Forcible Entry Simulator Proof of Concept Study

Matthew T. Wheeler, *Department of Mechanical and Aerospace Engineering*, Faculty Advisor: Dr. Jason Armstrong

Project Overview

The ability to quickly gain entry to a structure is a skill paramount to effective emergency service work. This CURCA funded proof of concept study sought to examine a scaled model of a forcible entry simulator designed in MAE 377/498 to determine if the design was feasible, as well as make clear areas of potential design improvements.

Under the guidance of Dr. Jason Armstrong the full scale design was modified to a testable size that involved studying the spring locking mechanism – the main difference between current forcible entry designs and the design being studied. Utilizing PTC Creo for 3D modeling and detail drawing generation, as well as the Engineering Machine Shop in Jarvis Hall for manufacturing, a prototype model of the locking mechanism was modeled, manufactured and tested.

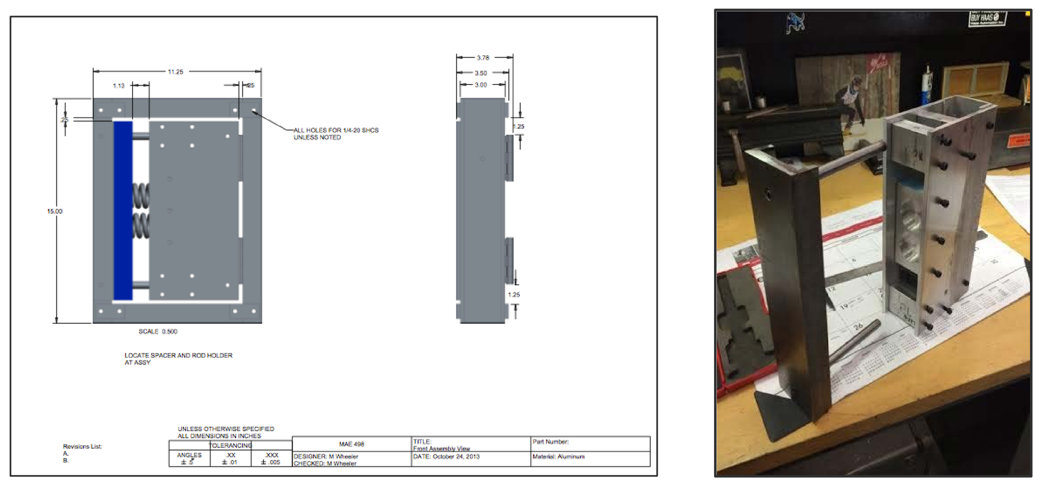

Figure 1 and 2: Detail Drawing and partially manufactured assembly

Project Management

In order to maintain effective project management, time was also allocated to ensuring proper documentation and reporting of findings. Weekly goals were mapped and discussed to ensure the project remained on schedule. This especially became important when certain components in the machine shop required extended periods to manufacture due to their size or difficulty in machining. Furthermore, Microsoft Excel was used to track all component costs with suppliers and dates of order.

Vendor	Date of Order	Invoice Total [USD]
McMaster-Carr	11/5/13	$152.4
Fastenal	11/14/13	$17.61
McMaster-Carr	11/20/13	$88.05
Lee Spring	11/14/13	$47.01
Amazon	11/6/13	$33.42

Total Expenses	$338.49
Allotted Budget	$315.64
Difference	$-22.85

Table 1: Project Budget

Technical Overview

Design Requirements and Desired Outcomes

In order to achieve the proof of concept being sought careful consideration was utilized to ensure that the scaled model met the requirements of the design as well as accurately represented the full scale model.

Requirements:

- Utilize hinges to demonstrate functional rotation of system under loading
- Maintain structural integrity under loading
- Provide similar means of access to full scale model
- Utilize identical "spring locking" components as full scale

Desired Outcomes:

- Validate system operation
- Validate spring force calculations with real life loading application
- Identify areas of potential or necessary redesign
- Maintain an effective project budget

Figure 3: Simulator in Open and Closed Position

Methodology

This project was first started in MAE 377 and progressed into MAE 498 with CURCA funding. The initial steps of the project surrounded generating a concept, creating a 3D model, conducting Finite Element Analyses, and lastly creating component level detail drawings. Once funding was procured in MAE 498, a new scaled model was designed and analyzed.

1. Generate concept
2. Create 3D model using PTC Creo
3. Complete FEA of components
4. Generate detail drawings
5. Complete component cost analysis
   1. Determine steel vs. aluminum components
6. Work with Engineering Machine Shop to create manufacturing plans
7. Manufacture and assemble components
8. Test and Validate System

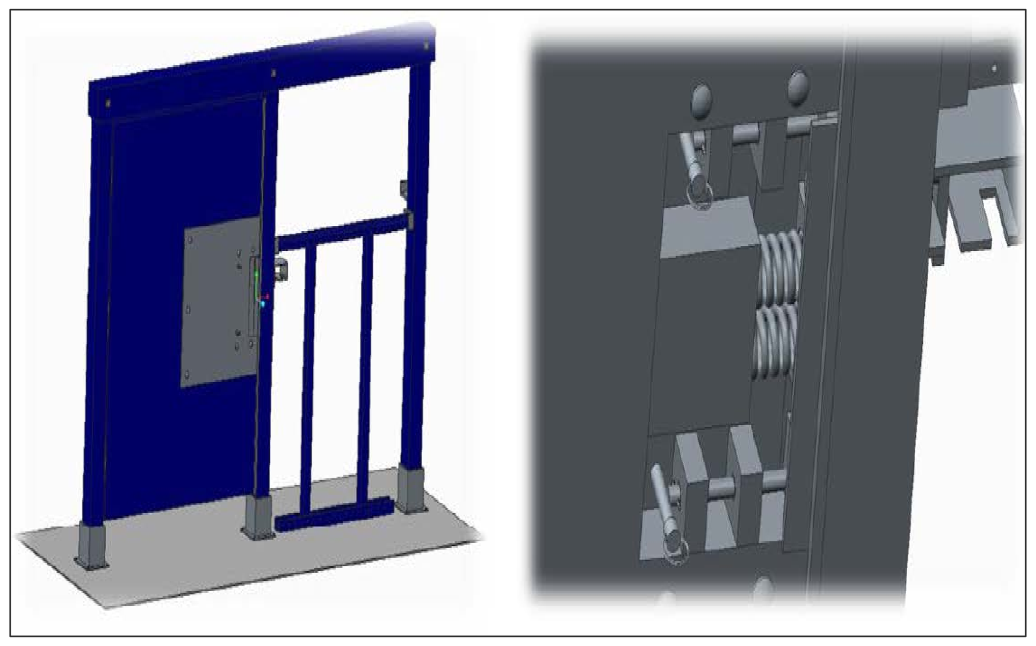

Figure 4: Full Scale Simulator

Testing and validation of the system was completed by using various tools from the fire service and operating the device in its intended manner. The findings of the validation are located in the results section.

Analysis

The foremost analysis conducted in this proof of concept was done use PTC Creo's Finite Element Analysis software. This analysis demonstrated that the maximum stresses applied to the "push guard" would not cause the material to yield while allowing the material thickness to be optimized to its smallest acceptable value.

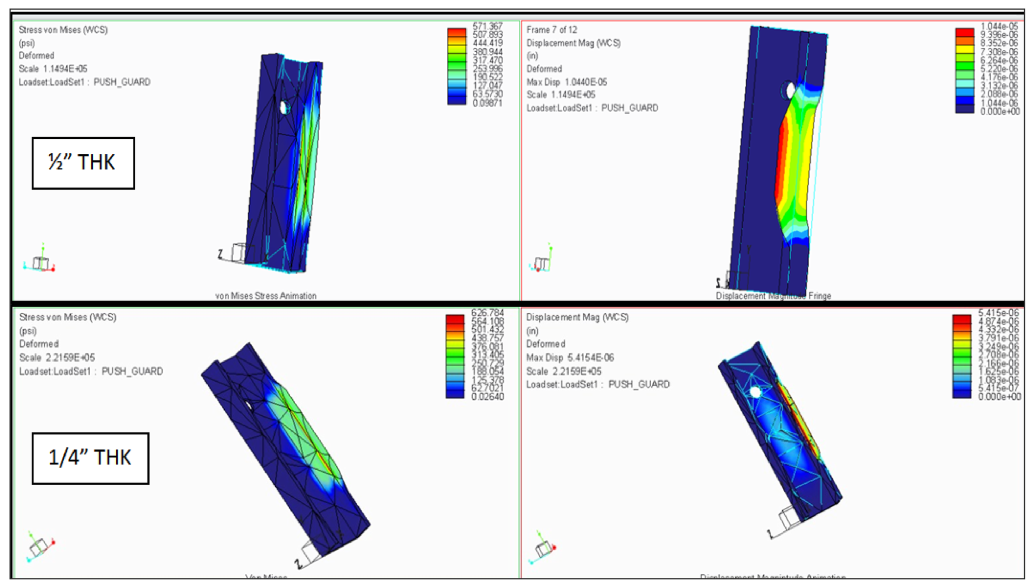

Figure 5: FEA of 0.5 and 0.25" THK Component

FEA demonstrated it was possible to optimize thickness from 0.5" to 0.25" while maintaining a maximum von Mises Stress of 600 PSI, well below the yield stress of mild steel.

Physical testing of the prototype demonstrated that although for small scale testing aluminum was an acceptable material choice, for actual production steels hardness and toughness would be required for component longevity.

Using a push/pull force gauge, an average force of 100lbs over a 30" moment arm (tool as seen in figure 3) was calculate, resulting in an applied force of about 3000lbs. This was used to generate necessary spring constants as well as material requirements.

Results/Areas of Future Interest

After completing the digital analysis and physical testing a few main issues were noted that should be addressed moving forward.

- All components should be steel for toughness strength – aluminum began to displace after extended testing
- NC or CNC based machining is required to ensure tolerancing amongst components remains intact
- A "ratchet" or similar style system should be investigated to maintain spring position once it has been began to be displaced
- Utilize additional screws in brackets to reduce prevent rotation as forces are applied (scaled model only)

Recognitions

A special thank you to the following Faculty/Staff/Mentors for their support and guidance!

- Dr. Jason Armstrong
- Professor Phillip Cormier
- Jarvis Hall Engineering Machine Shop Staff
- Captain Mike Leiston, Chili Fire Department
- All the staff of CURCA