Robotic Welding Arm Assembly for Manufacturing Automation

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Application Description

In the evolving landscape of manufacturing, achieving precision, efficiency, and safety is of utmost importance. This project focuses on designing and integrating a robotic welding arm to automate the welding process for the **motorcycle headstock**. The robotic manipulator, a 6-axis articulated arm, will perform precise MIG (Metal Inert Gas) welding to assemble the Headstock, ensuring strong, high-quality welds across critical joints. The robot will be integrated into an existing production line, programmed to handle various welding positions with a fixture, allowing for optimal welding angles and accessibility.

By using this robotic manipulator, the production process becomes more streamlined, reducing human intervention in hazardous tasks while ensuring high precision and consistency. This automated solution is expected to improve production quality, increase throughput, and foster a safer working environment for human workers.

Benefits of Using a Robotic Manipulator:

Precision and Repeatability: The 6-axis robotic arm maintains gap spacing of 1 mm and performs welding operations with accuracy within a 0.1 mm tolerance. This level of precision minimizes errors inherent in manual welding, ensuring each weld meets stringent quality standards and improving the overall reliability of the final product.

Increased Efficiency: Automating the welding process ensures a continuous workflow, reducing downtime and speeding up production. It is estimated that this automation will increase production throughput by 30%, with the potential to run 24/7 without the need for breaks.

Worker Safety: Welding exposes workers to extreme heat, fumes, and sparks. Automating this task significantly reduces health risks for operators, who can now supervise and maintain robots from a safe distance.

Consistent Quality: Robotic welds are highly repeatable, leading to uniform quality across all products. This consistency reduces defects, rework, and material waste, ultimately contributing to higher output quality and lower costs.

In conclusion, the robotic welding manipulator not only enhances production efficiency and safety but also ensures the consistent high quality required in motorcycle manufacturing, reducing operational costs and increasing overall output.

Environment Description

The robotic welding arm operates within a 2.75m x 0.1m welding cell, designed for safety and optimized operation. The six-degrees-of-freedom robotic manipulator, with five links and five rotational joints, is engineered for the precise and flexible execution of complex welding tasks on the motorcycle Headstock. The workspace contains strategically placed obstacles that the manipulator must navigate around, ensuring efficient operation without compromising accuracy.

Key Features of the Workspace:

Workspace Dimensions: The welding cell measures 2.75m x 0.1m, providing sufficient room for the robotic arm to operate within its full range of motion. The height of the cell is 2.25 meters, accommodating the arm's extended reach.

Safety Features: Physical barriers enclose the workspace, and light curtains at entry points serve as safety interlocks, immediately halting the robot's movements if personnel approach. Emergency stop buttons are also strategically placed around the cell for additional safety precautions.

Robot Arm Reach and Dimensions:

The robotic arm has a well-defined reach, allowing it to cover a significant area within the workspace:

Base to Joint 1: 194.95 mm

Joint 1 to Joint 2: 310.77 mm

Joint 2 to Joint 3 (Upper Arm Segment): 800.51 mm

Joint 3 to Joint 4: 532.99 mm

Joint 4 to End of Wrist Link: 371.40 mm

End-Effector Tool Length: 269.07 mm

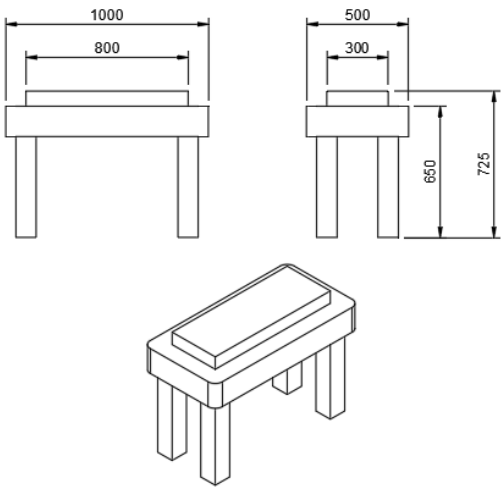
These link lengths and rotational joints enable the arm to access difficult welding positions, providing versatility in its movement. The arm's total reach from base to the end of the end-effector tool is approximately 2.48 meters, covering a large portion of the cell.

Obstacles within the Workspace:

Fixture:

Size & Location: The fixture, located at the centre of the cell, is 0.725 meters high and has a width of 0.5 meters. The fixture is 0.8m x 0.3m x 0.122m, creating a central obstacle for the robotic arm.

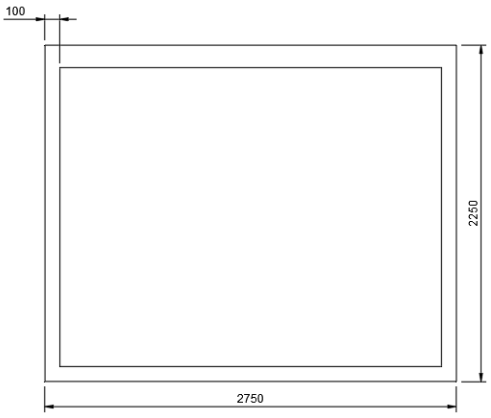
Impact on Movement: The arm must avoid colliding with the fixture as it welds different parts of the Headstock. The robot's flexibility and reach allow it to position the welding tool at optimal angles, adjusting to the rotating fixture's movements.



Safety Wall:

Size & Location: The safety wall is placed on all 4 sides of the robot and the fixture. The walls dimensions are 2.75m x 0.1m x 2.25m.

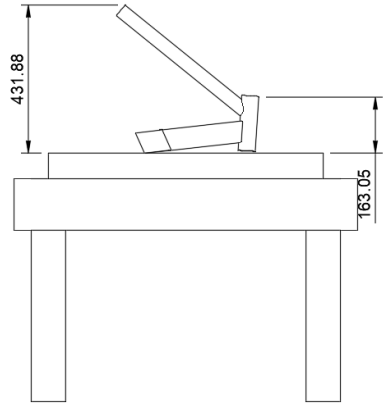
Impact on Movement: The arm's base must be positioned to prevent entanglement with the cables.



Headstock:

Size & Location: The headstock during the welding process has a height of 0.431m height on right side of the robot and 0.163m on the left side of the robot.

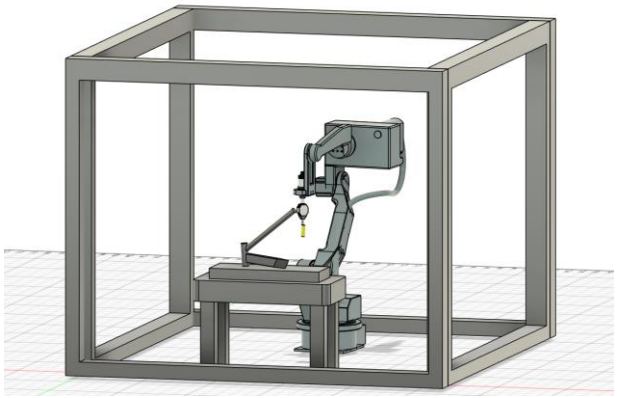
Impact on Movement: The arm needs to avoid the headstock while maintaining quality of weld.



Workspace Interaction:

The robotic arm, with its versatile reach, can maneuver around obstacles like the fixture and tool rack while maintaining welding accuracy. Its flexible joints enable the end-effector to approach difficult angles, avoiding collisions with surrounding objects. The arm's extended reach of over 2.48 meters ensures it can cover the entire welding area, performing precise welds even in the presence of obstacles.

This 3D workspace demands precise movement, as the robot must navigate around various obstacles while ensuring accurate, high-quality welds on the motorcycle Headstock. The combination of a spacious cell and a flexible robotic arm creates an optimized environment for efficient and safe welding operations.



Robotic Manipulator Design

The robotic welding arm is designed with six degrees of freedom, enabling it to execute complex welding tasks with a high degree of flexibility and precision. It consists of five links and five rotational joints (revolute joints), each precisely engineered to work in unison, ensuring the required welding accuracy for the motorcycle Headstock. The arm's design and movements are optimized for efficiently reaching each weld point while avoiding workspace obstacles.

Reach and Link Lengths:

Base to Joint 1: 194.95 mm

Joint 1 to Joint 2: 310.77 mm

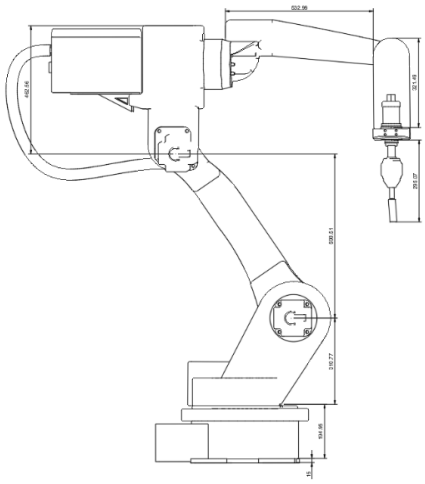
Joint 2 to Joint 3 (Upper Arm Segment): 800.51 mm

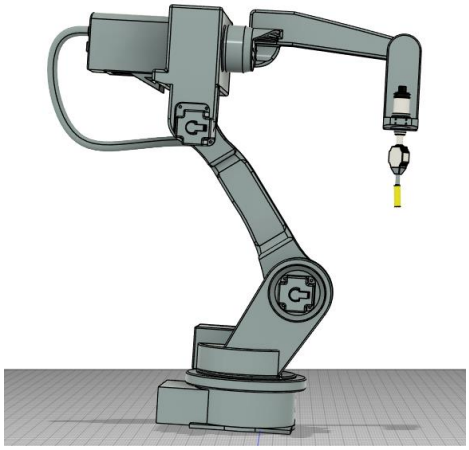
Joint 3 to Joint 4: 532.99 mm

Joint 4 to End of Wrist Link: 371.40 mm

End-Effector Tool Length: 269.07 mm

These dimensions give the arm a total reach of approximately 2.48 meters, allowing it to cover the entire welding area of the motorcycle Headstock, which measures 159.98 mm in length and 58.89 mm in width.





Headstock Dimensions (Motorcycle Component):

The motorcycle Headstock, a crucial part of the welding process, has the following dimensions:

Length 1: 159.98 mm

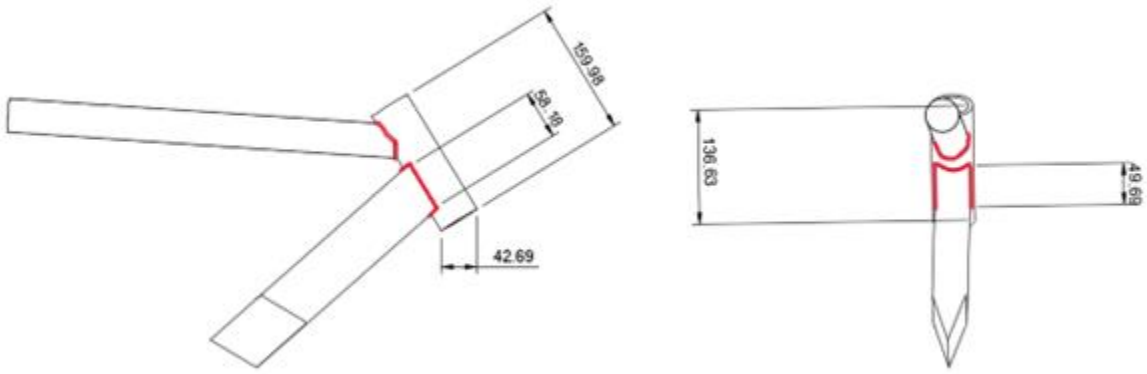
Length 2: 58.89 mm

Width: 42.69 mm

Height: 136.63 mm

Extension: 49.69 mm

The Headstock consists of one main tube with two holes, a square tube, and an additional tube. The robotic arm performs welding along the joints of these tubes, ensuring a consistent **1 mm gap** between the parts to facilitate high-quality welds with proper penetration.



The welding will take place on the area which

is highlighted in red

End-Effector:

The robotic arm is equipped with a **MIG welding torch**, selected for its precision and ability to create clean, high-quality welds. The torch is securely attached to the end-effector, allowing the robotic arm to maintain accurate positioning during welding tasks. The torch is designed to operate within the tight tolerances required for this welding process, ensuring that each joint is properly fused.

To enhance welding quality, the end-effector may be equipped with:

Integrated Sensors: These could monitor the weld temperature and penetration depth in real time, adjusting the torch's speed or current if necessary.

Nozzle Cleaning Mechanism: This mechanism would keep the torch free of debris, preventing clogs and ensuring consistent weld quality.

Joint and Movement Design:

Each joint is a **revolute (rotational) joint**, chosen for its flexibility and ability to position the end-effector at any required angle. The use of only rotational joints ensures that the manipulator can reach any point on the Headstock without needing linear translation, which simplifies the design and reduces mechanical complexity.

Joint Breakdown:

Joint 1 (Base to Link 1):

Type: Rotational Joint

Axis of Rotation: Vertical (Z-axis)

Function: Allows the arm to rotate around the vertical axis, providing a wide horizontal range for positioning.

Joint 2 (Link 1 to Link 2):

Type: Rotational Joint

Axis of Rotation: Horizontal (Y-axis)

Function: Adjusts the vertical height of the arm, ensuring that the end-effector can move upwards or downwards to access different welding points.

Joint 3 (Link 2 to Link 3):

Type: Rotational Joint

Axis of Rotation: Horizontal (Y-axis)

Function: Provides further vertical articulation, allowing the arm to adjust its height and reach elevated or recessed welding points.

Joint 4 (Link 3 to Link 4):

Type: Rotational Joint

Axis of Rotation: Horizontal (X-axis)

Function: Controls the orientation of the welding torch, aligning it for precise positioning relative to the Headstock.

Joint 5 (Link 4 to End-Effector):

Type: Rotational Joint

Axis of Rotation: Horizontal (Y-axis)

Function: Fine-tunes the alignment of the welding torch, ensuring that it can reach even the most intricate welding joints with accuracy.

End-Effector Joint (Welding Torch):

Type: Fixed Joint

Function: The welding torch is fixed in place at the end-effector, with its position controlled by the preceding joints. This configuration ensures that the torch can target weld points precisely, regardless of their location.

The robotic welding arm's six degrees of freedom, combined with its precise link lengths and rotational joints, provide the flexibility and accuracy required for welding the motorcycle Headstock. The end-effector, equipped with a MIG welding torch, ensures high-quality, consistent welds, while the revolute joint structure allows for seamless movement across the workspace. The overall design is tailored to handle complex welding tasks efficiently, even in a space with obstacles or difficult-to-reach areas.