FIRST Robotics Pit Cart: Design and Optimization

Senior Design Project

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Introduction

- MOE 365 is a FIRST robotics team that started in 2000
- The Pit cart was constructed in 2001 in order to provide an organized way to transport and store tools and spare parts
- Since then, many teams have requested blueprints for the design
  - None existed

Background

Background

- The Pit cart weighs about 400 pounds fully loaded
- The cart must be able to support a workbench with a vise on one end and a drill press on the other
- It must also support a shelf for boxes of parts
- The cart is constructed mainly of Bosch standard aluminum framing in 45x45mm and 45x90mm

Background

- Autodesk provides each FIRST team with a copy of Autodesk Inventor to use
  - This project used Autodesk Inventor 11
  - Inventor is a three-dimensional computer-aided design (CAD) program

Problem

- The original cart is 174 lbs unloaded, 400 lbs loaded, which is too heavy and unwieldy
- At least 8 people are required to lift it
  - The bulk poses significant risk to those lifting it

Goal

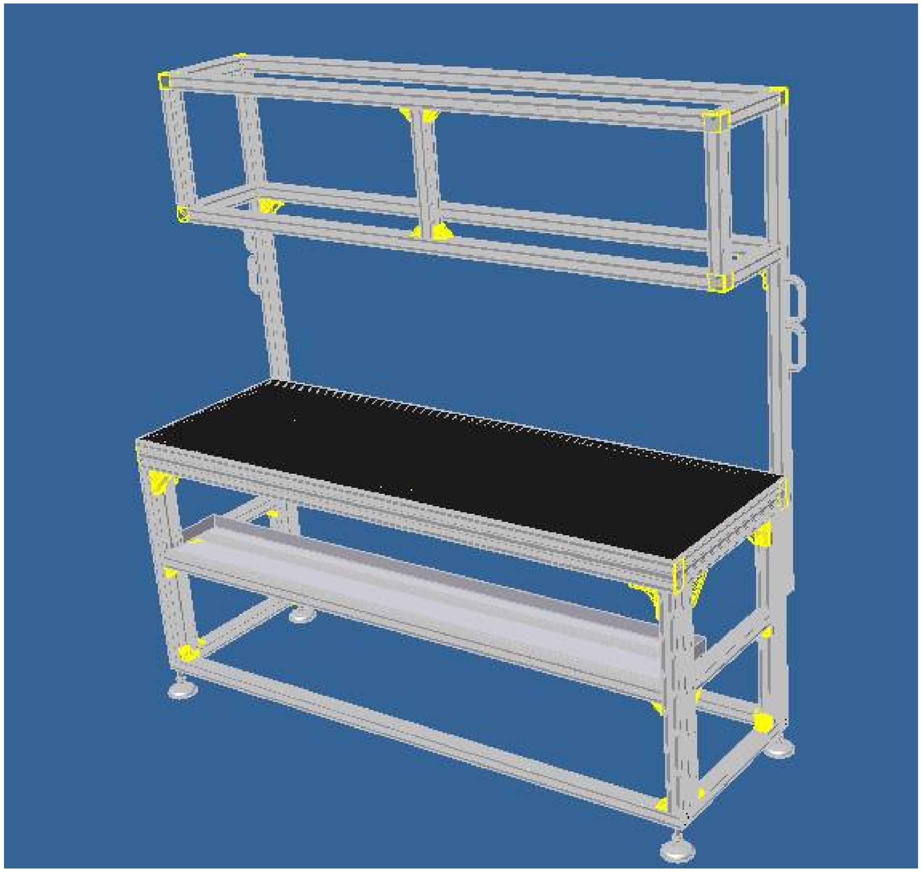
- Two goals:
  - Initial goal: to provide plans of the pit to other teams
  - Secondary goal: to improve the design through elimination of unnecessary frame parts, and thus unnecessary weight

Method: Autodesk Inventor

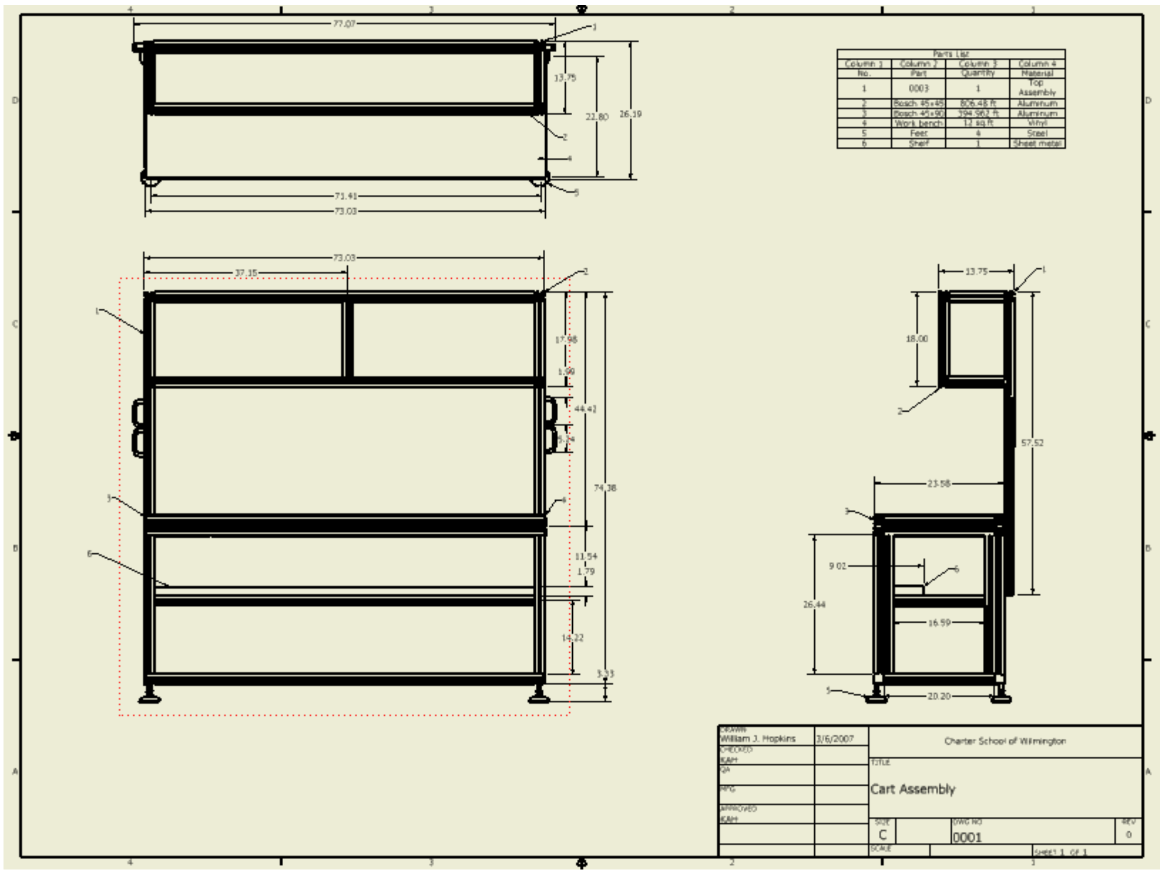
- Bosch-Rexroth website
  - The various cart parts available for download as modifiable 3D files

- Inventor 11
  - Bosch parts assembled
  - Detailed drawings created

Method: Autodesk Inventor



Method: Autodesk Inventor



Method: Statics

Beam analysis

Method: Statics

- Statics - Rigid body mechanics that deals with the equilibrium of bodies, either at rest or moving with a constant velocity
  - $\Sigma F = m*a$
  - Summation of forces equals mass times acceleration
  - acceleration equals zero

Therefore $\Sigma F = MA = 0$

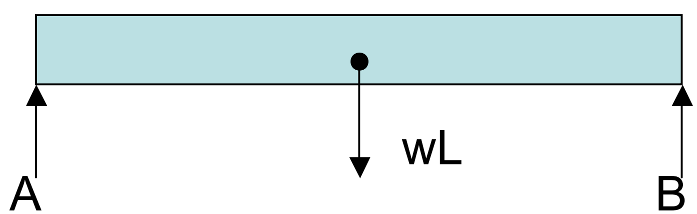
- Statics used to determine the members upon which the most and least force was placed

Method: Statics

- Equilibrium of a beam within the cart frame

$$\Sigma F_y = A + B - wL = 0$$

  - A and B are simply supported
  - w is the weight distribution across the beam, and L is the length of the beam



Method: Bending

- Maximum bending moment – Examines the internal stress and strain of cart frame beam
  - Analyzes how much force can be applied to the pit without failure.
- Bending analysis will determine:
  - The smallest size of the aluminum framing that can be used without significantly reducing the structural integrity and capacity of the pit
  - If the elimination of a beam will cause other beams to fail

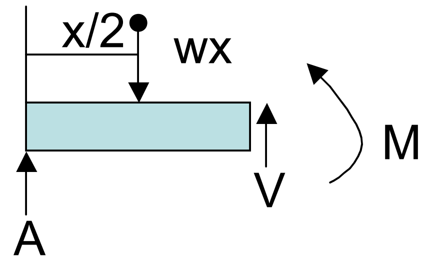
Method: Bending

- Bending analysis of a beam within the cart frame
  - examine shear force and moment in a beam segment

Method: Bending

$$\Sigma Fy = A - wx - V = 0$$

$$\Sigma Mv = -Ax + ([wx] * [x/2]) + M = 0$$



- Mv is the Bending Moment at the cut
- w is the weight distribution across the segment, x is the length of the segment being analyzed
- V is the shear force and M is the bending moment
- A is the resultant support force from equilibrium

Analysis

- From the bending moment, we can analyze stress and strain in a beam

$$\Sigma M_v = -Ax + ([wx] * [x/2]) + M = 0$$

Stress: $\sigma = Mc / I$,

Strain: $\varepsilon = \sigma / E$

Analysis

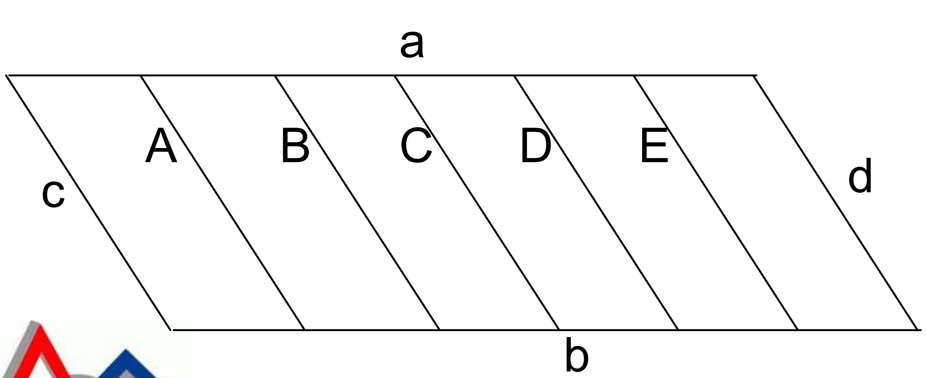
- Once the stress and strain are determined, it can be compared to the yield strength of the material being used.

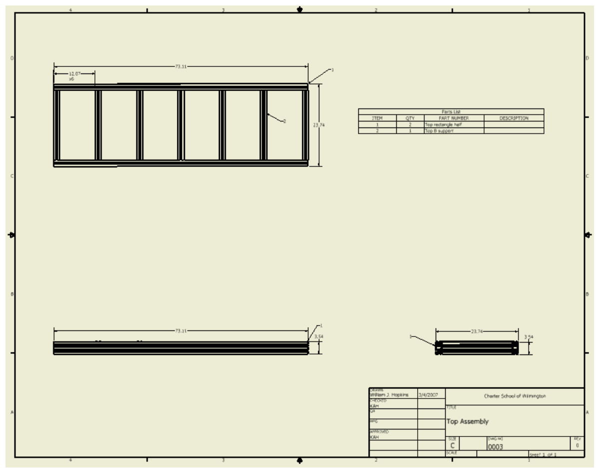
- If the applied stress and safety factor is well below the yield stress, the beam will not fail

Analysis: Cart Top Analysis

- The members A, B, C, D, and E, as shown below, experience little to no loading

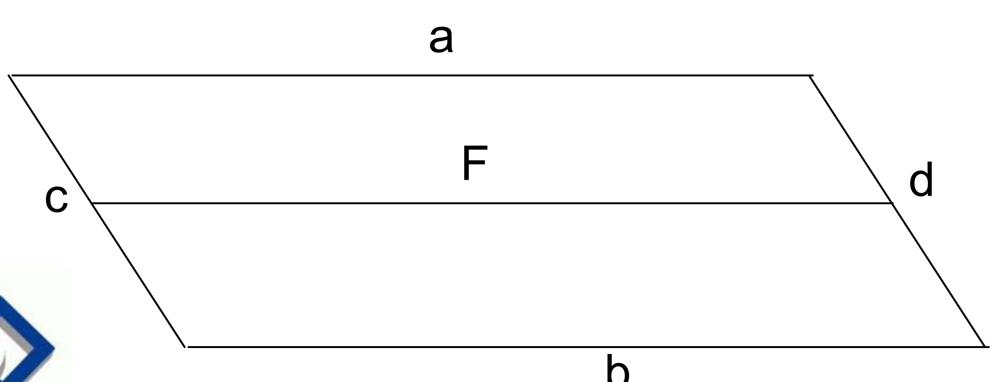
- They are included in the original design to prevent the deflection of the vinyl workbench top covering

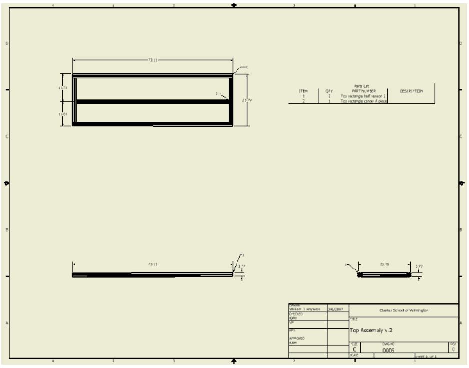




Analysis: Cart Top Analysis

- A, B, C, D, and E can be replaced by a single member F oriented horizontally to the floor and perpendicular to the five members as shown below.
- This new member will eliminate some unnecessary weight while still preventing deflection of the vinyl top





Analysis

- Members of the top section can be replaced by smaller Bosch framing
  - The stress in the most heavily laden beam in the top section increases from 52 psi to 211 psi
  - The yield strength of this member is 60,000 psi, a safety factor of 284

Results

- I identified 20 lbs of unnecessary weight
- The weight reduced was 11.5% of the total weight for a 174 lb base frame
- Pit designs will be submitted to the 2007 FIRST design book

Acknowledgments

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  - Kirstin Huesmann for her outstanding support and assistance
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