



# GE Tube Polishing System

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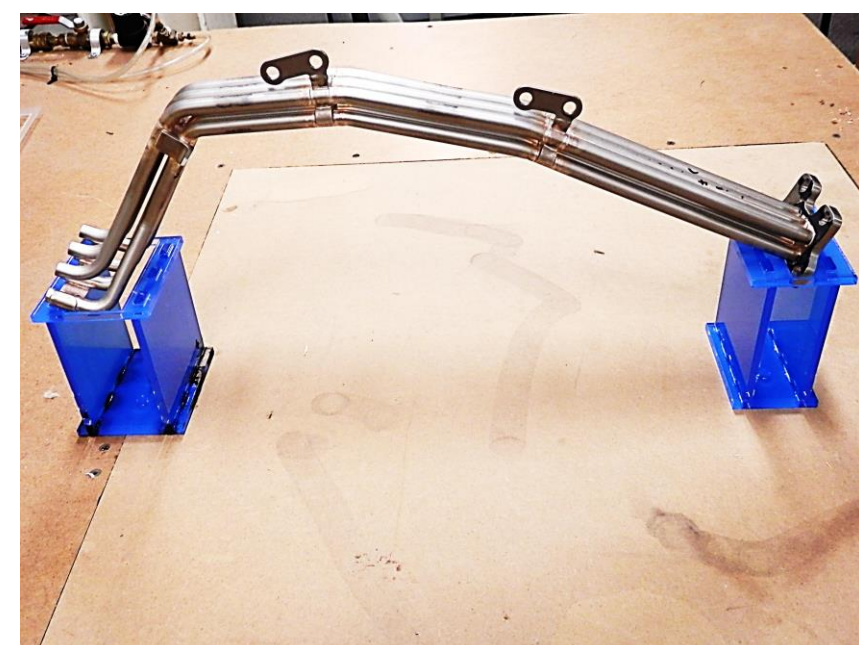


## Abstract

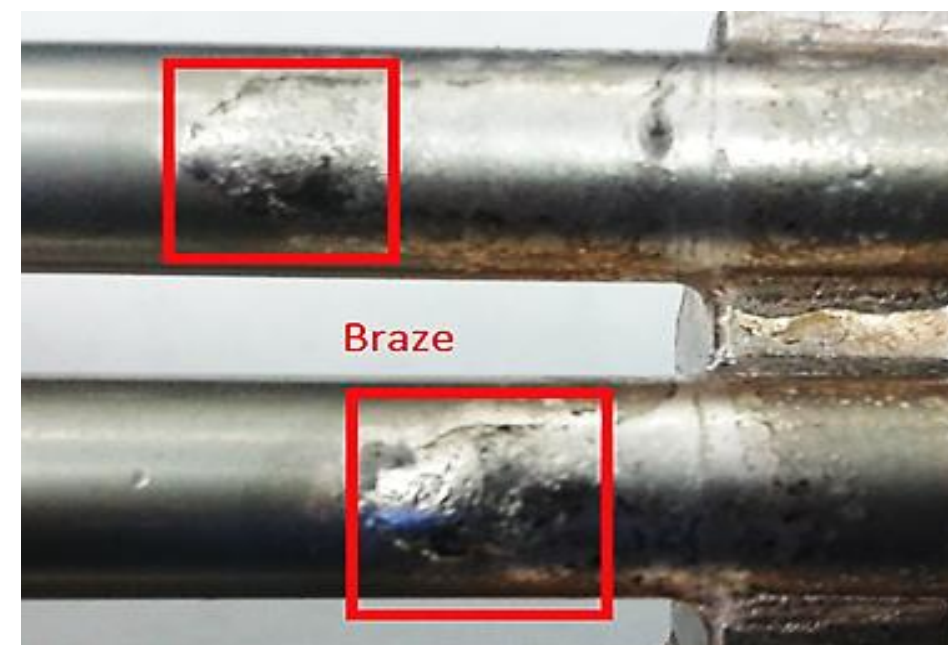
The goal of this project is to automate the process of polishing brazed or welded areas on a tube assembly supplied by GE Aviation. An end-of-arm-tooling for a Fanuc 200iB was designed and fabricated to manipulate the tube. A work cell layout was determined and part fixtures were developed. A force controlled grinding system was implemented and interfaced with the Fanuc 200iB. Analytical and experimental analyses were conducted to determine the necessary polishing forces. Design considerations were made for future enhancements to the automated tube polishing system.

## Background

GE Aviation utilizes a mix of manual and automated manufacturing methods to produce aircraft engines. These engines contain a large variety of tube assemblies with brazes and welds that need to be polished. Since a large quantity of tubes needs to be polished each day, GE Aviation desired to implement a robotic system that could polish these tubes automatically.



Tube Assembly



Brazed Areas in Need of Polishing

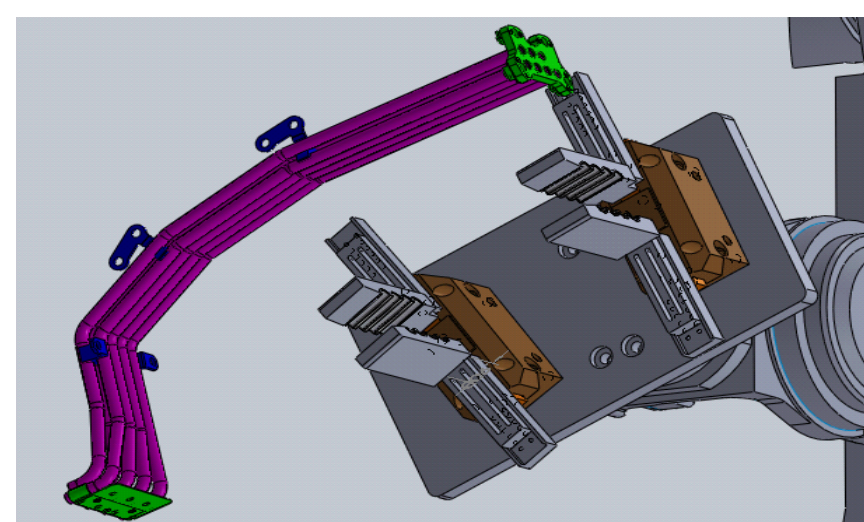
## Design Requirements

Action	Requirements
Gripping	The gripper must adapt to different shapes of tubes May not damage the tubes when gripping
Polishing	Must fully polish the brazed areas on the tubes May not over-polish the tubes

## Mechanical Design

### End-Of-Arm-Tooling

- Pneumatic controlled
- Oriented to specific tube shape
- GE supplied a complex seven-tube assembly that was challenging to pick up and manipulate.



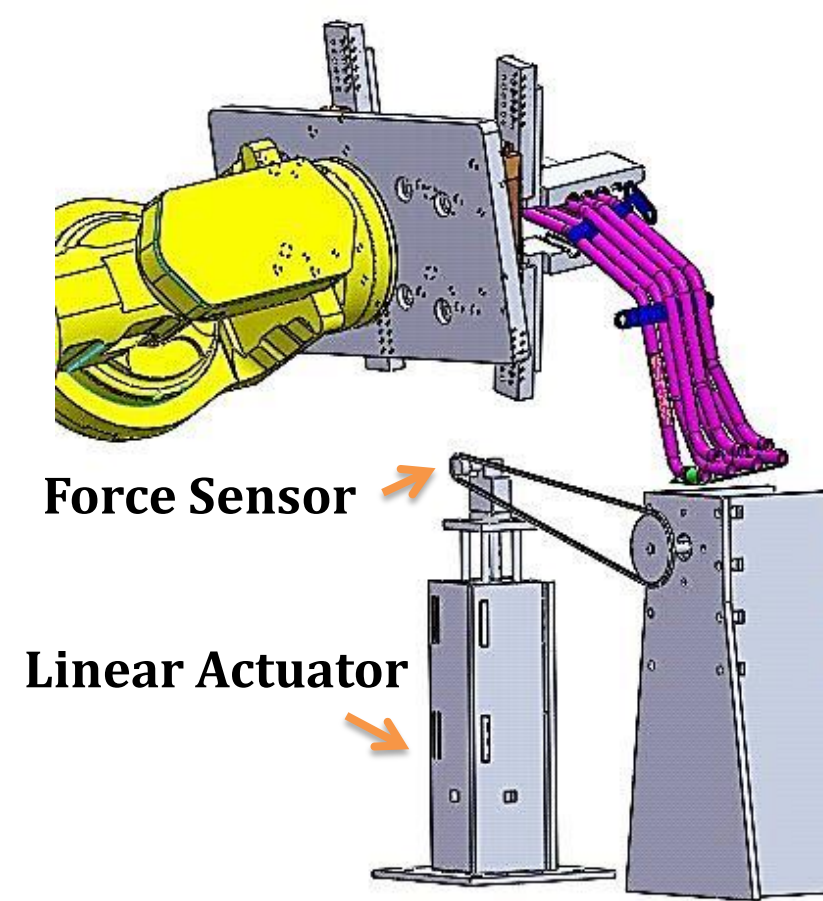
Two-Finger Pneumatic Gripper

## Polishing Station

- Force sensing capability
- Polishing belt
- Linear actuator that can control the force applied on the tube while polishing

## Force Calculation

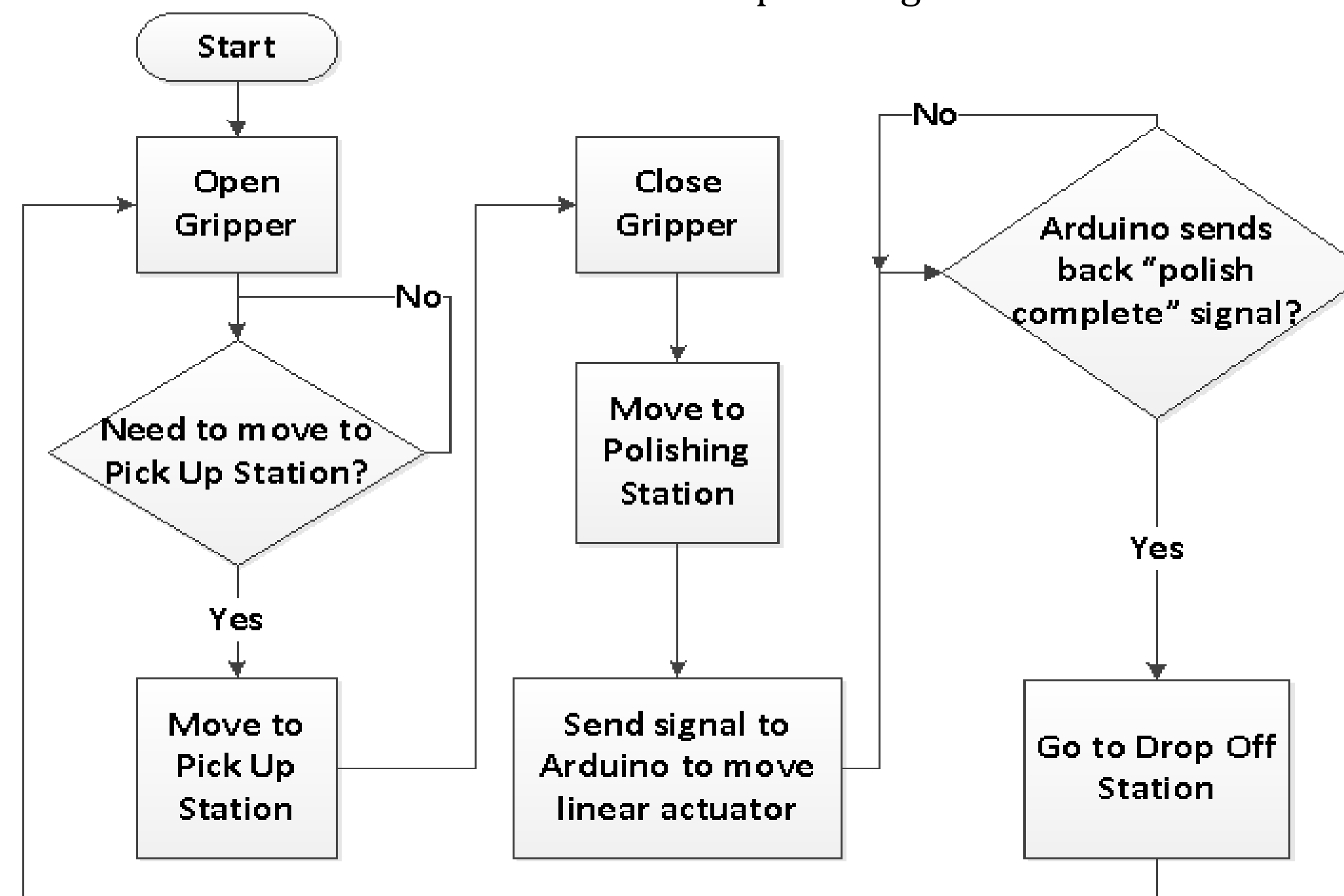
- Material Removal Rate (MRR): 0.0024 in<sup>3</sup> /min
- Force required to remove the brazes: 0.03 lbf (calculated), 1 lbf (reality)



Gripper and Polishing Station

## Software Design

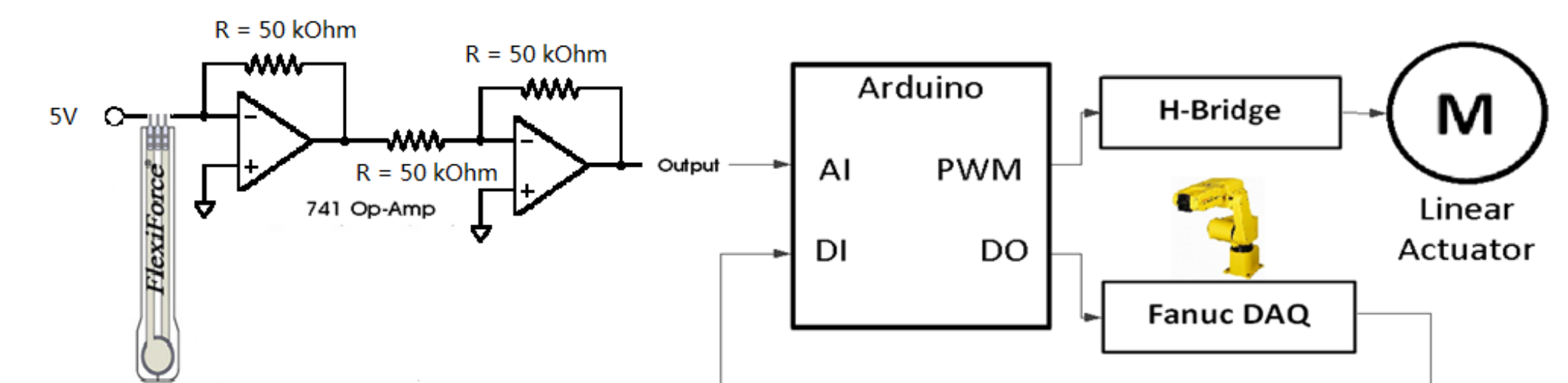
- Fanuc offline program controls the movement of the robot arm
- Fanuc robot was manually jogged to collect the position coordinates for the online program
- C++ was used to program the Arduino microcontroller for interpreting the data from the force sensor on the polishing wheel



Program Flow Chart

## Electrical Design

- An Arduino microcontroller is used to gather sensor data from the force sensor on the polishing wheel
- The signal goes through a negative feedback loop to the Arduino
- PWM signal is generated to control the linear actuator
- An output signal is generated to inform the robot when polishing process is completed.



Electrical System Schematic

## Conclusions

- A specific shape of gripper was implemented to pick up the tube assembly supplied by GE Aviation
- A work cell layout was setup on a 2 feet by 4 feet area in front of the robot
- Arduino microcontroller was able to control the force feedback loop in the polishing system
- Partial brazes were able to be polished by the system



Tube Polishing System



Polishing Station

## Future Recommendations

- Full designs of the Gripper Base EOAT can be implemented to adapt to different shapes of tubes
- Computer Vision can be added to this system in the future. The vision system will serve two purposes; the first is to detect the shape of a tube so that the robot knows how to grasp the tube with the manipulator and the second is to use the vision system for identifying the location of the brazing on the tube
- Another possible augmentation to incorporate into the design of the robot would be touch sensing in the fingers of the end of arm tooling

## Acknowledgments

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