



AILEEN

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them. PROJECT REFERENCE NO. 101103507



Co-funded by
the European Union

Automation of Welding Processes

Azeem Uddin Azeem Islam



CenSec
CENTER FOR DEFENCE, SPACE & SECURITY



Fraunhofer
FIT



SICNOVA



Outline



– Automation of Welding Process

- Introduction
- Different types
- Devices
- Advantages

Automation in Welding



- In general, automation in the workshop or factory means replacing manual work by mechanized and automated work.
- Such a replacement has already been accomplished in many factories engaged in series production with the use of CIM (computer integrated manufacturing) or CAM (Computer Aided Manufacturing)

Automation in Welding



- In welding, and manufacturing in general, automation refers to some or all of the steps in an operation being performed in sequence by some mechanical or electronic means.
- Machines and robots to perform welding tasks with minimal human intervention
- Certain functions may be performed manually (partial automation); or all of the functions may be performed without adjustment by the operator (total automation)

Automation in Welding



- History...
- The first welding automation systems appeared in the 1960s. ‘Unimation 001’, the first welding robot, was created in 1962
- E.g., General Motors deployed robots for spot welding on assembly lines. These improved safety (by removing people from the arc), and improved consistency
- In the 1970s–80s, new processes like gas-metal-arc welding (GMAW/MIG) and better controllers allowed more applications outside automotive.
- By the 1990s–2000s, computerized (CNC) controls and advanced multi-axis robots enabled unparalleled precision in complex tasks.
- Today (2010s–2025), adaptive technologies and cobots are the trend. Collaborative robots (cobots) introduced in the 2000s (e.g. KUKA’s LBR3 in 2004) allow robots to safely share workspaces with humans.
- Modern systems often use sensors, AI, and real-time monitoring to automatically adjust torch parameters, making automation accessible to more shops than ever.

Automation in Welding



- Degree of automation...
- Fixed Automation: Equipment may accommodate a single assembly/family of assemblies
- Flexible Automation: Equipment may be flexible enough to be quickly modified to perform similar operations on different components and assemblies

Automation in Welding



- Objective...
- To reduce manufacturing costs by increasing productivity, and improving quality and reliability.
- For new application (or applying automation to a new process)
 - Risk is, it may succeed or fail
 - requires careful planning, and the product, plant and equipment costs should be analyzed its feasibility

Automation in Welding



- Extent of successful integration (extent of automation in a process or application), several factors...
 - Product quality - better process control, product improvement and scrap reduction.
 - Production level - higher output & improved inventory turn-over may be the most significant advantages.
 - Manpower - automation may allow the welder to work outside a hazardous environment, and it may be possible to use cheaper semi-skilled labour; however education and training of personnel will be required to make optimal use of an automated system.
 - Investment - savings and costs resulting from an automated system must be identified, including availability/cost of capital.
- The importance of the factors will vary with the type of industry and application, and each should be considered.

Automation in Welding: Types



- Let's start from basic...
- **Manual Welding:** Defined as “welding with an electrode holder held and controlled manually”. A manual welder performs welding operations by controlling them directly with their hands while remaining in total control throughout the welding task.
- **Semiautomatic Welding:** Defined as “manual welding using equipment that automatically controls one or more welding conditions.” A welder manipulates their gun while an electrode feeds automatically into an arc.

Automation in Welding: Types



- **Mechanised welding** - Welding in which the welding parameters are controlled mechanically or electronically and may be manually varied during welding to maintain the required welding position.
- Mechanized welding can be defined as “welding done using equipment that requires manual adjustment of equipment controls in response to visual observation of welding operations—using either a torch gun or electrode holder held by mechanical devices.” Welder intervention consists of making adjustments according to visual observation by the operator.

Automation in Welding: Types



- **Automated welding** - Welding in which all of the welding parameters are controlled. Manual adjustments may be made between welding operations but not during welding.
- Automated welding can be defined as “welding using equipment which requires only occasional or no observation of the weld and no manual adjustment of equipment controls.” A welder may only need to activate their machine to begin the welding cycle and observe the process intermittently—if needed.

Automation in Welding: Types



- **Robotic welding** - Automatic welding using a robot which can be pre-programmed to different welding paths and fabrication geometries.
- Robotic welding can be defined as “any operation with equipment that moves along a pre-defined path using preset parameters and requires no manual intervention once the cycle has started.” With robotic welding there is no involvement from welding operators in performing welds because this task is done and controlled by robots themselves
- Both automated and robotic welding applications serve the same role: serving as quality inspectors during production processes.

Automation in Welding: Types



– Sub-types of robotic automation

System Type	Description	Best Suited For
Fully-Automated Robot Cell	Industrial 6-axis robot in safety cell, welding by pre-programmed path. No human needed during welds.	Mass production (e.g. automotive assembly, pipe production)
Collaborative Robot (Cobot)	Light, sensor-equipped robot arm that works alongside humans. Easy hand-guiding/programming (e.g. via joystick).	Small/medium shops, flexible or mixed production
Semi-Automatic System	Human-guided welding aided by automation (e.g. auto wire-feed, track torches). Human still controls part or torch.	Small batch or unique parts where budget is tight

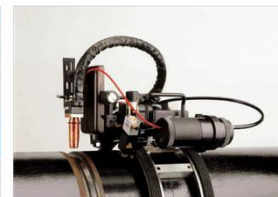
Welding Cobot



Welding Robot



Semi-Automatic



Automation in Welding: Types

- Sub-types of robotic automation

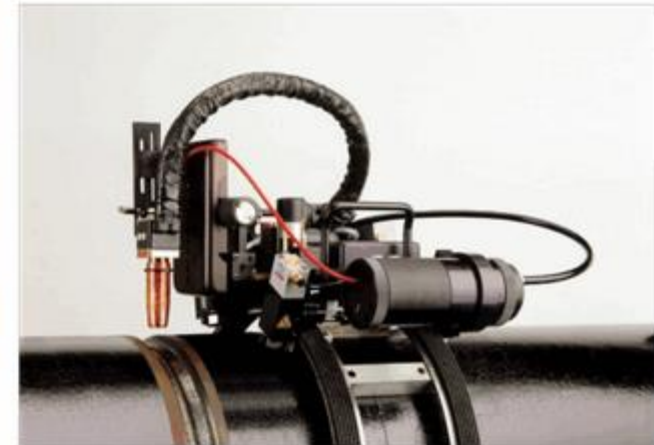
Welding Cobot



Welding Robot



Semi-Automatic



Automation in Welding: Types



- **Adaptive Control Welding:** Defined as “welding with an automated process control system that autonomously recognizes changes to welding conditions and directs equipment accordingly.” Sensors provide real-time data regarding any abnormalities to a computer controller which then makes any required modifications in welding parameters necessary to produce quality welds without operator intervention or supervision.
- (e.g., just like your adaptive options to charge battery in mobile, brightness, screen locking, etc.)

Automation in Welding: Types



- Successful application of mechanised/automated systems can offer a number of advantages. These include...
 - increased productivity
 - consistent weld quality (precise, repetitive) and efficiency (faster than manual) reducing defects and scrap
 - less skilled welders could be required
 - predictable welding production rates
 - reduced variable welding costs
 - lower part costs
 - lowering safety concerns

Automation in Welding: Types



– Limitations include...

- higher capital investment than for manual welding equipment
 - a need for more accurate part location and orientation
 - more sophisticated arc movement and control devices.
-
- As such, production requirements must be large enough to justify the costs of equipment and installation, the maintenance of equipment and the training of operators/programmers for automated/robot equipment.

Automation in Welding: Types



– Comparison

METHOD OF APPLICATION	MANUAL	SEMI-AUTOMATIC	MECHANIZED	AUTOMATED	ROBOTIC	ADAPTIVE CONTROL
Starts & maintains the arc	Person	Machine	Machine	Machine	Machine (with sensor)	Machine (robot)
Feeds the electrode into the arc	Person	Machine	Machine	Machine	Machine	Machine
Controls the heat for proper penetration	Person	Person	Machine	Machine	Machine (with sensor)	Machine (robot) (only with sensor)
Moves the arc along the joint (travels)	Person	Person	Machine	Machine	Machine (with sensor)	Machine (robot)
Guides the arc along the joint	Person	Person	Person	Machine via prearranged path	Machine (with sensor)	Machine (robot) (only with sensor)
Manipulates the torch to direct the arc	Person	Person	Person	Machine	Machine (with sensor)	Machine (robot)
Corrects the arc to overcome deviations	Person	Person	Person	Dose not correct (potential for imperfections)	Machine (with sensor)	Machine (robot) (only with sensor)

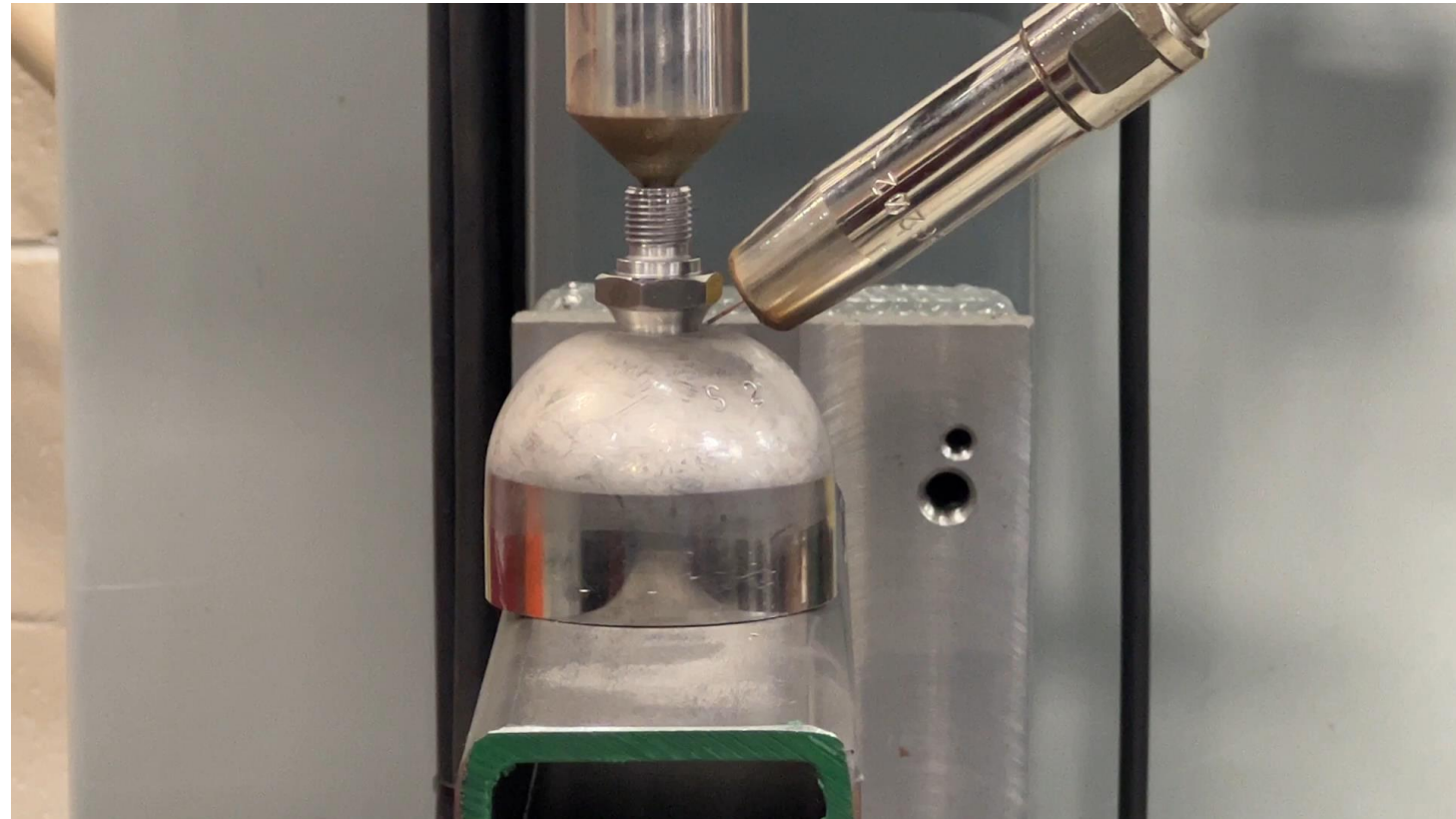
Automation in Welding: Machines



- Different machines/devices for welding automation...
 - Tasks or parts to weld (basically products/applications) determine the welding system (to be automated as no single automated system exists for all welding types)
- ‘Rotary welding machine’
 - These rotary welders are also commonly referred to as: fitting welders, circle welders, header welders or port welders.
 - Designed to weld circular components with high through-put. 360 degree welding
 - Can have both single or multiple torches to weld both small and large surface areas.
 - Multiple orientation
 - Can feed filler material

Automation in Welding: Machines

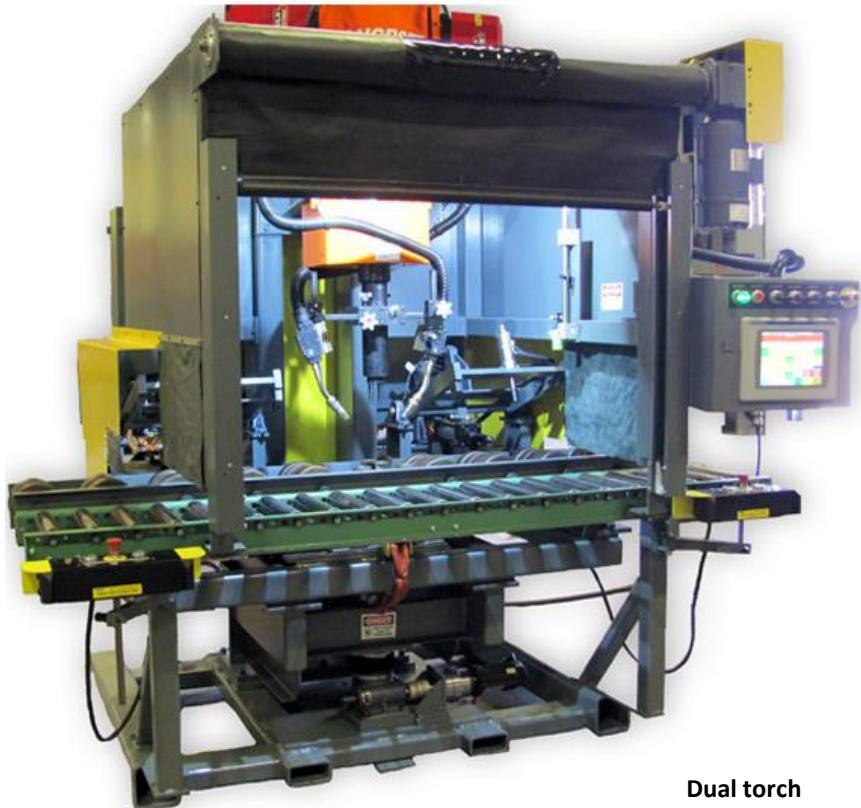
- ‘Rotary welding machine’



Credit: Bancroft

Automation in Welding: Machines

– ‘Rotary welding machine’



Dual torch



Credit: Bancroft

Automation in Welding: Machines



– ‘Rotary welding lathe’

- One of the most versatile ways to rotary weld production parts.
- Using lathe design and mechanism for welding
- Lathes can be supplied with vertical, horizontal, or inclined drive orientations to optimize the effects of gravity on the weld pool.
- Optional features include synchronized spindles and automatic fixtures, making them adaptable for a wide range of applications.
- Customization in terms of speed, feed, head, bed distance, different radial orientation etc.
- Can be equipped with multiple fusion torch configuration TIG, MIG, PAW, Laser
- Can do inner / outer welds as well in a cylinder. Inner welds subjected to torch reach.

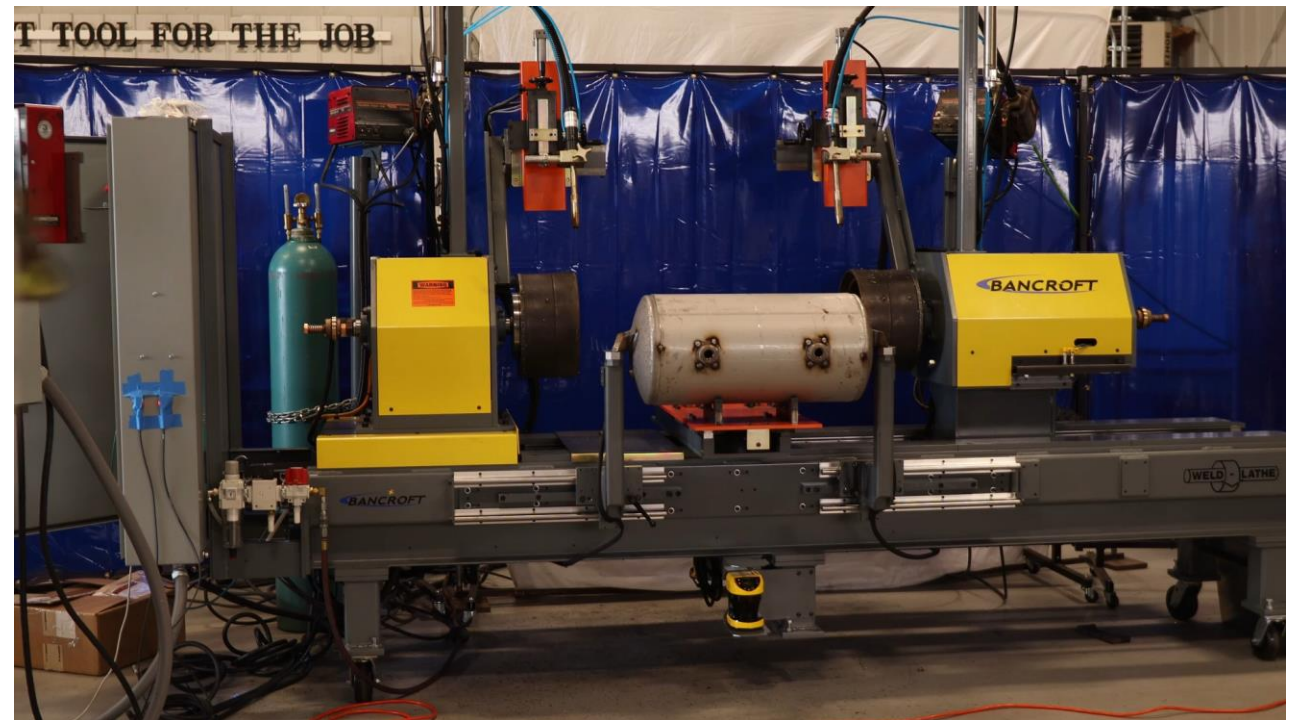
Automation in Welding: Machines

- ‘Rotary welding lathe’



Automation in Welding: Machines

– ‘Rotary welding lathe’

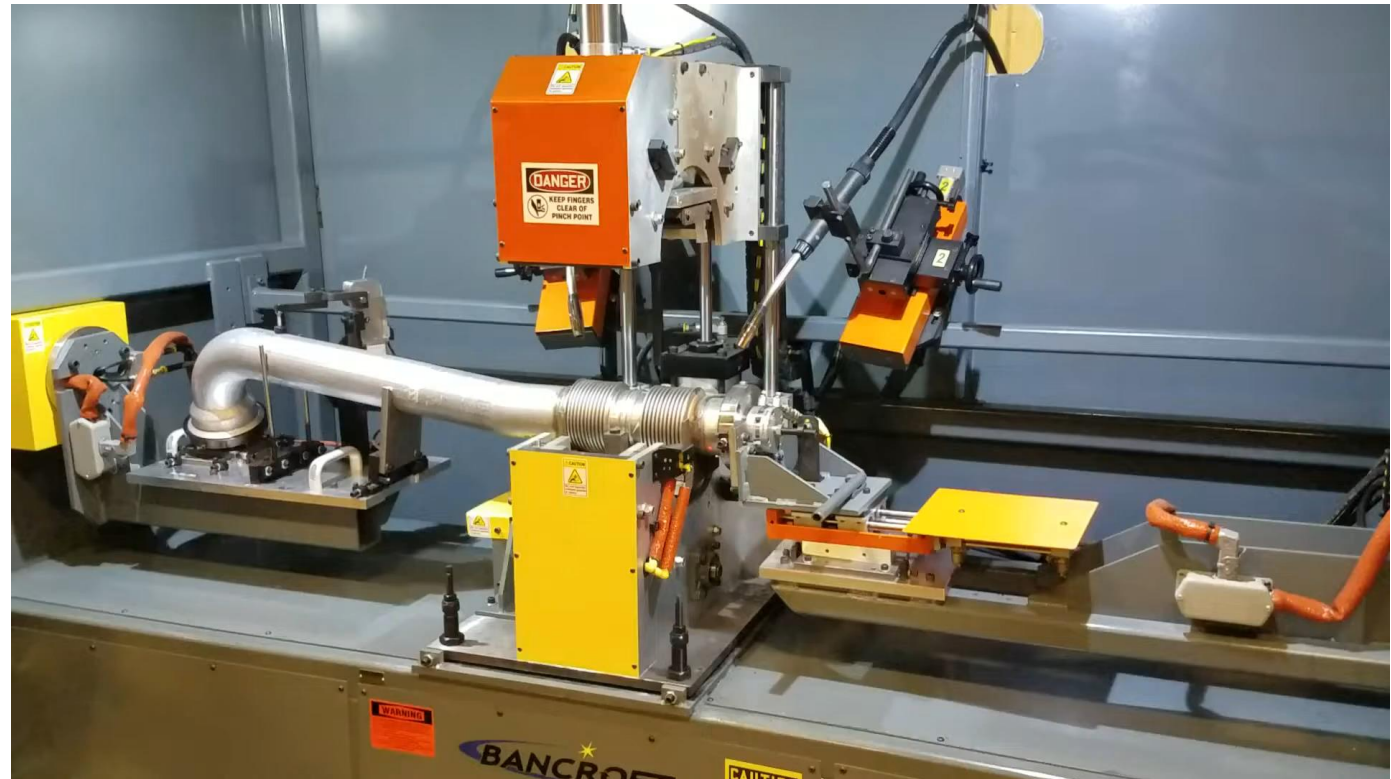


Automation in Welding: Machines

– ‘Rotary welding lathe’



Synchronized drive lathe



Automation in Welding: Machines



– ‘Automated welding positioner’

- Welding device with following features...
- Programmable rotation distance
- Variable speed and direction
- Rotation delay timers
- A repeatable tooling home location
- Manual or pneumatic torch shuttle
- Live center, tilt and pivot options (up to 90° possible) for better weld positioning
- Compatible with multiple welding types (stick, MIG, TIG etc.)



Automation in Welding: Machines

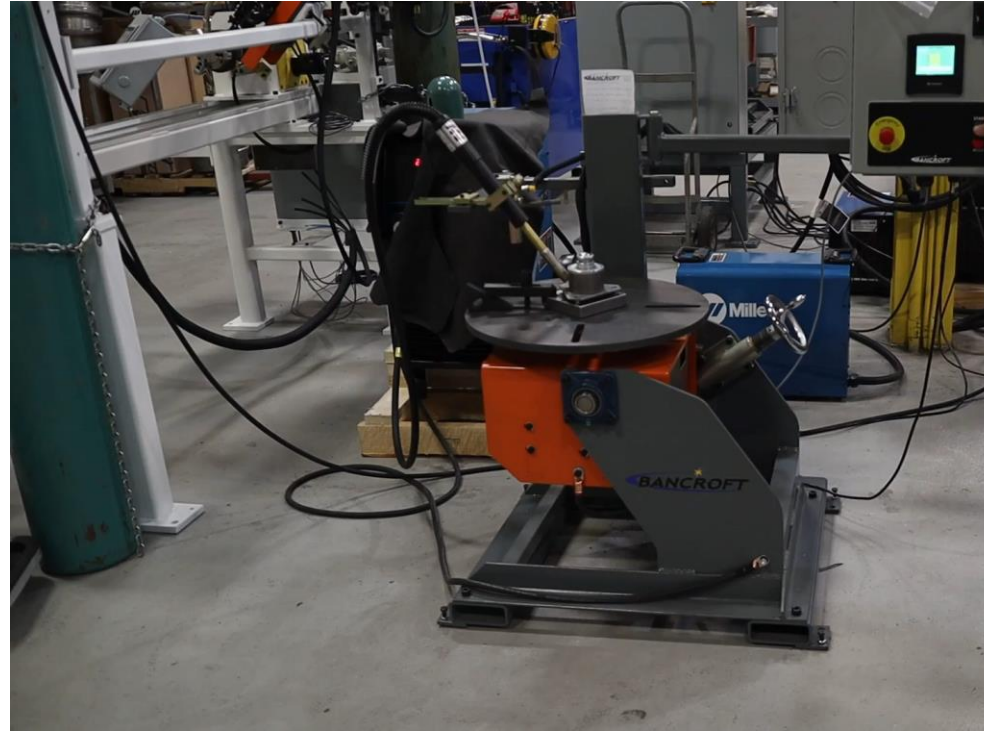
- ‘Automated welding positioner’



Credit: Bancroft

Automation in Welding: Machines

- ‘Automated welding positioner’



Credit: Bancroft

Automation in Welding: Machines



– ‘Linear welding systems’

- For beam, profile & seam welding
- Have dedicated travel cars that are driven on long travel beams
- For high volume production
- Can be incorporated with positioners and other equipment to weld simple or complex weld profiles
- Computer controlled servo-motors
- Seam tracking with integrated sensors
- Multiple torch configuration possible
- Internal and external beam welders are both common applications for construction equipment and telescoping boom sections



Telescopic beam in cranes

Automation in Welding: Machines

– ‘Linear welding systems’



Automation in Welding: Machines

- ‘Linear welding systems’



Automation in Welding: Machines



– ‘Hydraulic Press’

- **Flaring Press:** Hydraulic Flaring Press utilizes specially designed Flaring tools on both ends. This process is used in many tank manufactures for ease of assembly. This process is also seen on flaring welded rims before the rolling operation.
- **Head Setting Press:** Hydraulic press used for assembling tank heads to the shells. Used with orientation tooling to maintain radial orientation of the two heads.
- **Assembly Press:** Combination Assembly Press & Weld Lathe
- Vertical or horizontal positions with clamping capabilities

Automation in Welding: Machines

– ‘Hydraulic Press’



AILEEN

Automation in Welding: Machines



AILEEN

– ‘Hydraulic Press’



Automation in Welding: Machines



– ‘Weld cladding / Weld overlay machines’

- Joins one or more types of metals together by creating a layer out of the metal which is welded to the surface of the base metal.
- Helps with the preservation of more limited and costly materials by only requiring a small amount which welds to a more common base
- Top surface overlay techniques for applications that require corrosion-resistant materials.
- It can also provide weld quality enhancement in hardness, wear characteristics, conductivity, prolong service life, or serve as a repair.
- For harsh environment protection (marine, offshore, oil & gas, chemical, agricultural, etc.)



Automation in Welding: Machines



AILEEN

- ‘Weld cladding / Weld overlay machines’
 - Support multiple processes such as flux-core, sub-arc, GTAW for steel, stainless and other alloys
 - Can be integrated with other automated systems such as lathes, travel carriages, or positioners with manipulators are used to apply arc welded overlays.

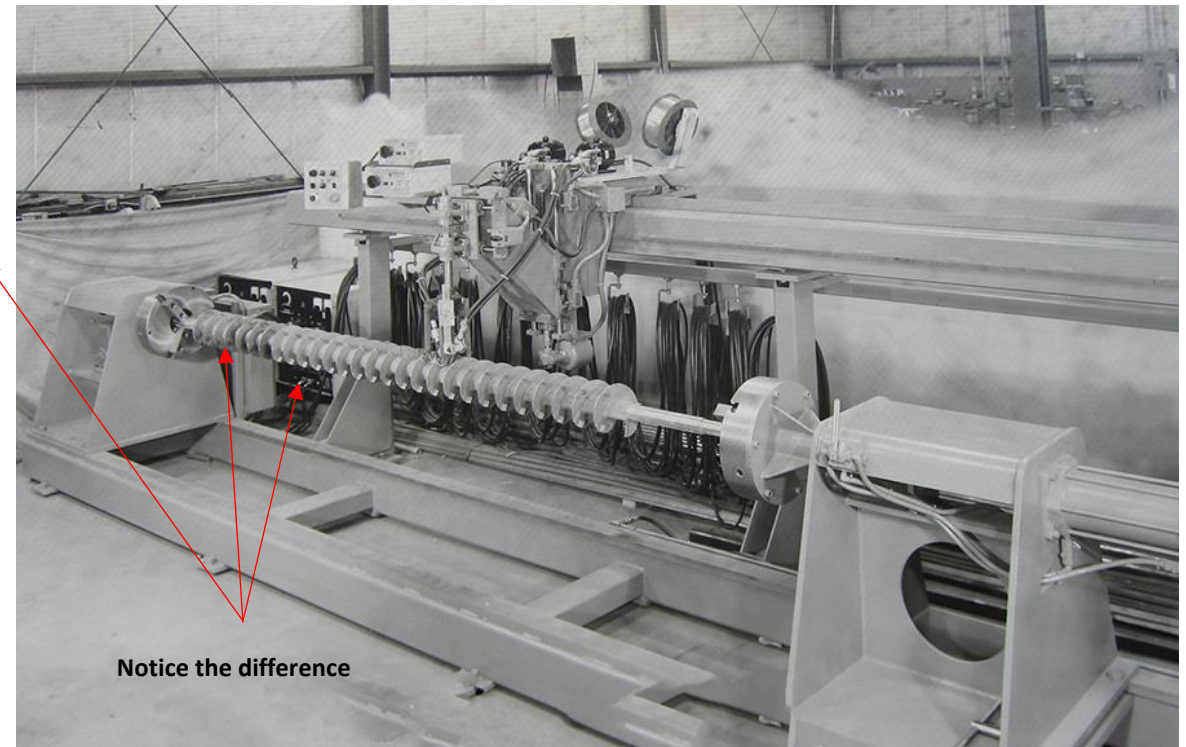
Automation in Welding: Machines

- ‘Weld cladding / Weld overlav machines’



Automation in Welding: Machines

- ‘Weld cladding / Weld overlay machines’



Automation in Welding: Machines



– ‘Weld planisher machine’

- Planishers are useful tools to improve the weld’s cosmetic appearance of parts as well improving the welded metal joint’s strength.
- Used for both ferrous and non-ferrous metals.
- To smoothen and strengthen seam welds on both the inside and outside of a part.
- Planishing blends the weld bead into the base material for a clean, flat finish without distortion, improving both appearance and joint integrity.
- Compatible with fusion processes in GMAW, MIG, TIG and Plasma/PAW welds

Automation in Welding: Machines



AILEEN

- ‘Weld planisher machine’
 - The tough seamer-style tabletop design secures the part during operation making alignment easy. This allows the operator to be hands-free during planishing.

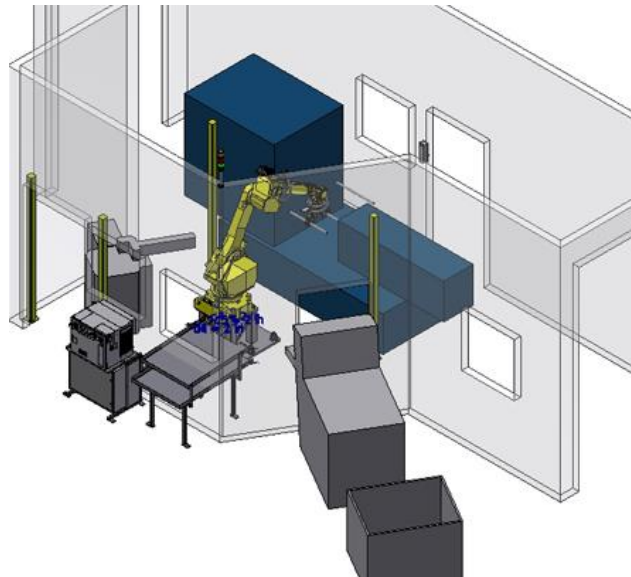


Automation in Welding: Machines

– ‘Robotic welding systems’

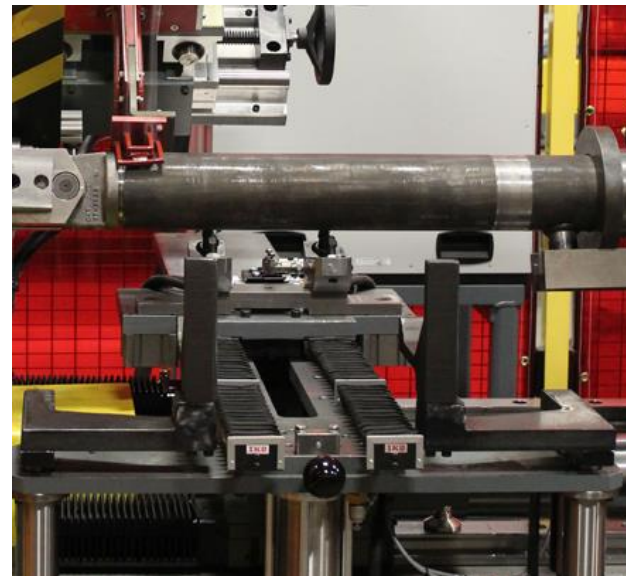
- For flexible or unique welding applications
- Programmed, modular and/or are vision-guided (using laser vision technology – makes these adaptive automation)

Some applications in welding



Loading & unloading

Transferring (here shown beam)

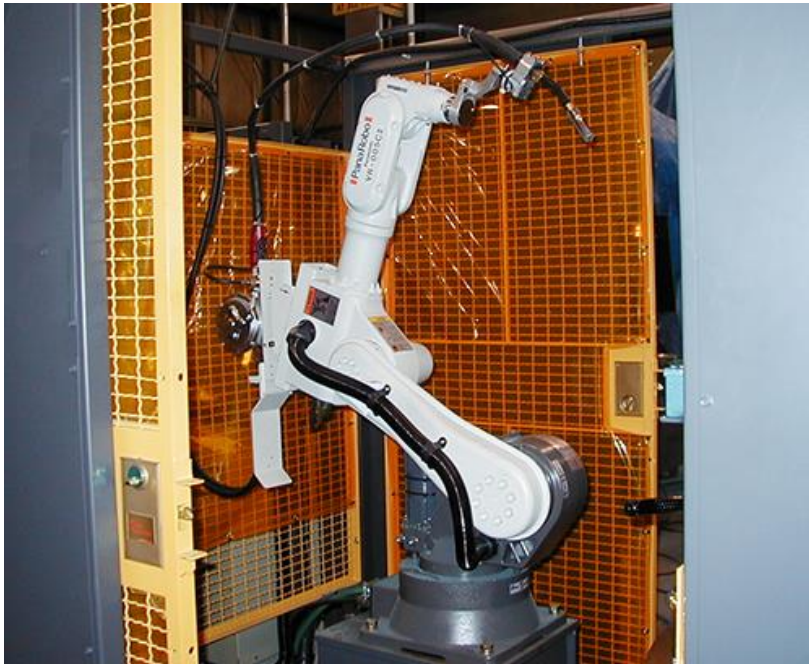


Weld torch holder / Cleaning



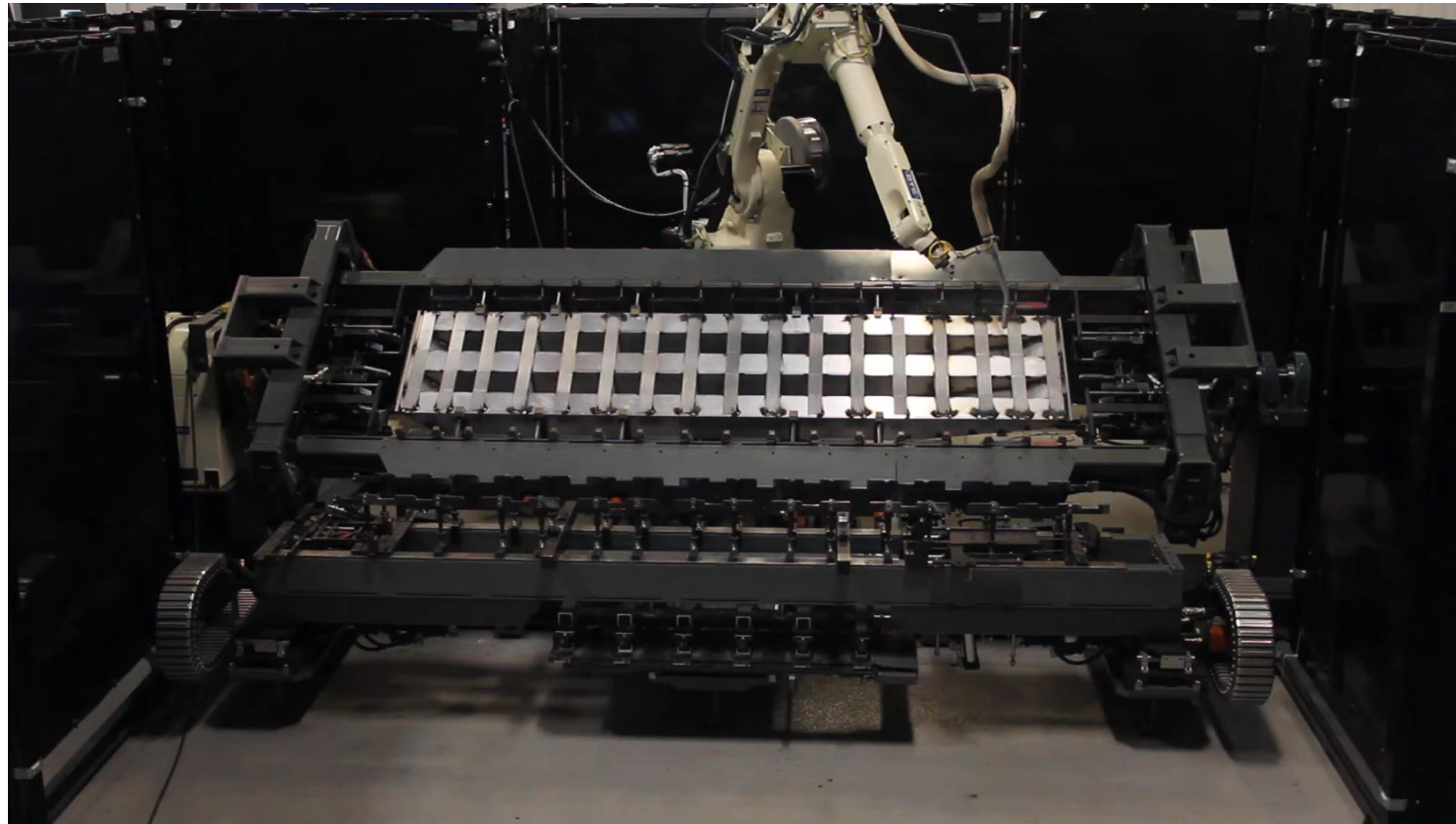
Automation in Welding: Machines

– ‘Robotic welding systems’



Automation in Welding: Machines

- ‘Robotic welding systems’



Automation in Welding: Machines

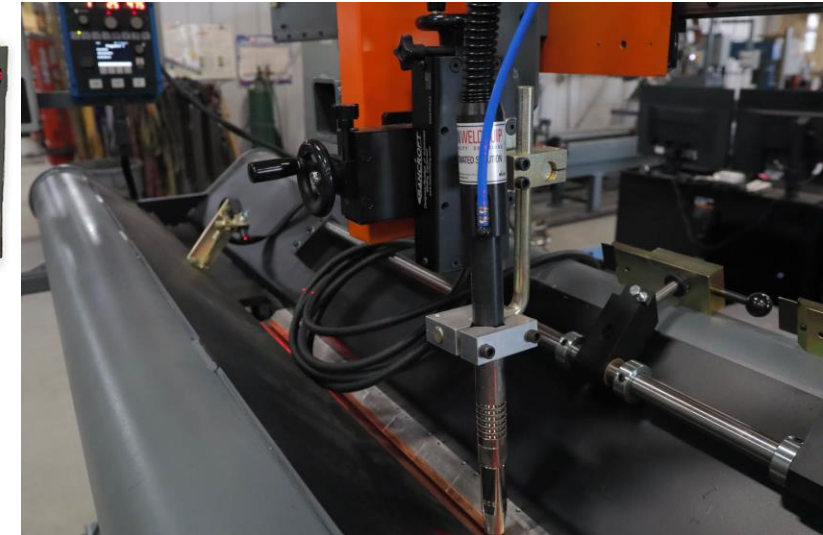
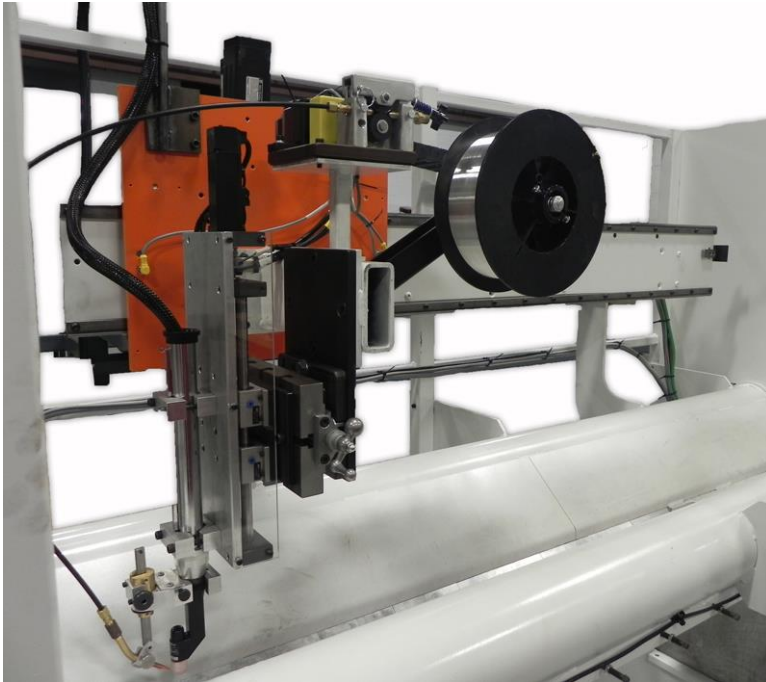


– ‘Seam welders’

- For smooth seam welds (linear flat sheets or curved parts – cylinders, cones, boxes)
- To produce high quality welded seams with 100 percent penetration
- Laser alignment
- Inner or outer welds
- Can weld ferrous and non-ferrous alloys
- Can be equipped with TIG, Plasma Welding (PAW), Submerged Arc, or MIG welding processes.

Automation in Welding: Machines

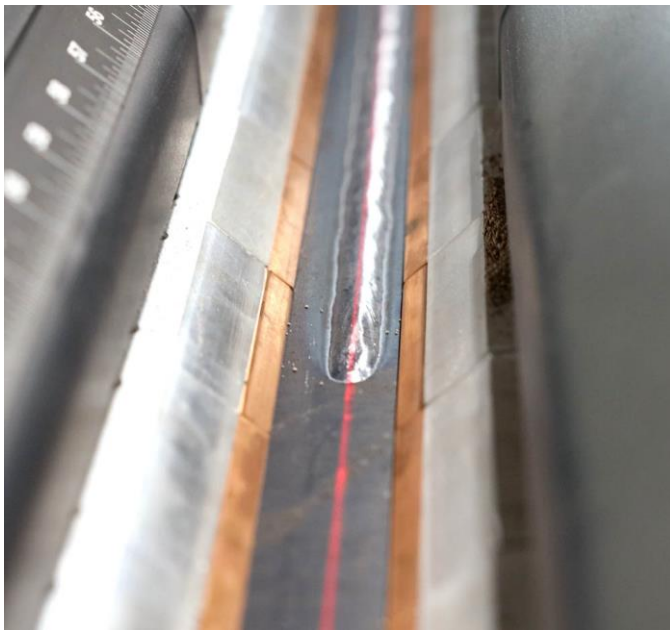
– ‘Seam welders’



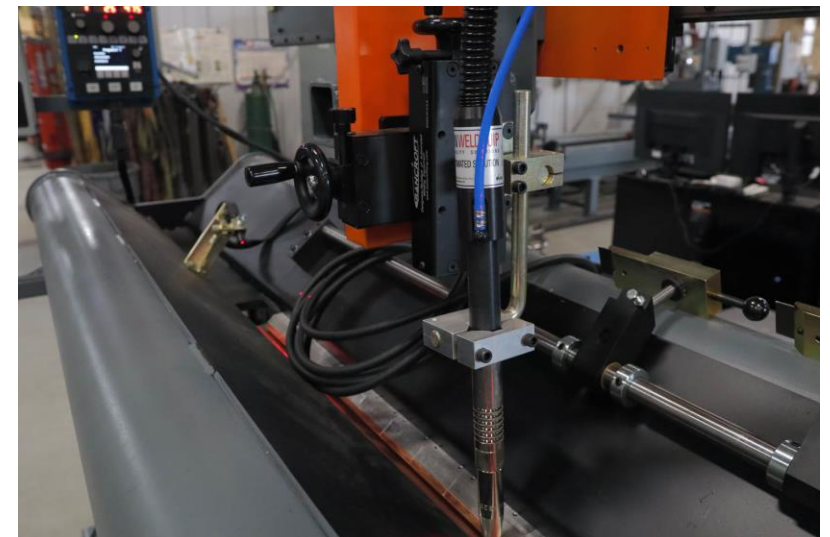
Multiple Welding Torches
can be equipped

Automation in Welding: Machines

– ‘Seam welders’



Weld seam with laser alignment (red line)



Multiple Welding Torches can be equipped

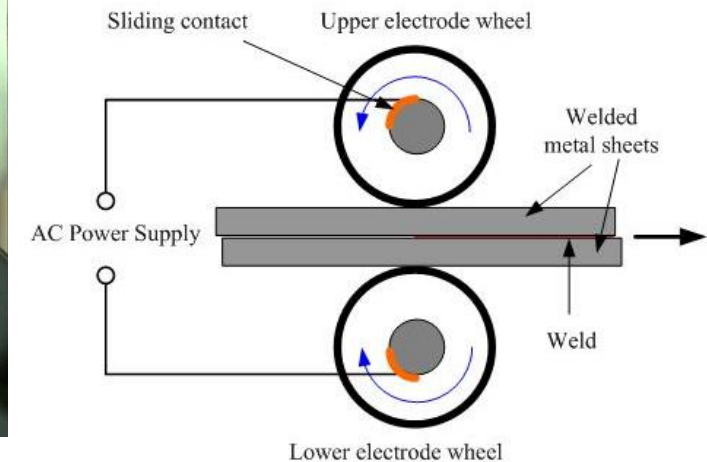
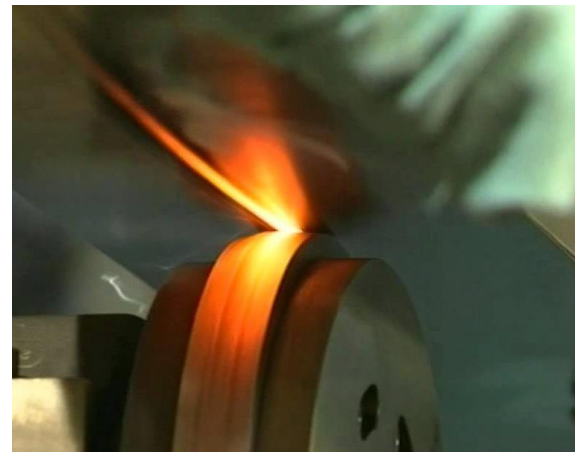
Automation in Welding: Machines

– ‘Seam welders’



Seam welding of a cylinder
Linear / longitudinal arc weld

Rotary type seam welding



Automation in Welding: Machines

– ‘Seam welders’



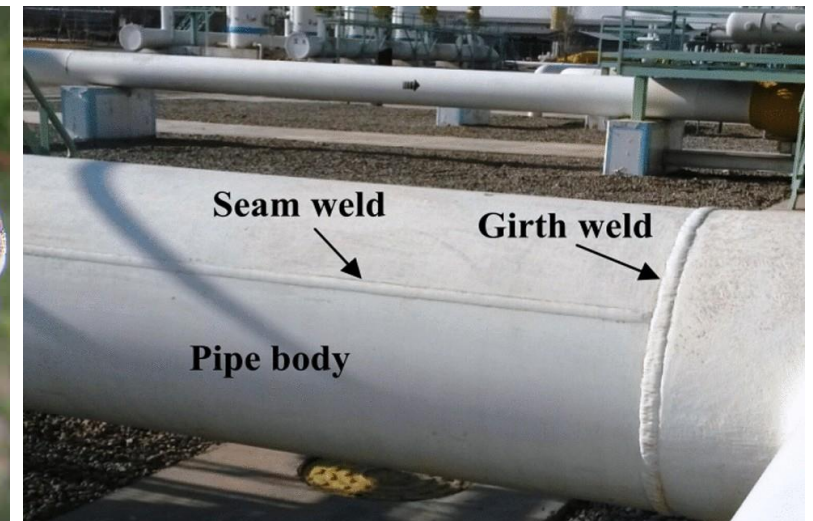
Large conical part sheets



Smooth seam weld



Certainly not a seam weld



Automation in Welding: Machines

- ‘Dedicated wheel welders’
 - Similar to seam welding machines
 - For wheel rims (up to 32” with 16” deep)
 - Steel or aluminium rims, GMAW welding torch



Acts as welding positioner



Automation in Welding: Machines

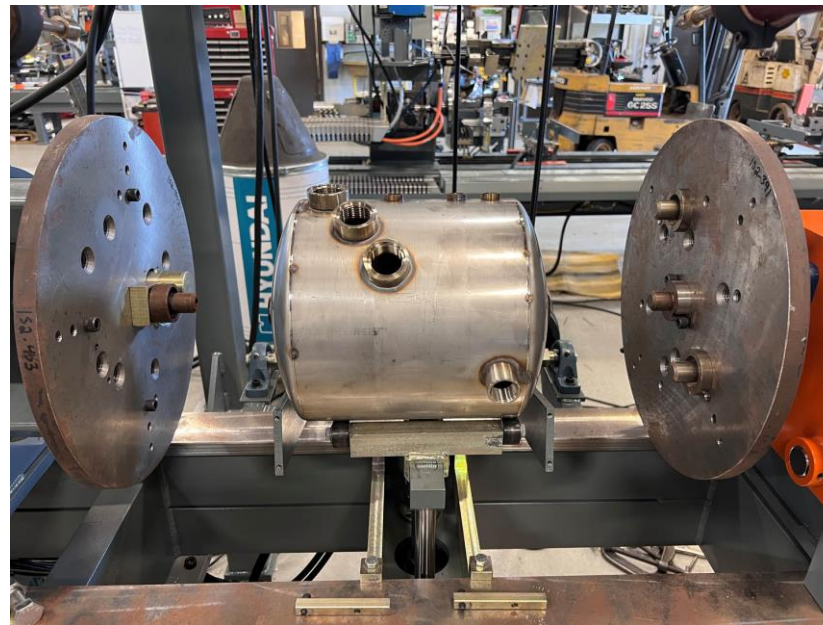


AILEEN

- ‘Automation welding Fixtures & Tooling’
 - Supportive devices for automation



Welding fixture



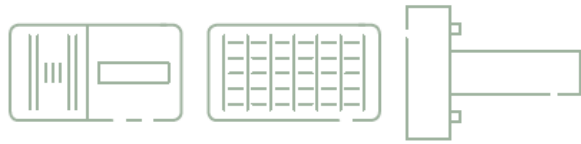
Lathe tooling

Automated clamp tool

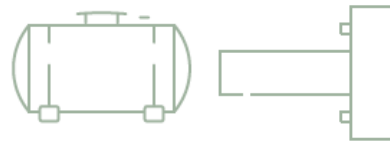


Automation in Welding: Machines

- Again, different devices for welding automation...
 - Tasks to weld determine the welding system



Housing, flange & web joints



Boiler & tank connections



Housing joints



Robotic welding system



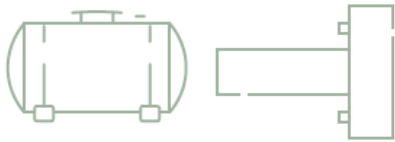
Longitudinal / circumferential welding system



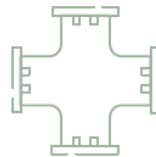
Robotic welding system

Automation in Welding: Machines

- Again, different devices for welding automation...
 - Tasks to weld determine the welding system



Vessels, pipes, flanges with



Cladding of valves



Cylindrical components such as container shells



Compact circular seam welding system with two weld heads



Cladding system with endless rotating torch



Longitudinal welding system for internal / external cylindrical welds

Automation in Welding: Machines

– ‘Ancillary equipment in welding’

- Support hand driven manual tasks (tools)
 - Spanner
 - Nozzle cleaner
 - Spark lighter
 - Stainless steel wire brushes
 - Chip hammer (wood, spring)
 - Cables
 - Cable lugs
 - Cable connectors (plug/socket)
 - Earth clamps
 - Etc.

Ancillary items in welding



Automation in Welding: Robotic Welding



AILEEN

– Robotic welding

1. Power source
2. Wire feeder
3. Wire feeder roller kit
4. Water cooling unit
5. Robot interface module
6. Interconnection cables
7. Interconnection cable brackets
8. Earth return cable
9. Wire conduit
10. Wire spool holder
11. Wire spool protective cover
12. Floor stand for wire spool holder
13. Wire feeder mounting bracket
14. Wise processes
15. Welding gun package
16. Welding gun cleaning station



Automation in Welding: Robotic Welding

– Robotic welding

- Simply put as;
- ‘Robotic welding is the use of robotic arms and automation to carry out welding tasks’
- Robotic arms = mechanical
- Automation = the technology behind making robot / its machine components move, analyze, adapt etc.
 - E.g., software based, machine learning, AI, run timed-motors, sensors, data collection and interpretation etc.
- In robotic welding, programmed ‘robots control the motion or movement axes’.



Automation in Welding: Robotic Welding



– Robotic welding

- Performed by a welding robot, which is a special type of industrial robot
- Robots are typically stationary and firmly installed at welding sites (vibrations)
- Programmed to perform repetitive welds but can be re-programmed for other tasks
 - E.g., to move material, parts, tools, or specialized devices through varied programmed motions for the purposes of loading, unloading, assembling, material handling, machine loading & unloading and other manufacturing operations (Robot becomes typical industrial robot)
 - Are used in assembly lines and other manufacturing applications
- There are multiple ways in which robots work - a pre-programmed position, machine vision, or a combination of both.
- Can reach locations that are inaccessible by human hands and can perform complicated tasks much more precisely

Automation in Welding: Robotic Welding



AILEEN

– Robotic welding: how it works

- The weld robot consists of...
- an arm which is capable of moving in three dimensions and weld metals together
- a wire feeder sends a filler wire to the robot
- a high-heat torch towards the end of the arm melts metals during the welding process (similar to a human welding manually)
- Some certified human operators are employed to program & maintain the robots
- a control box, which an operator uses to control the robot's programs / start it
- Sometime, wire feeder supplies extra metal wire to the arm and torch if needed
- Sometime, the torch moves toward the cleaner (manual or self cleaning) to clear any metal splatters off the arm that may otherwise freeze or solidify
- Equipped with arc-shields to protect workers and nearby locations
- The arm can simultaneously be equipped with multiple torches and/or shielding gas cables

Automation in Welding: Robotic Welding

– Robotic welding: capabilities

- Weld tracking: sensors for guiding and checking welds visually (High-res camera)
- Design and weld: equipped with software to simulate welds in 3D
- Tracking automatically offsets weld deviations
- Touch sense enables the robot to determine positions for offsetting component tolerances.
- Automatic replacement of contact tips in seconds (otherwise time consuming)
- Automatic wire change (two wires in one welding system if a component requires)
- Automatic torch cleaning

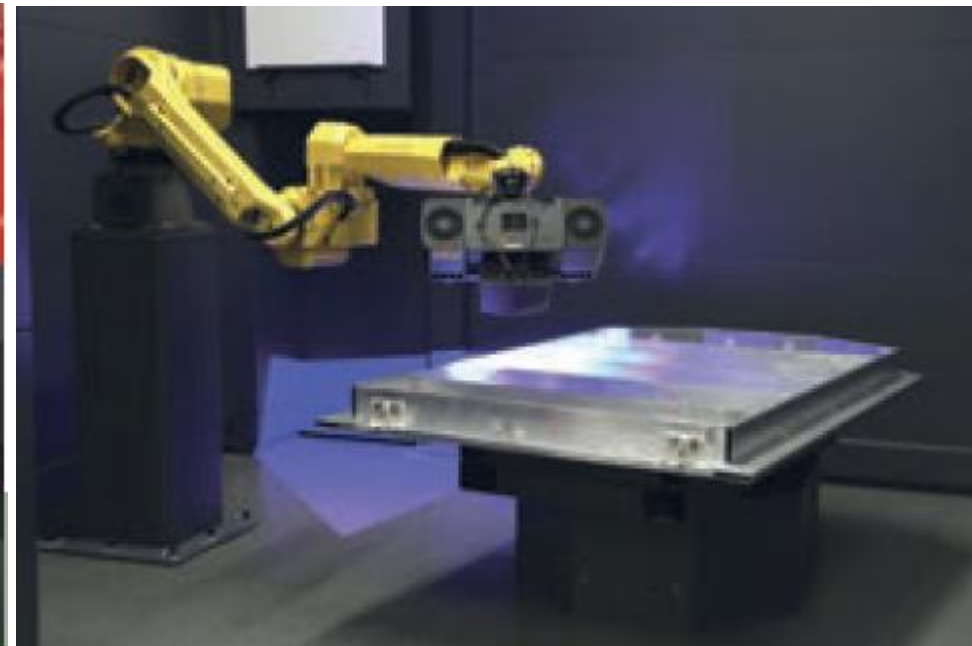


Automation in Welding: Robotic Welding

- Robotic welding: capabilities



Robot welding cell with monitoring camera



Robot controlled component measurement cell

Automation in Welding: Robotic Welding

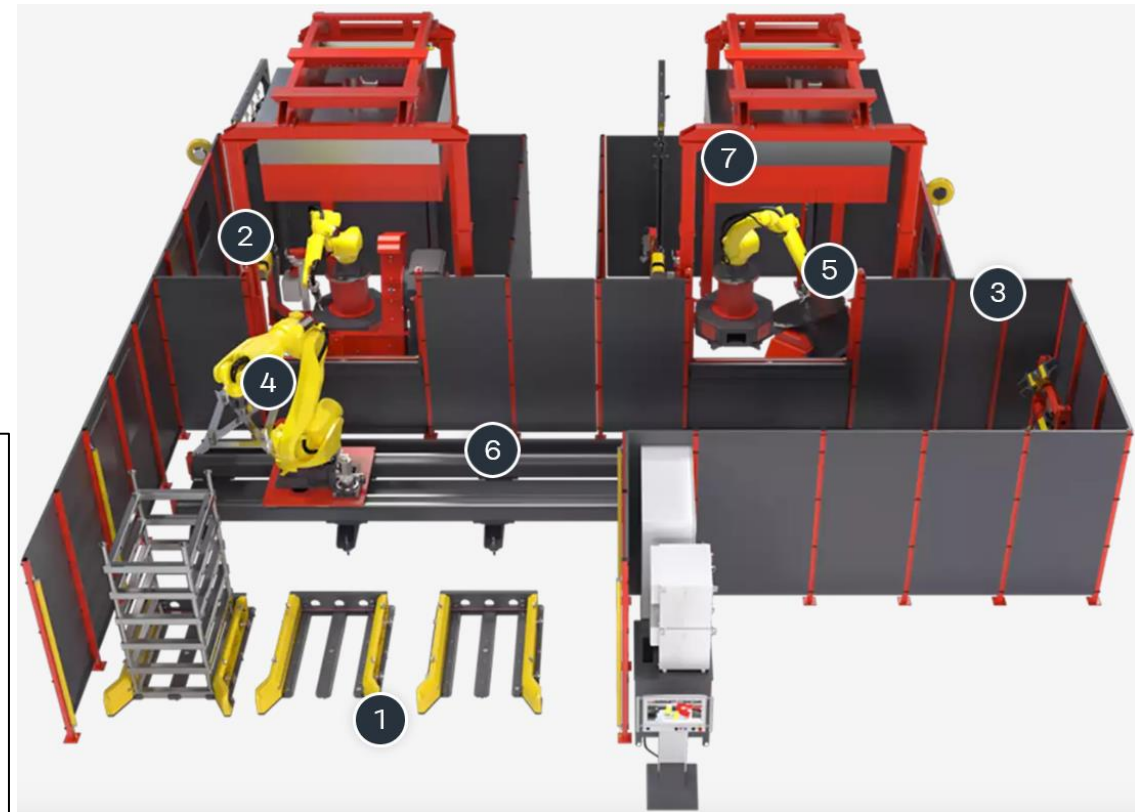


AILEEN

– Robotic welding: capabilities

- Can be integrated with other automated welding systems (it is called a Robotic Cell)
- With real-time 3D visualization on control screen

1. Component gates (incoming and outgoing of components)
2. Welding torch systems (cleaning, replacement, tip replacement)
3. Gripper system (different size components, processes – preheating, cleaning etc.)
4. Handling robot
5. Positioner (rotating/tilting, turnover, heavy-duty)
6. Robot track (platform for welding, extendable track length)
7. Six-axis welding robot



Automation in Welding: Robotic Welding



AILEEN

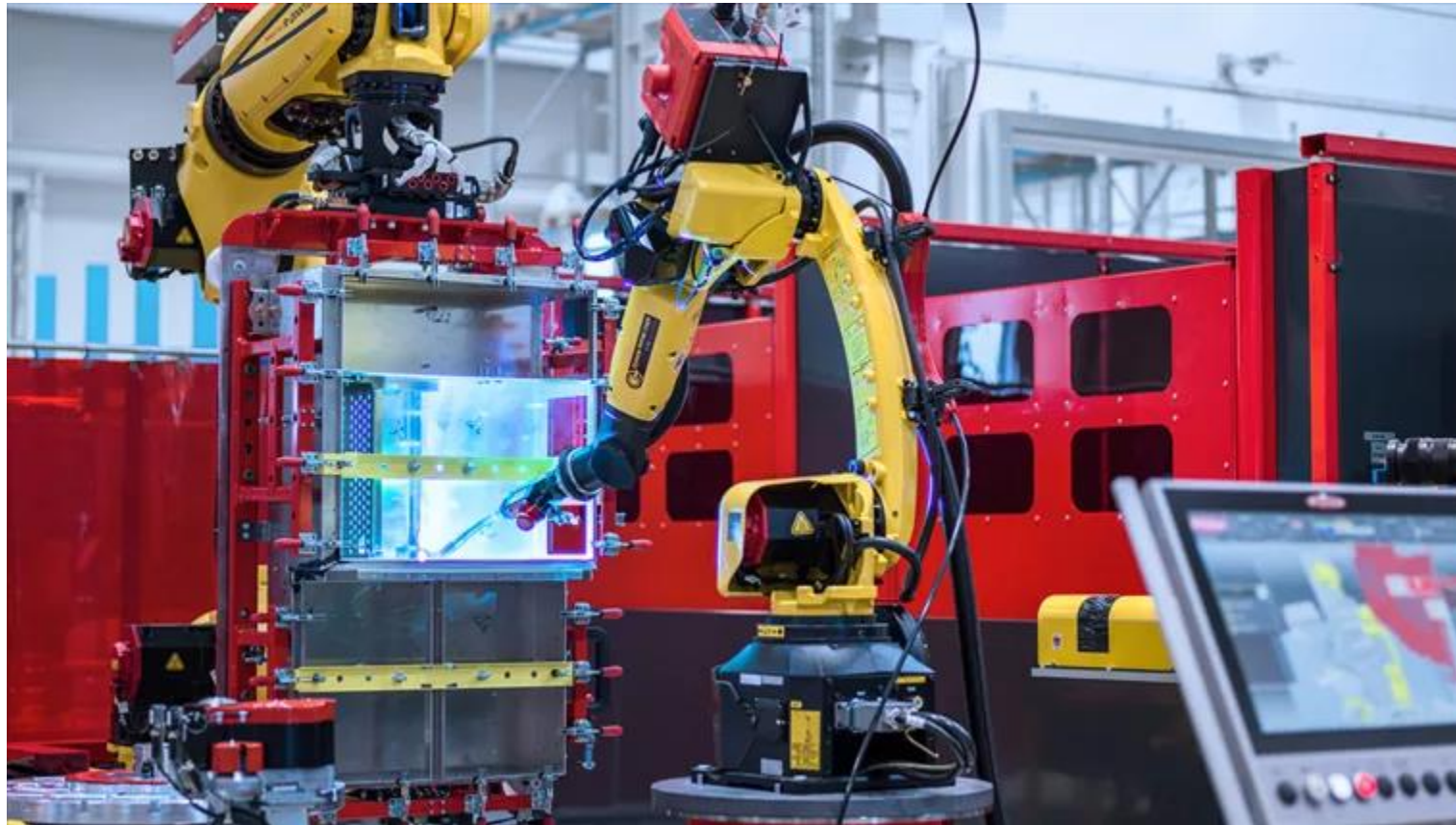
Robotic welding cell with shielding



Automation in Welding: Robotic Welding



Multiple robots can be employed to speed up welding a single job



Control box

Automation in Welding: Robotic Welding



AILEEN

– Robotic welding: compatible processes

- Arc welding (most common)
- MIG welding
- TIG welding
- Laser welding
- Plasma arc welding (PAW)
- Resistance welding
 - A stream of electricity forms a pool of molten metal as it flows between the two metal bases throughout this operation
- Spot welding
 - Robotic welders join two thin metal sheets in a single area (spot); variant of resistance welding

Automation in Welding: Robotic Welding



AILEEN

– Benefits

- **Higher output rates:** Robotic welders deliver faster cycle times and 24/7 operation, exponentially increasing the volume of parts a factory can produce. Less down-time also improves production scheduling.
- **Enhanced quality:** Robots perform extremely uniform welds to strict parameters for improved joint integrity and fewer errors needing re-work. Automated quality data collection also aids defect prevention. Exponentially less waste
- **Reduced labour costs:** While requiring some technician oversight, it slashes direct welding labour expenses and downtime costs relative to manual approaches.
- **Flexibility:** Modern robotic welding cells adapt to handle quick product changes, allowing economic production of customised or small batch parts.
- **Greater Safety:** Automating dangerous welding tasks leads to fewer worker accidents. The use of its enclosures also protects nearby employees from fumes and sparks.

Automation in Welding: Robotic Welding



– Future of robotic welding

- Mind-Controlled Welding Robots
 - Researchers have developed a headgear that converts brain signals into robotic welding arm motions. If used in industry, this method might reduce the amount of training required for existing manual welders to become robotic operators and eliminate the instructions through computer interface & programming.
 - However, this technology, on the other hand, is unlikely to materialise anytime soon
- Collaborative robots (cobots)
 - Already exists. These feature a user-friendly design that allows for simple human interaction. Sensors enable these robots to acquire data and respond to changing circumstances.
 - Work alongside humans
 - Continues to develop

Automation in Welding – Applications



- **Automotive:** manufacturing relies heavily on robotic MIG welding for car bodies, chassis, powertrains, and other automotive components in high-volume vehicle assembly plants. Self-driving welders meet the production demands of auto manufacturing.
- **Aerospace:** self-driving MIG, TIG and spot welding robots enable airframe assembly lines to improve both speed and precision. Execute thousands of exactly repeatable, clean, precise, highly reliable welds on wings, fuselages, bulkheads and control surfaces upholding the safety standards

Automation in Welding – Applications



- **Defence:** enhance quality for critical components like armour, vehicles, aircraft, vessels, and weapons systems. Self-driving welding automation assists with fabricating hulls, turrets, and panels needing extensive welds to meet structural integrity standards.
- **Construction:** Using common methods like MIG and TIG welding, robotic welding speed suits high-demand structural components. For complex or artistic architectural elements needing watertight, blemish-free welds, or stainless steel welds, robotic TIG welding excels.

Automation in Welding – Limitations



AILEEN

- **High Upfront Investment:** Automated systems require substantial capital. A traditional welding robot cell (robot, power source, positioners, safety enclosure) can easily cost \$175K–\$250K. Even cobots, though cheaper, often run \$50K–\$150K once the robot, peripherals, and installation are included.
- **Training and Programming:** Automation demands a different skill set. Operators must be trained to program, operate, and maintain the machines. Traditional industrial robots often required engineers or programmers, though modern cobots are easing this burden.
- **Part Design and Fixturing:** Automated welding with complex or inconsistent parts may require custom fixturing with more accurate part location and orientation. Inflexible fixtures can limit flexibility for one-off jobs.
- **Maintenance Requirements:** While robots run reliably, components (welding guns, torches, sensors) wear out. Preventive maintenance and occasional repairs become new tasks. Maintenance costs adds.
- **Suitability for Low Volume:** Adaptability is primarily limited by high equipment costs, restricting welding robots to high-production applications. However, this is changing with cobots, which are designed for higher-mix, lower-volume jobs.
- **Change Management:** Introducing robots can require rethinking shop layout and processes. Employees may fear job loss or new responsibilities.

Automation in Welding – Limitations



- Why cannot all welding be automated?
 - There are limits to what machines can handle (a machine is for specific purpose)
 - Robots need precise working environment (clean, wide, firm installations and positioning). Automotive welding is 90% automated
 - In the real world field welding, e.g., construction sites, oil rigs, and shipyards, nothing is ever perfect, angles are wrong, parts are bent etc. (trained worker is required for adaptivity)
 - Materials mismatch, wrong grades
 - Sensors cannot sense everything as yet (humans instincts can hear sounds, feel vibration, the flow resulting in timely judgment and grit)
 - Welders still control and supervise the welding robots
 - But, the automation continues to progress everyday

Thank You



AILEEN



CenSec
CENTER FOR DEFENCE, SPACE & SECURITY



PRI
PERFORMANCE REVIEW INSTITUTE



KATAMER

Fraunhofer
FIT

TURKISH
AEROSPACE

Mercantec

IPH

mtc where progress happens

SICNOVA

Laser
AKADEMIE



ASTURIAS HUB
DEFENSA

CESOL

iSQ

IDONiAL
TECHNOLOGY CENTRE



FAN 3D

Brunel
University
London