

## UNIT – IV

### Welding Technology and Automation

Welding is a process that permanently joins pieces of metal (or sometimes thermoplastics) by heating them to a melting point and allowing them to fuse together. There are many different welding techniques, but they all share the core principle of creating a strong bond between the materials.

#### **Applications of Robotics in Welding**

**Increased Productivity:** Robots can weld faster and more consistently than humans, leading to higher production rates.

**Improved Quality:** Robots can precisely control the welding parameters (heat, travel speed, etc.), resulting in more consistent and higher-quality welds.

**Enhanced Safety:** Welding involves exposure to heat, fumes, and sparks. Robots can perform welding tasks in these hazardous environments, protecting human workers.

**Versatility:** Robots can be programmed to perform a wide variety of welding tasks, from simple spot welds to complex multi-pass welds.

**Repeatability:** Robots can consistently repeat the same welding process over and over again, ensuring consistent weld quality.

Some specific examples of how robots are used in welding:

**Automotive Industry:** Robots are widely used in car manufacturing to weld together car bodies, frames, and other components.

**Construction:** Robots can be used for welding steel beams and other structural components in buildings and bridges.

**Shipbuilding:** Robots are used to weld together the hull sections and other parts of ships.

**Consumer Electronics:** Robots can be used for welding small electronic components in devices like smartphones and computers.

#### **Different types of robots design in welding:**

- Resistance Spot Welding Robots
- Collaborative Welding Robots
- Shielded Metal Arc Welding Robots (SMAW)
- Robotic Gas Metal Arc Welding (GMAW/MIG)
- Robotic Gas Tungsten Arc Welding (GTAW/TIG)
- Robot Laser Welding

- Plasma Welding Robot

### **Resistance Spot Welding Robot**

The automotive manufacturing industry commonly uses resistance spot welding. It's a resistance welding process that uses larger electrical currents to join two or more sheets in a single location.

Spot welding robots are articulating robots. They are robots that have rotary joints that have a range of anywhere from two to 10 axes. Spot welding robots have a servo motor equipped with a high-resolution encoder that accurately controls the motion of the spot welding gun. The welding gun has a pair of electrodes that can open and close. It also comes with software that controls the acceleration, position, and force of the robotic arm.

### **Collaborative Robot Welding**

Collaborative robot welding, or **cobot welding** for short, is also a robotic arm, usually 6-axis, with a welding torch as its end effector. Unlike industrial robots, cobots can work alongside humans. Because of this, there is no need to house them in a welding robot cell. You can only take care of the welding safety (flash, splatter). They are also easy to deploy and redeploy to different tasks.

### **Shielded Metal Arc Welding Robots (SMAW)**

Shielded Metal Arc Welding (SMAW) is also called stick welding. In this type of welding, an arc is created between a consumable flux electrode and the welded material.

A SMAW robot needs to consider a variation of the tool center point (TCP). A TCP is a variable used in robots for the computer to keep track of the tip of the tool, here the consumable electrode. The consumption rate of the electrode determines the direction of the robotic arm.

### **Robotic Gas Metal Arc Welding (GMAW/MIG)**

Usually, robots are used for GMAW welding when high deposition rates are needed to get a high production rate. In GMAW welding or MIG welding, a consumable electrode is melted and acts as a filler material. Robotic GMAW welding or **robotic MIG welding** is used for welding stainless steel, copper, nickel, carbon steel, and aluminum. It's usually used for metals that have high melting points of conductivity.

### **Robotic Gas Tungsten Arc Welding (GTAW/TIG)**

Gas tungsten arc welding (GTAW) robots are used when welding thin parts or wanting aesthetic and precise welds.

In Robotic GTAW, variables such as torch movement, shielding-gas pre flow, pulse frequency, etc., are automatically controlled. Arc length can also be automatically maintained with automatic voltage control. **Intelligent GTAW robotic welding systems** have cameras that help with joint location tracking and error detection. In this type of system, the operator calibrates the camera and teaches the robot the weld path. The robot then takes a picture before the arc is established and compares this image to the reference image. This type of system is ideal for welding thin materials where the placement of the arc plays an important factor.

### **Robot Laser Welding**

A laser welding robot is a type of welding that uses a focused laser beam as the energy source. Laser welding can either be through heat conduction or deep laser.

The robot laser welding machine is composed of a fiber laser head, a tracking system, a fiber laser, and an industrial robot. It's usually used to weld materials of different thicknesses from different angles and different directions. Medical devices and the aerospace industry typically make use of robot laser welding.

### **Plasma Welding Robot**

This type of robot welder uses a plasma arc as the heat source to melt the junction of the two metals that needs welding. Plasma welding robots are equipped with a plasma torch. A tungsten electrode is suspended inside the torch. The electrode compresses the arc, so the plasma flows from the torch at high speed. Plasma welding robots usually make use of six-axis articulated robots.

Plasma robots are used for welding a variety of metals regardless of their thickness. Robotic plasma welding is well known for precise welds and short cycle times. These robots can also weld both narrow and welds without part distortion.

### **Welding Procedures Suitable for Robotic Welding:**

Robotic welding excels in tasks that are repetitive, precise, and require consistent quality. Here are some welding procedures well-suited for robotic automation:

#### **1. Arc Welding:**

This versatile process uses an electric arc to create intense heat that melts the metal at the joint. A filler material can be added to create a stronger weld.

Arc welding is a popular choice for robotic applications due to its adaptability. Robots can precisely control the heat input, travel speed, and wire feed for consistent and high-quality welds.

- Gas Metal Arc Welding (GMAW/MIG)

- Flux-Cored Arc Welding (FCAW)
- Tungsten Inert Gas Welding (TIG)

## **2. Spot Welding:**

This resistance welding process uses electrical current to create a localized heat that melts and fuses the overlapping areas of thin metal sheets.

Spot welding is ideal for robots due to its repetitive nature and focus on specific weld locations. Robots can precisely position the welding gun and control the current for consistent spot welds.

### **Applications:**

- Automotive industry
- Appliance manufacturing
- Sheet metal fabrication

## **3. Laser Welding:**

This process uses a high-powered laser beam to melt and fuse the metal at the joint. It offers high precision and deep penetration for strong welds.

Laser welding is well-suited for robotic automation due to its precise control and ability to weld intricate shapes. Robots can accurately position the laser beam and achieve consistent weld quality.

### **Applications:**

- Automotive industry
- Medical devices
- Electronics manufacturing

## **Programming a welding robot:**

There are two main approaches to programming robots for welding:

### **Teach Pendant Programming:**

- This involves physically guiding the robot's arm through the desired weld path using a handheld controller (teach pendant).
- The robot records the movement points and creates a program for automated welding.
- This method is intuitive for simpler welds but can be time-consuming for complex paths.

## Offline Programming:

- This involves creating the robot program using specialized software on a computer.
- 3D CAD models of the workpiece and welding torch are used to simulate the robot's movement and define the weld path.
- Offline programming offers greater flexibility and precision for complex welds but requires expertise in the software and robot kinematics.

A typical robotic welding program consists of several key elements:

- **Motion Commands:** These instruct the robot to move its arm to specific points along the weld path.
- **Tool Control Commands:** These control the welding torch (turning on/off, adjusting wire feed rate for MIG), shielding gas flow, and other parameters.
- **Sensor Integration:** In some cases, sensors might be used for seam tracking or weld quality monitoring, requiring additional program logic.
- **Safety Protocols:** Safety interlocks and emergency stop procedures are essential to ensure safe robot operation during welding.
- **Welding Parameters:** The robot program needs to integrate the welding parameters like heat input, travel speed, etc., based on the specific welding procedure and material.
- **Calibration:** Regular calibration of the robot and welding torch ensures accurate positioning and consistent weld quality.
- **Error Handling:** The program should include error handling routines to address potential issues like wire feed problems or torch malfunctions.

## TOLERANCE IN ROBOTIC WELDING

Tolerance in robotic welding refers to the acceptable range of variation in key dimensions that ensure a successful and high-quality weld.

### Importance of Tolerance:

**Weld Quality:** Maintaining proper tolerances is crucial for achieving strong, consistent, and defect-free welds. Deviations from specified dimensions can lead to issues like poor penetration, incomplete fusion, or excessive spatter.

**Repeatability:** Robots rely on precise movements to perform welds consistently. Tight tolerances ensure the robot can accurately position the welding torch and achieve consistent weld geometry throughout the production run.

**Manufacturing Efficiency:** Maintaining proper tolerances minimizes the need for rework or weld repairs due to dimensional inconsistencies. This improves overall production efficiency and reduces costs.

### **Factors Affecting Tolerance in Robot Welding:**

**Part Tolerances:** The tolerances of the parts being welded significantly impact the robot welding process. Parts with excessive dimensional variations can make it difficult for the robot to achieve consistent weld quality.

**Welding Process:** Different welding processes have inherent tolerance capabilities. For example, laser welding offers tighter tolerances due to its focused heat source compared to arc welding.

**Robot Accuracy:** The robot's inherent accuracy and repeatability play a role. High-precision robots can achieve tighter tolerances compared to less accurate models.

**Fixturing:** The welding fixture that holds the parts in place needs to be designed and manufactured with tight tolerances to ensure proper part alignment and positioning for consistent welds.

### **Typical Tolerance Ranges for Robot Welding:**

It's difficult to provide a single tolerance value for robotic welding as it depends on various factors mentioned above. However, here are some general guidelines:

**Sheet Metal Welding (MIG, Spot Welding):** +/- 0.1 mm (0.004 inches)

**Arc Welding (Thicker Materials):** +/- 0.5 mm (0.02 inches)

**Laser Welding:** +/- 0.2 mm (0.008 inches)

### **Achieving Tight Tolerances in Robot Welding:**

- **Part Design:** Parts should be designed with appropriate weld joint geometries and minimal dimensional variations to facilitate robotic welding with tight tolerances.
- **Fixturing:** Invest in high-quality fixtures that precisely hold the parts in place and minimize part movement during welding.
- **Robot Selection:** Choose a robot with the necessary accuracy and repeatability to achieve the desired weld tolerances for your application.
- **Process Optimization:** Fine-tune the welding parameters (heat input, travel speed, etc.) to achieve optimal weld penetration and fusion within the specified tolerances.
- **Quality Control:** Regularly monitor weld quality through visual inspection and non-destructive testing methods to ensure adherence to tolerance specifications.

## AUXILIARY DEVICES IN ROBOTIC WELDING:

Auxiliary devices in robotic welding play a crucial role in expanding a robot's capabilities and optimizing the overall welding process. Here are some commonly used auxiliary devices for robot welding:

### 1. Welding Positioners:

**Description:** These devices rotate and tilt the workpiece, allowing the robot to access all weld locations from a single position. This eliminates the need for complex robot arm movements and simplifies programming.



### Types:

- **Turnarounds:** Rotate the workpiece on a horizontal axis.
- **Tilt Tables:** Tilt the workpiece on a vertical axis.
- **Combination Positioners:** Offer both rotation and tilting capabilities for complex weld access.

### Benefits:

- Improved weld accessibility for complex joints.
- Simplified robot programming and reduced cycle times.
- Improved weld quality by maintaining consistent torch angles.

### 2. Seam Tracking Sensors:

**Description:** These sensors track the joint seam between the workpieces in real-time. This allows the robot to adjust its torch path dynamically to compensate for minor variations in part geometry and ensure consistent weld quality.



### Types:

- **Vision Systems:** Use cameras to track the joint seam based on visual features.
- **Laser Scanners:** Utilize lasers to create a 3D profile of the joint and guide the robot path.

### Benefits:

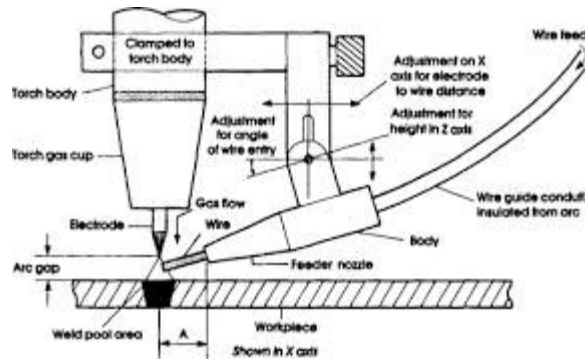
- Improved weld quality by compensating for part variations.
- Reduced risk of weld defects due to inconsistent joint geometry.

### 3. Wire Feeders (for MIG/MAG welding):

These devices continuously feed the electrode wire into the weld pool during Gas Metal Arc Welding (GMAW/MIG) or Flux-Cored Arc Welding (FCAW). They maintain a consistent wire feed rate crucial for proper weld penetration and quality.







**Types:** Push-pull and spool gun feeders depending on application requirements and wire material.

**Benefits:**

- Ensure a consistent supply of electrode wire for uninterrupted welding.
- Allow for precise control of wire feed rate for optimal weld parameters.
- Improve overall welding efficiency and reduce downtime.

**4. Welding Torches:**

While not strictly auxiliary devices, different welding torch options can optimize robotic welding for specific needs:

- **Standard Robotic Torches:** Designed for various welding processes and offer good maneuverability.
- **Water-Cooled Torches:** Used for high-heat welding applications to prevent torch overheating.
- **Swinging Torches:** Provide additional movement capabilities for complex weld paths.

**5. Welding Fume Extraction Systems:**

**Description:** These systems capture and remove welding fumes generated during the process. This protects the robot and surrounding environment from harmful airborne contaminants.

**Types:** Fume guns integrated with the welding torch or stationary extraction booths.

**Benefits:**

- Ensure a safe working environment for robot operators and personnel.
- Improve air quality in the welding area.
- Reduce health risks associated with welding fumes.

**6. Tool Changers:**

**Description:** These devices allow robots to quickly swap between different welding tools (torches, sensors, etc.) within a program. This increases robot flexibility and enables it to perform various welding tasks without manual intervention.

**Benefits:**

- Increased robot versatility for handling multiple welding processes or applications.
- Reduced downtime for tool changes during production runs.
- Improved automation capabilities in a robotic welding cell

**New generation of welding robots:**

The world of robotic welding is constantly evolving, with new technologies emerging to improve efficiency, precision, and capabilities. Here's a glimpse into some exciting advancements in the new generation of welding robots:

**Vision-guided and Sensor-integrated Welding:**

- Advanced vision systems and sensors are being incorporated to enhance robots' perception and adaptability.
- Cameras and laser scanners can track weld seams in real-time, allowing robots to adjust their path and torch position for consistent welds even with part variations.
- This is particularly beneficial for complex geometries and materials sensitive to joint positioning (like laser welding).

**Collaborative Welding Robots (Cobots):**

- Cobots are lightweight, user-friendly robots designed for safe human-robot interaction.
- In welding, cobots can assist with tasks like part loading/unloading, seam tracking with handheld sensors, or performing simple spot welds.
- This collaborative approach reduces risk and opens doors for integrating robots in smaller workspaces or tasks requiring human expertise alongside automation.

**Artificial Intelligence (AI) Integration:**

- AI is playing an increasingly important role in robotic welding.
- Machine learning algorithms can analyze welding data to optimize parameters, predict potential issues, and even perform self-calibration.
- This can lead to improved weld quality, reduced rework rates, and ultimately, higher productivity.

### **Cloud-based Monitoring and Control:**

- The rise of cloud computing allows for remote monitoring and control of robotic welding systems.
- Welding data can be accessed and analyzed in real-time, enabling proactive maintenance and optimization.
- This improves overall system uptime and facilitates better management of multiple robots across a production facility.

### **Advanced Welding Techniques:**

New-generation robots are being equipped to handle advanced welding processes like laser beam welding with higher power densities.

This allows for deeper penetration, faster welding speeds, and joining of dissimilar materials, expanding the applications of robotic welding.

### **Self alignment due to current variation:**

Self-alignment with current variation is a concept that's still under development. It refers to the ability of a robotic welding system to automatically adjust its parameters based on fluctuations in the welding current during operation.

Self-alignment with current variation allows for :

- **Real-time Monitoring:** The robotic system continuously monitors the welding current through sensors in the welding torch.
- **Adaptive Control System:** An intelligent control system analyzes the current variations in real-time.
- **Automatic Parameter Adjustment:** Based on the analysis, the system automatically adjusts welding parameters (e.g., travel speed, wire feed rate) to maintain a consistent and optimal welding current for high-quality welds.

### **Challenges of Self-Alignment with Current Variation:**

**Sensor Accuracy:** Welding current sensors need to be highly accurate and reliable to capture the subtle variations for effective control.

**Data Analysis and Control Algorithms:** Developing robust algorithms that can interpret current variations, differentiate between noise and actual changes, and determine the appropriate adjustments requires advanced data analysis and control techniques.

**Welding Process Complexity:** The relationship between current variations and optimal parameter adjustments can be complex and depend on the specific welding process and material being used.

## AUTOMATION

Automation refers to the use of technology to perform tasks with minimal human intervention. It involves using machines, computers, and software to automate repetitive, dangerous, or tedious processes. Automation can improve efficiency, productivity, accuracy, and consistency in various industries.

### Types of Automation:

There are several types of automation, each suited for different tasks and applications:

- **Fixed Automation:** Machines perform a specific task in a predetermined sequence, with little to no variation. Assembly lines in car manufacturing are a common example.
- **Programmable Automation:** Robots and computer-controlled machines can be programmed to perform a variety of tasks with some flexibility. This allows for changes in production processes without major hardware modifications.
- **Flexible Automation:** Highly adaptable systems can handle different product variations and respond to changes in production requirements. This is often used in custom manufacturing or short-run production.
- **Intelligent Automation:** This advanced level of automation uses artificial intelligence (AI) and machine learning (ML) to make decisions and adapt processes in real-time. It allows for self-optimizing systems that can learn and improve over time.

### Industry 4.0 and Factories of the Future

Industry 4.0, also known as the Fourth Industrial Revolution, is a term used to describe the current trend of automation and data exchange in manufacturing. It involves the integration of various technologies like:

- **Internet of Things (IoT):** Physical devices equipped with sensors and internet connectivity, allowing for data collection and communication.
- **Cloud Computing:** Storing and accessing data and applications remotely over the internet.
- **Big Data Analytics:** Analyzing large sets of data to identify patterns, improve processes, and make data-driven decisions.
- **Cybersecurity:** Protecting interconnected systems and data from cyberattacks.
- **Factories of the future** are envisioned as highly automated and intelligent manufacturing environments that leverage Industry 4.0 technologies. These factories will be:

- **Highly connected:** Machines, devices, and systems will communicate and share data seamlessly.
- **Autonomous:** Robots and intelligent systems will handle many tasks with minimal human intervention.
- **Data-driven:** Real-time data analysis will be used to optimize production processes and predict maintenance needs.
- **Flexible:** Factories will be adaptable to changing market demands and product variations.

### **Machine Learning Applications in Industry 4.0**

Machine learning (ML) plays a crucial role in Industry 4.0 by enabling machines to learn and improve from data. Some examples include:

- **Predictive Maintenance:** ML algorithms can analyze sensor data from machines to predict potential failures and schedule maintenance before breakdowns occur. This can minimize downtime and maintenance costs.
- **Quality Control:** Machine vision systems with ML can inspect products for defects with high accuracy and speed, improving overall product quality.
- **Process Optimization:** ML can analyze production data to identify inefficiencies and suggest adjustments for optimal performance.
- **Demand Forecasting:** ML models can analyze sales data and market trends to predict future demand for products, allowing for better inventory management and production planning.
- **Robot Learning:** ML algorithms can be used to train robots to perform tasks more efficiently and adapt to new situations

### **Impact of Automation and Internet of Things in Welding:**

Artificial intelligence (AI) and the Internet of Things (IoT) are poised to significantly influence welding in the future, leading to a more automated, efficient, and intelligent welding process.

#### **Impact of AI:**

**Self-Optimizing Welding Parameters:** AI algorithms can analyze data from sensors (welding current, travel speed, etc.) in real-time. This allows for automatic adjustments to welding parameters (heat input, wire feed rate) to achieve optimal weld quality based on the specific material and joint geometry.

**Predictive Maintenance:** AI can analyze sensor data from welding robots and equipment to predict potential failures. This enables proactive maintenance, preventing downtime and minimizing repair costs.

**Adaptive Welding for Variations:** AI can analyze slight variations in workpiece dimensions or material properties and adjust the robot's path or welding parameters accordingly. This ensures consistent weld quality even with minor inconsistencies.

**Defect Detection with Machine Learning:** Machine vision systems powered by AI can analyze weld pool characteristics or post-weld images to identify defects with high accuracy. This can improve quality control and reduce the need for human inspection.

### **Impact of IoT:**

**Remote Monitoring and Control:** With IoT integration, welding robots and equipment can be monitored and controlled remotely. This allows for centralized management of multiple welding stations, troubleshooting issues from a distance, and optimizing production processes across a facility.

**Data-driven Insights:** IoT enables real-time data collection from sensors on welding machines, robots, and workpieces. This data can be analyzed to identify trends, optimize welding processes, and improve overall welding efficiency.

**Improved Collaboration with Cobots:** Collaborative robots (cobots) equipped with AI and connected through IoT can work safely alongside human welders. Cobots can handle tasks like part loading/unloading, seam tracking with handheld sensors, or performing simple welds, while AI assists with real-time adjustments and decision-making.

### **Combined Impact of AI and IoT:**

The combination of AI and IoT creates a powerful force for intelligent welding systems. Some potential benefits includes:

- **Increased Throughput and Productivity:** Faster welding with consistent quality due to AI-powered optimization and fewer disruptions from breakdowns with predictive maintenance.
- **Reduced Rework Rates:** AI-based defect detection and self-correcting adjustments minimize the need for rework, saving time and materials.
- **Improved Safety:** Remote monitoring and AI-powered analysis can help identify potential safety hazards and ensure safe operation of robotic welding systems.
- **Enhanced Flexibility and Adaptability:** AI can handle variations and adjust processes in real-time, while IoT enables communication and data exchange for a more responsive production environment.