GE Aviation Tube Polishing System
Major Qualifying Project

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Outline

• Introduction
• Project Goal
• Design Requirement
• Solution
  • Gripper Design
  • Polishing Methods
• Implementation
• Results and Conclusion
• Future Recommendation
• Acknowledgement
Aircraft

Introduction

Engine
Introduction
Introduction
The goal of this project is to automate the process of polishing brazed or welded areas on a tube assembly supplied by GE Aviation.
Initial Design Requirement

**Grip**
- A robotic gripper that can adapt to various shapes of tubes
- May not damage the tubes upon gripping
- Make use of robotic arm supplied by GE Aviation

**Inspect**
- Use computer vision to locate the brazed areas
- Decide if polishing is necessary

**Polish**
- Fully polish brazed areas on the tube assembly
- Must not damage tube, cosmetically or physically
Final Design Requirement

**Grip**
- Unique gripper design for the tube supplied by GE Aviation
- Must not damage tube upon gripping
- Use Fanuc 200iB located in Washburn Shop

**Inspect**
- Was outside of the scope for the project
- To be left for future MQPs

**Polish**
- Fully polish brazed areas on the tube assembly
- Must not damage tube, cosmetically or physically
Polishing Prototype System
Gripper EOAT
Candidate Solution – Gripper

**Grip**
- A robotic gripper that can adapt to various shapes of tubes
- May not damage the tubes

**Gripper Base**

**Tube Follower**
# Solution – Gripper Metrics

<table>
<thead>
<tr>
<th>Methods</th>
<th>Gripper Base</th>
<th>Tube Follower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Difficulty</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Programming complexity</td>
<td>4 (Need to adapt to different tubes)</td>
<td>2 (Highly customized design)</td>
</tr>
<tr>
<td>Mechanical design complexity</td>
<td>3</td>
<td>5 (Highly customized design)</td>
</tr>
<tr>
<td>Resources</td>
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<td>4</td>
</tr>
<tr>
<td>Cost (Budget)</td>
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<td>4</td>
</tr>
<tr>
<td>Time cost (for GE)</td>
<td>4 (May change gripping locations)</td>
<td>3</td>
</tr>
<tr>
<td>Performance</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Precision</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Desired functions absence</td>
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<td>5 (Cannot polish branches)</td>
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</tbody>
</table>

| Total            | 20           | 22            |

Rate from 1 to 5, 1 means the most desirable
Candidate Solution – Gripper

Gripper Base

Pros:
+ Capable of grabbing tubes at all different angles
+ Flexible joints adapt to different tubes
+ Interchangeable gripper fingers

Cons:
- Complex design
Final Gripper Design
Polishing Station
Candidate Solution – Polishing

Moving Tube, Fixed Polisher

Moving Polisher, Fixed Tube

Combined: Moving Tube, Moving Polisher
## Solution – Polishing Metrics

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Methods</th>
<th>Design Difficulty</th>
<th>Resources</th>
<th>Performance</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Moving tube, fixed Polisher</td>
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<td></td>
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<td>Moving tube, moving Polisher</td>
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<tr>
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<td>4</td>
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<td>Need to pass the tube</td>
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<td>3</td>
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<tr>
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<td>Need tool changer</td>
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<tr>
<td>Time cost (for GE)</td>
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<td>5</td>
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<td>Need to pass the tube</td>
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<td>Precision</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
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<td>Force sensing on a more complex EOAT</td>
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<td>Desired functions</td>
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<td>2</td>
<td>2</td>
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<tr>
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<td>22</td>
<td>27</td>
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</tbody>
</table>

Rate from 1 to 5, 1 means the most desirable
Polishing System
Polishing System

- Force Sensor
- Linear Actuator
- Tension Pulley
- Polishing Belt
- Motor
Polishing System
Polishing Process

Pick Up
Move to Polishing Station
Polish
Move Away
Drop Off
Programming

- Force sensor collects data => Arduino
- Arduino generates PWM signals to linear actuator
- When desired force reached, Arduino sends signal to NI DAQ
- NI DAQ sends signal to Robot Fanuc DAQ
- Robot reacts
Results and Conclusion

• Created polishing system
• EOAT works for specific tube
• Polishing routine implements force feedback controller
• Program maneuvers tube on polisher
Future Work

• New Fanuc 710iC
• Computer vision
  • Identify welds/brazes
  • Determine the gripping positions
  • Check quality
• Built-in force sensor on the gripper
• Movable polishing finger belt to allow a finer polishing technique
We would like to thank our project sponsor General Electric Aviation and our advisors for their support.

- Our advisors
- Robotics lab
- Washburn labs
- Higgins machine shop
- FRC Team
Questions?

GE Aviation Tube Polishing System
Major Qualifying Project
Candidate Solution – Gripper

Gripper Base

Linear Tube    Planar Tube    Non-Planar Tube
Candidate Solution – Gripper

Gripper Base

Gripping Different Positions
Polishing Comparison

Moving Tube, Fixed Polisher

Pros:
+ No need for tool changing
+ Can pick up the tube then starts to polish immediately

Cons:
- EOAT design requires two grippers that can adapt to the tube

Moving Polisher, Fixed Tube

Pros:
+ Fewer kinematics calculations

Cons:
- Need to change tools
- Need to pass the tube to the gripper base (tube fixture)
Polishing System

- Force sensor: 25lb FlexiForce
- Linear Actuator: screw mechanism driven by 12V DC motor
- Motor: CIM motor 884
- Polishing belt: 120 grit
Force Sensing

Output Reading from Arduino vs. Force Applied to the Force Sensor
GE Work Cell
GE Robot 710iC