IPRO 324 – Design of a Simulator for Mechanical Loading of Garage Door Operator Systems over a Wide Temperature Range

Sponsor:

The sponsor of this project is The Chamberlain Group, Inc., which is the world's largest manufacturer of residential and commercial door operators, as well as access control products and gate operators.

Goals:

The goal of this project is to develop algorithms to be used in a virtual simulation of a garage door's operation and to construct a working prototype that functions in the Thermotron environmental test chamber in The Chamberlain Group, Inc. facility in Elmhurst in order to collect data under a range of temperatures and humidity as well as a range of loading conditions. The simulator had to be made to fit as many of the operators under test as possible inside the limited size Thermotron that is not large enough to take the operator and a full garage door.

Basic Organization / Tasks:

Data Reduction Using EXCEL:	Peter M., Jimoh, Tom
AutoCAD / Working Model:	Guillermo, Tonny, DongHoon
Website:	Yoshikazu, Jimoh
Assembly Design:	Tom, Matt, Tonny
Strain Gage Calibration:	Peter M.
Field Data Collection:	Peter M., Peter S., Matt
Meeting Organization, Agendas and Minutes:	Viola
Labview:	Peter S., Jimoh, Yoshikazu
Electrical Components Research:	Peter S., Viola
Assembly:	All team members

Critical Technical and Non-Technical Issues:

Technical Issues:

- Finding the right mechanical and electrical devices to use for the simulator
- Having detailed AutoCAD drawings with correct dimensions because the design of the simulator changes gradually
- Delays in building the assembly because of lack of materials or tools at the moment
- Working with software programs (Labview and Working Model) the team has never used before

Non-Technical Issues:

- Dividing the work load equally among team members because some are less willing to work than others
- Having members of the same subgroup work together due to the lack of communication

Current Design

- An operator loading system driven using a similar load profile to that determined on actual garage doors at Chamberlain. The entire system is small enough to fit several systems into the environmental chamber at Chamberlain.
- Proof of concept is to run the operator with its loading simulator until failure occurs in one or more parts on the operator. The failure cycles should approximate those seen in actual service (e.g., 25,000 to 50,000 cycles).
- In order to facilitate further design work and to allow actual construction of an environmentally hardened simulator, drawings have been made of the current design using AutoCAD, and ProE. An additional animation simulator has been constructed using MSC "Working Model."

Future Development

- Gathering additional field data, (e.g., residential garage doors at various locations)
- Future model improvements will include adding DC motors to drive the brake system or a set of programmable servomotors, the addition of springs and other design modifications to better match the resonance load profile
- A comprehensive 4D Working Model will be constructed in Spring 2004
- In Summer 2004, the model will be rebuilt for use inside the Thermotron system at Chamberlain

Faculty Mentor and Advisers:

Professor Sheldon Mostovoy   Professor Daniel Ferguson   Mr. Russell Janota

Team Members:

Viola Wing Shan Tang	Fourth Year in Electrical Engineering
Peter Sveum	Fourth Year in Electrical and Computer Engineering
Peter Muliere	Fourth Year in Materials Science Engineering
Tom Majnert	Fifth Year in Aerospace and Mechanical Engineering
Tonny Lukongwa	Third Year in Aerospace and Materials Engineering
DongHoon Lee	Third Year in Mechanical Engineering
Yoshikazu Komano	Fourth Year in Computer Science
Jimoh Durodola	Third Year in Computer Engineering
Matt Cerney	Fourth Year in Materials Engineering
Guillermo A. Casas	Third Year in Aerospace and Mechanical Engineering

PROBLEM

In collaboration with Chamberlain Group, students are to devise a method with which to test and examine the various loads that are present in the operator assembly of garage door systems.

The Chamberlain Group, Inc., located in Elmhurst, Illinois, is the world's largest manufacturer of residential garage door operator systems. Through its Advanced Development group, Chamberlain is interested in working with an IPRO team at IIT to build a load simulator that recreates the range and behavior of the loads imposed on a garage door during operation. This load, being a function of speed and position, varies in direction, applied angle, and amplitude during its course of travel. Chamberlain plans to use this simulator in an existing thermal test chamber, called Thermotron, so the simulator must be able to fit and function within the available space in the thermal test chamber.

BACKGROUND

Chamberlain is one of the cornerstone companies of Duchossois Industries, Inc., a privately-owned, diversified, multinational company that carries the added strength, respect and financial stability of a billion dollar-plus corporation.

The Chamberlain Group, Inc. is the world´s largest manufacturer of residential and commercial door operators, access control products and gate operators.

LEADING THE INDUSTRY IN PRODUCT INNOVATION

Chamberlain leads the industry in product innovation and quality. Our ongoing commitment to excellence in every aspect of what we do has positioned the company for sustained profitable growth and future success.

As a manufacturer of some of the world's most reliable and efficient products in our markets, we are determined to build on our established reputation as the industry leader. We will continue to grow by exceeding our customers´ expectations.

ORGANIZING AN EFFECTIVE TEAM

In order for this project to be successful, the student design team needed to be organized quickly into subgroups with individual output goals. Working as a high performance organization we put together sets of ad hoc teams, supervised through management by professor Sheldon Mostovoy, and our weekly agendas set forth by each subsidiary group.

With multiple students from diverse fields we teamed up based upon interests and relative contributions possible from our backgrounds.

BASIC ORGANIZATION / TASKS:

Data Reduction: Peter Muliere, Jimoh Durodola, and Tom Majnert.

The data reduction team was responsible for interpreting collected data through acquired programs such as Excel and LabView for analytical purposes.

Visual Design: Guillermo Casas, Tonny Lukongwa, and DongHoon Lee.

This team was charged with producing visual and graphic models of the team's design concept. Using AutoCad and Working model, to-scale representations were developed.

Website: Yoshikazu Komano and Jimoh Durodola.

The website team designed an easily accessible private info page with a supply of data links and current up to date information for other teams to collaborate from. For final presentation purposes the site was outfitted with movies and design concepts from the projects timeline.

Assembly Design: Tom Majnert, Matt Cerney, Tonny Lukongwa.

The design team was organized in order to innovatively design an assembly structure capable of supporting the current concept under development. This team had to be flexible in time and ability to structurally craft a frame with limited resources and time.

Strain Gage Calibration: Peter Muliere.

The strain gage is the main data-gathering component of the assembled design. However, strain gages are very small and have a tedious application procedure. For this the organization felt best to instruct one student through this task. In total, 4 gages were affixed about a ¾" hole that was drilled into the arm in order to produce more prominent readings.

Field Data Collection: Peter Muliere., Peter Sveum., Matt Cerney.

The Field data collection team was responsible for traveling out to the Chamberlain Group floor lab in order to collect data from supplied simulations.

Meeting Organization, Agendas and Minutes: Viola Wing Shan Tang.

Weekly agendas were used to update the organization on team accomplishments and provide management tasks to be overviewed by our administrative professor.

LabView: Peter Sveum, Jimoh Durodola, and Yoshikazu Komano.

Once data was being gathered a process for analyzing the data continuously and in real-time was needed. Using LabView this team was able to setup a program capable of managing multiple inputs in order to output load profiles for both cycles of the design.

Electrical Components Research: Peter Sveum, Viola Wing Shan Tang.

From electrical brakes to servo controlled motors, during the design process many electrical components needed to be researched for applicable purposes.

Assembly: All team members

The entire organizational team worked on the many concepts and final design layout for the project.

TEAM BACKGROUND

Team Member Names	Current Degree at IIT
Viola Wing Shan Tang	Fourth Year in Electrical Engineering
Peter Sveum	Fourth Year in Electrical and Computer Engineering
Peter Muliere	Fourth Year in Materials Science Engineering
Tom Majnert	Fifth Year in Aerospace and Mechanical Engineering
Tonny Lukongwa	Third Year in Aerospace and Materials Engineering
DongHoon Lee	Third Year in Mechanical Engineering
Yoshikazu Komano	Fourth Year in Computer Science
Jimoh Durodola	Third Year in Computer Engineering
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DESIGN PROCESS AND TECHNICAL ISSUES ENCOUNTERED

The teams most instrumental to the design process and the problem solving, were the data collection team, the design team, the construction team, and the CAD team. The first load profile data we were working with was given to us by Chamberlain. This data is shown below.

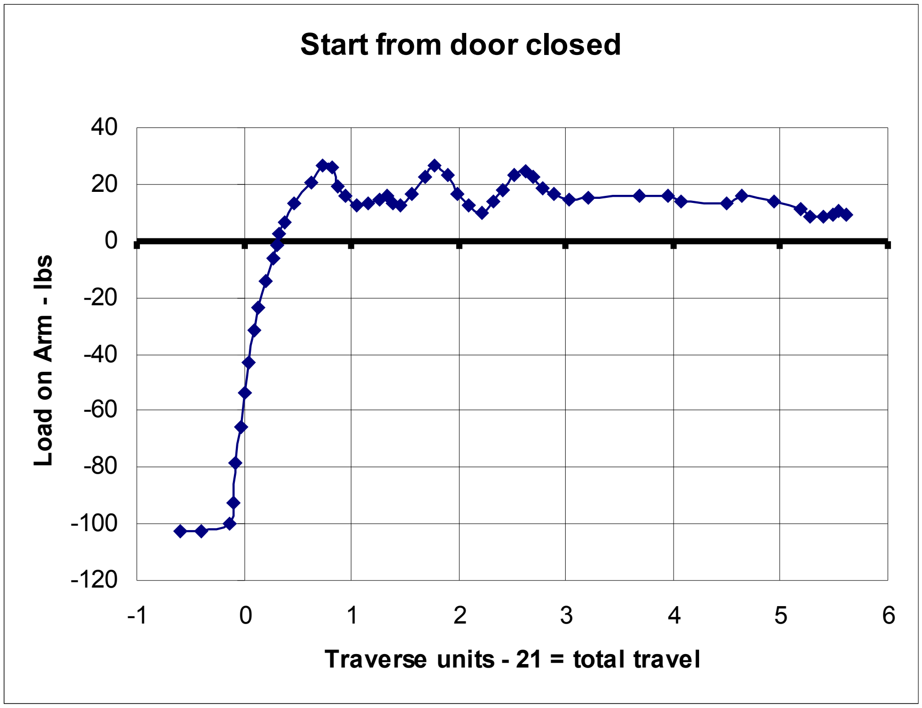


Chart 1

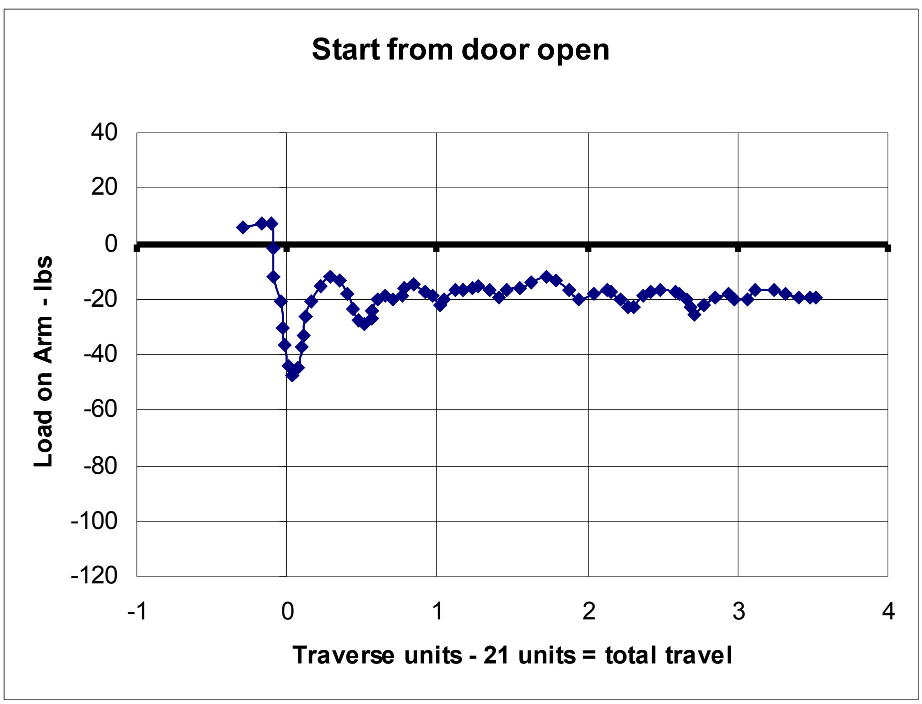
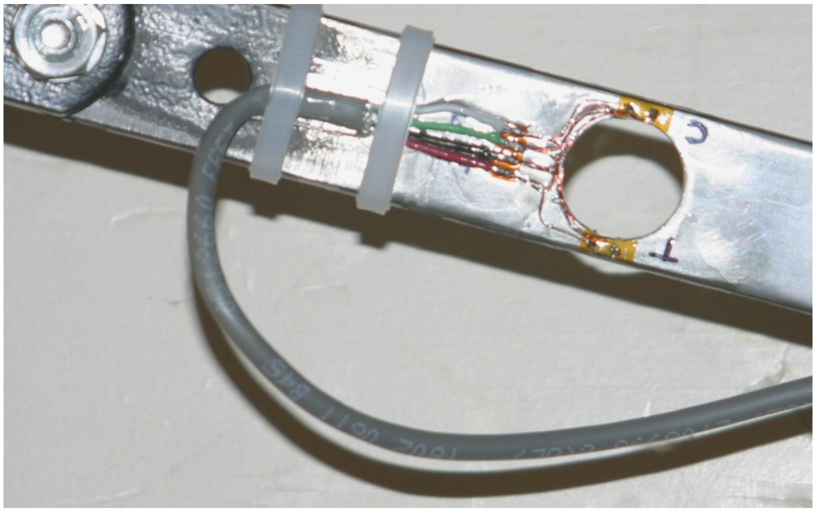


Chart 2

From this data, we concluded that the door arm saw only tensile forces during opening cycles, and only compression forces, during closing cycles. This meant that our design needed only to restrict the motion of the door panel, in order to match the load profile. Thus, a brake would be sufficient to accomplish this.

In order to determine the accuracy of our simulation we needed to have a method of measuring the loads on the door arm. To do this, we attached four strain gauges to the arm. Initially the arm was too hefty to accurately measure loads, because the stresses applied by loading the arm resulted in minimal strain. We then drilled a large hole through the arm. This stress concentration magnifies strains so that the strain is measurable at low loads.



Picture 1

As shown in the picture, two strain gauges were attached to the tension side of the arm and two on the compression side as this bent arm sees both when loaded.

We went back to Chamberlain to collect our own load profiles with the same arm we would be using to match them. We collected data from two different doors. We found that the data Chamberlain had provided us was inaccurate. According to our data, the arm sees both positive and negative loads during both the opening and closing cycles of operation, as shown by chart 3.

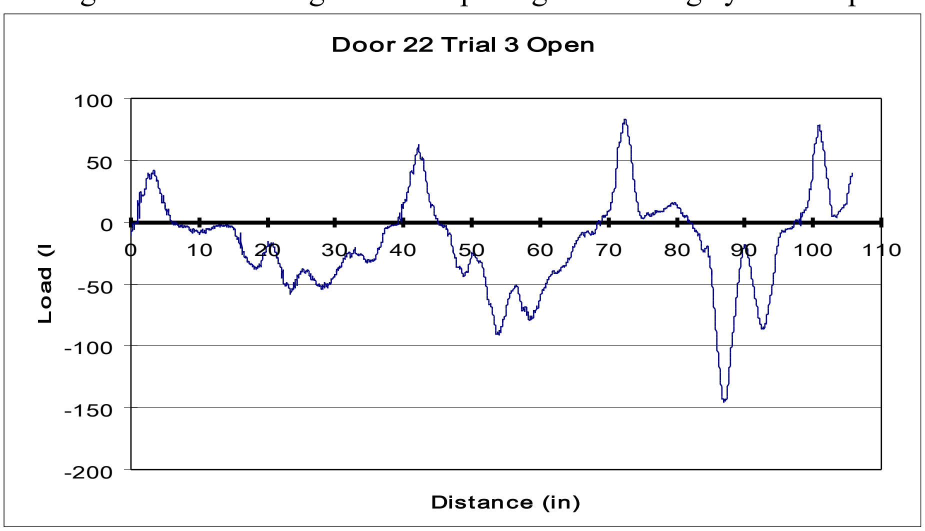


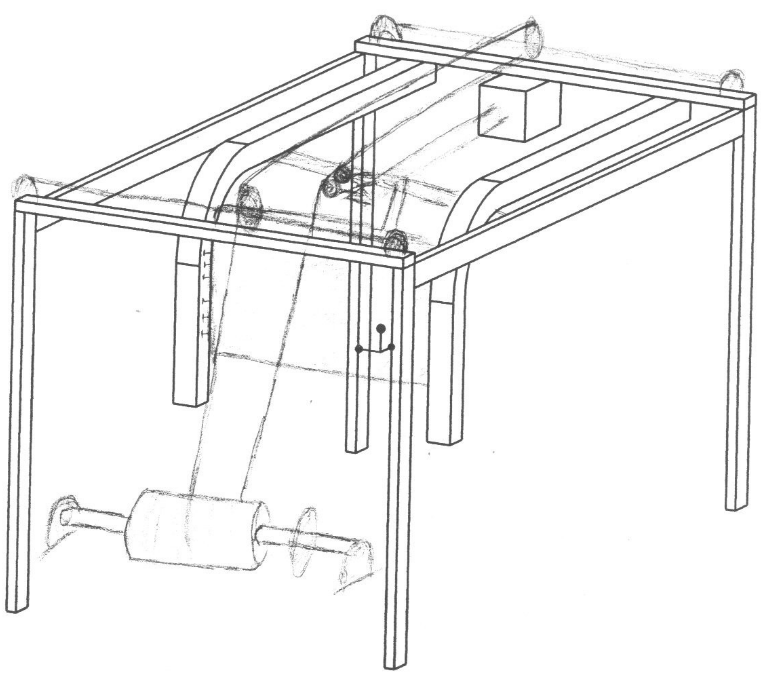
Chart 3

This led us to realize that a simple brake, which could only apply loads opposing direction of motion, was insufficient to accurately model the actual load profiles seen by the arm. Do to time constraints of the problem, we had already begun to implement a braked system by the time we made this discovery.

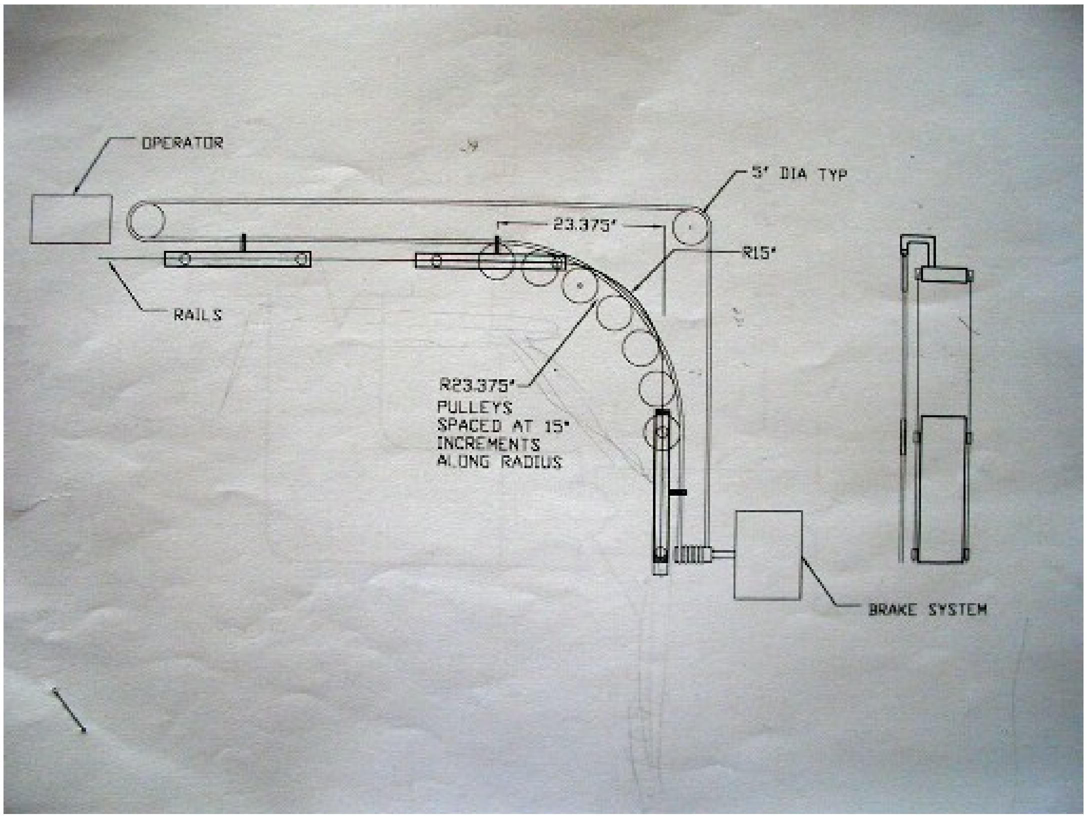
At the very beginning of the semester, our design team began brainstorming a design to simulate the load profiles in the limited space of the THERMOTRON chamber.

As space was a primary constraint of the problem, one small garage door panel in a simple frame was agreed upon as the best initial design. In a real garage door, the arm is attached to the center of the top panel. Thus, we used a panel only 18” wide allowing for a thin design. We also used only one panel, instead of three or four. This allows our design to have less height than a full door, while the arm can still go through its full range of motion. Further design work consisted of how to apply variable load profiles to the door.

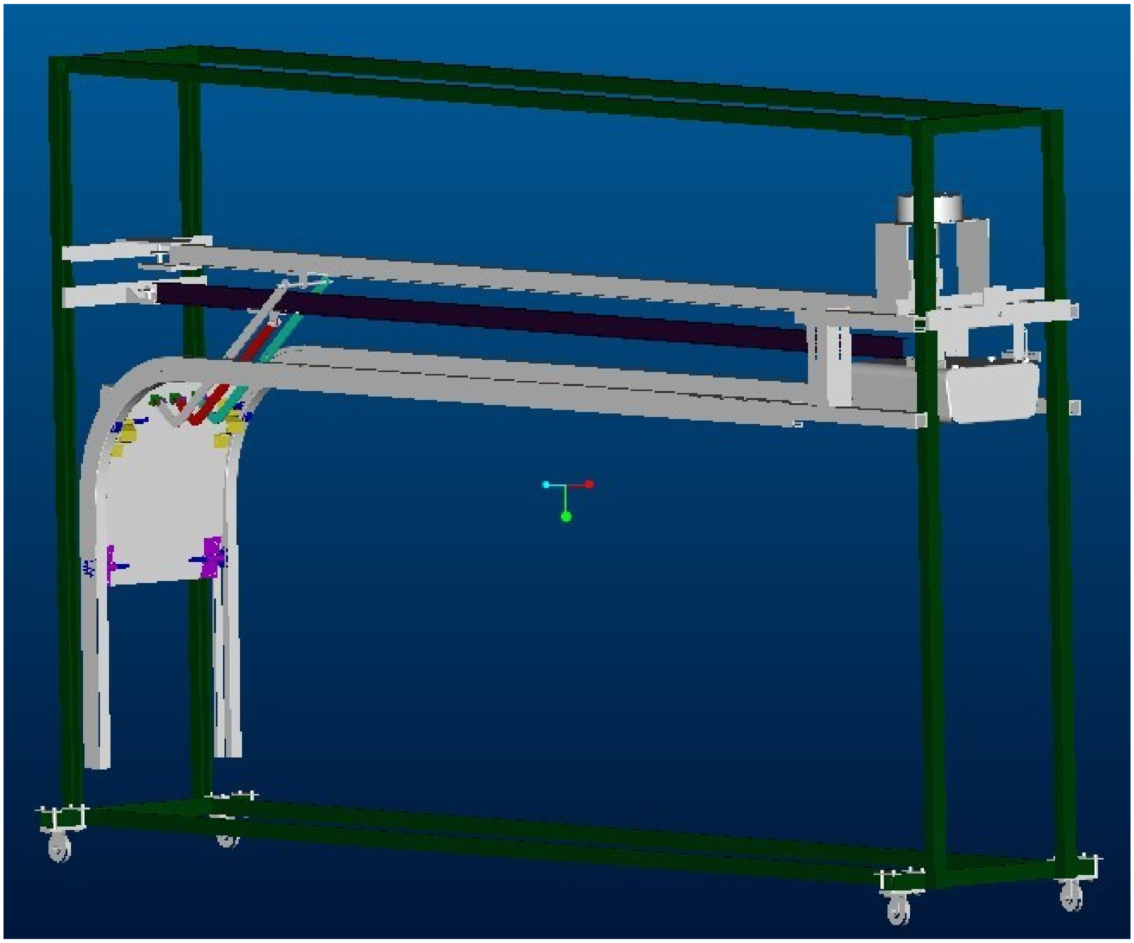
The first design developed was a system of servo motors and pulleys. Cables attached to the servo motors would be run over pulleys and attached to the door panel. These servo motors would be able to apply the proper loads by turning in the proper direction and pulling on the panel. This design has a number of drawbacks. First of all, the cost of servo motors is very high. Also we were unsure whether they could supply the proper torque required to achieve loads up to and over 100 pounds.



The next design was the first to implement a brake. This design has a ski-lift arm attached to the door. This arm is connected to a cable that runs parallel to the path of the door, along a system of pulleys. This continuous loop of cable is coupled to a brake, which can restrict the movement door, applying the necessary forces. This design had the advantage of requiring only a single brake to load the arm, thus lowering the cost dramatically. One drawback to this system is the amount of mechanical lag in the system. In addition to the lag present from a long cable, deflection in the ski lift arm would lower the response time of the brake. This would make it incredibly difficult to match the load profile.



Our third and final design was much simpler. A second chain-driven rail, a standard garage door operator part, was attached to the frame above the first rail. Two arms attached this rail to the door panel. The sprocket at the end of this second chain is coupled to an electric brake. This design allows us to apply friction loads to the arm while using existing parts from Chamberlain. The simplicity of this design is one of its greatest strong points.



Another important technical issue our team had to tackle was the issue of designing programs to collect data, and control the brake. To do this we used Labview, a powerful laboratory program. One major issue was how to reference the load data. One initial thought was load vs time, but the problem with this is that it does not always take the same amount of time to open the door, and time is often variable due to the load. We decided it was better to reference the data with pips. Inside the operator, attached to the motor is a wheel with five teeth. As the motor spins, these teeth break an optical sensor and create “pips”. This is essentially a square wave that can be measured. Using the gear ratio and sprocket size, these pips can be translated into distance. The operator uses this to know how far to open/close the door. We used it to create a load vs distance graph.

The next program designed was one that would output voltage signals to the electric brake to apply the correct loads. The program created successfully accomplished this while simultaneously recording incoming load data, to assure that we were matching the desired load profile.

Another part of our team was in charge of CAD drawings of our design. This team made accurate 3D drawings of our entire prototype. This helps tremendously with visualization of the design, as well as reproduction of the prototype. The team then imported the drawings in program called Working Model. This program is capable of creating realistic simulations of mechanical systems taking an enormous variety of variables into account such as weights, coefficients of friction, stresses, and different material types. Due to the limited time constraints of the project the team had time to begin learning the program but were not able to complete a full simulation.

CONCLUSIONS

Our final design successfully can match load profiles in which the load is confined to the opposite direction of motion. This means that we can accurately match many of the load profiles we obtained from our own data acquisitions, excluding some of the more complex profiles. However our design is still very useful for failure testing of operator parts. The parts that most frequently fail in service are the bearings and sprockets. Through applying maximum loads during simulation, we could simulate maximum wear.

Our design is also very compact. At a mere 20" in width, the 4' wide Thermotron could comfortably fit two simulators within it. This would allow two different operators to be simultaneously tested under adverse temperature and weather conditions.

One problem with our current design is that the small size of the door panel results in very low inertia. This low inertia leads to large mechanical vibration in the system. This makes it harder to obtain a smooth control of applied loads.

RECOMMENDATIONS

The first task for next semester is fully automating the process and testing it. The current program can record data and control the brake. The next step is to have Labview control the opening and closing of the door on an 80 second timing cycle. Once this is done we must test our current prototype to failure. If the operator fails within the 25,000 to 50,000 cycles expected, then we currently have an accurate testing method. Either way, more improvements can be made.

Our door panel must be heavier to lower the mechanical vibrations. We would also need to add a spring system to counter the added weight. This addition would have the added effect of more closely simulating a real garage door. Secondly it would be beneficial to couple a motor with the brake. The motor could apply a large constant force in the direction of door-panel motion, while the brake could be used to counter these forces when necessary. This would allow us to match load profiles with both positive and negative loads.

Another important task for next semester is to complete the work began by our CAD team. If an accurate simulation can be created in Working Model, it would allow us a lot of freedom in simulating the garage door operator under a nearly infinite range of variables. We could then change different aspects of the prototype and see in the simulation how it would work before making alterations in the real system.

Lastly, we believe it is important to do data collection from real garage doors in the field. All of our data was obtained from garage doors operating within a laboratory setting at Chamberlain. Even in this setting we found that different doors result in different load profiles. It would be useful to perform tests in real peoples' homes in order to see if real operating conditions possibly result in different load profiles to be simulated by our prototype. If all of these recommendations are implemented successfully, it would result in a nearly perfect simulation of garage door operator simulation in the limited space of the Thermotron.

ACKNOWLEDGEMENTS

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