Industrial Consultant Memorandum

To: Eric Walstra
CC: Preferred Quality Services
From: Michael Bissetta, Josh Tempelman, Nathan Casey, Alex Keizer
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TEAM MEMBERS:




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BRIEF DESCRIPTION OF PROJECT

The team is tasked with designing and implementing a robotic material handling cell for Preferred Quality Services. Unfortunately, the team had a project change in late November due to customer complications. The part originally to be automated was no longer to be produced by PQS. At this point, the team was given a new part to automate. This part is a triangle shaped flange which is processed in a single CNC lathe.

SUMMARY OF REQUIREMENTS

The following requirements are outlined upon request or demand of the customer, outside consultants, or government safety administrations.

1. General
    - 1.1. The system shall be self-sustaining for durations of at least 200 machining operations (the time of which is subject to vary) when beginning in a fully-loaded condition.
    - 1.2. The system shall conform to OSHA and ANSI safety requirement, and the system must not place unavoidable labor burdens on operators.
    - 1.3. The system components shall be procured and manufactured with an emphasis on versatility in order to allow components to be re-used in future endeavours of PQS.
2. Part Loading System
    - 2.1. The part loading machine must be accessible to employees during the operation of the system, and the configuration must allow for the loading of at least one hundred parts at a time without seizing the operability of the system.
    - 2.2. The system must mitigate any possibility of worker injury. The following happenings must be prevented.
        - 2.2.1. Blunt force of the part loading table in motion
        - 2.2.2. Pinching of worker appendages
        - 2.2.3. Failure of mechanical systems resulting in collapse of table and part stacks

2.3. The part loading machine shall secure parts firmly and not allow for variation in presentation greater than 0.188” of tolerance total.

3. Industrial Robotic Arm
    3.1. The robot in use must be capable of repeating its position to within a 0.005”.
    3.2. The robot must have a moment capacity and payload capacity which is compatible with the end-of-arm when fully loaded. The robot shall have a load capacity of 30 lb and a moment capacity of 60 in-lb to ensure this requirement is met.
4. Device Communication
    4.1. The machine cell will have many interface requirements. A PLC must be selected capable of interfacing with the part loader module, the robot arm, an operator interface, the peripheral safety features, and sensors required for the cell. The robot arm has its own controller so the PLC doesn’t need to control its precise movements, but it must still coordinate with the other devices in the cell.
5. End of Arm Tooling
    5.1. The end-of-arm tooling must not exceed 30 lb when fully loaded to ensure that it does not exceed the capacity of the robotic arm.
    5.2. The end-of-arm shall not span beyond 9.00” from the J6 axis in any direction orthogonal to the J6 axis in order to ensure it is compact enough for maneuverability in the part loader and the Haas SL-20 lathe.
    5.3. The geometry of the end-of-arm components must be configured such that they can interface properly with the part loader fixture pins as well as the pins within the lathe itself.
    5.4. The vacuum-actuated gripping system must be capable of applying at a force of at least 22 lb normal to the part surface in order to ensure a safety factor of 4 is obtained under 1.5 G’s of acceleration.
6. Measurement System
    6.1. Measurements shall be conducted manually with interference gages by PQS staff. This manual check will occur in two situations - a tool change is made or a part is requested. After shutdown, an operator can enter the cell to replace the tools in the lathe. At that time, they will measure the previously machined part and the next part. Additionally, the operator can request a machined part with a press of a button. When this button is pressed, the next machined part will be removed from the CNC and placed in a slot in the cage wall, easily and safely accessible by an operator.
7. Security Cage System
    7.1. The team designed a security system with a variety of electrical components and caging. Caging will be used to surround the cell to prevent injuries from moving moving equipment. The door to the cell will be latched with a safety hinge and relay. When the door is locked and the safety circuit is closed, the system becomes operational. If the door is open at any point, the system will shutdown or pause. Additionally, the team’s design contains a variety of buttons and a pressure mat for safety purposes. Two E-stop buttons are readily available and accessible for any emergencies. Other buttons, including the “Stop/Pause” and “Shutdown,” can be pressed while maintenance is in order. Finally, a pressure mat, near the part loading system (where an operator will be located), will stop any part loader movement when a member of the PQS staff is stepping on it.

MAJOR DESIGN DECISIONS

1. Method of Storage

   The original project utilized stacks of parts that were dispensed to a ramp below. This approach had to be altered, however, due to the size of new part. A design alternative for the old part was an indexing table. To meet the customer specifications, this was the method used.

   A table had to be designed that could fit the amount specified by the customer. To do this, the team came up with a fixture design using locating rods which is relatively similar to the original project's design. This design has been prototyped, and works very well.

   The next critical selection to storage of parts is the method of indexing. The plan was to utilize a Kaydon ring bearing which would have been internally toothed such that a servo motor and gearbox could rotate the table. This approach was scrapped once the Mechanical students met with Koops on February 19. Further justification for the design change was received later that week when a quote was returned stating the part had a 22 week lead time. Luckily, Koops provided the team with a solution: an Oriental Motor indexer. This motor significantly lowered cost and is conveniently packaged in one unit, not four (ie motor, gearbox, pinion gear, ring bearing). One drawback to this item is that it cannot take a large moment load. However, this has been accounted for using screw-jacked rollers to support the table.

2. Robotic Arm

   The method for choosing a robot was driven by payload, reach, and cost. The part weight is 2.1 lb. Accounting for all end of arm tooling, the robot should be capable of holding approximately 15 lb minimum. Additionally, the robot must have the reach to carry parts from the rotary table, load and unload them in the CNC, and bin them once machining is complete. Lastly, cost is important for the company as they intend to implement this project to reduce cost. To satisfy these requirements, the team looked for refurbished robotic arms. Antenen Robotics supplies these, and has good pricing and customer support. Using their help, the team selected the Fanuc M16iB20 capable of holding 44 lb, reaching 65", and costing only $25,000 compared to similar new models nearing $75,000.

3. Part Manipulation

   The methods for part manipulation transpire from the constraints already placed on the system. Since budgeting constraints removed the possibility of using a linear actuator to manipulate parts on the table, the end-of-arm tool must pick parts from all locations of the part stack. To do this, a laser and a proxy sensor is added to the end-of-arm tool in order to detect parts. Vacuum suction is used to secure parts to the end-of-arm tool, and a pressure sensor on the tool confirms that a good mate has been secured. The raw part is taken to the lathe, and it is loaded after the finished part is removed by a second appendage of the end-of-arm tool. After the raw part is loaded, the finished part is taken to a finished part bin and stacked. From there, the robot returns to the part stack and repeats the part manipulation processes. It is required from the customer that parts are to be made available for dimension checks periodically, and an angled tray is constructed which is accessible to PQS employees, and the robot will place a finished part in this tray once in every 50 machine runs.

4. Sensors

   When the project was changed to a larger part, we no longer needed to measure the part, cutting out many sensors. However our new method of part distribution, necessitated by the size, required several more sensors. A distance sensor was added to check how high the stacks of parts were, several photo eyes were included to track the parts and the bin, vacuum sensors were added to grip the heavier part, and a pressure mat was added to protect employees from the rotating table.

5. PLC

   An Allen Bradley Micrologix PLC controls the processes. It communicates with the robot arm, the table motor(drive), and the HMI (touch screen) using ethernet IP. There are pre-existing software packages for connecting the HMI and robot arm to the PLC; it will take more work to connect the motor to the PLC. To communicate between the PLC and the lathe, the team is hoping to tie into the relays for starting the lathe and closing the chuck. If this fails, the team will either send the lathe M-code through a serial cable or use a converter.

SIGNIFICANT ISSUES

Getting communication through ethernet IP and programming the robot arm with the teaching pendant will be a time consuming task, because it is a new experience for the team. The customer would like the robot to palletize the parts, as well as bin them. Since brute force programming is required for this, it will be a challenge, and the team may need to forgo palletizing in favor of simple binning. The team is also concerned about the lead time of the robot arm as it needs to be in the plant as soon as possible to have enough time to program it.

CURRENT STATUS

The current status of the project is very promising. The team is finalizing a budget currently when they anticipate being given the go-ahead by the company. From a mechanical perspective, there is not too much left to complete. Drawings must be created, and then the ME’s will wait for the parts to come in. Once they arrive, they will be assembled so that the controls team can begin programming.

Nearly all electrical/control components are accounted for, excluding a few fuses, one relay, and HMI software. Despite that, design work has started and is expected to be completed the week of March 5th. All of the electrical design work is being quantified with Autocad E drawings. When all designs are finalized, they will be reviewed by Controls Design Engineers at Koops, Inc. and Progressive Surface. Additional research is being done on communication to cut down on learning time when the parts arrive. At this point, the electricals are confident in completing this project with the occasional assistance from experts at PQS, Koops, Progressive Surface, Antenen Robotics, and Industrial Controls.

MOVING FORWARD

The mechanical systems of the system have been modeled in CAD and have been verified with FEA simulation. All mechanical systems have been accounted for on the teams bill of materials, and drawings of the custom-machined parts required for the system will be sent out on the customers command. The end-of-arm components will not be machined immediately, however, as the specific robot which will be purchased has not been confirmed. Nevertheless, the mechanical components which compose the end-of-arm will be mostly invariant to choice of robot. Hence, the mechanical design portion of the project will begin transitioning into mechanical construction in the coming weeks. Once this concludes, assembly of the whole system with all mechanical components will commence at the customers location.

During this week, the electricals plan on purchasing all necessary equipment - specifically equipment with long lead times (i.e. Fanuc Robot). The team will continue to design all electrical and controls components, so the team is prepared to begin to wire and program the system with equipment is received. Additionally, the electricals plan on beginning to design all PLC ladder logic within the next few weeks, after the electrical and controls designs are approved by controls experts at Koops and Progressive Surface. As components arrive, the team will wire, code, and test the equipment. If and when the team is unfamiliar with a process or an issue that arises, more research will occur, and the team will contact an expert for assistance.