Cobot: Robotic Flange Assembly
A Multidisciplinary Effort

Client: Siemens

Design Project Team Name: Robotic Flange Assembly

Team Members: See Below

Academic Term: Spring 2019

Introduction

Siemens was established 1847 and primarily contributes to the energy, automation, healthcare, and infrastructure industries. All four of these industrial disciplines are responsible for exponential growth of the company.

- Siemens has been one of the largest producers of energy efficient technology solutions, being at the forefront of the industry.
- Siemens is headquartered in Germany and runs on Global Business Operations due to its high impact in several different nations.
- In 2017, it was reported that Siemens revenue came in around $83 billion.
- Figure 2 is the final design for this iteration of the process improvement for robot assisted pipe flange assembly

Figure 1. Manual Labor.

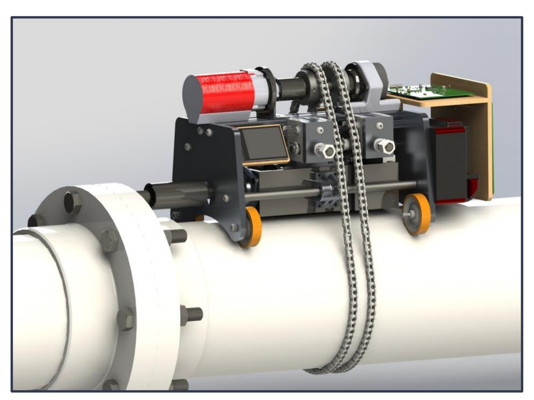


Figure 2. Cobot V4

Problem Statement

The manual pipe flange assembly process is time consuming, physically demanding, and at times, inconsistent. Introducing a robotic helper to the process with automation will minimize human error and allow for the reduction of cycle time. Our Cobot will:

- Reduce Cycle Time
- Improve Safety
- Improve Quality

Management desires to reduce cycle time since this process only takes place when a power plant is shut down. Adding automation will streamline the process which translates to savings in time and money for the client.

Scope Statement and Project Assumptions

The key requirements the team set out to accomplish include:

- Reach torque up to 40 ft-lbs
- Rotate around surface of the pipe
- Align to bolt
- Interface socket with nut
- Provide Software Foundation
- Adapt to different pipe sizes

The assumptions for the design are:

- Flange is positioned horizontally
- Flange has and 8'' diameter
- Bolts are properly aligned or aligned within allowable tolerances
- Bolts are axisymmetric
- Bolt tightening follows ASME standards

Project Objectives

The objectives of this design project are the following:

1. Reduce cycle time through comparing manual assembly times to Cobot cycle run times
2. Improve quality by achieving a consistent process with repeatable results
3. Consider the human factors to improve safety aspects
4. Provide ideas for future improvements

Process Map - Current State

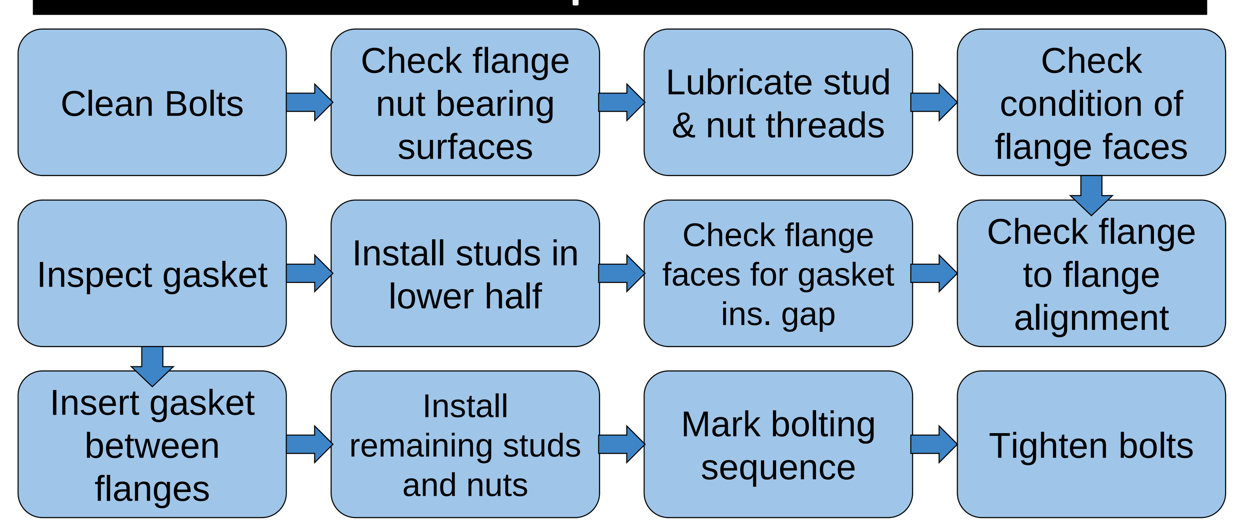
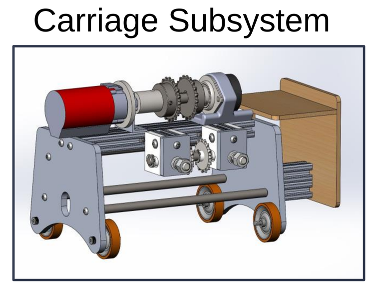
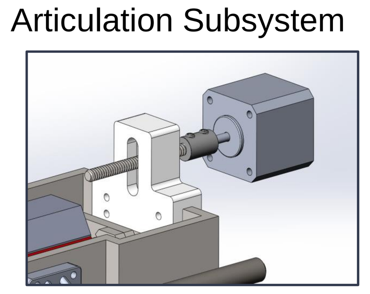


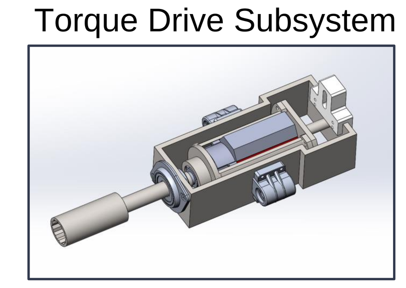
Figure 5. AS IS High Level PMAP

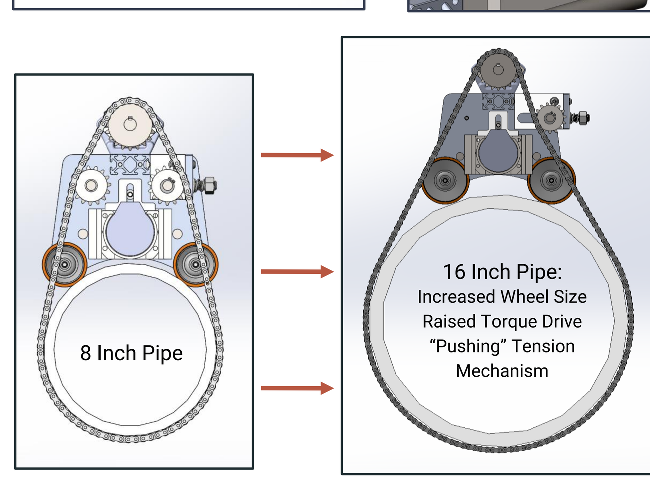
Based on Literal reviews, tech memos, and manual trials of pipe flange assembly, we have model the high level process in Figure 5. In the scope of this project we are going to focus on the last three processes.

Design for Quality - Mechanical


Carriage Subsystem


Articulation Subsystem

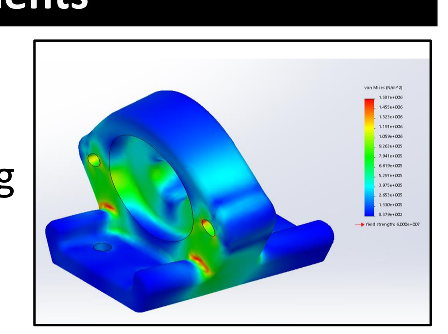

Torque Drive Subsystem



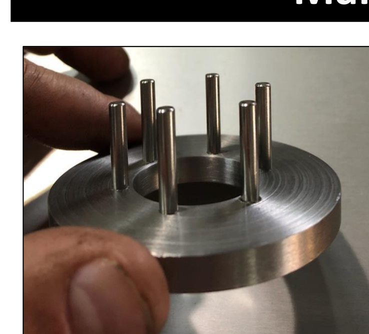
- The 3 subsystems are shown above. As the main support for components, the Carriage rotates the Cobot around the Pipe. The Torque Drive tightens the bolts, and the Articulation moves the unit forward to attach.

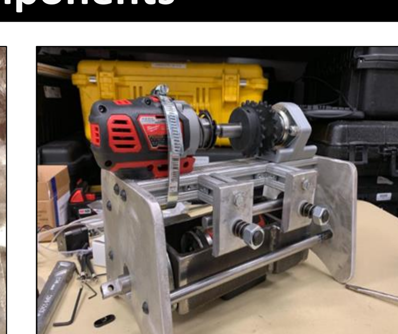
Analysis of Components

- The designs for components were analyzed using SolidWorks as well as calculations for holding torque, climbing torque, required shaft thickness, ideal sprocket size, encoder values



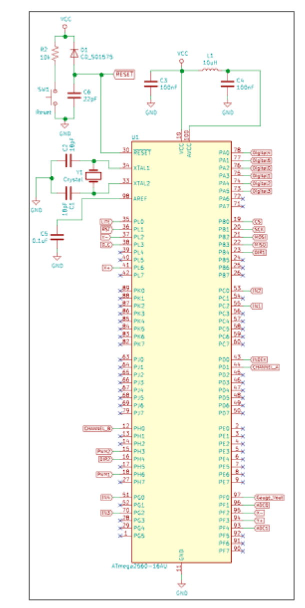
Manufacturing of Components

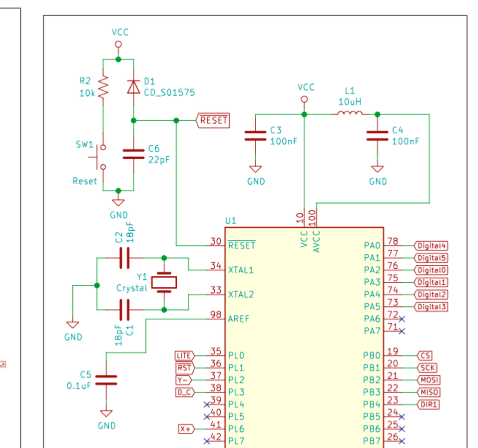




Design for Quality - Electrical Components

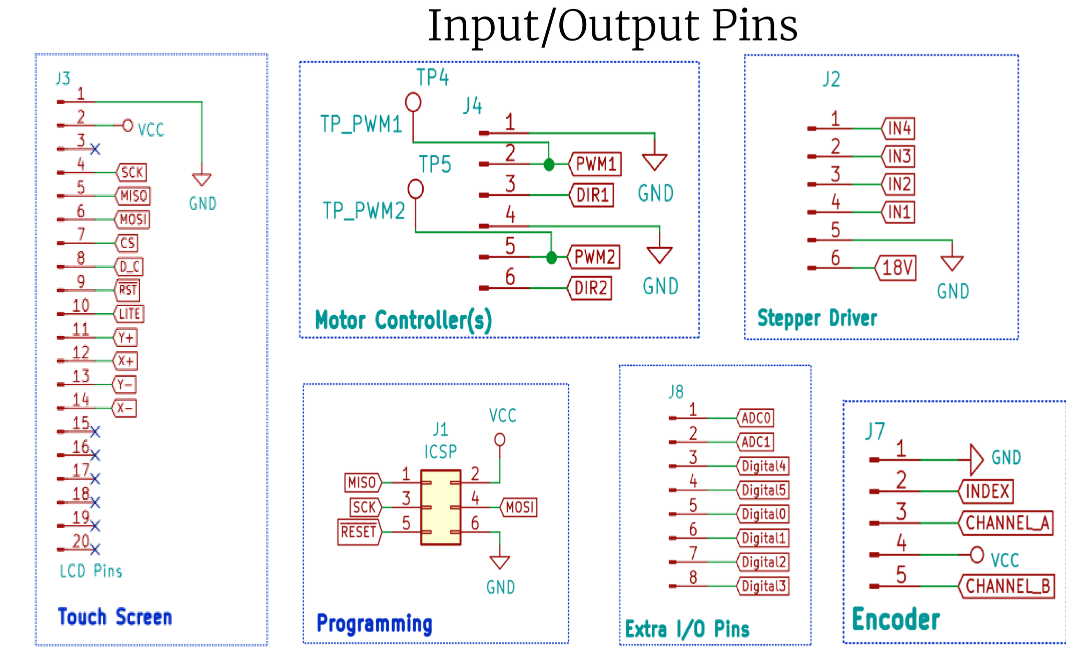
Multipoint Control Unit (MCU)



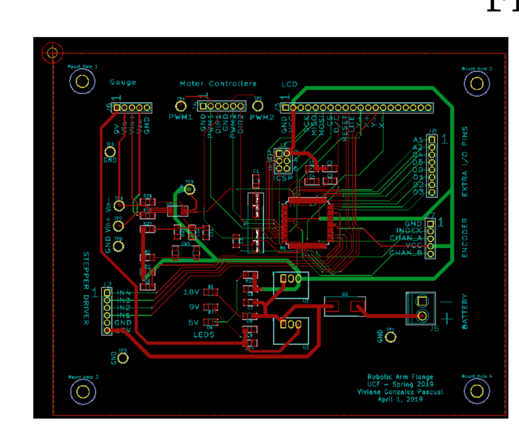


The MCU to the left is responsible for reading the coded instructions. Below: The Input/Output Pins show the final schematic to map the components on the PCB as shown below.

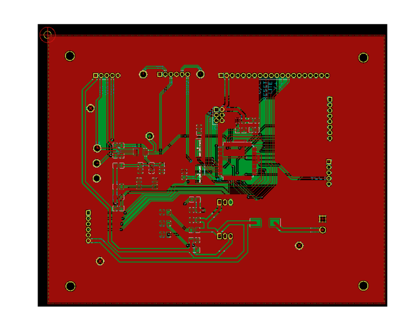
Input/Output Pins



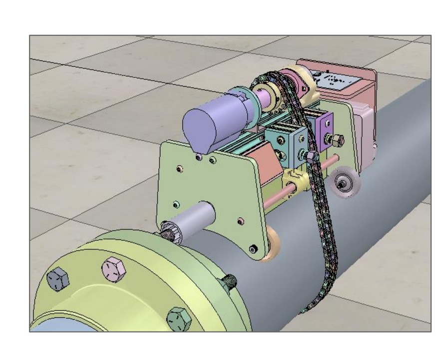
Printed Circuit Board (PCB) Final Layout

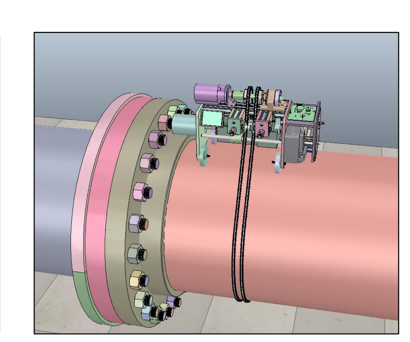


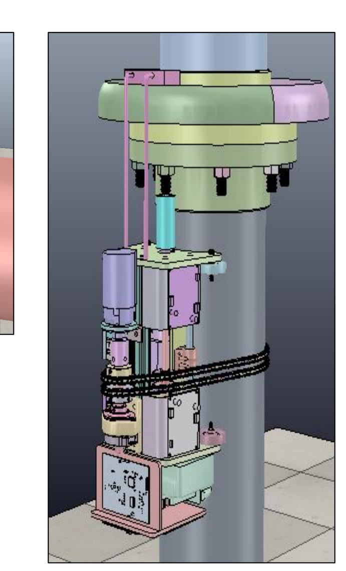
Shown: The Final Layout of our Printed Circuit Board which integrates components of the Cobot.



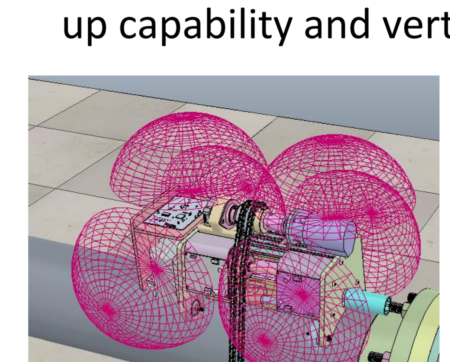
Computer Science - V-REP Simulation







- The Simulation shown uses V-REP (Virtual Robot Experimentation Platform): A highly customizable robotic simulator and shows the scale up capability and vertical case.



- Safety was considered in design through 6 proximity sensors as displayed to the left. If the sensors pick up on any interference, the Cobot will stop all movements and won't start up again until the obstacle is removed.

Continuous Improvement: Analysis of Design Alternatives

The following design concepts were considered for continuous improvement:


Figure 10. A Camera and sensors can be added for more robust bolt to bolt and socket to nut alignment using edge detection software


Figure 11. A Commercial Torque Multiplier can meet target torque of 1400 ft-lbs, cancel reaction torque, and accurately measure and meter torque, but costs about $13,000

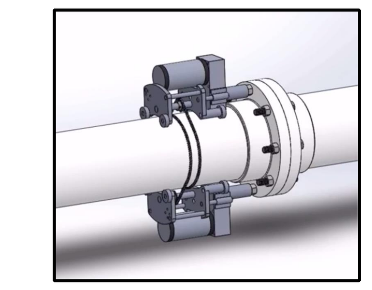


Figure 12. The Two Cobot Concept will improve run time, being more than twice as fast as one Cobot. As two Cobot traverse the pipe on two separate chains, they will have to travel less than half the distance.

Process Map - Future State

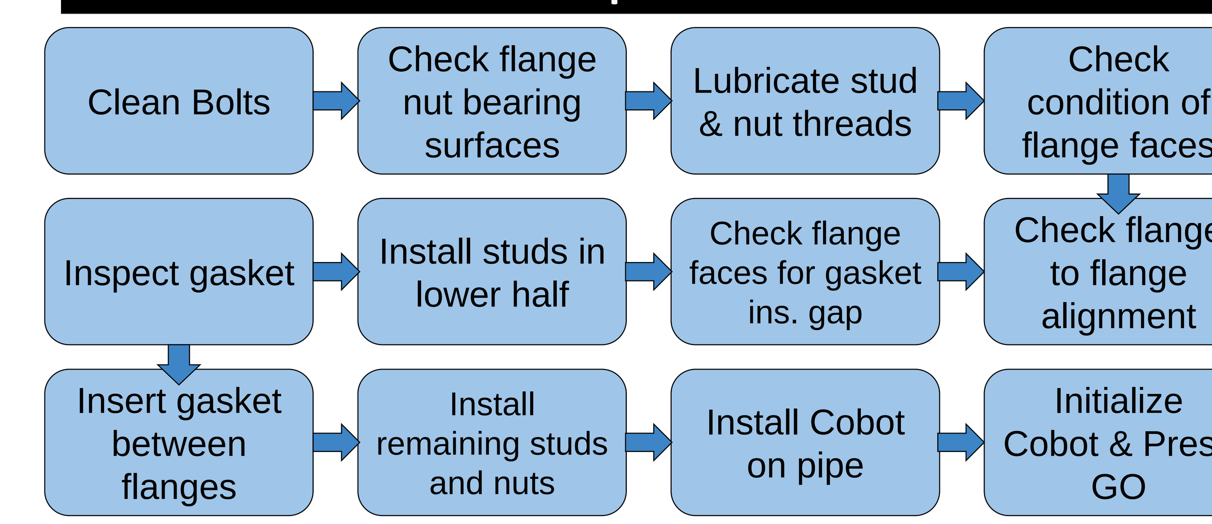


Figure 5. TO-BE High Level PMAP

The process of assembling a flange with the assistance of a cobot is adjusted to include setup and initialization.

Summary

- The Multidisciplinary team was able to successfully produce a functional prototype that achieves set of system requirements while improving quality, safety, and productivity. The concept of a cooperative robotic solution for flange tightening has great opportunity for optimization by future semesters.

Results

Total Time	Manual	COBOT	% Difference
Interface w/nut	19.99	95.394	477%
Tighten first round	133.94	10.088	8%
Change Position	41.94	21.133	50%
Total	195.87	126.615	**65%**

- Using the Cobot results in a 35% time reduction compared to manual labor

Acknowledgments

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- Siemens Sponsors: Gerald Feller, Paul Zombo, Matt Johnson
- Kurt Stresau, Mike Conroy, Mark Heinrich, Samuel Richie
- Luis Rabelo, Senior Design Course Instructor
- Bonnie Marini, UCF Adjunct Professor, Faculty Mentor

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- Ask to see references

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