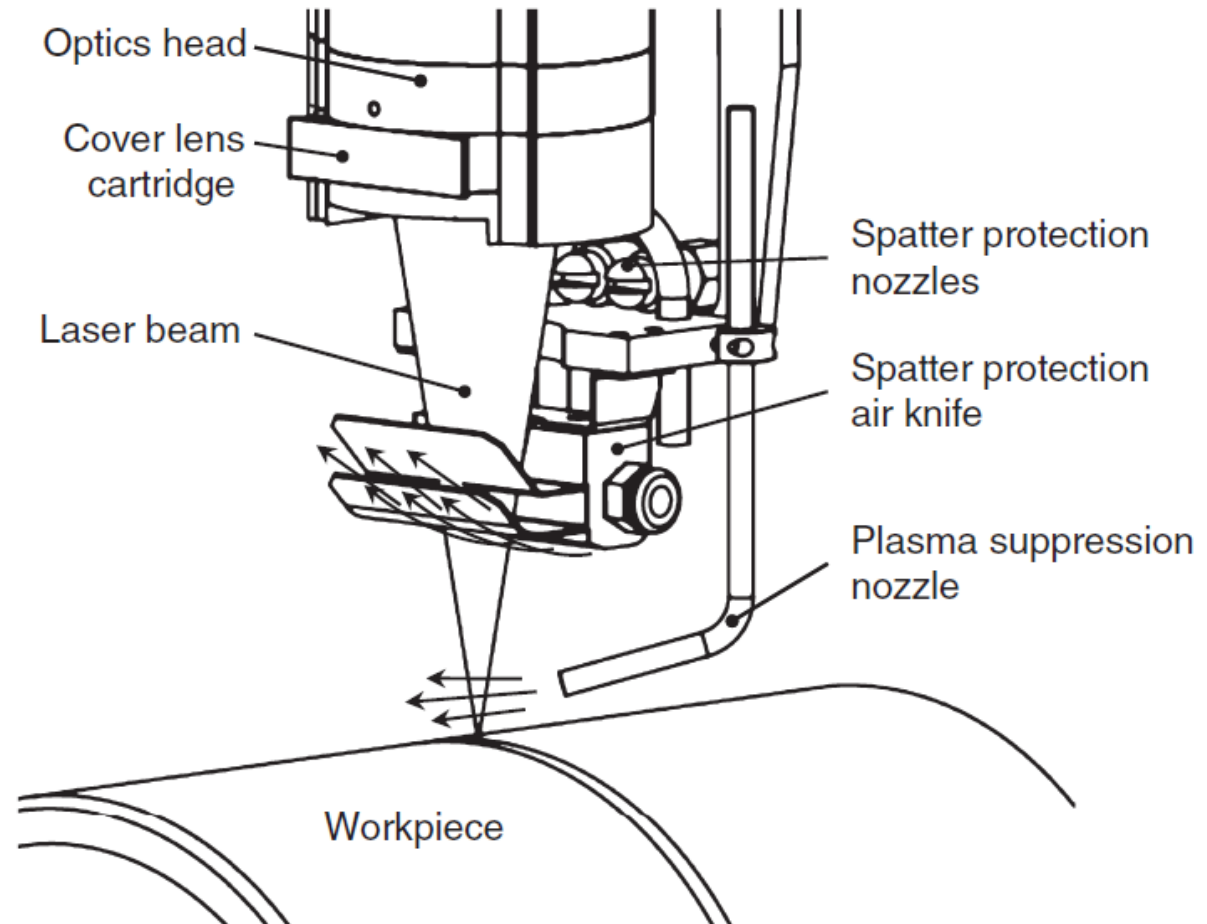
– Schematic of GMAW process

- Mechanized consumable electrode feed



Hybrid LW

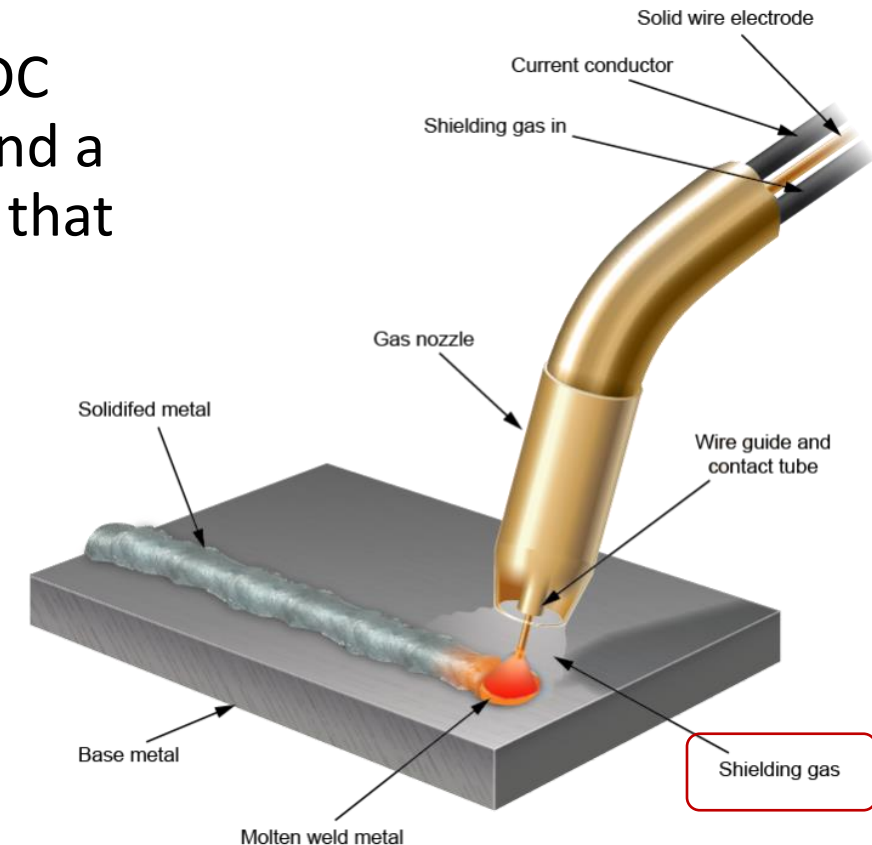
- Schematic of LW setup
 - With multiple protective gas assists



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– Key differences between MIG and MAG

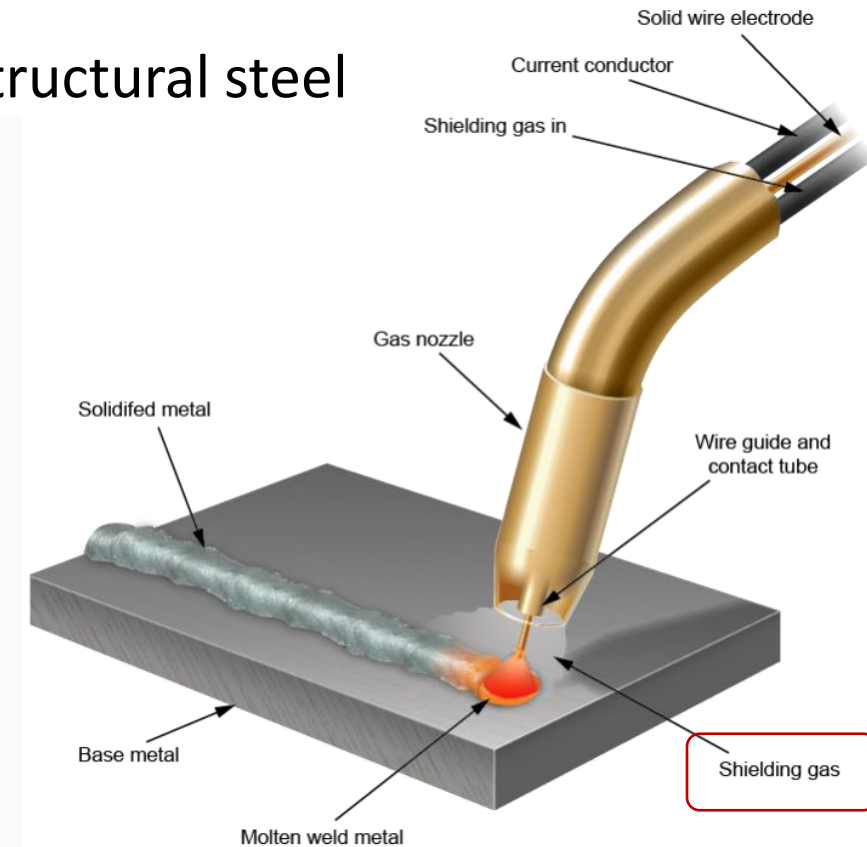
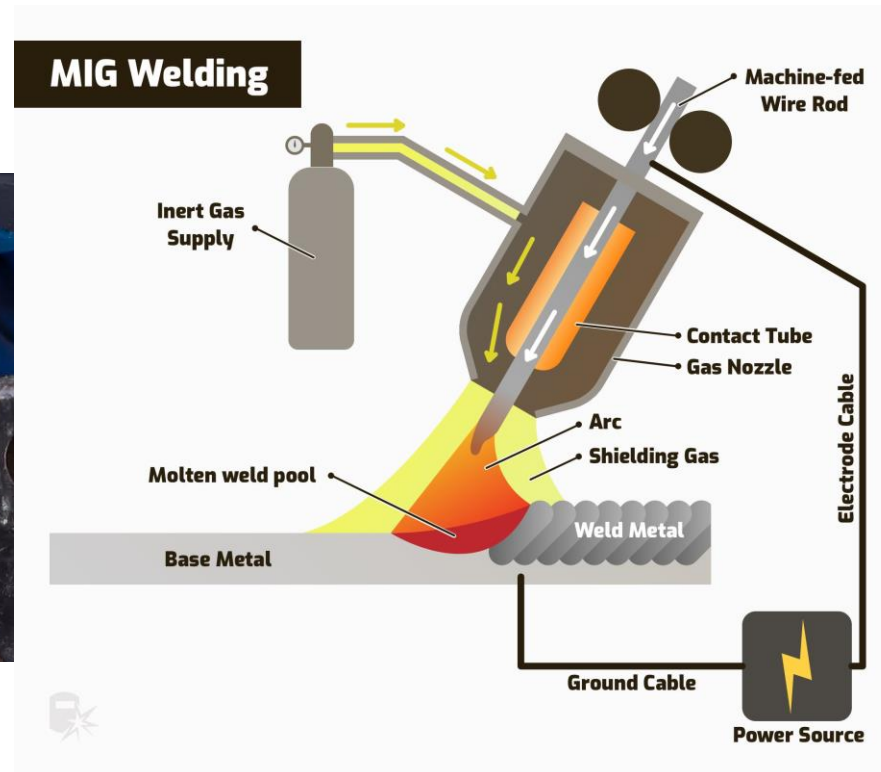
- Both are GMAW processes, use heat created from a DC electric arc between a consumable metal electrode and a workpiece which melt together to create a weld pool that fuses to form a joint
- MIG – metal inert gas, MAG – metal active gas
- Key difference is the shielding gas
- MIG – uses inert gas (He, Argon)
- MAG – uses active gas (mixture of Argon, CO₂, O₂)
- Gas stabilizes the arc, metal flow, spatter
- In US, both MIG/MAG commonly known as GMAW



Hybrid LW

– MIG welding

- Suitable for medium-thickness plates, carbon steel, structural steel & Al-alloys



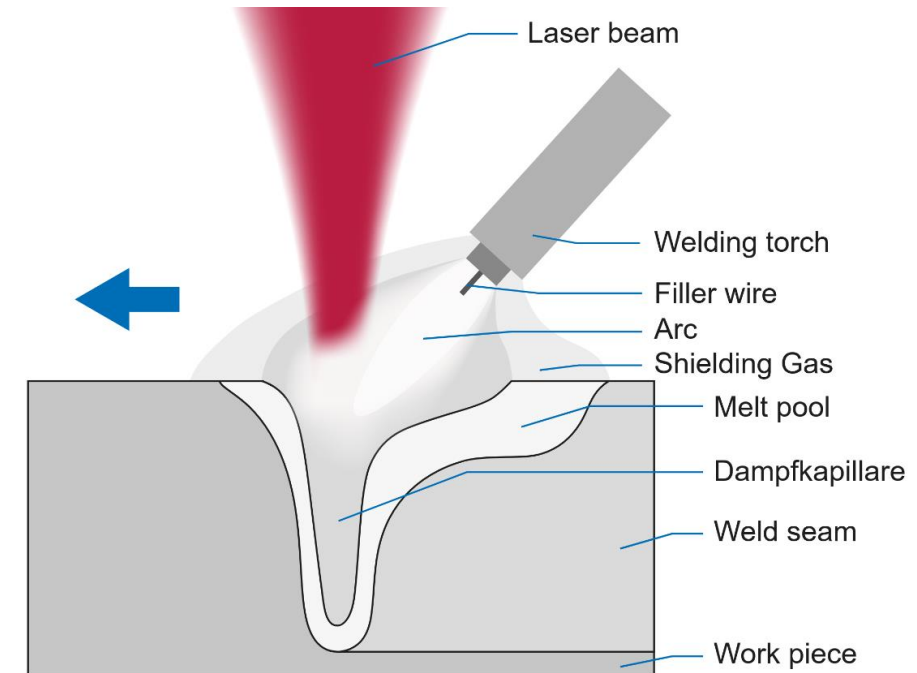
Hybrid LW



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– Process (LW+MIG/MAG)

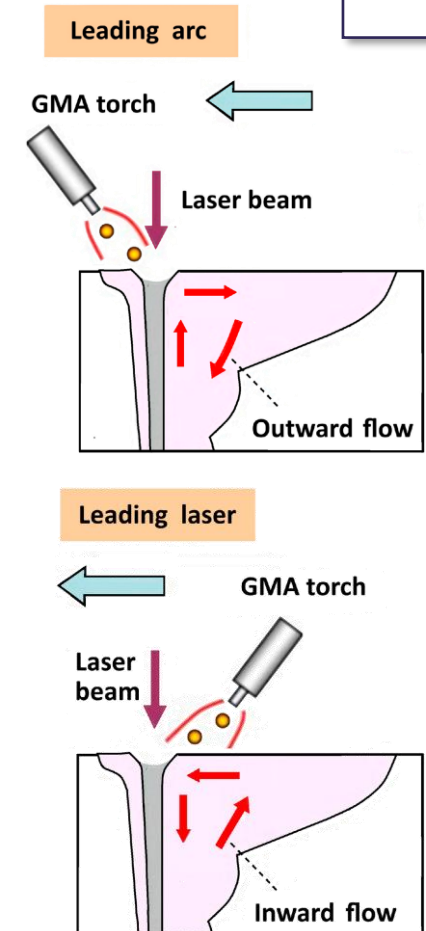
- Keyhole welding, laser beam is used to achieve sufficient welding depth, especially for high material thicknesses.
- Since seam preparation is often not carried out in an ideal fashion for particularly thick sheet metal, resulting in larger gaps, the missing material must be filled in with an additional wire.
- For this, combines welding with the MIG/MAG welding process. The filler material fills the laser beam funnel and optimizes the flank connection.
- Both processes work within one process zone, enabling the advantages of both processes to be utilized.



Hybrid LW

– Process (LW+MIG/MAG)

- The laser beam is generally directed perpendicular to the welding direction to get the maximum possible weld penetration
- During arc leading process the torch is positioned at a drag angle, and during laser leading process the welding torch is positioned at a push angle
- Laser leading setup produces larger width of arc zone, narrow width of laser zone, and higher penetration depth

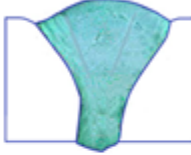


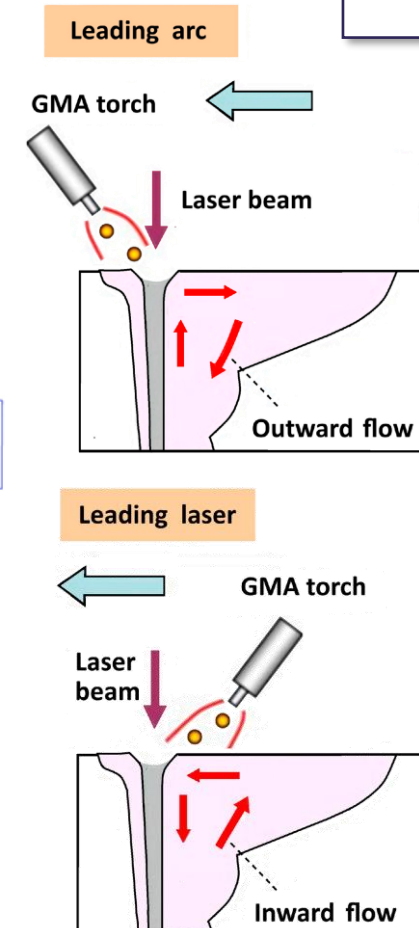
Hybrid LW

– Process (LW+MIG/MAG)

- Laser leading, weld shape is like cone-shaped
- Arc leading, welding is like cocktail-cup shaped

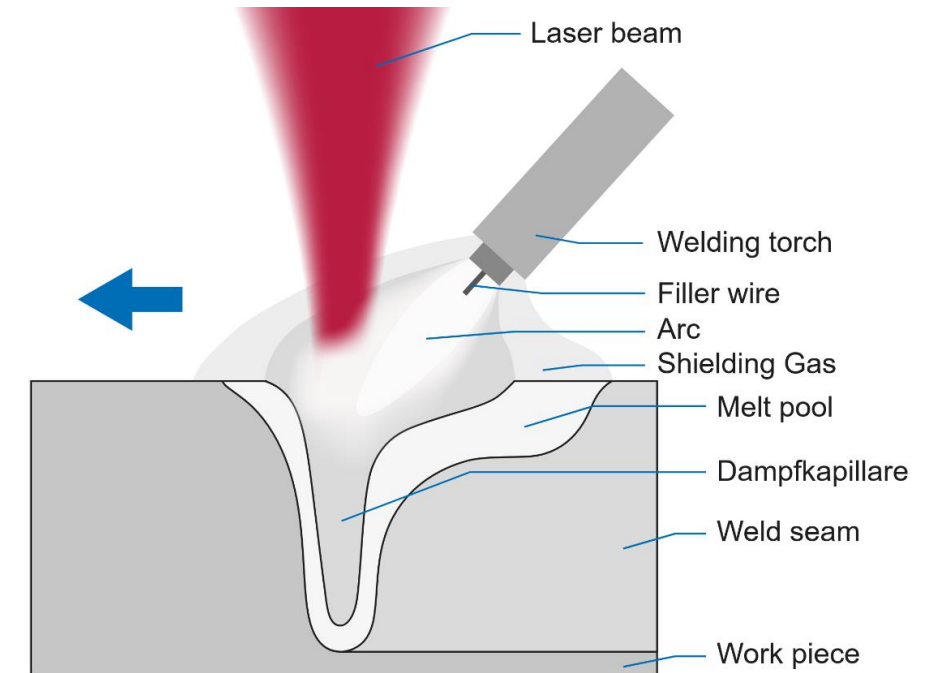
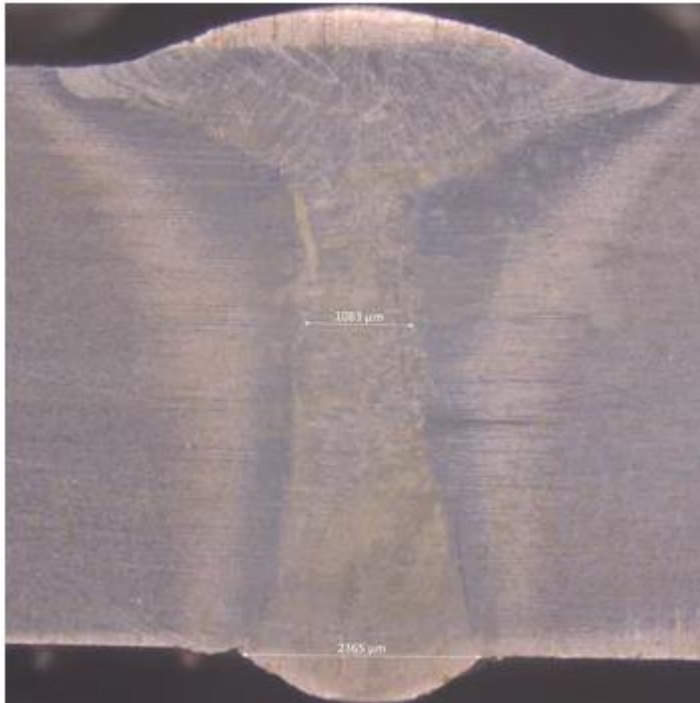
Process configurations' effects on the weld shape and the extension of the arc and laser zones (given the same welding parameters)

Material/ Plate Thickness	Edge Geometry	Setup/ Inter-Distance	Total Linear Heat Input	Total Surface Heat Input	Laser/Arc Power Ratio	Weld Shape/ Reference
High-strength steel 6.6 mm	Single-sided Y, 40° groove angle, 0.8 mm gap	GMAW (leading) + Nd:Yag 3 mm	618 kJ/m	93,636 kJ/m ²	0.44	
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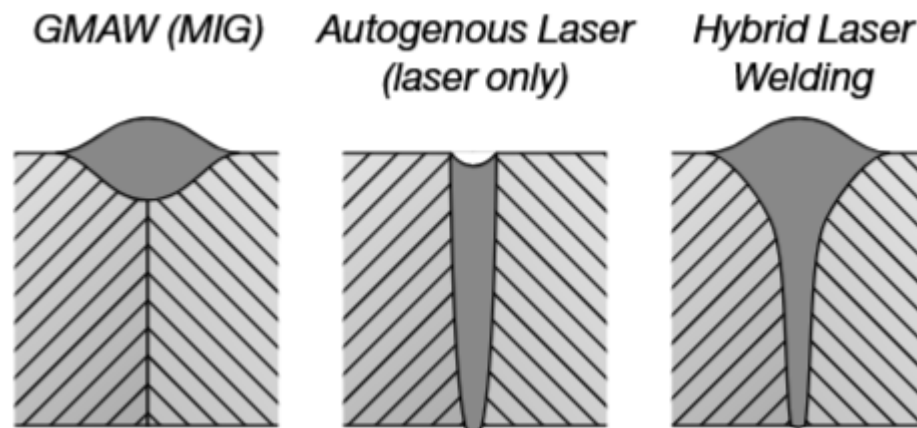
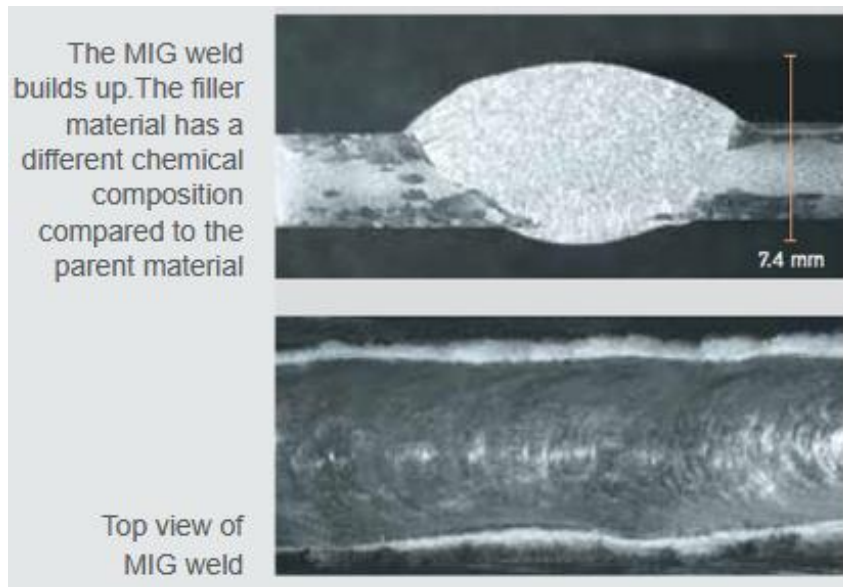
Hybrid LW

– Process (LW+MIG/MAG)

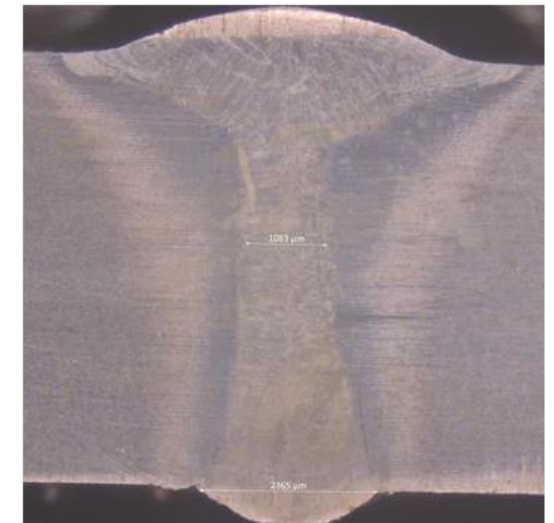


Hybrid LW

– Process (LW+MIG/MAG)

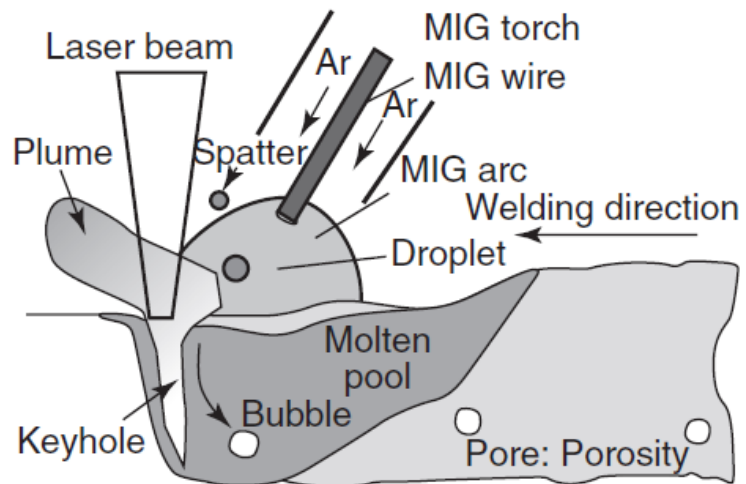


Graphic illustrating differences between GMAW, Laser and Hybrid Laser Welding weld profiles

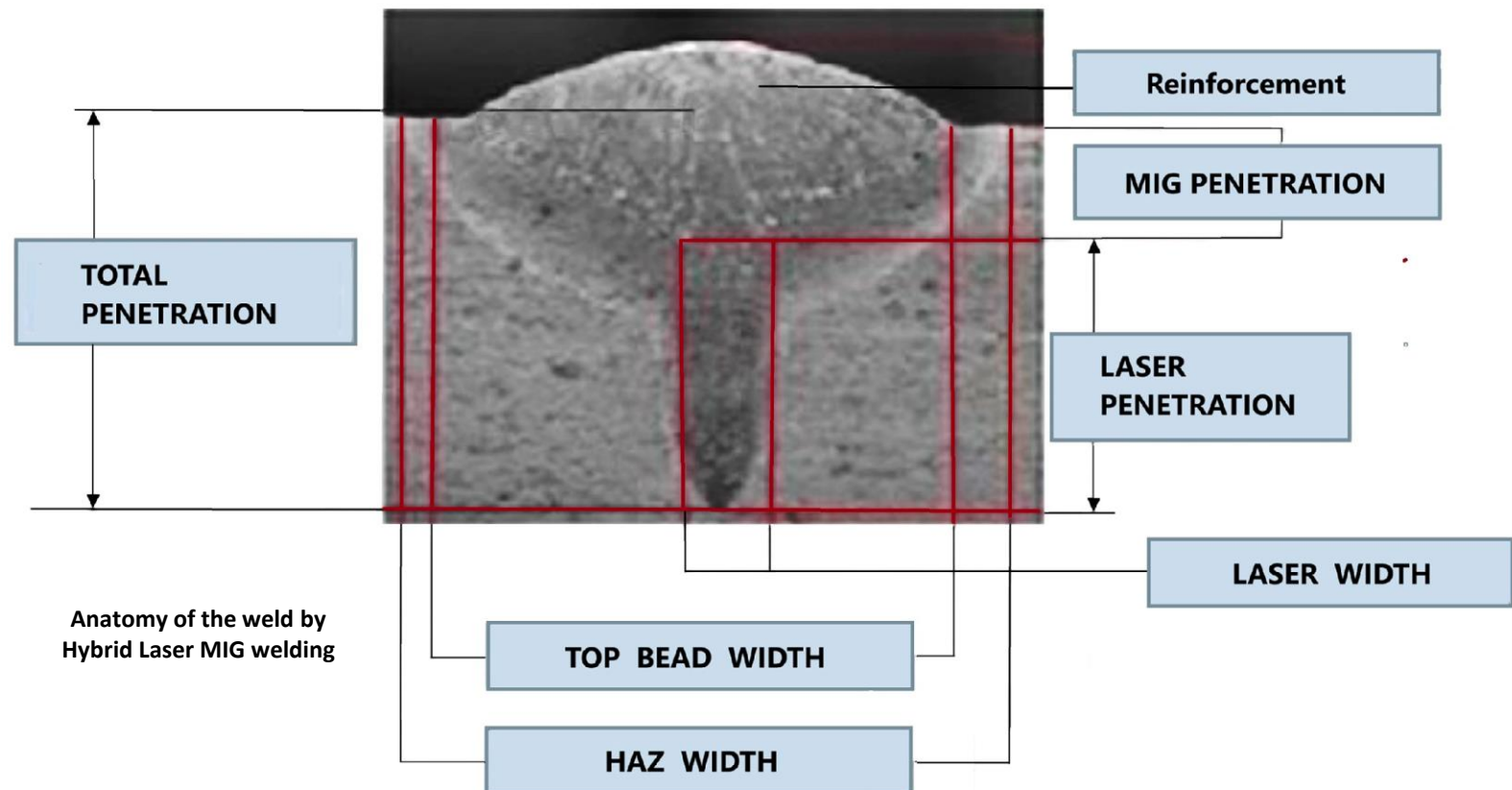


Hybrid LW

– Process (LW+MIG/MAG)

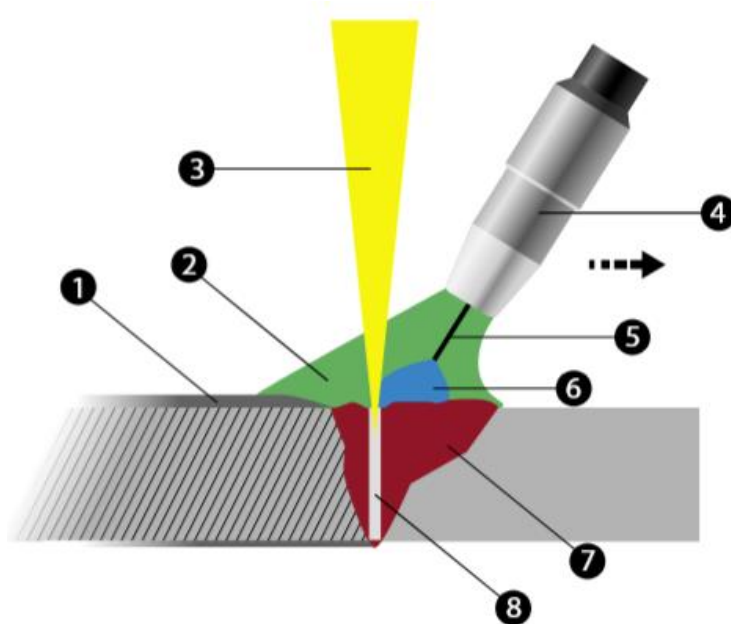


Schematic of Hybrid Laser
MIG welding

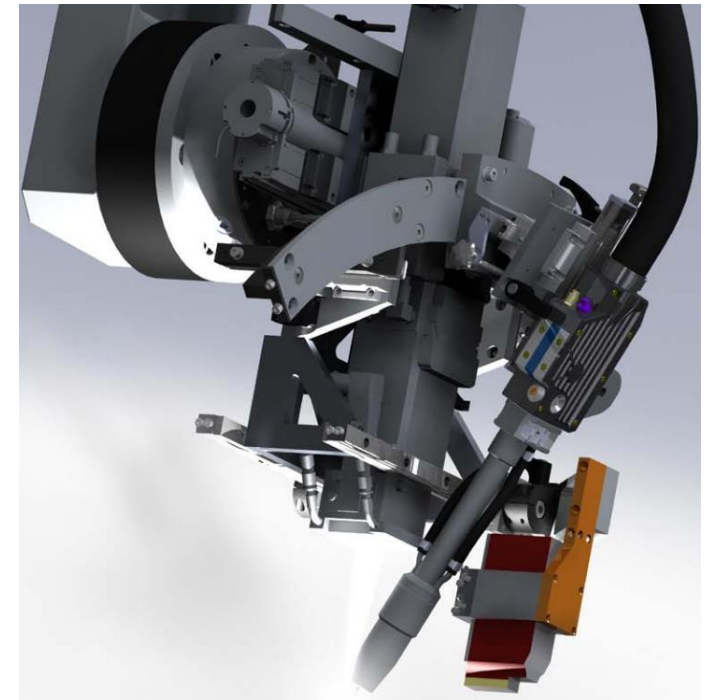


Hybrid LW

– Equipment



- 1 Newly formed weld bead
- 2 Inert shielding gas
- 3 Focused laser beam
- 4 GMAW torch
- 5 Wire electrode
- 6 Electric arc
- 7 Molten pool
- 8 Keyhole



Hybrid LW

- Equipment
 - Can be robotized



Hybrid LW

– Process (LW+MIG/MAG)

- Prefers high power laser diodes for faster welding



Laser Beam + Gas Metal Arc Hybrid Welding with a 10kW Laser

High-quality welding seams for high material thicknesses and large gap widths.

LDF high-power diode lasers are ideal beam sources for laser hybrid welding.

Laser power	10 kW	
Speed	3.5 m/min	
Material	S355	← High strength structural steel
Sheet thickness	5 mm	
GAp width	0.2 mm	

Credit: Laserline

– Process

- Possible two configurations for different applications
- If laser source is leading (dominant) = butt welds
- If arc / torch is leading = fillet welds
- In both, laser penetrates deeply in the joint, draws filler material and also finally shapes the softened filler material to produce desired weld geometry and properties

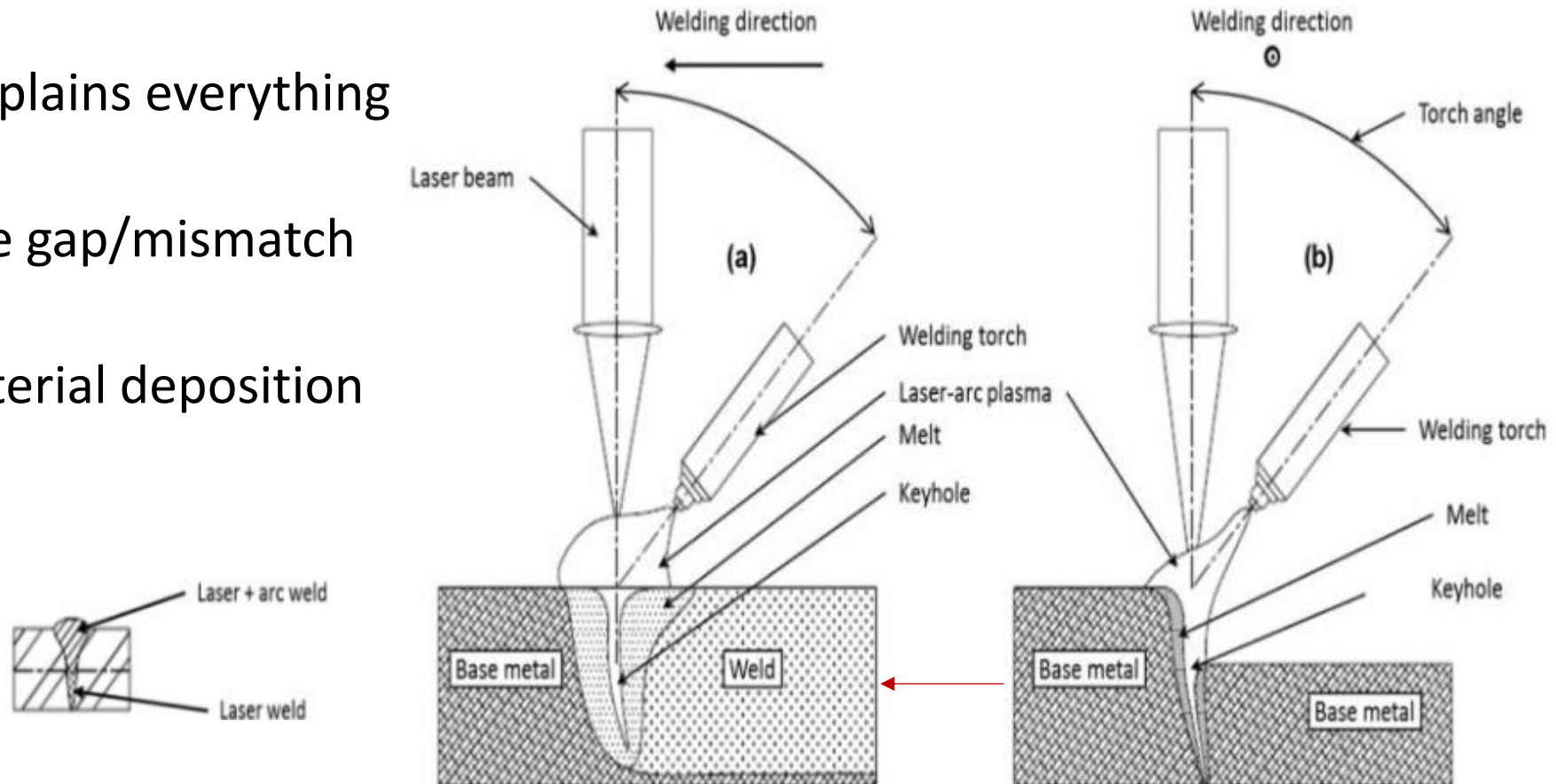
– Process

- Hybrid welds are stronger, durable and ductile similar to conventional ways
- But are faster, more durable.
- Low heat input creates fine grain structures minimizes base material dilution thus high toughness
- Smooth welds by hybrid laser welding have shown to improve fatigue limits on fillet welds by factor of 3 vs conventional welds.

Hybrid LW

– Process

- Figure explains everything
- Filling the gap/mismatch
- Filler material deposition



Hybrid LW



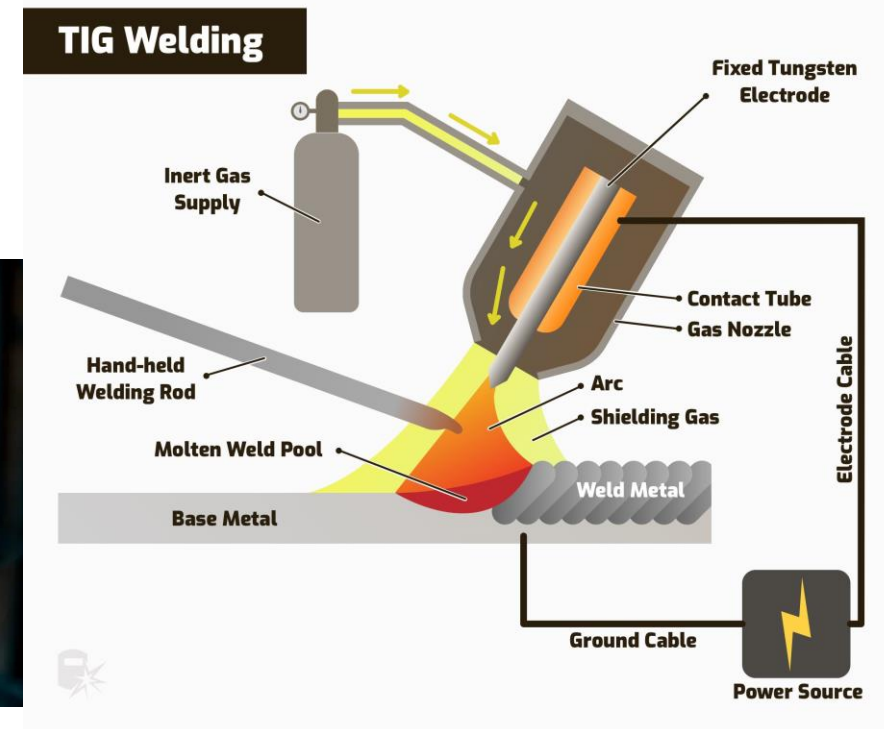
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- Other integrated processes
 - LW + TIG (tungsten inert gas)
 - LW + PAW (plasma arc welding)

Hybrid LW

– Individual processes

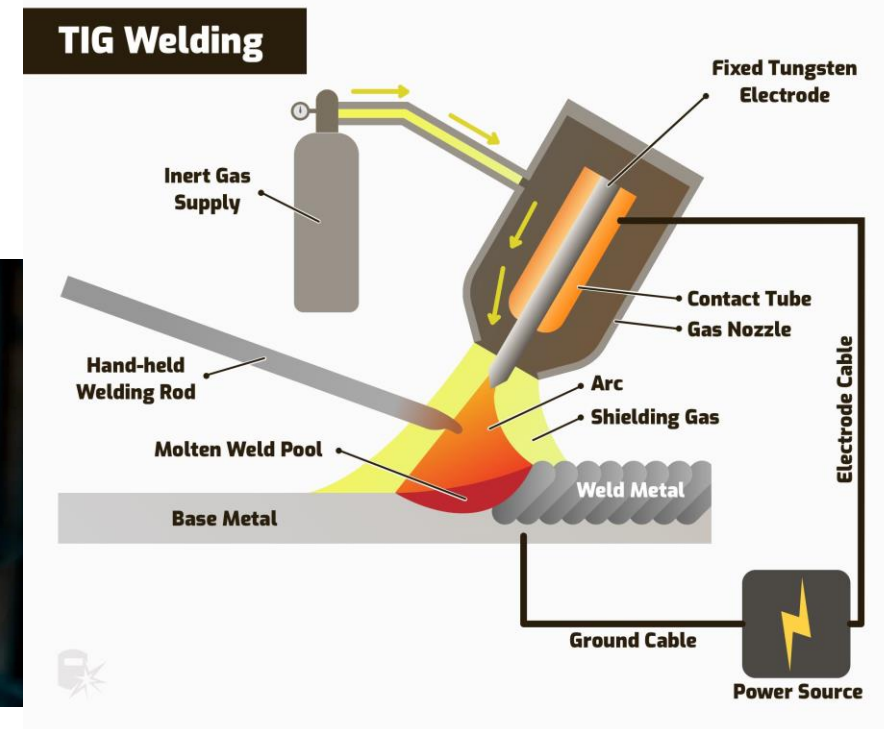
- TIG (tungsten inert gas) welding
 - TIG differs from other processes is by electrode.
 - The electrode in the torch is a short tungsten rod, sharpened to a point.
 - Non-consumable electrode just to melt the filler wire
 - Hand held filler wire feed
 - Require expert control vs MIG welding (no auto feed rod)
 - Aerospace & automotive applications



Hybrid LW

– Individual processes

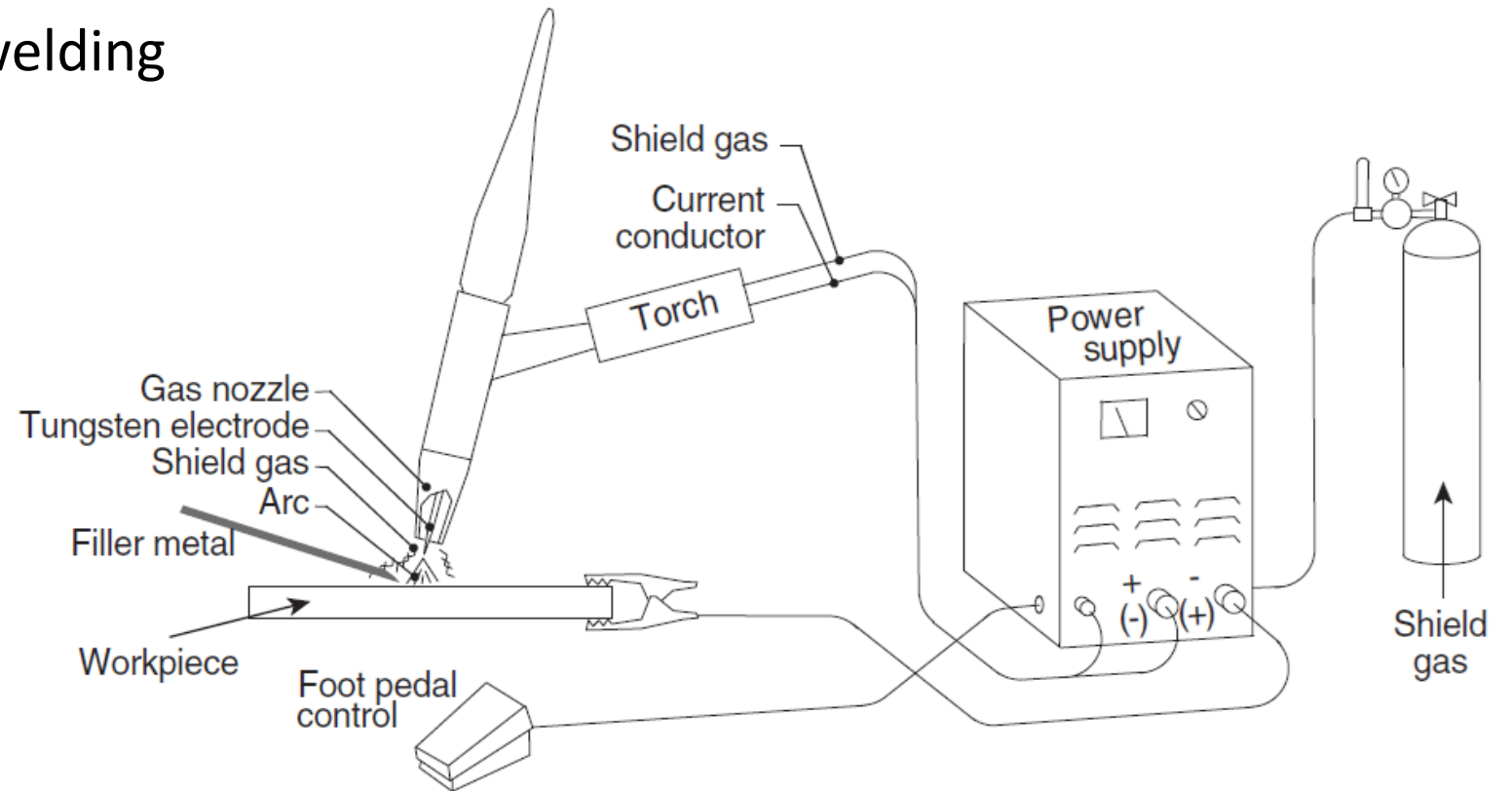
- TIG (tungsten inert gas) welding
 - Welding thickness 0.1~6mm, ideal for thin wall welding of stainless steel and titanium alloys.
 - Weld seam surface is clean, flat, grain like fish scales.



Hybrid LW

– Individual processes

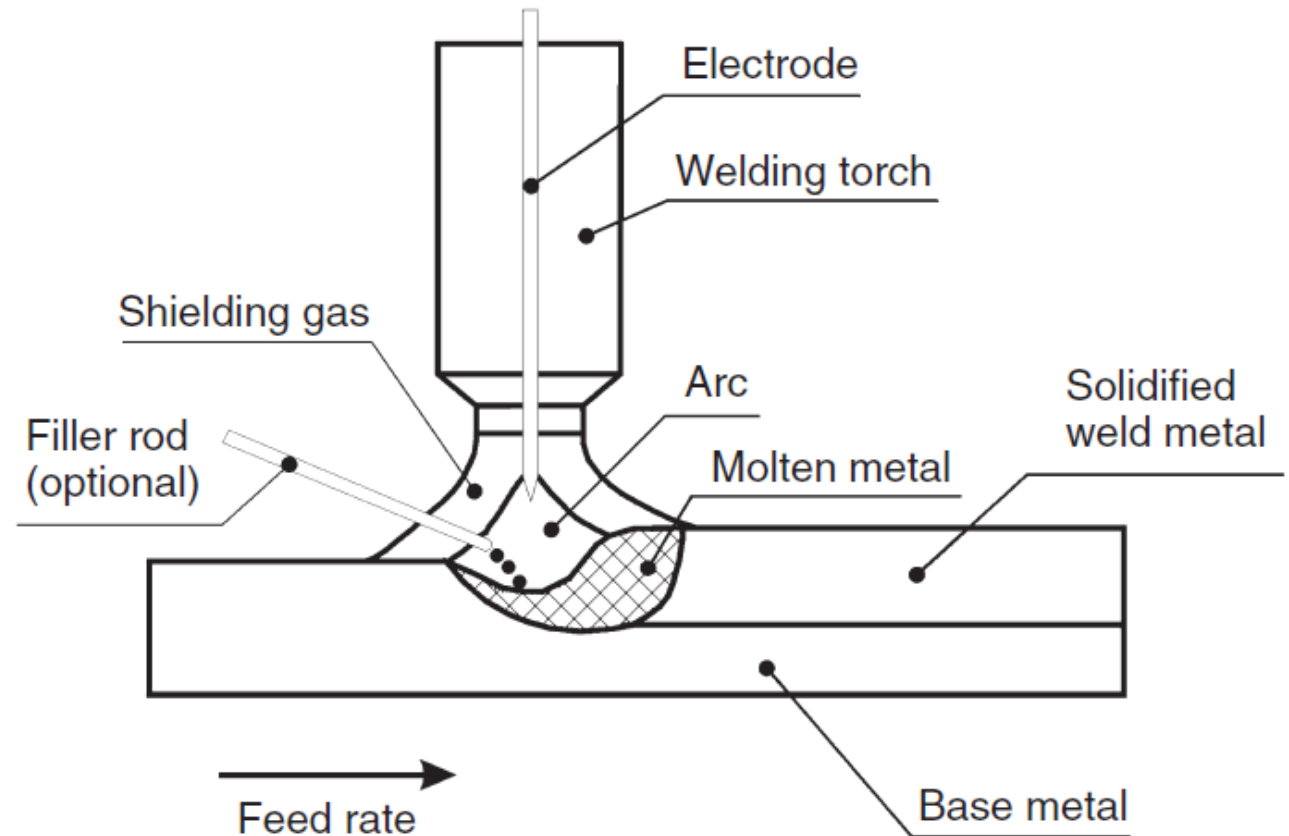
- TIG (tungsten inert gas) welding
 - Setup schematic



Hybrid LW

– Individual processes

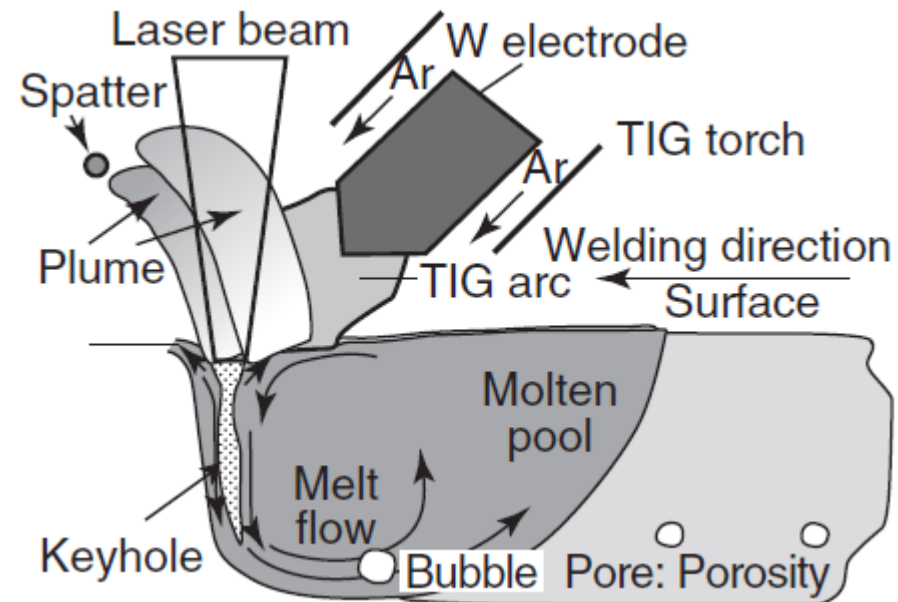
- TIG (tungsten inert gas) welding
 - process schematic
 - Non-consumable electrode



- Other integrated processes
 - LW + TIG (Tungsten inert gas)
 - Similar to MIG/MAG, change is the use of ‘Tungsten’ electrode (non-consumable)
 - Generally used for hard-to-weld metals such as stainless steel (SS304), Al-Mg alloys
 - Metal deposition is much lesser than MIG/MAG (where electrode itself is the filler)
 - Fraction of heat is enough to melt filler wire
 - Similarly, inert shielding gas is used to protect melt pool/electrode/oxide formation/or other contamination
 - In hybrid process, TIG arc is used to preheat the base material for easy laser absorption
 - Common problems: contamination due to hot metal vapor, tip erosion by strong arc, tungsten affinity with oxygen

Hybrid LW

- Other integrated processes
 - LW + TIG (Tungsten inert gas)



Hybrid LW



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- Individual processes
 - PAW (plasma arc welding)

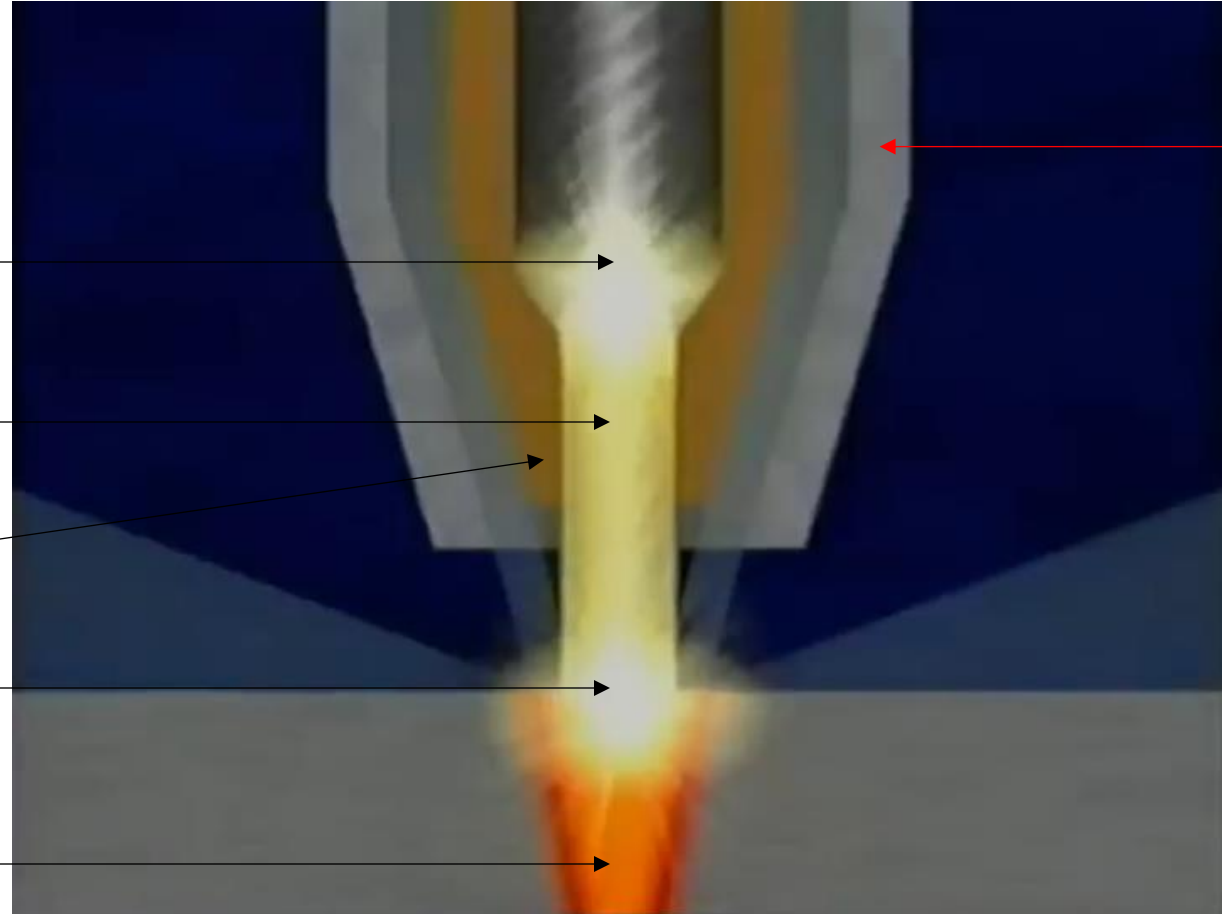
Plasma created by heating inert gas in orifice

High temperature / high velocity plasma

Second shielding gas from outer ring in the torch

Constricted plasma arc due to shrinking nozzle design

Weld pool



Plasma torch

Electrode
recessed in

– Individual processes

- PAW (plasma arc welding)
 - Torch is designed in a manner that the inert gas exits the nozzle at a higher velocity in a narrow and constricted path
 - Plasma is created as the arc is struck with the inert gas (argon/helium etc.), ionizing as it flows into the region (like a jet stream)
 - Non-consumable tungsten electrode is used (but do not contact weld material, remains inside the torch ionizing the inert gas inside the orifice ('orifice gas') and producing plasma)
 - Second shielding gas is also used to protect the weld pool and torch (flows from torch outer ring)
 - Welding temperatures can reach up to 28000 °C, which can melt any metal
 - The high operating temperatures of plasma torches enable the processes to be used for welding and cutting
 - Plasma welding is one of the cleanest welding techniques since the highly concentrated heat creates a narrow bead, which results in minimal spatter, therefore neat welds vs MIG (more spatter, wide seam)
 - Applications: aerospace manufacturing that require pinpoint precision
 - Wide range, 0.1mm thin plate to 10mm thick plate, capable of keyhole mode welding.

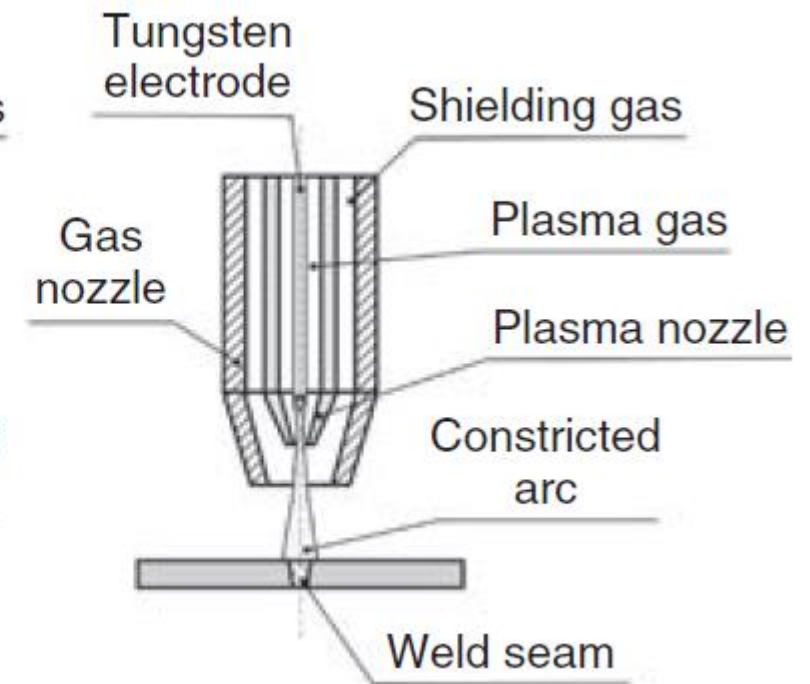
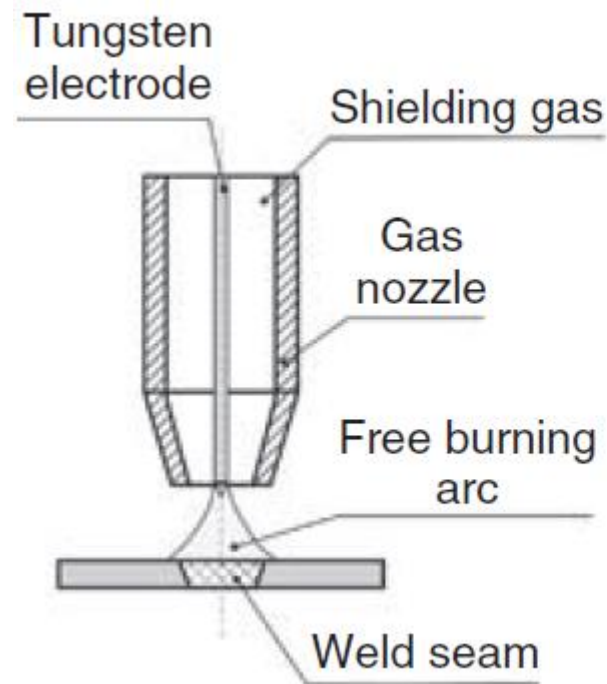
– Other integrated processes

- LW + PAW (plasma arc welding)
- Secondary heat source = plasma arc (formed by shrinking nozzle squeezing the arc)
- Compared to TIG, plasma arc is more stable, concentrated and pointed (can weld thick plates with deep melting)
- Arc heat input can be reduced up to 40% vs LW+TIG (due to high concentrated arc density)
- Resulting in deeper penetrated welds

Hybrid LW

– Other integrated processes

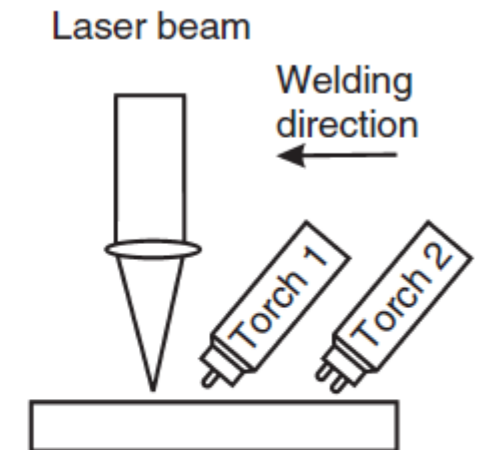
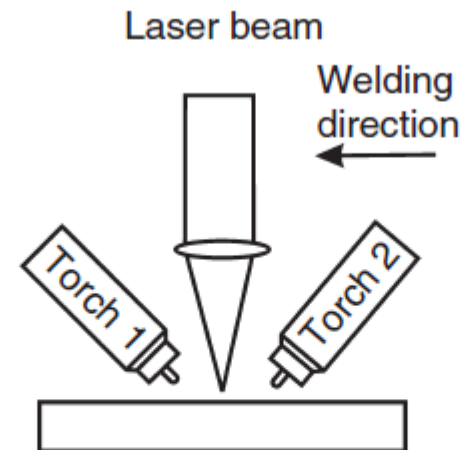
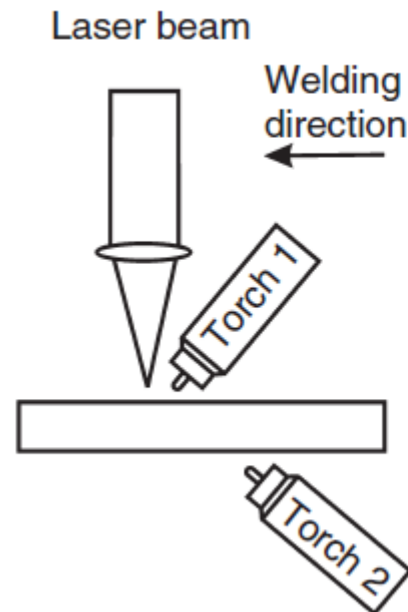
- TIG vs PAW
 - Shows TIG wider weld seam vs narrow, neat from PAW



Hybrid LW

– Other integrated processes

- LW + GMAW
- Can have more than two heat sources other than laser (differ in material / thickness / applications)



Hybrid LW – Applications



– Advantages

- By combining LW+GMAW,
- Enables high welding depths with high gap bridging/resistance (due to filler fill or deposition) to be brought together simultaneously, especially for larger thickness
- The filler material enables the properties of the weld seam
- High welding speeds and deeper penetration
- Dramatic reduction consumable consumption (filler material if GMAW acts alone)
- Improved mechanical performance contrary to single process
- Reduced joint volumes, heat input and distortion
- Avoids multiples passes in either processes to achieve quality weld

Hybrid LW – Applications



– Advantages

- Hybrid welding serves complicated conditions as well. This includes welding varied materials with different melting points and welding base materials with varying thicknesses.
- High-quality weld through filler addition
- Control of metallurgical variables, such as cracking tendency, through filler addition
- Higher electrical efficiency, up to 50% reduction in power consumption
- Lower capital cost

Hybrid LW – Applications



– Applications

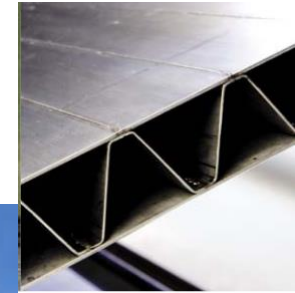
- Particularly suitable for shipbuilding (even aircraft carriers), vehicle construction and construction machinery
- Reason: High material thickness in sheets or parts, larger gaps filling by filler
- Typical welds can be of 30 m long and 15 mm thick plates
- Other similar applications where thickness is high, subjected to materials compatibility
- Energy: production of generator turbines, wind towers, utility towers etc.
- Mobile equipment: cranes, mining, agricultural and other earthmoving machinery where high strength-to-weight ratios are required (e.g., high performance steels)

Hybrid LW – Applications

- Ship building, Construction and Construction machinery



Can be used in steel bridge structures to reduce weight and improve fatigue life



Hybrid LW – Applications



– Applications



Hybrid LW – Applications



– Applications



Golf V plant with dedicated HLAW equipment

Hybrid LW – Applications



– Materials:

Type of Welding	Same Metal	Dissimilar Metals	Dissimilar Materials	Metal-Plastic	plastic-plastic	Thickness *
Laser Beam Welding	YES	YES	YES	YES	YES	3mm
Laser Arc Hybrid Welding	Steels	To some extent	X	X	X	6mm to 15mm (even to- 50mm)
Laser MAG Hybrid Welding	Steels	YES	X	X	X	10 mm
Laser MIG Hybrid Welding	Steels	YES	X	X	X	10 mm
Laser TIG Hybrid Welding	Steels	YES	X	X	X	10 mm

Hybrid LW – Limitations



- Weld defects (porosity, spatter)
- Fumes
- Arc being closed to operator, requires high skill (manual welding)
- Mostly limited to thicker welds industry

Thank You



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