Senior Capstone Project: A Gantry Crane Utilizing Fluid Power

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Objective

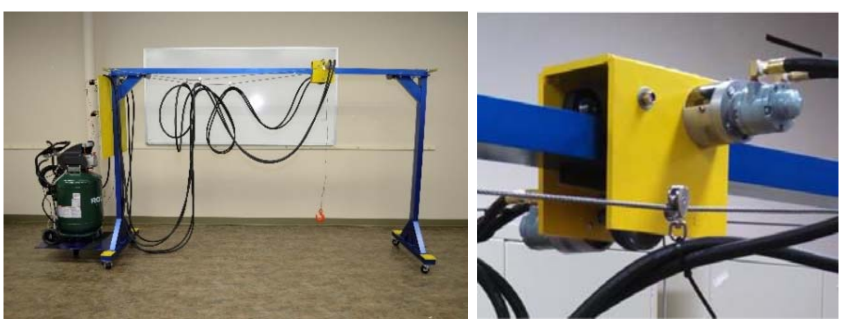
Gantry cranes are used to move large loads horizontally and vertically. In industrial applications gantry cranes are an important part of the fabrication and production process as they aid in the transportation of materials to and from work cells (Fig. 1). The use of overhead gantry cranes can reduce labor costs and can improve working conditions and safety.

Figure 1: An industrial gantry crane

The objective of this project was to design and fabricate a classroom-scaled gantry crane for material handling. The crane is fluid powered and capable of supporting at least a 50 lb. load while moving across a 10 ft. work space in a single axis and lifting to a height of at least 2 ft. The structure was to designed for disassembly for storage. Operation of the crane is controlled by a human interface system. In future semesters, the gantry crane will serve as a test bed and instructional tool in fluid mechanics, instrumentation, and control theory at both the undergraduate and graduate level.

Mechanical Design

The structural design of this project consists of two T-frame sides with a single beam connecting them at the top (Fig. 2a). The frame structure has locking swivel caster rollers at the base allowing for easy movement of the crane. The frame structure was fabricated from 2 in. × 4 in. rectangular aluminum tube. The top beam is attached with four bolts and may be removed from the sides for easy storage. The columns are 2 in. wide by 6 ft. tall and support the top beam which measures 9 ft. long by 4 in wide. A shelf was attached to one side to support the air compressor.



(a) (b)

Figure 2: (a) Gantry crane structure; (b) Trolley section

A trolley (Fig. 2b) moves across the top beam and is powered by two low speed pneumatic motors. One motor with pulley provides the vertical movement of the load. The second motor drives the horizontal movement with two 3 in. wheels. The trolley was balanced to avoid binding between the trolley and beam.

Fluid Power Distribution System

Mechatronic control of the system is provided through a pair of pneumatic H-bridges, one proportional regulator, 2.5 hp air compressor, and custom control circuit with microcontroller (Fig. 3a). The pneumatic H-bridges, made of four solenoid valves each, provide directional control of the trolley and the crane hook (Fig. 3b) while the proportional regulator controls the flow rate and resulting speed. A single regulator was selected based on the decision to allow only one motor to operate at a time. A single pneumatic H-bridge was prototyped on a Festo pneumatic testbed. The prototype validated the design using available equipment prior to purchasing solenoid valves and assembling the system.

(a) (b)

Figure 3: (a) Pneumatic H-Bridge; (b) Connection to the pneumatic motors on trolley section.

Following successful prototyping, the H-bridges were implemented using brass tubing and quick disconnect fittings for the hoses. Calculations were performed to estimate the frictional losses throughout the system and validate that the flow rate at the motors would be within the manufacturers specifications.

Electrical Design

The electrical design includes a custom printed circuit board (PCB) with Arduino microcontroller. The PCB (lower left corner in Fig. 3a, Fig. 4) mimics a typical pendant remote control. Five pushbuttons are used to enable the system and control the vertical and horizontal movements of the crane’s trolley and hook. The enable pushbutton acts as a safety switch which must be held in order to operate the crane. The other four pushbuttons each control the up, down, left, and right motions of the hook.

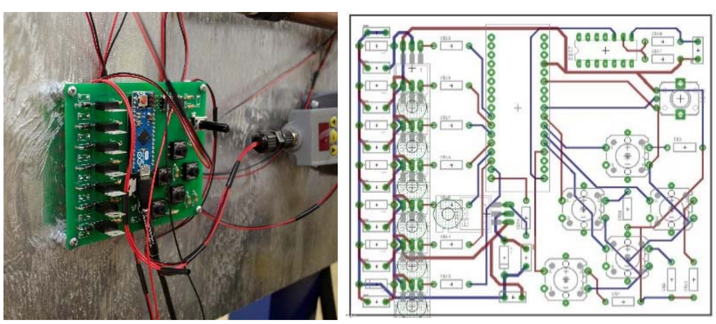


Figure 4: PCB Tethered Remote Circuit

Software control was implemented with a finite state machine. Pressing a directional button and the enabler simultaneously triggers a digital input signal to the system’s control unit. The Arduino Micro then changes the current state and triggers digital output signals to control the corresponding solenoid valves via two of the eight discrete transistors which switch the 24 VDC power supply. The flow rate of the proportional regulator can be varied using a potentiometer in a voltage divider configuration. This arrangement allows the operator to control the speed of the trolley and the hook by controlling the pressure being supplied to the motors.

System Testing

Following design and assembly, the competed gantry crane was tested to verify that it met design specifications. The crane was able to lift an appropriate load and move the full length of the track using the five button control panel. Based on this testing, the advisors judged the project a success.

Several parts of design were identified for future work. First, the gantry crane was unable to hold the load without vertical motion in the absence of airflow. Second, the weight of the hoses changed the balance of the trolley on the beam causing a tendency to bind. Finally, the finite state machine provided a simple logical framework for control but neglected the dynamics of the system. Each of these problems can be incorporated into the future curriculum as problem-based learning exercises, increasing student exposure to applications of fluid power.

Summary

This project involved the design and building of a fluid powered gantry crane for material handling. The project started in August 2013 and ended in June 2014. Five students and three faculty advisors were involved in the work. On May 2nd, the team presented their work and product to the Department of Mechanical Engineering faculty as well as the Industrial Advisory Board. The finalized crane will serve as an instructional tool in dynamics, fluid mechanics, and control theory at both the undergraduate and graduate level.