Flexible Luggage

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Problem

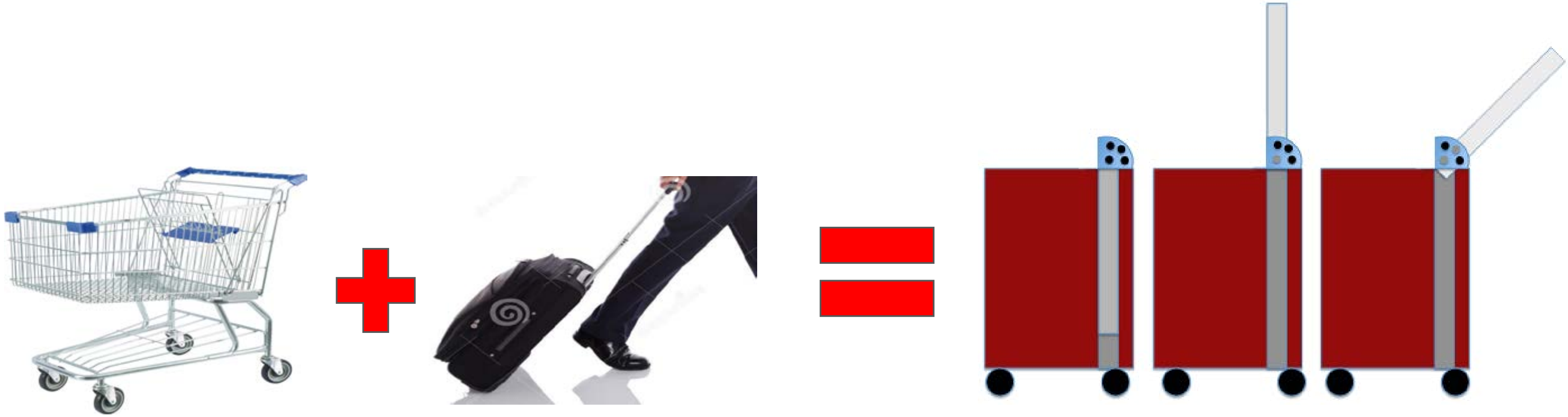
932 Million passengers flew domestically and internationally in 2016 [2]

“Between 9 and 20% of the injury claims for low back pain are the result of pushing and pulling activities” [1]

Problem

Problem

Solution



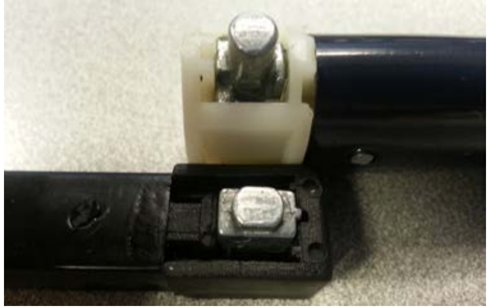
Solution

(Critical Stresses)

- Given the typical use cases of luggage bags, we perceive the most important stresses to analyze in the system include:
  - Static stress under horizontal and vertical loading conditions
  - Fatigue stress
- The overall life of a suitcase depends on how frequently it is used (i.e. how frequently the user travels)
  - For someone who travels infrequently: 10 years or more
  - For someone who travels frequently: Roughly 5 years (typical warranty period)

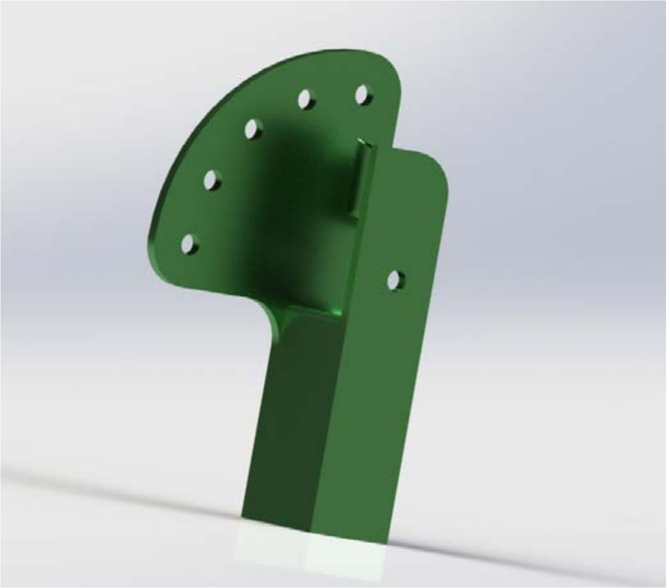
Materials and Manufacturing Processes

- Handle Rods and Sleeves:
  - Aluminum, Extrusion
  - Under some load; Uniform Cross-Section and Thin-Walled



- Rod End Caps
  - ABS Plastic, Injection Molded
  - Not under significant load, but complex geometry
- End Cap Pins
  - Aluminum, Die Cast
  - Under high load, has complex geometry

Materials and Manufacturing Processes



- P-Bracket
  - Aluminum, Permanent Mold Casting
  - Under high load; Complex geometry with undercuts
  - With some redesigning could possibly be die-casted
- Pivot Holder
  - ABS Plastic, Injection Molded
  - Not under significant load, but complex geometry with undercuts

Hand calculation

Strength criteria:

worst case load: the user apply weight to the luggage handle

$$F = G = 1130\ N$$

$$A = td = t(0.005\ m)$$

$$\sigma = \frac{F}{A} = \frac{1130}{0.005t} \leq \frac{\sigma_y}{FoS} = \frac{280\ MPa}{2}$$

$$\boldsymbol{t \geq 0.8\ mm}$$

Fatigue criteria:

For Aluminum 6061-T6, for number of cycles 1.0e+06, the endurance stress under zero mean stress is 55.5 MPa.

worst case loading: the user press and lift the luggage handle reversely with his weight.

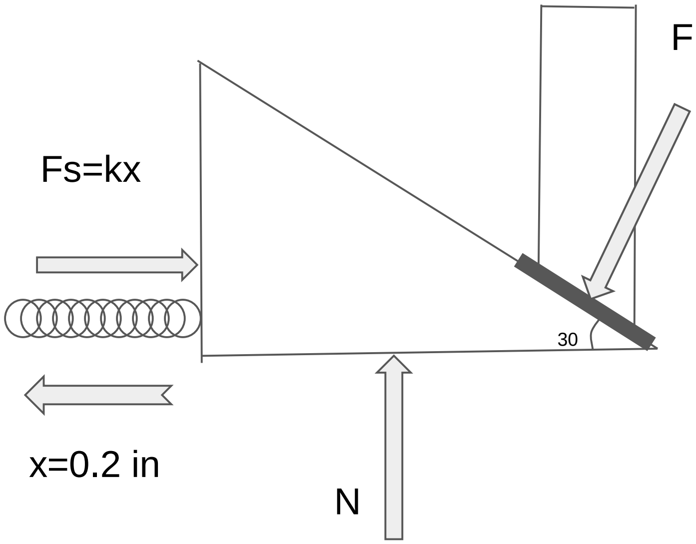
$$F = G = 1130\ N$$

$$A = td = t(0.005\ m)$$

$$\sigma_y = \frac{F}{A} = \frac{1130}{0.005t} \leq \frac{\sigma_e}{FoS} = \frac{55.5\ MPa}{2}$$

$$t \geq 4.0\ mm$$

Product: Spring Design



$$F_1 = \cos(30) * 5\ lbs = 4.33\ lbs$$

$$F_{s1} = \frac{F_1}{2} = 2.17\ lbs$$

$$k_1 = \frac{F_{s1}}{x_1} = \frac{8.66\ lbs}{0.2\ in} = 10.8\ lb/in$$

$$F_2 = \cos(30) * 20\ lbs = 17.32\ lbs$$

$$F_{s2} = \frac{F_2}{2} = 17.32\ lbs$$

$$k_2 = \frac{F_{s2}}{x_2} = \frac{17.32\ lbs}{0.2\ in} = 43.3\ lb/in$$

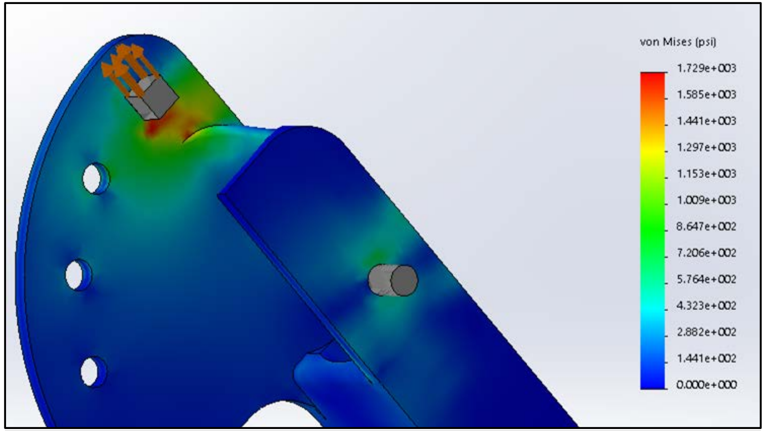
Design Constraints

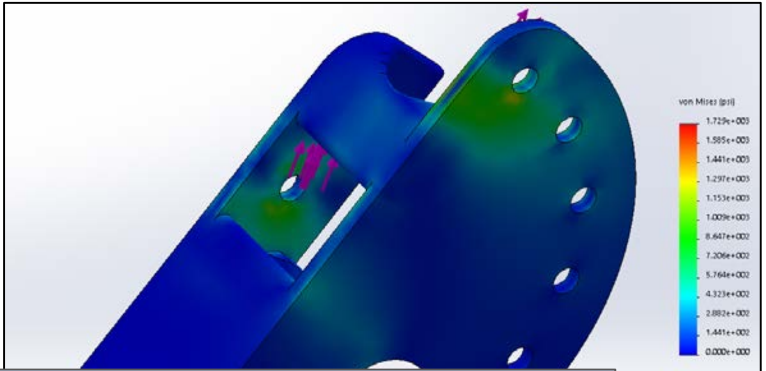
Specific Design Constraints

- Functionality
  - Must retain height adjustment mechanism
  - Must withstand loading conditions that luggage bags typically go through
- Geometry
  - For prototyping purposes, the dimensions of custom components had to be compatible with the other suitcase components
- Aesthetics
  - Minimal changes to outward appearance of suitcase

Design Constraints

Stress Analysis of P-Bracket

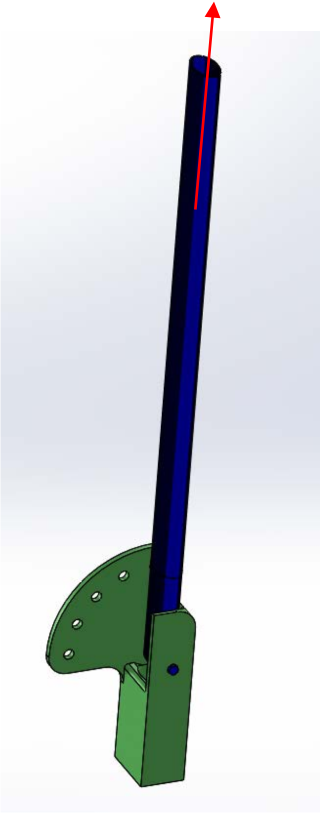




Loading scenario: the user attempts to lift the bag using the handle

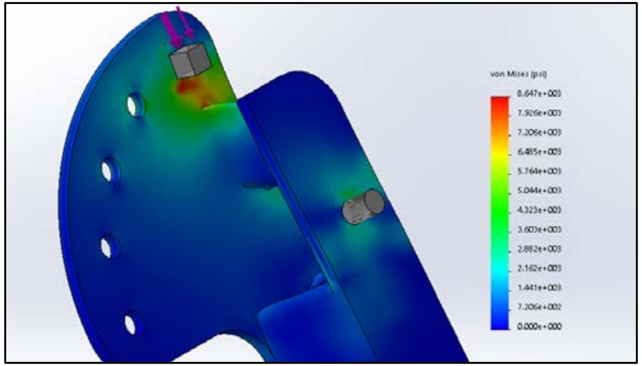
Assume the bag has a mass of 23 kg (The maximum allowed luggage weight on airlines)

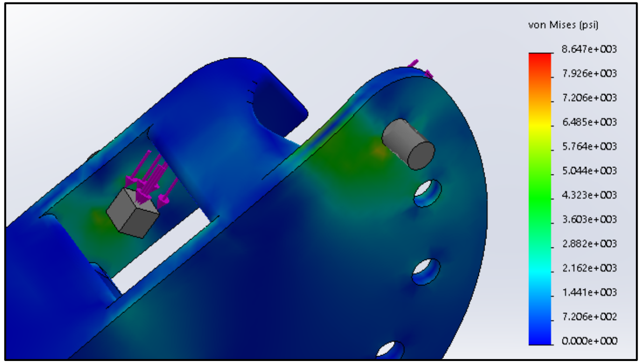
The peak stress in the bracket is roughly 1.7 kpsi, which yields a **safety factor of about 5.2**



Actual Design/Description

Stress Analysis of P-Bracket

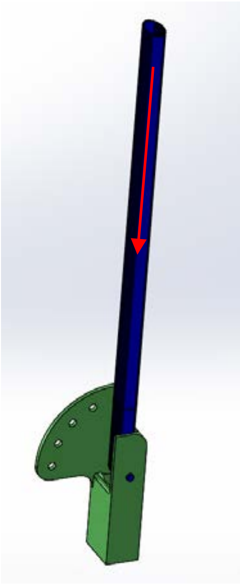




Loading scenario: the user puts all his weight (250 lbs) on the handle

The peak stress in the bracket is roughly 8.6 kpsi, which yields a **safety factor of about 1**

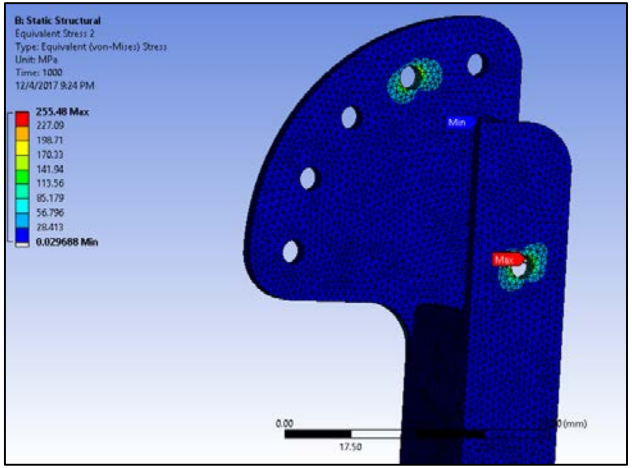
However, we believe that this loading scenario is somewhat unrealistic

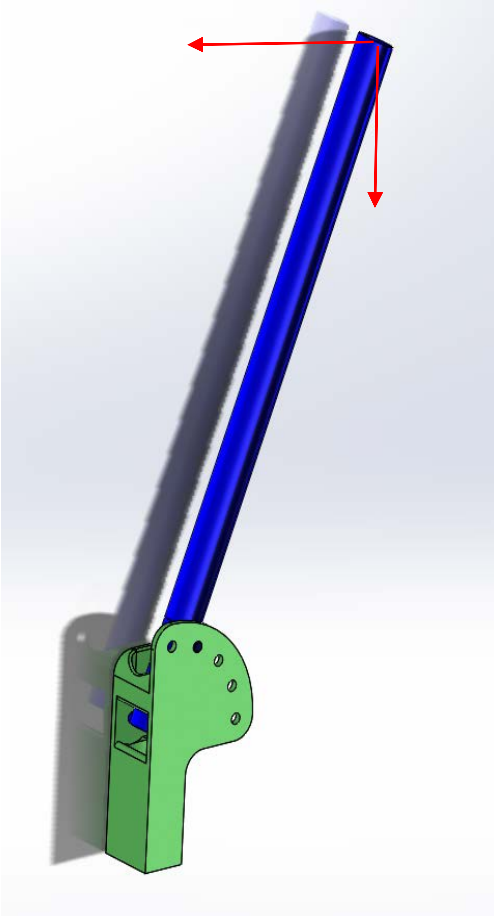


Actual Design/Description

Position 1:Stress Analysis

- 115 N horizontal force applied to the handle
- 50N Vertical force applied to the handle
- Housing material: Al Alloy
- Max Principal Stress: 255.4 MPa **Safety Factor: 1.10**

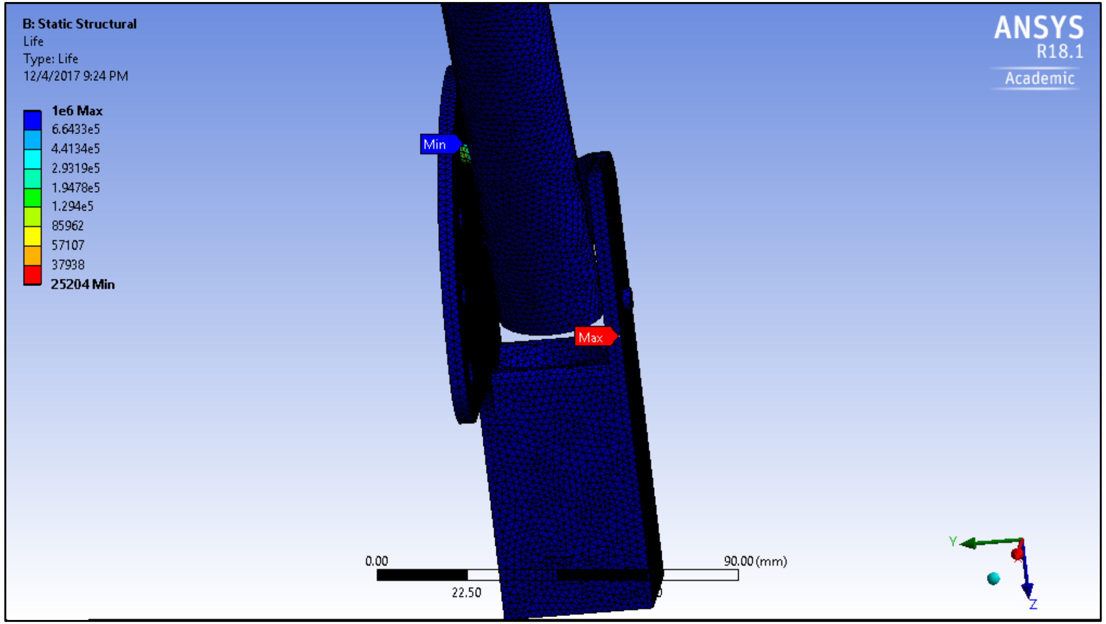




Actual Design/Description

Position 1: Fatigue Analysis

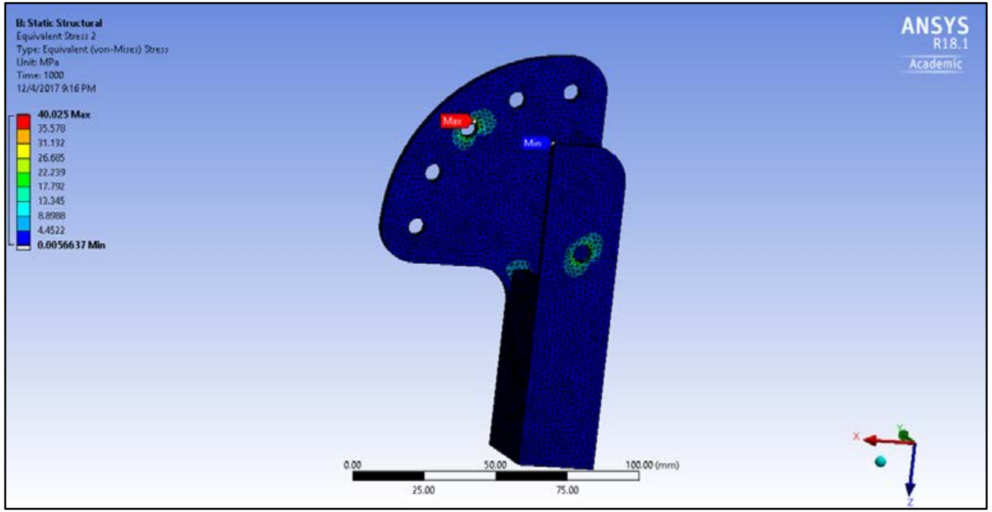
- 115 N horizontal force applied to the handle
- 50N Vertical force applied to the handle
- Zero based loading
- Housing material: Al Alloy
- **Life: 25204 cycles**

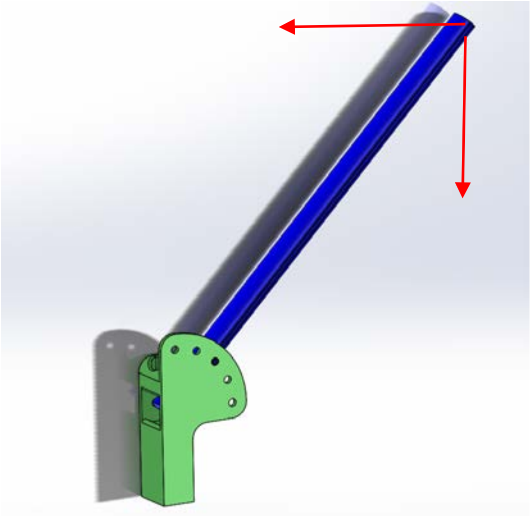


Actual Design/Description

Position 2: Stress Analysis

- 115 N horizontal force applied to the handle
- 50N Vertical force applied to the handle
- Housing material: Al Alloy
- Max Principal Stress: 40.02 MPa **Safety Factor: 7**

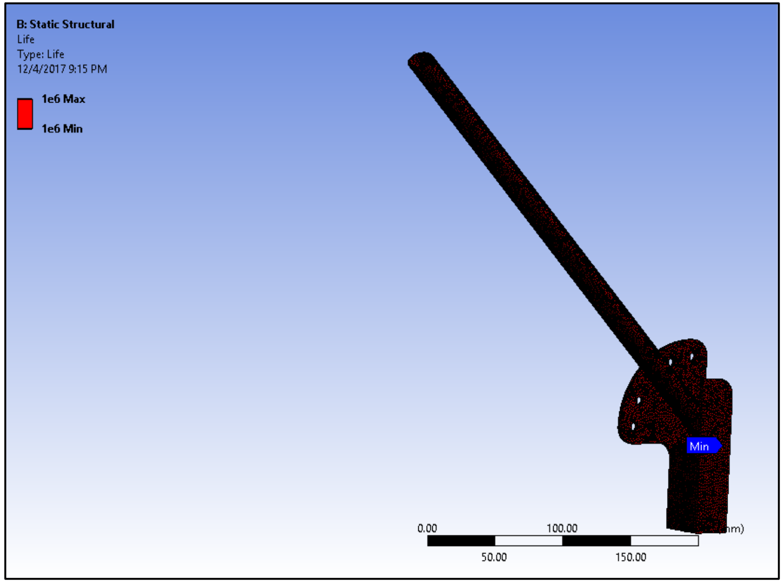




Actual Design/Description

Position 2: Fatigue Analysis

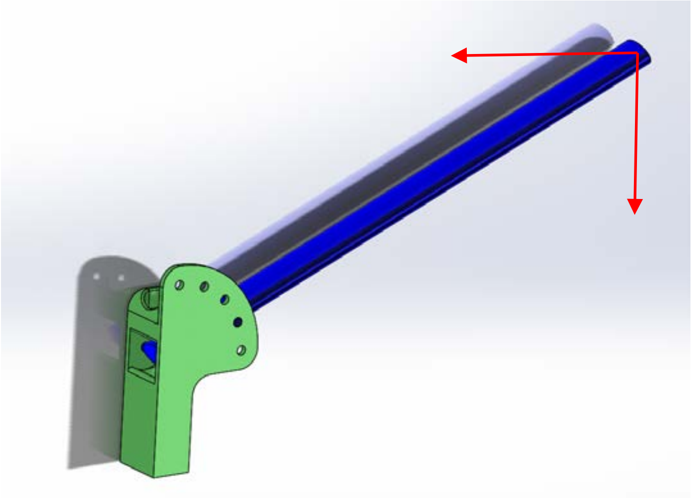
- 115 N horizontal force applied to the handle
- 50N Vertical force applied to the handle
- Zero based loading
- Housing material: Al Alloy
- **Life: 1e6 cycles**

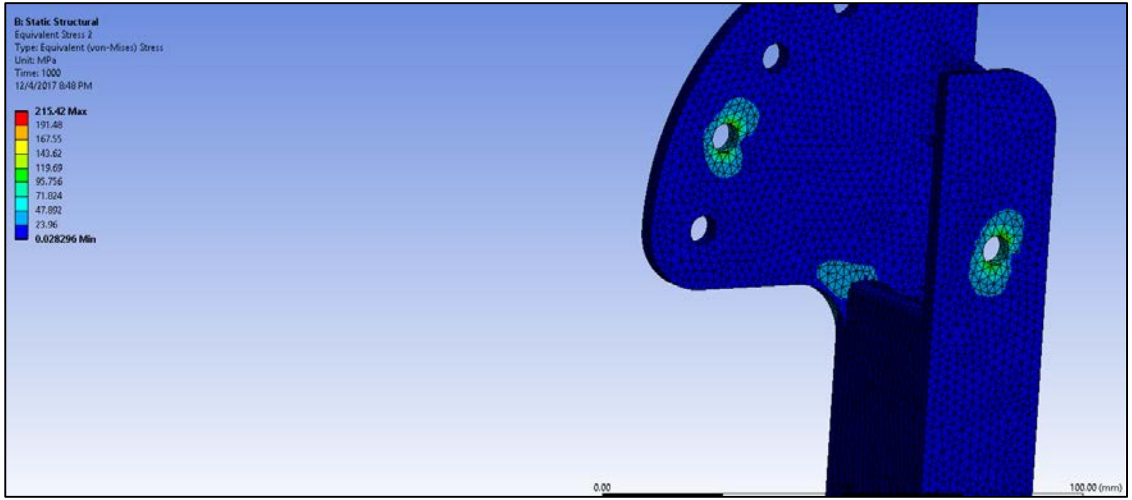


Actual Design/Description

Position 3: Stress Analysis

- 115 N horizontal force applied to the handle
- 50N Vertical force applied to the handle
- Housing material: Al Alloy
- Max Principal Stress: 215.152MPa
- **Safety Factor: 1.3**

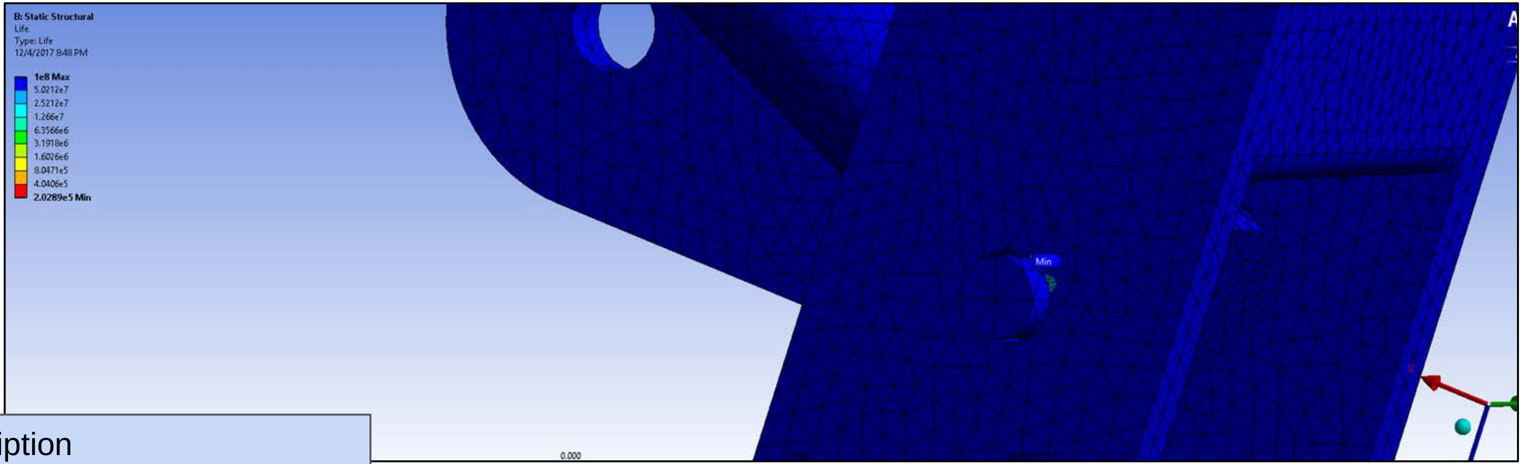




Actual Design/Description

Position 3: Fatigue Analysis

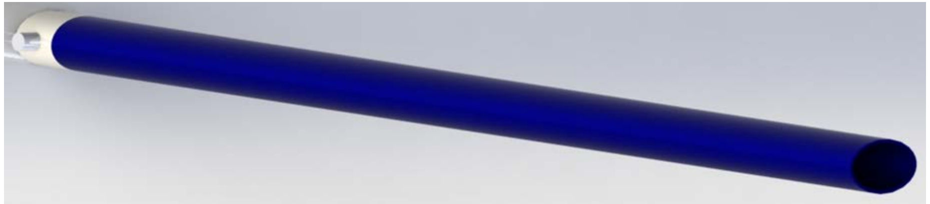
- 115 N horizontal force applied to the handle
- 50N Vertical force applied to the handle
- Zero based loading
- Housing material: Al Alloy
- **Life: 2e5 cycles**



Actual Design/Description

Cost Analysis: Handle Rods and Sleeves

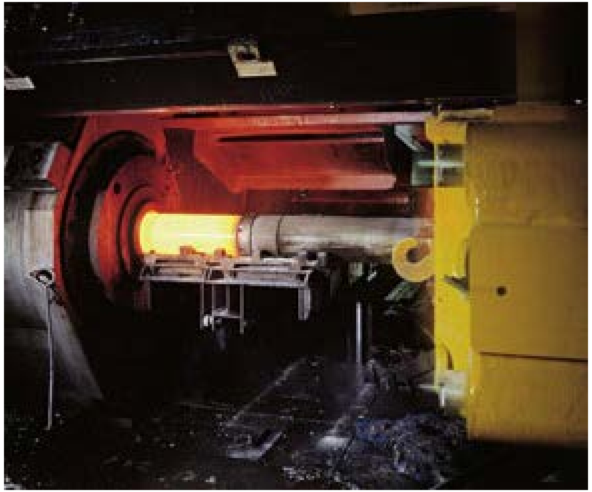
- **Aluminum Extrusion**
- Tooling Cost: ~$1200
- Material Cost: ~0.94 USD/lb



0.15 lbs

0.18 lbs

0.02 lbs

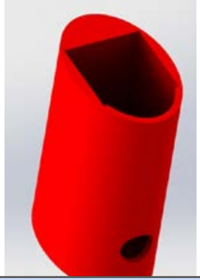


Total Tooling Cost	$1200 * 3 profiles = $3600
Total Material Cost (per unit)	$0.94/lb * 0.35 lbs * 2 handles = $0.66/unit
Total Cost	**$3600 + 0.66 * n**

Cost Analysis: Rod End Pieces and Pivot Holder

- **Plastic Injection Molding (ABS)**
- Tooling Cost: ~$12,000
- Material Cost: ~$1.20/lb

0.02 lbs

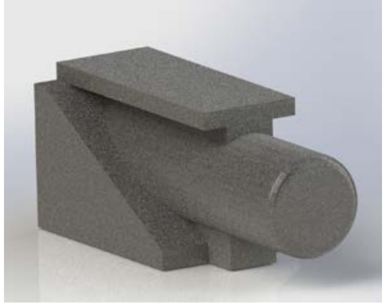


0.02 lbs

Total Tooling Cost	$12,000 * 3 patterns = $36,000
Total Material Cost (per unit)	$1.20/lb * 0.04 lbs * 2 handles = $0.096/unit
Total Cost	**$36,000 + 0.096 * n**

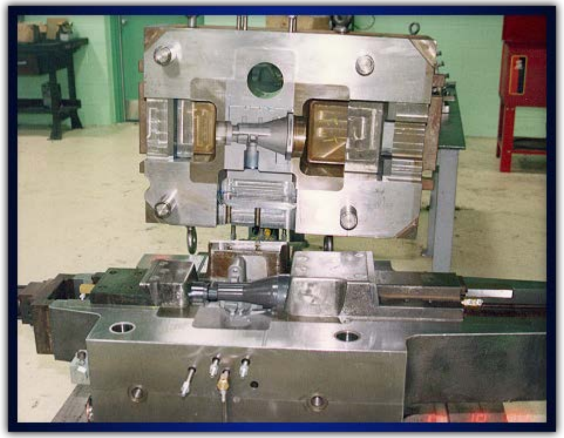
Cost Analysis: Rod End Piece Pins

- **Aluminum Die-Casting**
- Tooling Cost: ~$4,000
- Material Cost: ~$0.94/lb



0.01 lbs

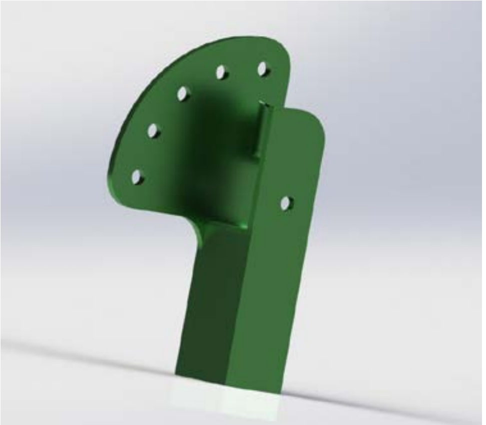
0.06 lbs



Total Tooling Cost	$4,000 * 2 patterns = $8,000
Total Material Cost (per unit)	$0.94/lb * 0.07 lbs * 2 handles = $0.066/unit
Total Cost	**$8,000 + 0.066 * n**

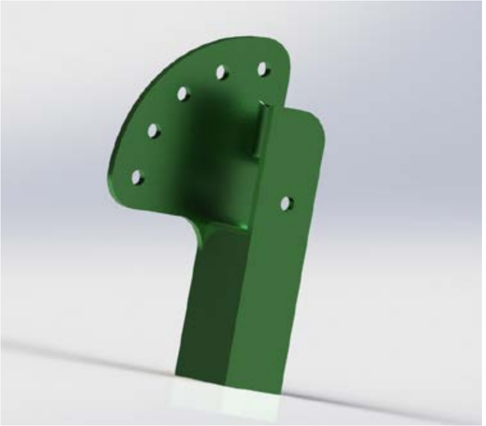
Cost Analysis: P-Bracket

- **Aluminum Investment-Casting**
- Wax Mold:
  - Assume same fixed cost as if injection molding
  - Known Quantities:
    - Projected Area: 7 in * 9.5 in = 66.5 in2
    - Part Depth = 1.47 in
    - SP = 6
  - **Fixed Cost: $22,593.73**



Cost Analysis: P-Bracket (cont.)

- **Aluminum Investment-Casting**
- Variable Cost:
  - Assume same variable cost as if sand casting
  - Known quantities:
    - N = n
    - V = 3.57 in3
    - A = 7 in * 9.5 in = 66.5 in2
    - Density = 0.098 lbf/in3
    - Price of material = $0.94/lb
    - Assume 2% waste
  - Material Cost = (1.02)(n)(0.94)(0.098)(3.57) = 0.335n
  - Setup = n
  - Ladling = (0.03)*n = 0.03n
  - Cooling = (0.008)(n)(66.5) = 0.532n
  - **Variable Cost = 1.897n**



Total Tooling Cost	$22,593.73
Total Material Cost (per unit)	$1.897* 2 handles = $3.794unit
Total Cost	**$22,593.73 + 3.794 * n**

Cost Analysis Summary

Assumptions for fixed cost:

Total Tooling Cost	$22,593.73
Total Material Cost (per unit)	$1.897* 2 handles = $3.794/unit
Total Cost	**$22,593.73 + 3.794 * n**

Total Tooling Cost	$12,000 * 3 patterns = $36,000
Total Material Cost (per unit)	$1.20/lb * 0.04 lbs * 2 handles = $0.096/unit
Total Cost	**$36,000 + 0.096 * n**

Total Tooling Cost	$1200 * 3 profiles = $3600
Total Material Cost (per unit)	$0.94/lb * 0.35 lbs * 2 handles = $0.66/unit
Total Cost	**$3600 + 0.66 * n**

Total Tooling Cost	$4,000 * 2 patterns = $8,000
Total Material Cost (per unit)	$0.94/lb * 0.07 lbs * 2 handles = $0.066/unit
Total Cost	**$8,000 + 0.066 * n**

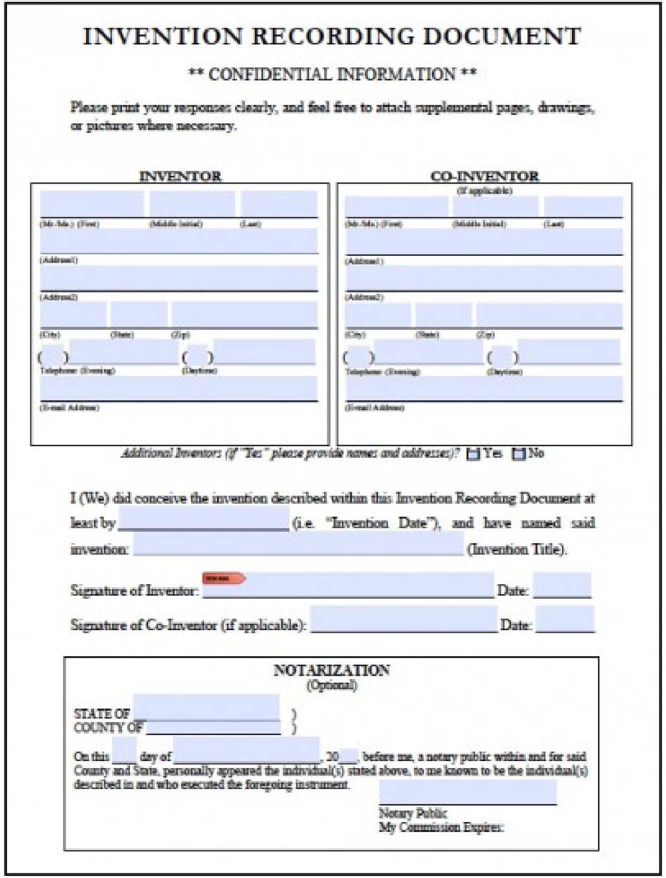
Total Product Manufacturing Cost	$70,193.73 + 4.616n

Conclusion

- For a production run of 100,000 units, we have a unit cost of **$5.32 per luggage bag**
  - Only includes cost of handle mechanism
  - The price of a luggage bag varies between $50-$300
  - The “Flexible Luggage” handle system increases the cost of luggage bags by **$7.50** assuming a 40% profit margin

Next Steps

- File Invention Disclosure
- Planning to build a more robust design
  - Better aesthetics
  - Modular design; can be fitted onto different models of luggage bags



INVENTION RECORDING DOCUMENT

** CONFIDENTIAL INFORMATION **

Please print your responses clearly, and feel free to attach supplemental pages, drawings, or pictures where necessary.

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Additional Inventors (if "Yes" please provide names and addresses)? ☐ Yes ☐ No

I (We) did conceive the invention described within this Invention Recording Document at least by ____________ (i.e. "Invention Date"), and have named said invention: ____________ (Invention Title).

Signature of Inventor: ____________ Date: ______

Signature of Co-Inventor (if applicable): ____________ Date: ______

NOTARIZATION

(Optional)

STATE OF ____________)

COUNTY OF ____________)

On this ___ day of ____________, 20___ before me, a notary public within and for said County and State, personally appeared the individual(s) stated above, to me known to be the individual(s) described in and who executed the foregoing instrument.

Notary Public

My Commission Expires:

Questions?

Appendix