

# **Automatic and robotized applications of welding processes**



**GRUPPO**

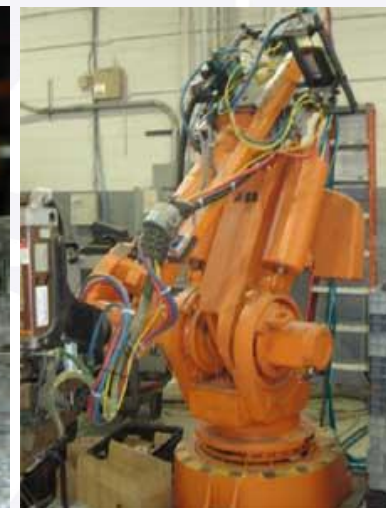
**ISTITUTO ITALIANO DELLA SALDATURA**

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## Automation in welding

- Welding processes can be subjected to **different levels of automation**, also based on the complexity of the work to be done and depending on the production.
- The processes that are **better suited to robotic applications** are:
  - GMAW;
  - GTAW;
  - PAW;
  - laser and electron beam welding;
  - resistance welding.

	Type of production		
	Job shop (low volume)	Batch (medium volume)	Mass (high volume)
Lot size			
Large complex parts	1–10	10–300	Over 300
Small simple parts	1–300	300–15,000	Over 15,000
Weld setup	Manual	Fixture, manual loading	Fixture, automatic loading
Welded	Manual or semi-automatic weld	Standardized welding machine	Dedicated welding machine
Estimated percentage of U.S. production	10–20%	60–80%	20–30%



# Levels of automation in arc welding

Level	Manual	Semiautomatic	Mechanized	Fully - mechanized	Robotized	Robotized / Adaptive
<b>Ignition and operation of the arc</b>	MANUAL	AUTOMATIC	AUTOMATIC	AUTOMATIC	AUTOMATIC (SENSOR)	AUTOMATIC (ROBOT)
<b>Filler metal feeding</b>	MANUAL	AUTOMATIC	AUTOMATIC	AUTOMATIC	AUTOMATIC	AUTOMATIC
<b>Control of the depth of penetration</b>	MANUAL	MANUAL	AUTOMATIC	AUTOMATIC	AUTOMATIC (SENSOR)	AUTOMATIC (SENSOR)
<b>Advancement and wobbling</b>	MANUAL	MANUAL	MANUAL	AUTOMATIC	AUTOMATIC (SENSOR)	AUTOMATIC (ROBOT)
<b>Arc positioning</b>	MANUAL	MANUAL	MANUAL	AUTOMATIC	AUTOMATIC (SENSOR)	AUTOMATIC (SENSOR)
<b>Correction of the arc</b>	MANUAL	MANUAL	MANUAL	No correction is possible	AUTOMATIC (SENSOR)	AUTOMATIC (SENSOR)

## Type of robots employed in welding

- On the basis of the architecture is possible to **distinguish different types of robots**:
  - **anthropomorphic** (revolute)
  - **cartesian**
  - spherical or polar
  - cylindrical
  - SCARA
- For each of these categories, is important to define:
  - **degrees of freedom**, ie the possible movements (linear or angular) of the end effector
  - **workspace**, ie the area of possible motions that can be achieved from the end effector

REVOLUTE  
Jointed Arm  
Vertical  
Articulated Arm



CARTESIAN  
Rectangular Coordinated



SPHERICAL  
or Polar Coordinated



CYLINDRICAL  
Coordinated

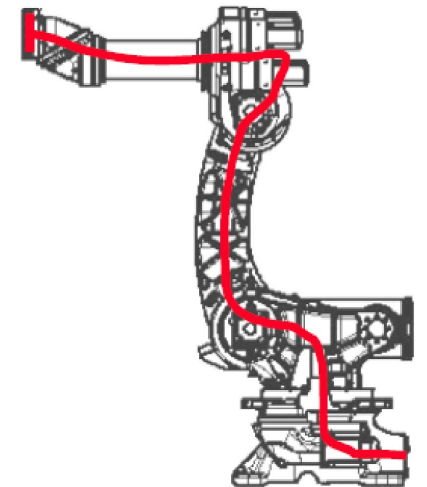
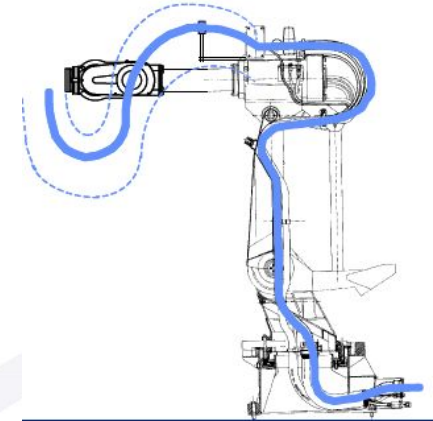
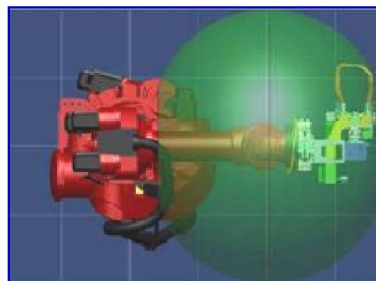
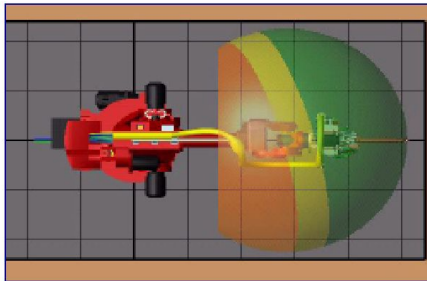
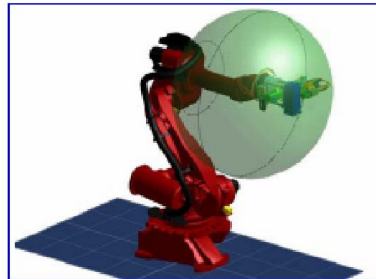
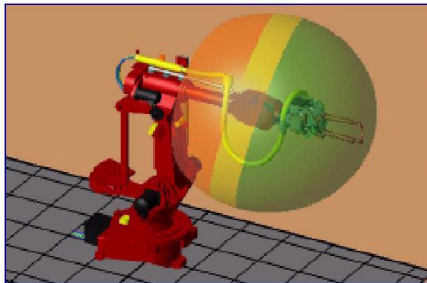


SCARA  
Horizontal  
Articulated Arm



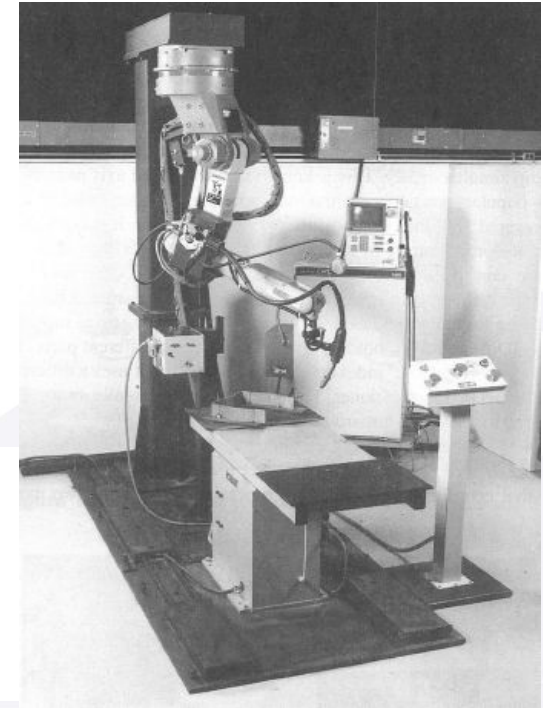
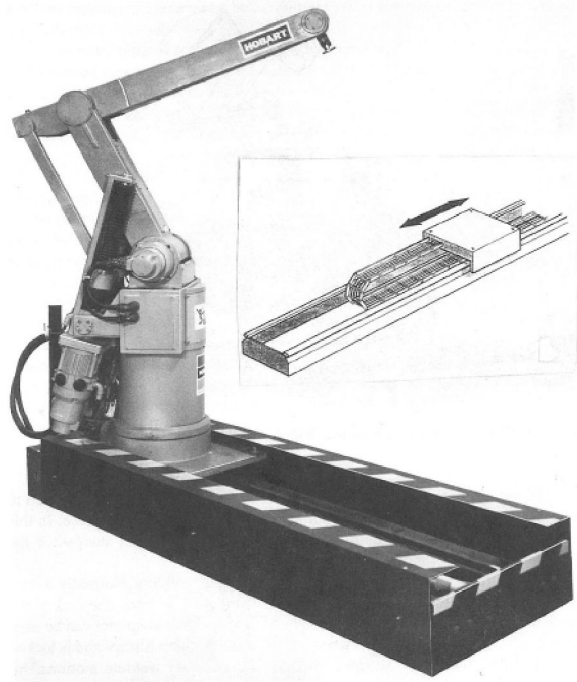
## Anthropomorphic robot configuration

- An interesting opportunity is the ability to use **hollow wrist robots**:
  - easier movement;
  - wider workspace;
  - easier PC simulation.



## Type of robots employed in welding

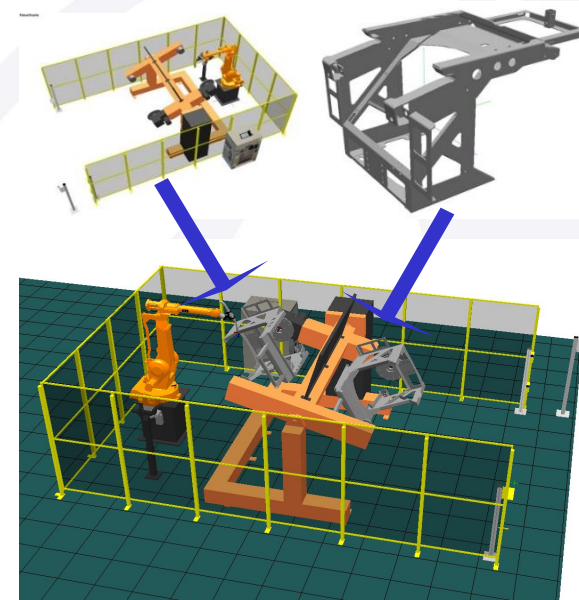
- In the case of **positions on multiple workspaces**, or complex elements, is possible to use a **hybrid geometry**
  - portals with robots (also mounted in the **reverse position**)
  - sliding rails with anthropomorphic robots





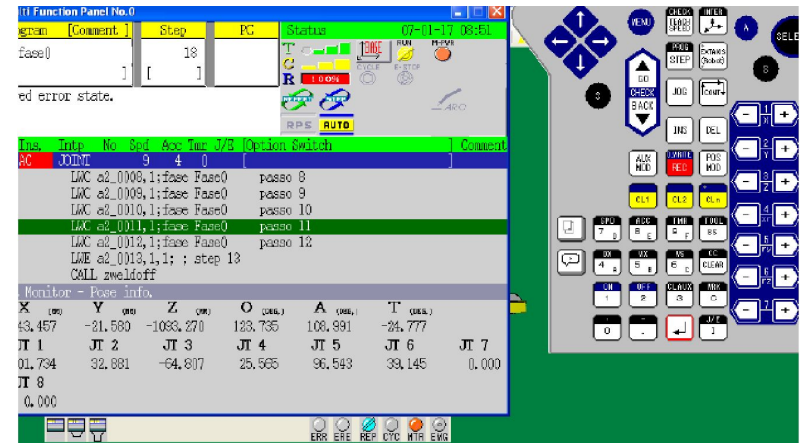
## Programming and simulation of the process

- Programming tools for the robot:
  - **teach pendant**, simple to use, but with reduced functionality;
  - **PC with dedicated programming languages**, very versatile, but requires specific knowledge of the interface (rarely "user friendly")
  - **advanced simulation tools**
- The main tool to reduce the time of finalization of the program is the simulation, which allows you to identify trajectories and programs given the input characteristics of the work and the 3D model of the final product.
  - Advanced Programming Systems
  - Virtual reality systems



## Virtual programming

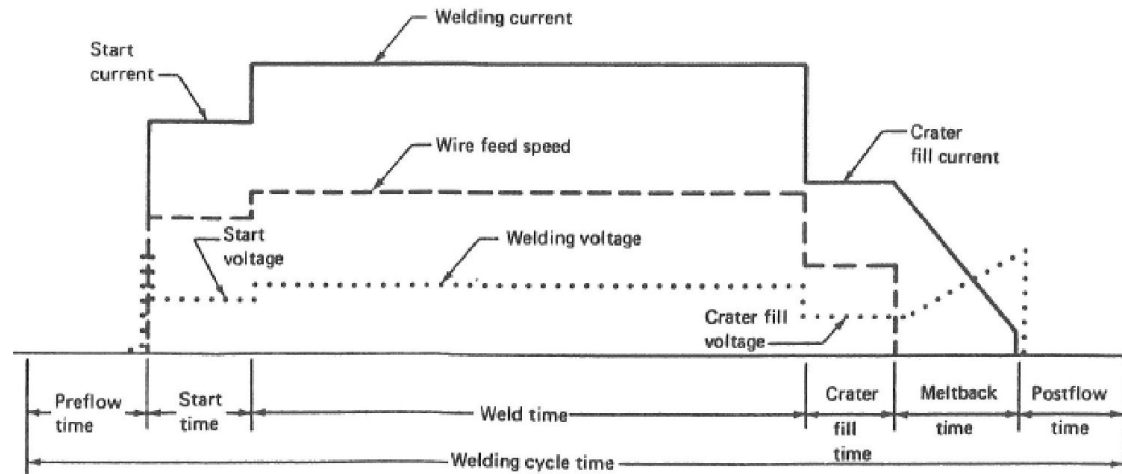
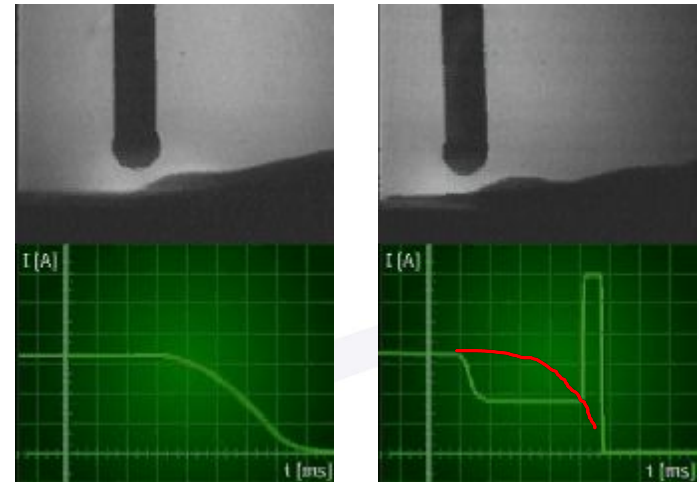
- Testing the robot motion detection with interference, use of sensors and program fixes with keyboard.
- Compiling a complete program in a virtual system calibrated with the real system (no post processing):
  - virtual self learning programming using the mouse to carry the torch on point and save it in a single click
  - ways of taking a point on the workpiece with the mouse pointer
- Ability to transfer programs from the virtual to the real robot (upload) for elaboration and verification.
- The differences in calibration between the virtual world of simulation and the real world are corrected by the research and the pursuits made with appropriate sensors.





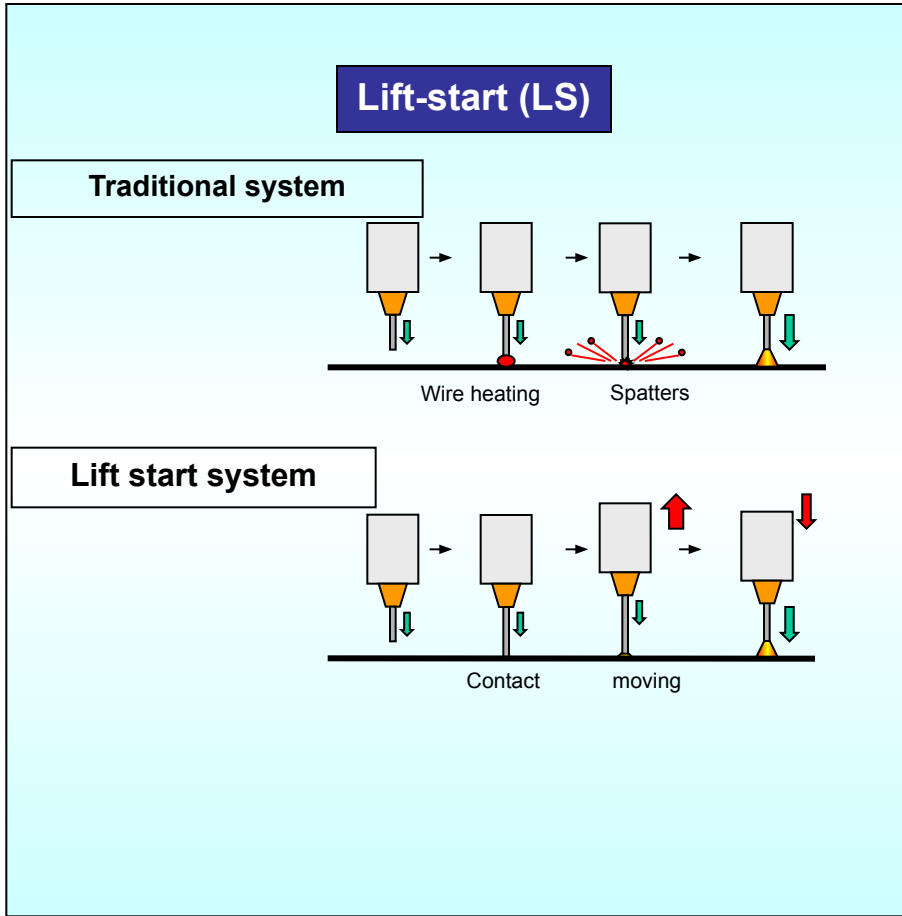
## Application to the welding processes: GMAW

- The **particular characteristics of the process** allows a particularly effective control of the parameters:
  - **constant voltage** (generator)
  - **constant current** (self regulating system)
  - the **position control** can be carried out by managing suitably the value of the **stick - out**.
- The **arc ignition** doesn't pose particular problems, but is important to manage it in order to avoid spatters.
- Arc extinction** is realized with appropriate programs (eg. crater filler)

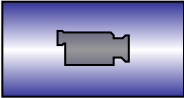
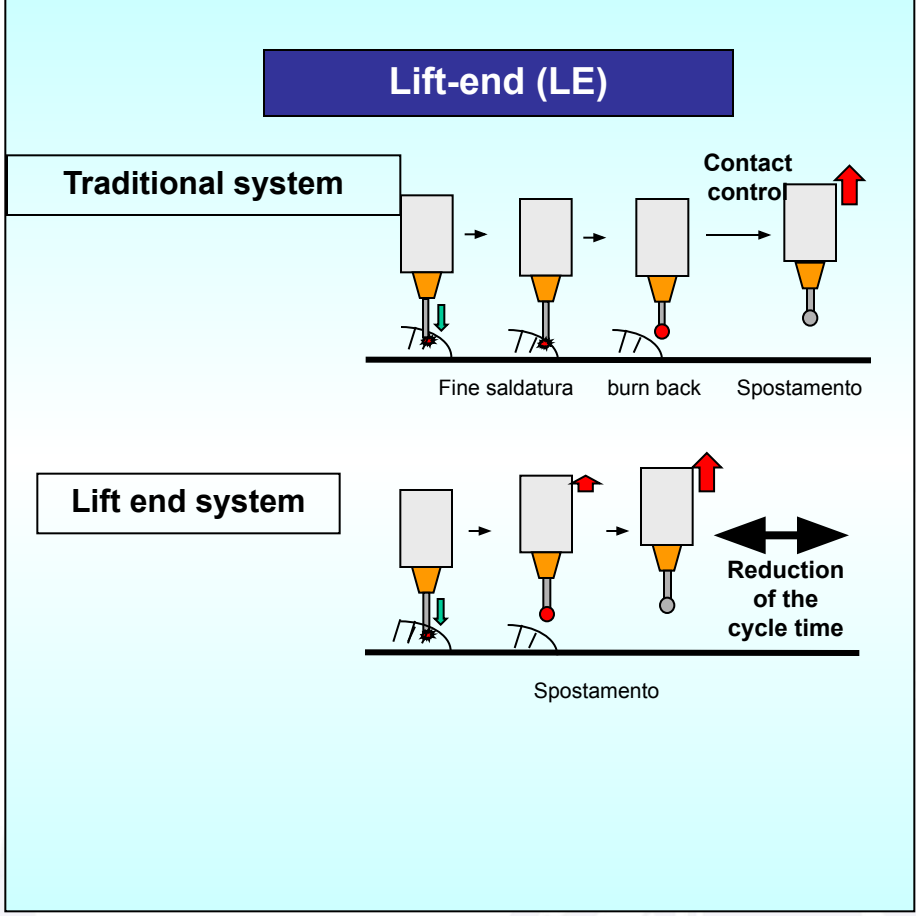


# Arc ignition and arc extinction systems

## Lift-start (LS)

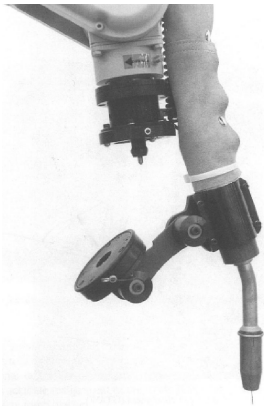


## Lift-end (LE)



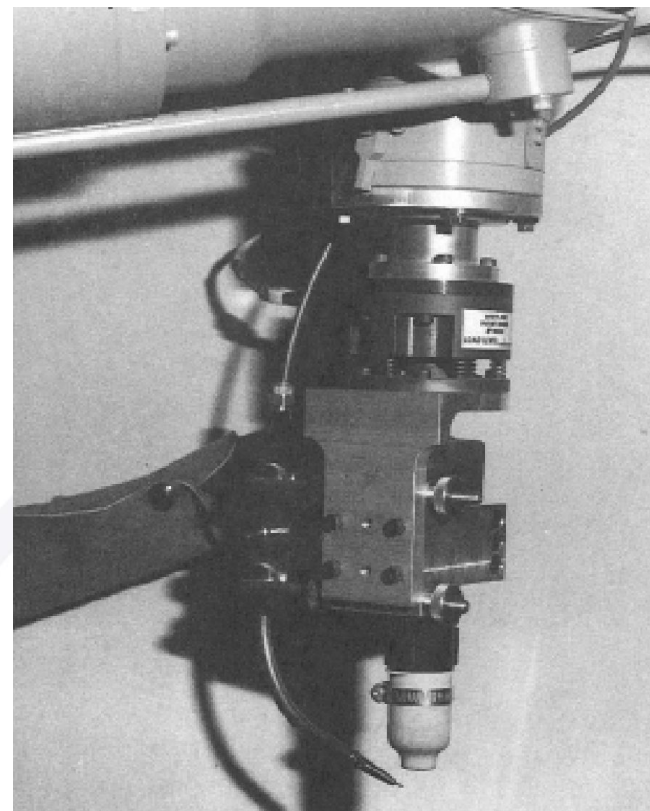
## Application to the welding processes: GMAW

- Other devices employed:
  - device for the cleaning of the nozzle (and possible spraying of non-stick substances)
  - device for the cutting of the wire (when necessary)
  - antirupture systems

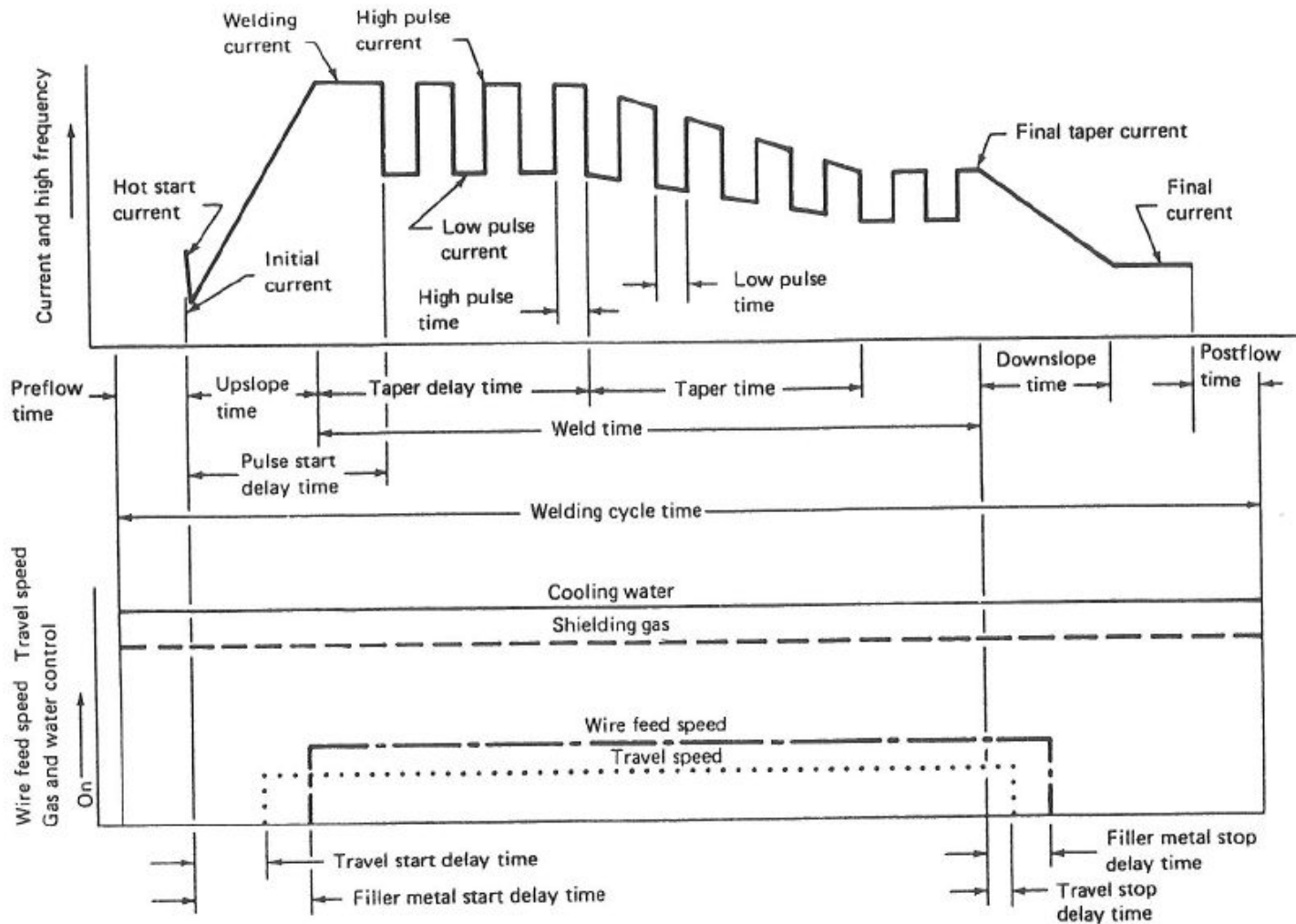


# Application to the welding processes: GTAW

- The process is suitable for robotic applications **with some limitations**:
  - **arc ignition** system with high voltage and high frequency;
  - applications with **filler metal**:
    - the welding direction is a process parameter
    - the presence of the wire reduces the criticality of the arc length
  - **for applications without filler metal**, are required devices for an accurate management of the arc length



## Application to the welding processes: GTAW

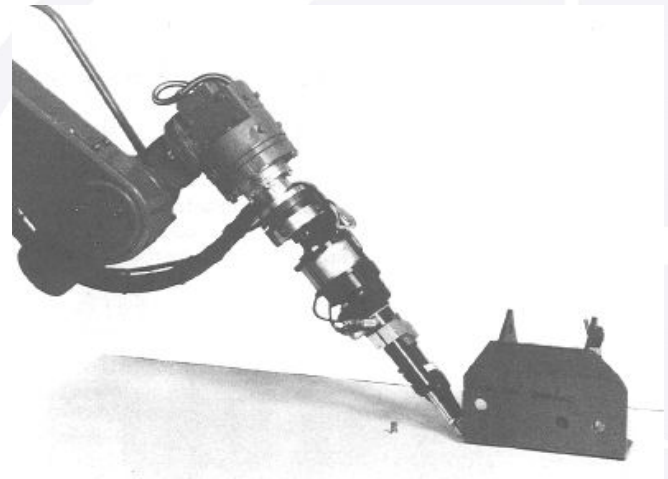
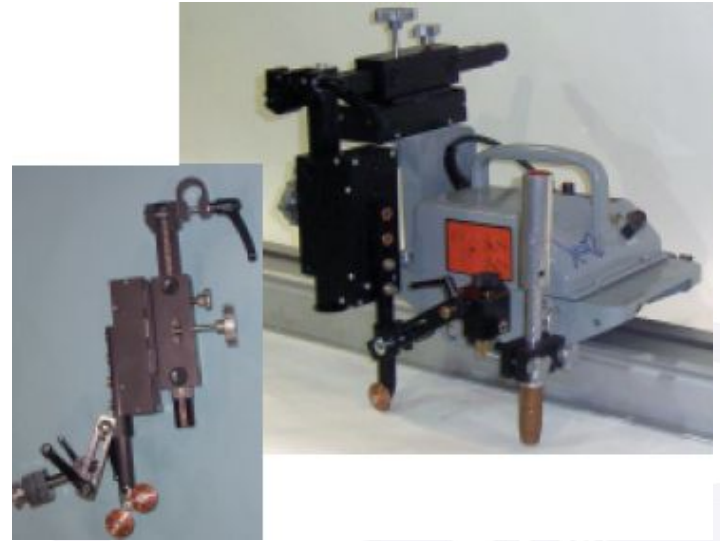


Ciclo di saldatura con processo TIG robotizzato



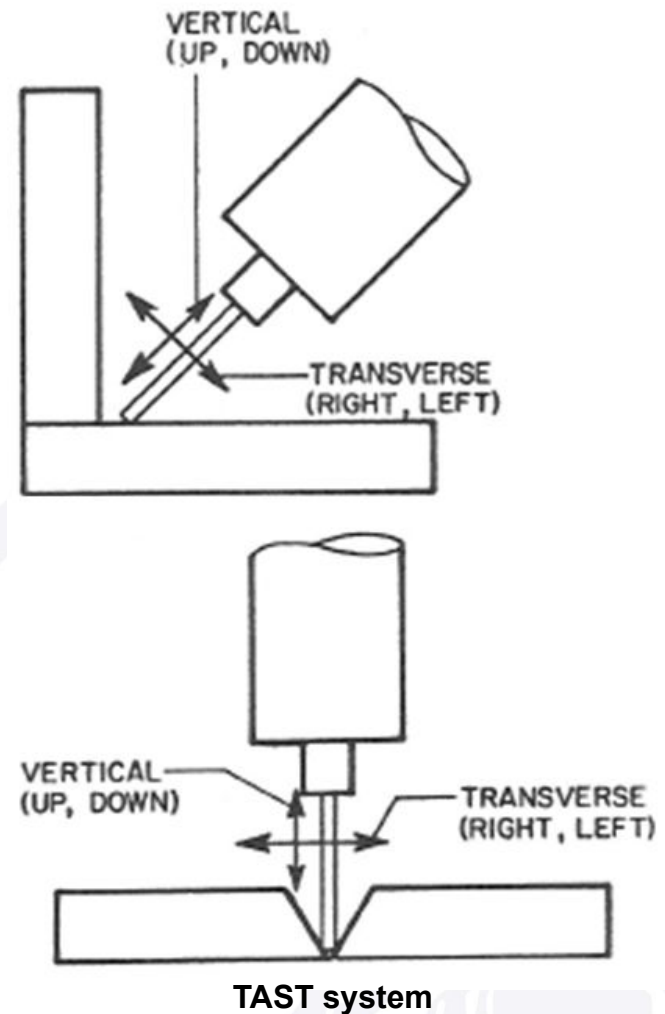
## Contact sensors for arc welding

- They are primarily used for the **tracking of the joint**.
- Can be **simple probes or complex electromechanical systems**, generally oscillating along the bevel.
- The **distance between the sensor and the arc** can be a source of problems for complex paths (high distance) or for overheating (low distance).



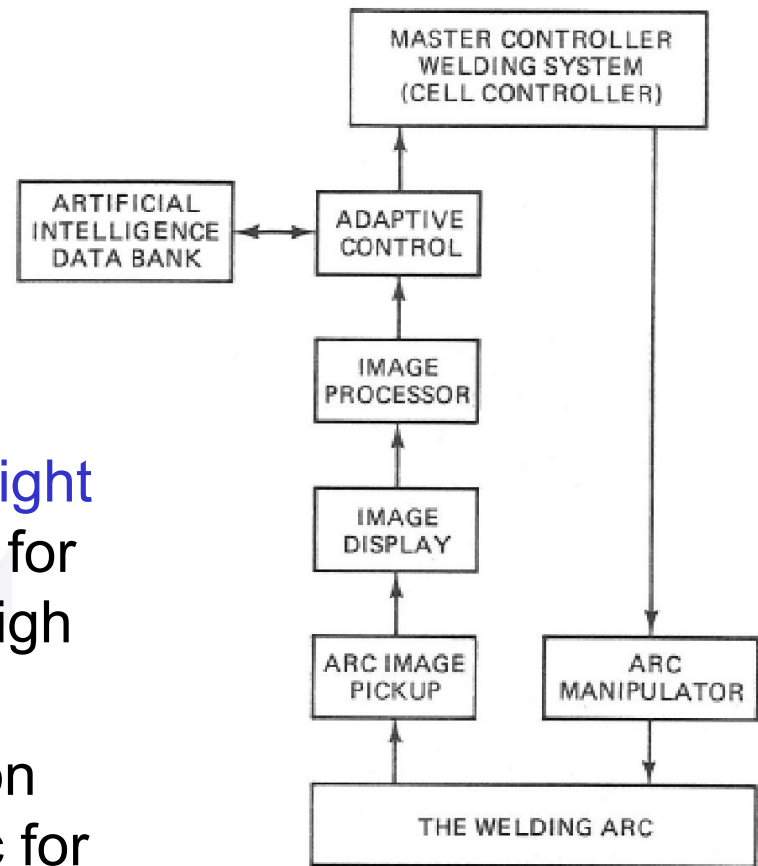
## Arc based sensors

- The **simplest system is based on the arc voltage** (eg, submerged arc).
- The most common case is that of tracking systems of the joint, based on **torch movements and consequent variation of the values of voltage and / or current** (the movement of oscillation is adjusted in order to obtain the constant fluctuation of these parameters).



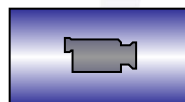
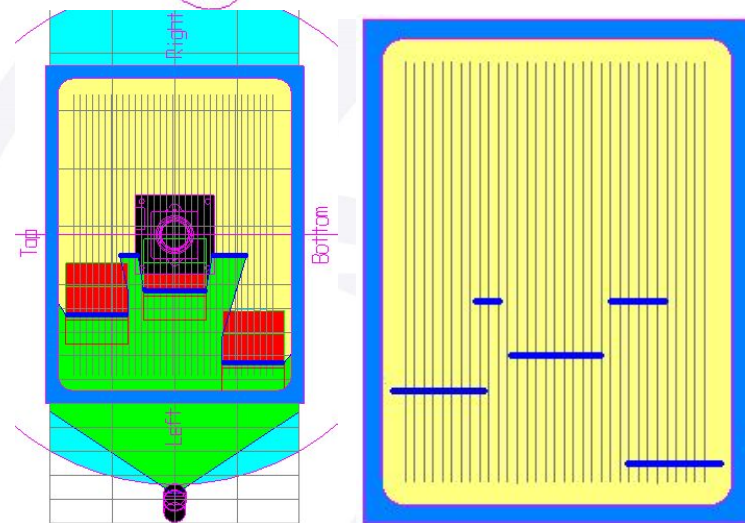
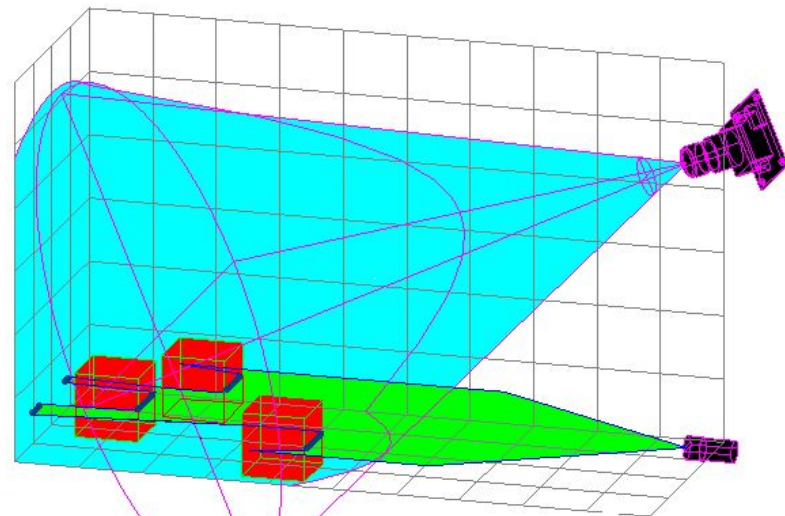
## Vision base sensors

- These systems can **capture an image and process it to handle**:
  - tracking of the joint
  - penetration
  - size of the melt pool
  - shape of the deposit (for example for welding in position)
- To make the system **less sensitive to light emission of the arc**, are used sensors for specific wavelengths coupled with a high power laser beam.
- **The complexity** is related to information management systems and to the logic for the correction of the welding parameters



## LASER sensors

- These are the **sensors that provide greater sensitivity.**
- Principle of operation
  - a **light source** emits a laser beam that illuminates objects;
  - the **signal** is sampled by a digital camera;
  - a **dedicated software** filters the signal and interprets it, providing information to the control system.
- The system works even **if the arc is off**, and allows the identification of the joint



# Comparison between sensors for arc welding

	<b>TAST</b> (Through Arc Seam Tracking)	<b>AVC</b> (Arc Voltage Control)	<b>Laser</b>	<b>Contact</b>
<b>Find the joint</b>	N	N	Y	Y
<b>Joint tracking</b>	Y	Y	Y	N
<b>Adaptive control</b>	Y	N	Y	Limited
<b>Type of joint</b>	Lap, Fillet, Butt,	Lap, Fillet	All	Lap, Fillet
<b>Materials</b>	Steels	Steels, Aluminium	Not shining	all
<b>Minimum gap</b>	2 mm	4 mm	0.8 mm	2 mm
<b>Time of cycle</b>	none	none	< 1 s per search	1.5 s per search
<b>Welding process</b>	GMAW, SAW	GTAW, PAW	All	All



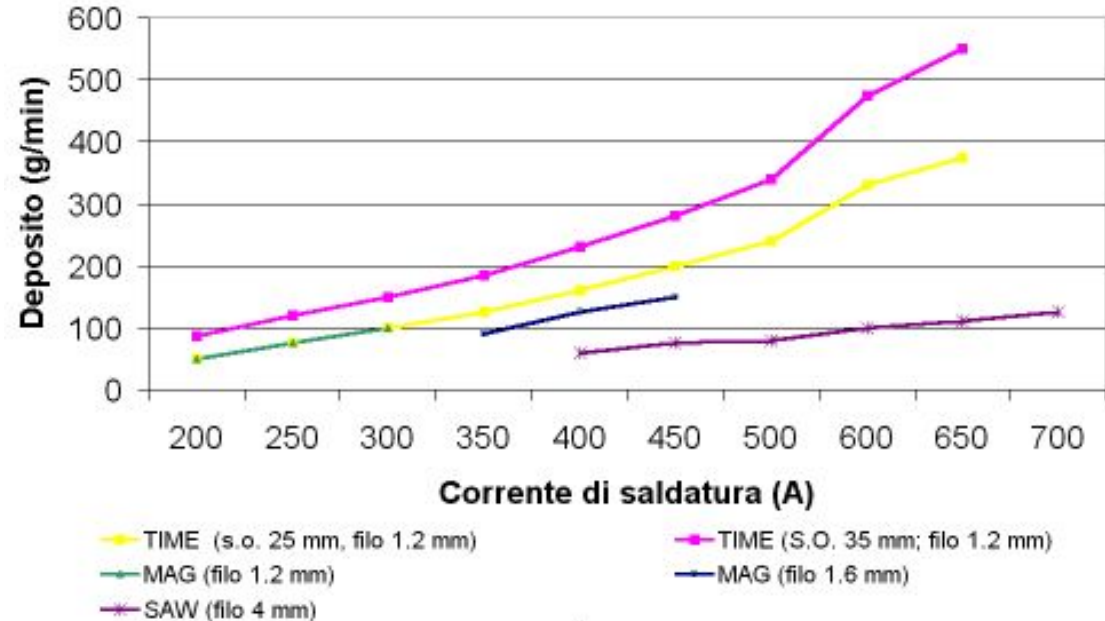
## Robot – sensor communication

- Influence the **possibility to manage in real time** the movements of the system (adaptive management of the welding process).
- **Analogic** one-way connection:
  - a calibration is required between the robot and the generator because of the imprecision of the analog signal
- **Digital** connection:
  - digital connection decreases the differences between the real and the set parameters
- **CPU connection (single CPU)**:
  - total process and movement control via software by eliminating the differences between set and real values



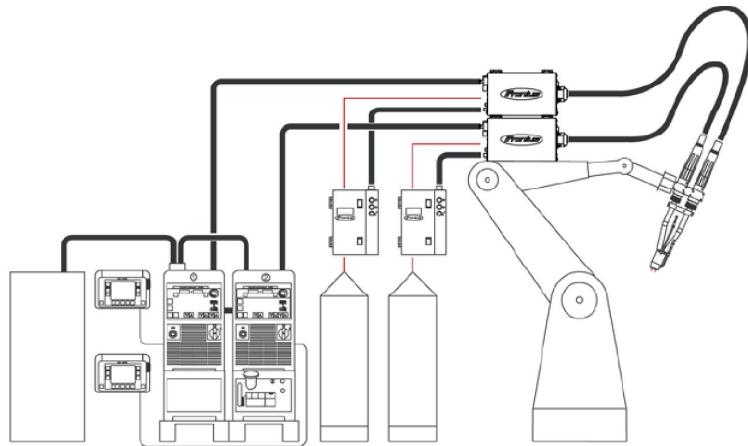
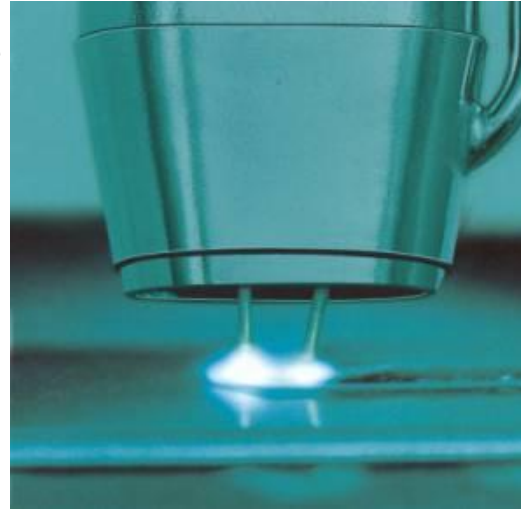
## TIME Process (GMAW)

- Used for **processes with high productivity** and exclusively in conjunction with robotic equipment, allows higher deposition rate and welding speed if compared to a traditional GMAW process:
  - Wire feed speed very high, up to 30 m / min and stick out up to 35 mm, resulting in high values of welding current and up to 30 kg / h (1.2 mm wire)
  - welding speed even higher than 700 cm/min



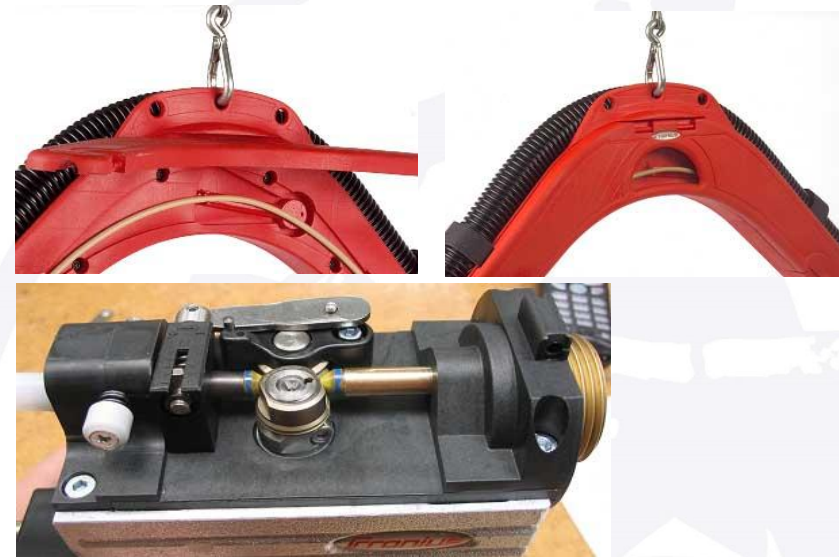
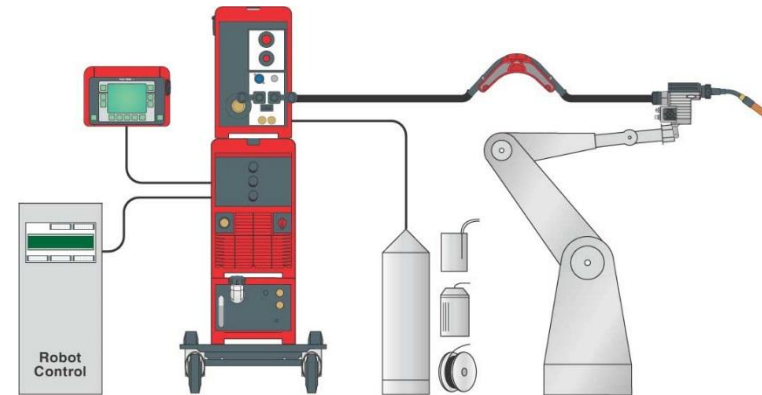
## Multiwire applications (GMAW)

- **Multiwire torches** allow an increase in productivity, with exclusive use in automated applications
- Typical areas of **application**:
  - rail;
  - shipbuilding;
  - automotive;
  - tanks and reservoirs;
  - pipeline.



## MIG Brazing (CMT)

- A particular system for the advancement of the wire (in the torch) allows the obtaining of pulse speed of the wire:
  - operation similar to the short-arc, with current values lower and greater regularity



# Resistance welding

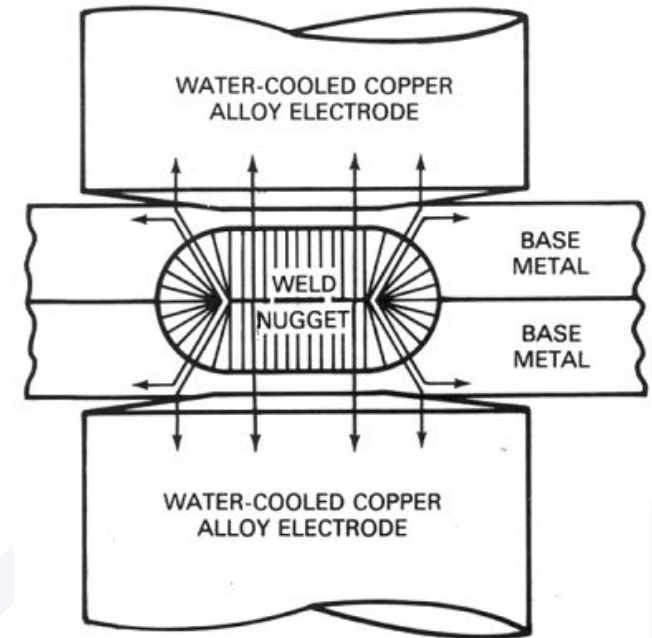
- Autogenic fusion process by pressure
- Applicable to all materials
  - Automotive
  - Railway vehicles and components
  - Microjoining
  - Small thickness pressure vessels
  - ...
- The technical principle can be applied to:
  - Resistance spot welding
  - Projection welding
  - Flash welding
  - Upset welding





# Welding metallurgy: the weld nugget

- Heat is generated at the center of the joint
- The interface between liquid phase and solid phase is solid state welded
- The final microstructure has a dendritic shape, which solidification of grains starting from periphery of the nugget



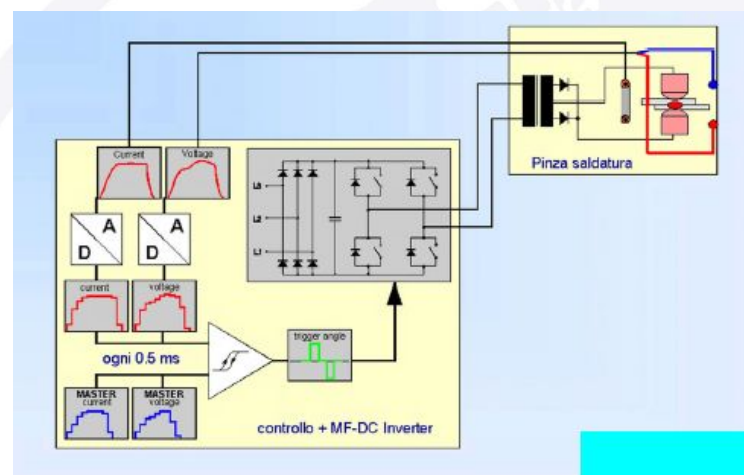
# Robotic applications of RSW

- The **resistance welding process** is suitable for robotic application
- The **critical issues** are:
  - the weight of the gripper
  - services (air, cooling system)
  - the size of the gripper, which influence the ability to reach working points in complex structures
- **Load capacity** of the robot
  - up to 10 times higher than those for the arc welding (up to 80 kg)
  - unlike the manual application, the clamp is not counterbalanced with ceiling supports, to ensure greater mobility

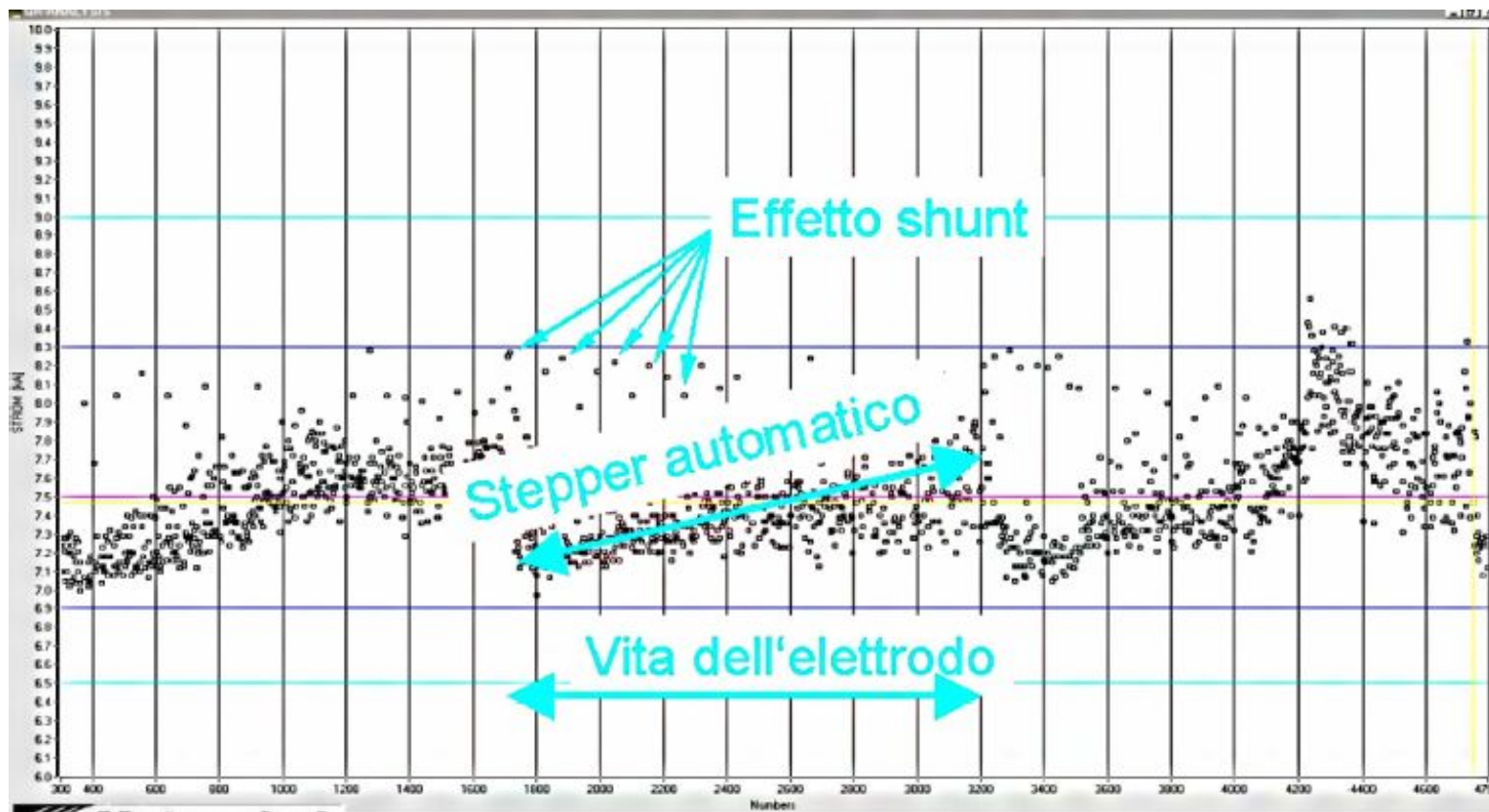


# Sensors and control for the spot welding

- The development of **inverter generators** makes **response times in the order of 20 ms**, and consequently the application of adaptive controls.
- The **electrical and pressure parameters** are given to a control unit, which brings them back to the standard parameters (the operation is based on the control of the resistance between the toes during welding).
- During the welding process, the values **recorded in the system will be compared, every millisecond, with the measured values.**



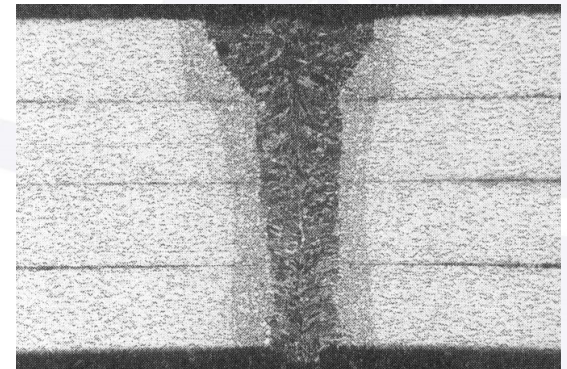
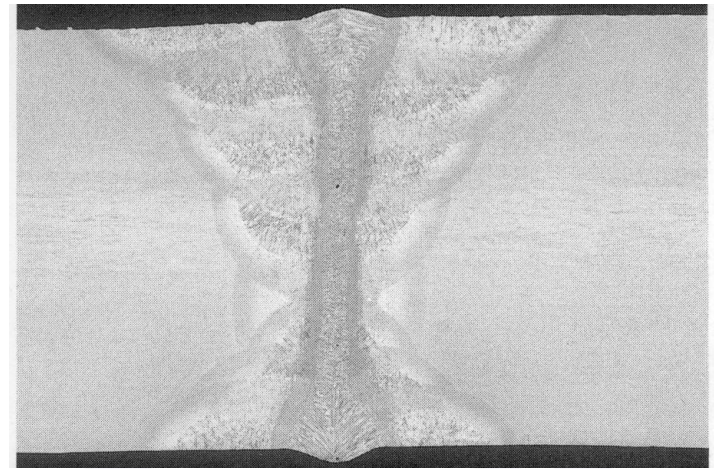
## Adaptive controls





## Main characteristics of a LASER welded joint

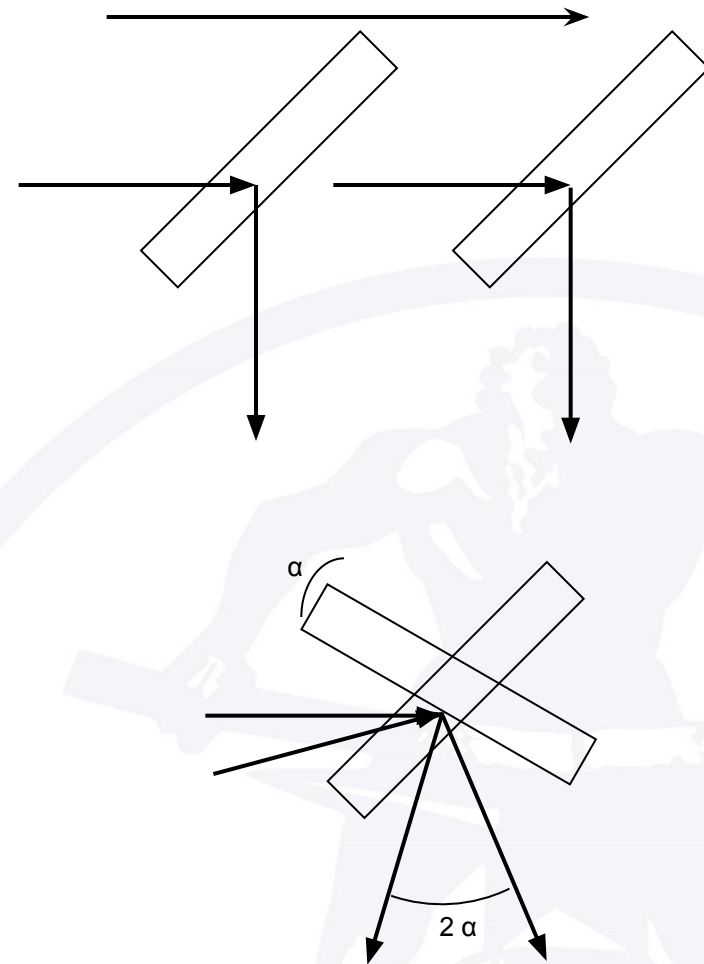
- Being a welding process with keyhole technique, **the conductivity of the material influence to a lesser extent, as the heat is transferred to "direct contact" between the material and the source, ensuring the welding of large thickness in one pass and small HAZ.**
- The ability to **travel great distances in the air** makes it possible to weld in areas with poor access.
- They are, however, **necessary preparations and movements very accurate.**





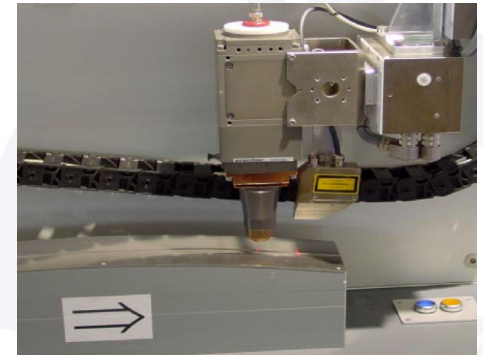
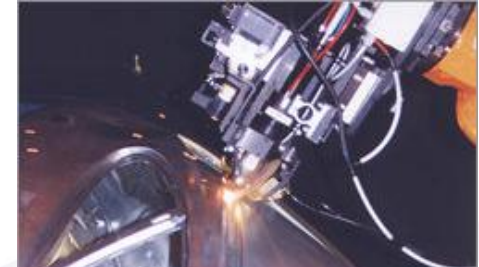
## Equipment for LBW

- Optical devices for deflection and focusing of the beam:
  - lenses (used for low power, because of the expansion due to overheating);
  - mirrors in Cu, Au or Mo (more reliable when cooled by recirculation of water).
- Protective devices of the melt pool:
  - welding in free environment;
  - welding in a closed room (highly reactive materials, for leak testing or special containers to seal).
- Devices for the reduction of the plasma plume.



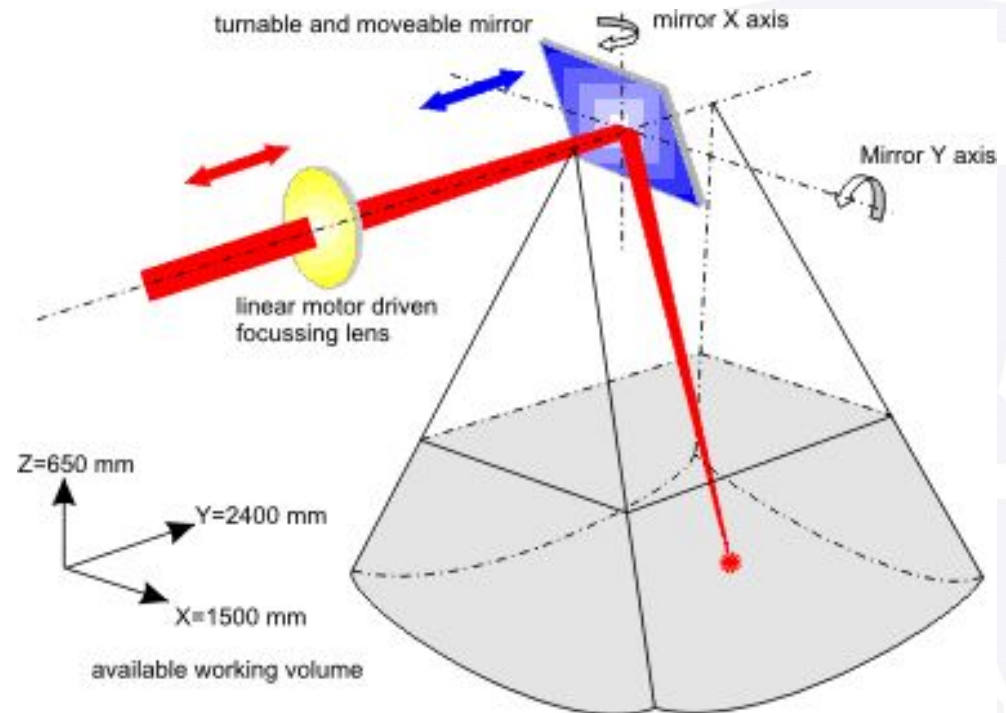
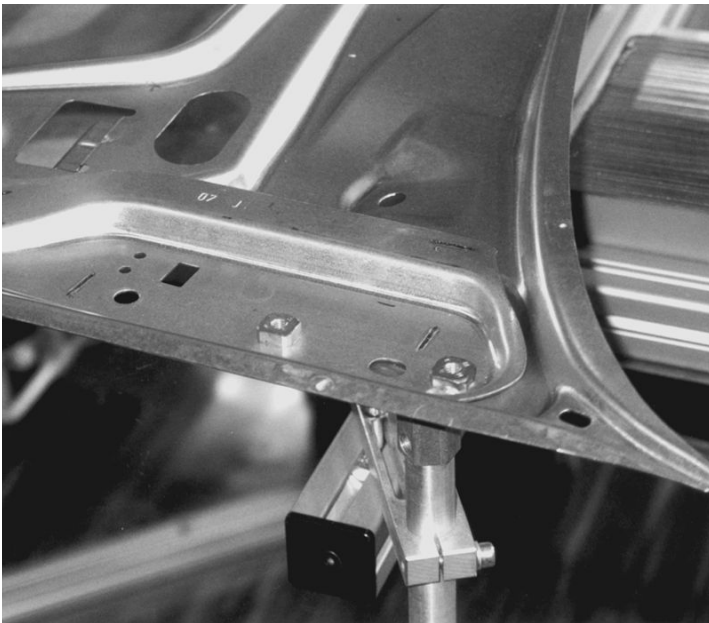
# Application to the welding processes: LBW

- The **geometry of the robot** is influenced by the type of laser and the transmission system (Fiber or mirrors):
  - **anthropomorphic systems** (Nd: YAG laser, fiber);
  - **Cartesian systems** (CO<sub>2</sub>);
  - laser Remote welding.
- The **key features of the systems**
  - welding speed (also higher than 2 m/min);
  - accuracy (required accuracies of the order of tenths of a millimeter).
- The **absence of contact between the end effector and the workpiece** requires the development of dedicated sensors, able to guarantee the benefits provided.



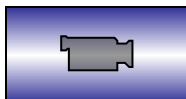
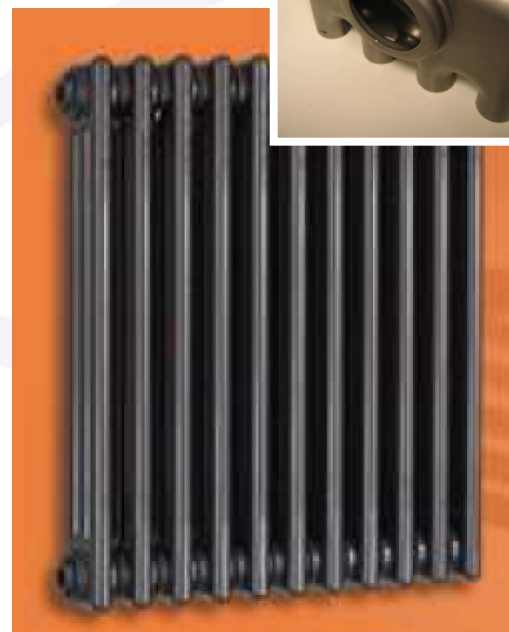
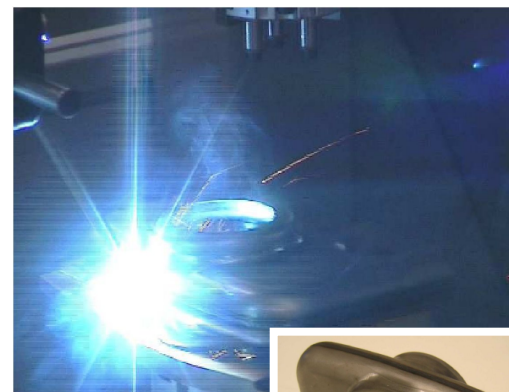
## Laser remote welding

- The **applications of RW** (remote welding) provide welds at distances between 0.5 m and 3 m from the LASER source
  - reduces the problems of accessibility;
  - the welding can be performed **only without gas protection**.



## Applicability of the laser process

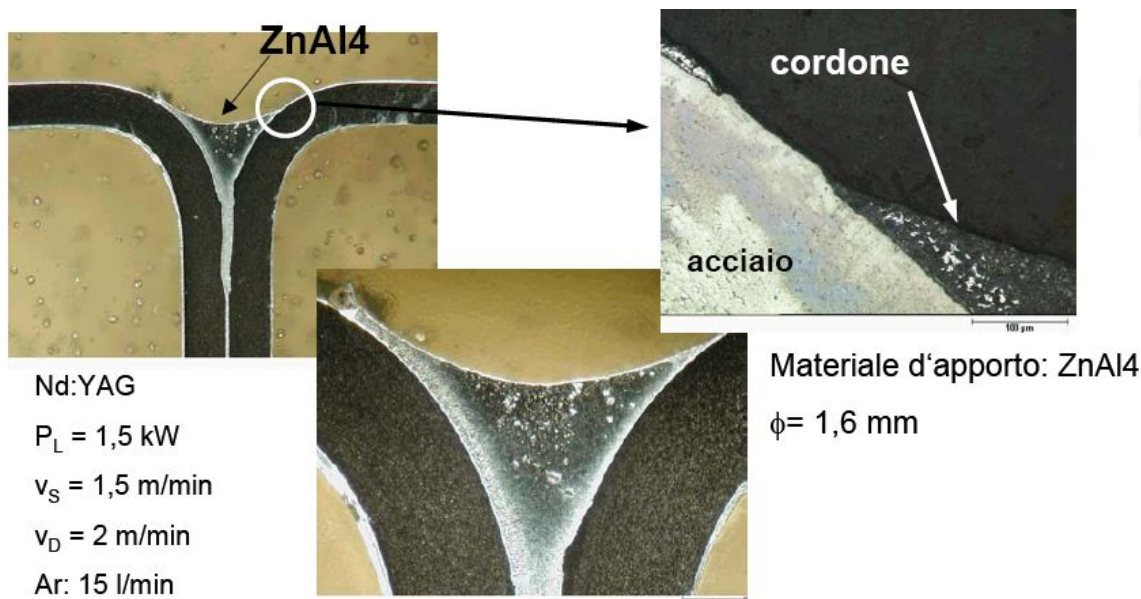
- The **choice of application of a laser process**, in substitution of a traditional process, must consider the following factors:
  - **accuracy** in the preparation of the parts and in its coupling;
  - **complexity of the system**, which requires the presence of dedicated tools and flexibility;
  - **investment**, referred on the installation, use, maintenance and the cost of preparations and coupling.



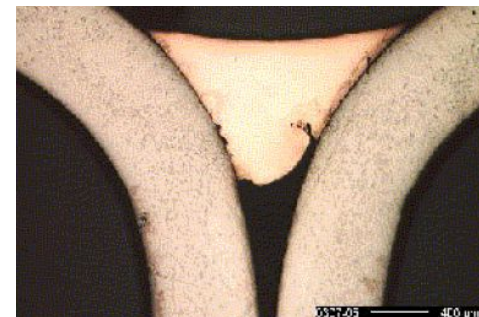


## Applications: LASER weldbrazing

- The **regularity and welding speeds** allow to use low-power lasers (YAG) laser for **brazing activities**.
- **Typical applications** are:
  - braze welding of galvanized steels with copper (CuSi3), silver (Ag55Sn) and zinc (ZnAl14) based alloys
  - braze welding of etherogeneous steel - aluminum joint



Nd:YAG  
 $P_L = 1,5 \text{ kW}$   
 $v_S = 1,5 \text{ m/min}$   
 $v_D = 2 \text{ m/min}$   
Ar: 15 l/min



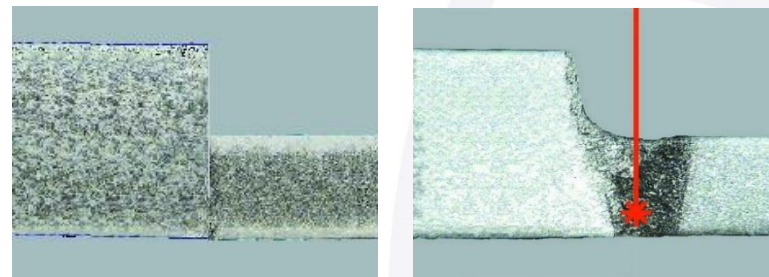
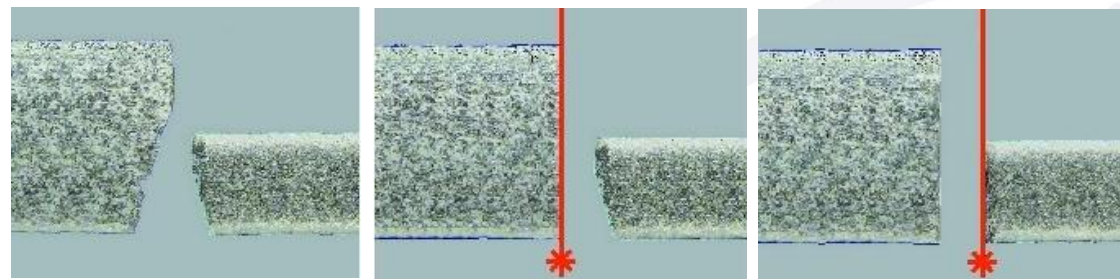
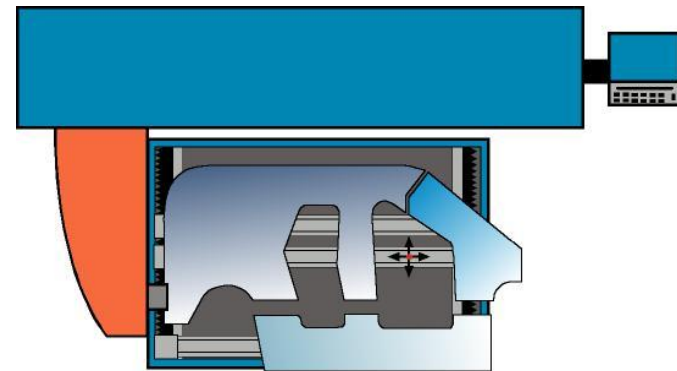
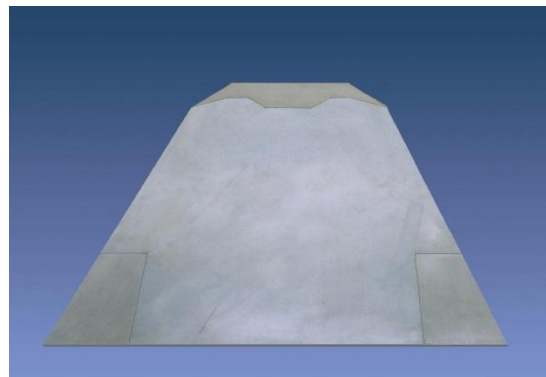
Braze welding of galvanized steel with CuSi<sub>3</sub> alloy  
 $P = 1.1 \text{ kW}$ ,  $v = 1,0 \text{ m/min}$



Braze welding between C-steel and aluminium alloy with ZnAl14 alloy  
 $P = 1.1 \text{ kW}$ ,  $v = 1,0 \text{ m/min}$



## Applications: LASER welding of tailored blanks



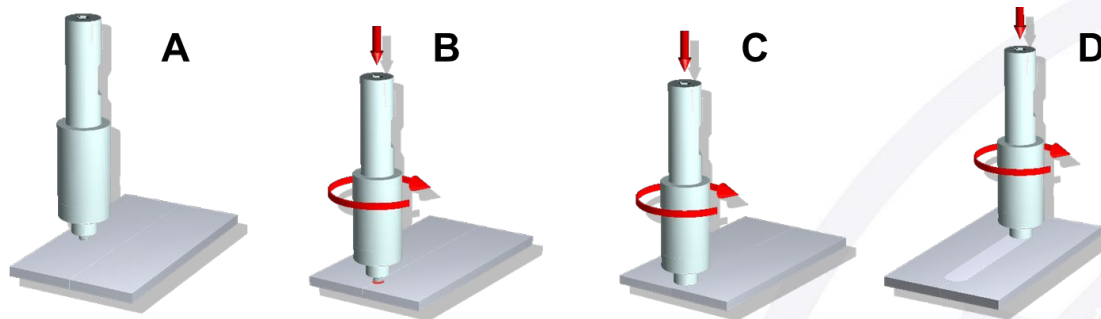
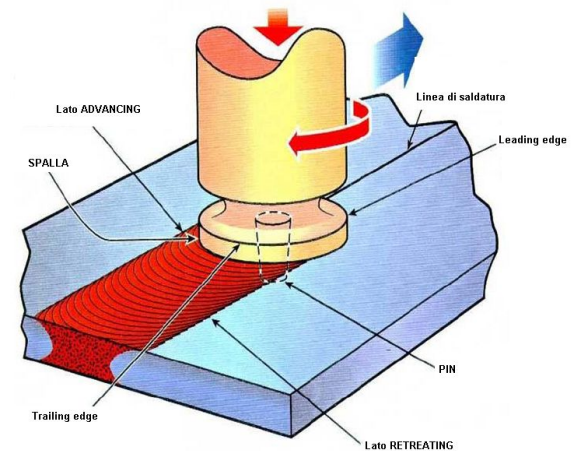
## Friction Stir Welding

- Friction Stir Welding is a solid state process based on dynamic recrystallization.
- Patented in 1991 by the TWI.
- This process employs a rotating tool characterized by a pin and a shoulder in contact with the surface of the component.
- Classified, according to UNI EN ISO 4063, 43



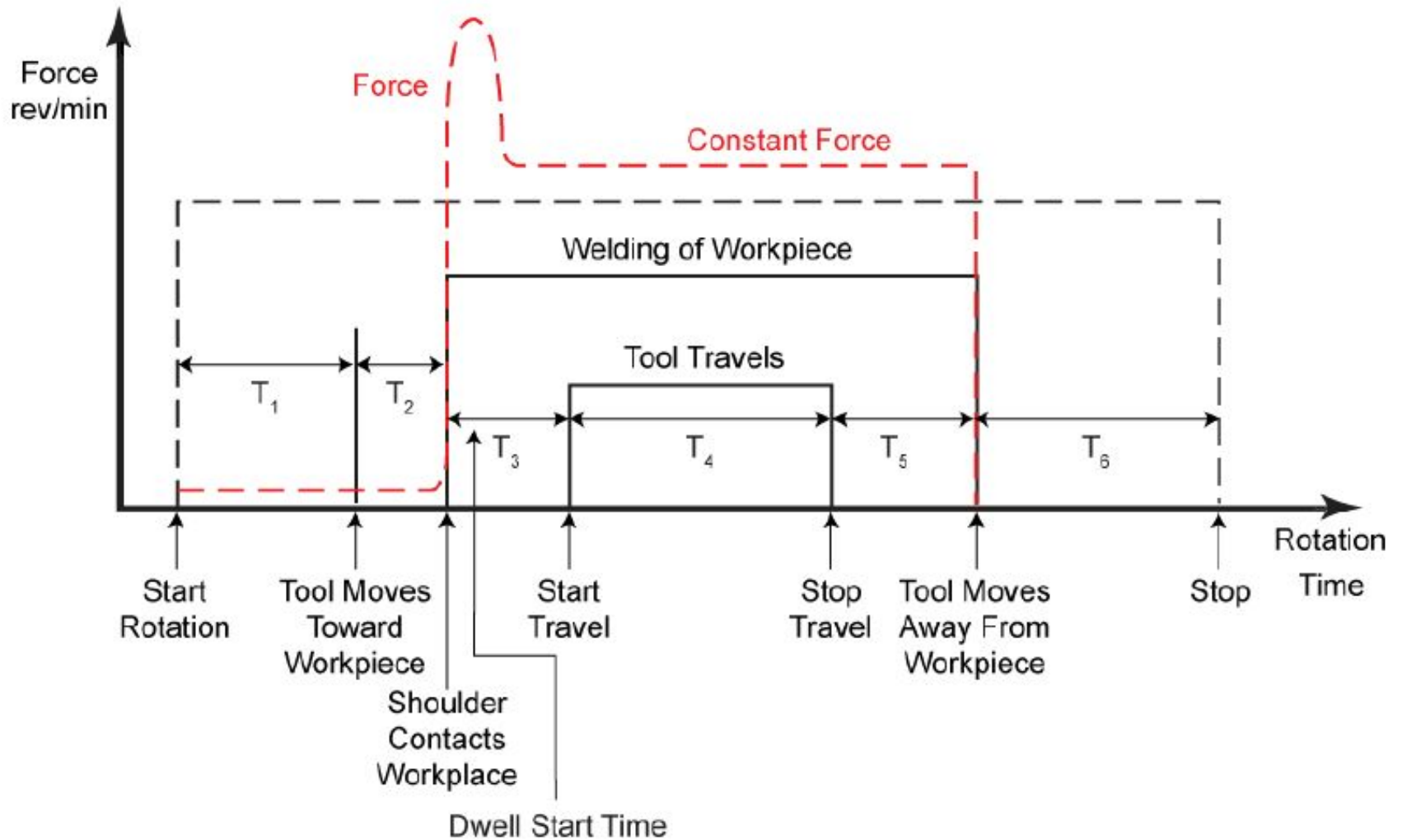
## FSW: working principles

- The friction between the tool and the parent material provide the heat required for the plasticization of the joint.



- A: descent of the tool
- B: contact between the tool and the plate
- C: penetration of the pin and contact between the shoulder and the piece
- D: movement of the tool along the joint.

# FSW: Phases of the welding



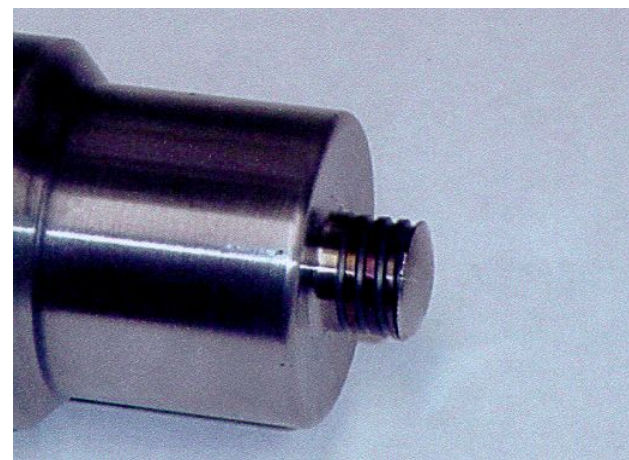
Ciclo di saldatura FSW





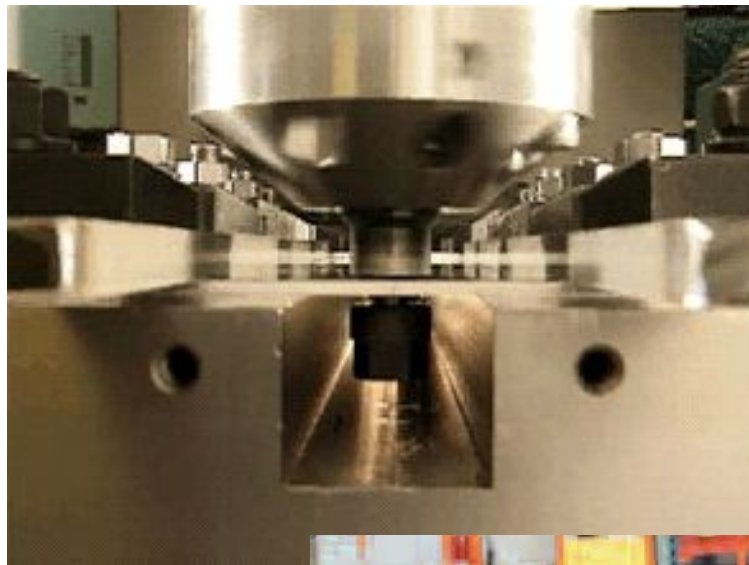
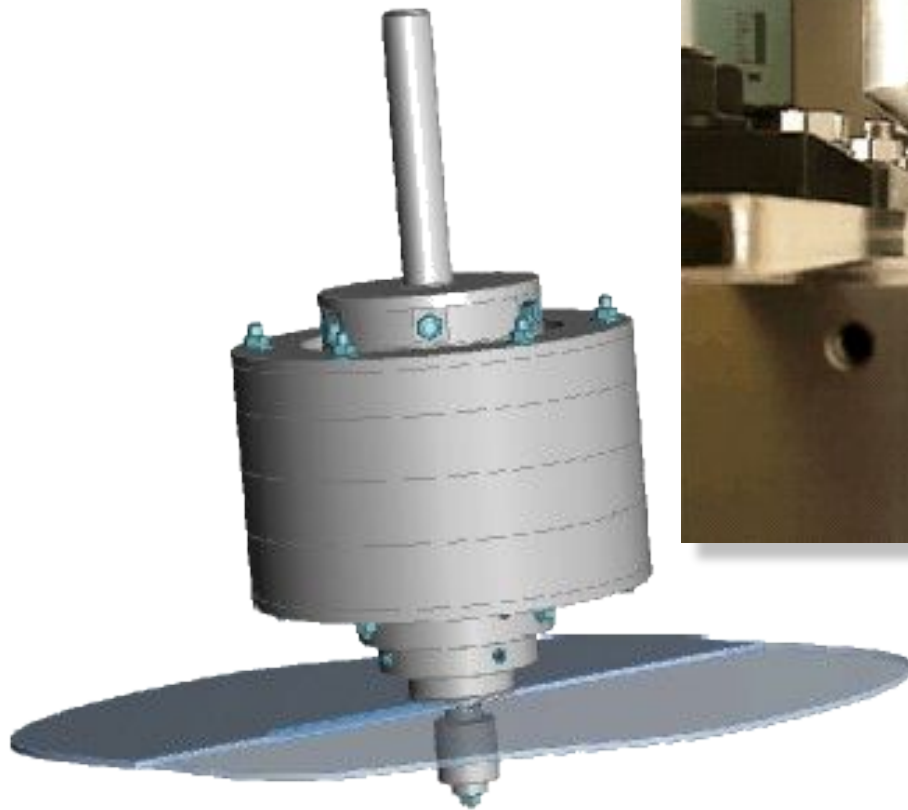
## Characteristics of the tool

- As regards the geometry of the tool, the main parameters are:
  - pin diameter;
  - shoulder diameter;
  - pin length.
- A big **operative limitation** is related to the wear of the material constituent the tool:
  - the **hardness** is one of the most important parameters.



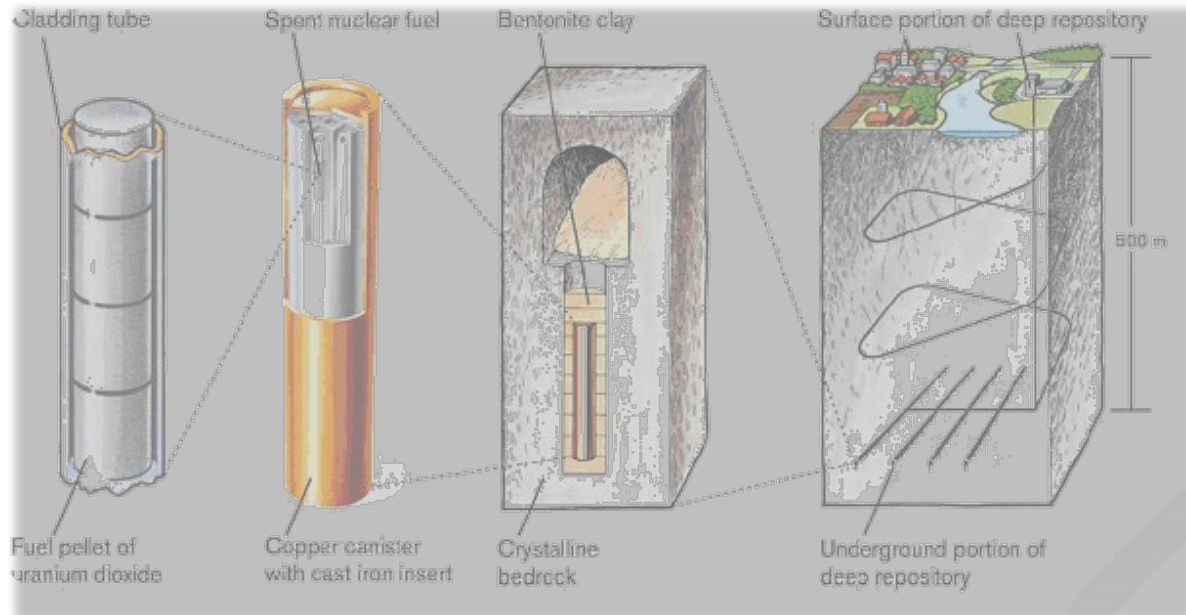


# Geometries of the tools: Bobbin tool® typology



Esempi applicativi della tecnologia Bobbin Tool®

# FSW of Copper alloys: applications



**FSW**

