Trine University
Biomedical Engineering

Kayak Lift and Transport Assist System

Madison Howard[1*], Kortney Helm[1*], Connor Moon[1*], Melanie Watson, Ph.D.[1]
[1]Bock Department of Biomedical Engineering, Trine University, Angola, Indiana 46703

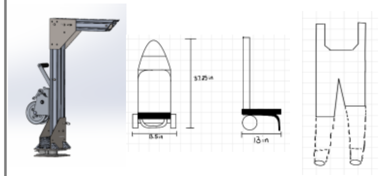
BAE SYSTEMS

Motivation

Our motivation is a Marine Corps Veteran who is now a bilateral above the knee amputee. He loves being outdoors and, on the water, and frequently goes kayaking. He gets around using a wheelchair which makes his current kayaking routine difficult. His current kayaking routine is inefficient and causes excess stress on his shoulders and lower back.

Introduction

The kayak assist group designed a new system that is safer and more efficient for the veteran. The new system consists of three subsystems corresponding to the three major issues Chris currently faces when kayaking.



There are three subsystems associated with the project. The first subsystem (Left) addresses the issues with loading and unloading the kayak from the truck. The second subsystem (Center) addresses the issues with transporting the kayak to and from the water. The third subsystem (Right) addresses the issues associated with getting in and out of the kayak in the water. This project is sponsored by BAE, so close communication and approval from associated individuals was taken into account during the design and manufacturing process.

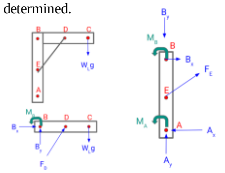
Project Specifications

After generating a list of requirements and constraints from the customers list of needs, the group generated a **table of specifications for each subsystem.**

Description	Value	Units
Lifts kayak with a safety factor of 5:1 [1]	250	lbs
Fits into allotted space in the back of the truck	11 x 53	inches
Height of mechanism does not exceed cab height	40	inches
Mechanism is able to rotate	90	degrees
Mechanism is corrosion resistant	Lose <10	Weight %
Hand crank height is accessible to customer in wheelchair	<55	inches
Mechanism does not inhibit normal wheelchair function	Yes/No	----
Reduces force required to move kayak	<40	lbf
Wheels traverse all terrains [2]	0.04-0.08	µ
Holds the weight of the kayak plus a safety factor of 2:1 [3,4]	100	lbs
Lightweight	<20	lbs
Mechanism is easy to store	11 x 25 x 18	inches
Fits right leg length	14	in
Fits left leg length	10	in
Leg width fits Chris	6	in
Fits Chris's waist	32	in
Waterproof [5]	Gain <5	Weight %
Tear resistant [6]	10	MPa
Does not slip while in kayak [7]	0.5	µ

Modelling and Analysis

Mathematical modelling utilized static analysis of crane beams to determine the reaction and supporting needed to withstand a 250 lbf load. The maximum force was determined to be the shear force, so the minimum cross sectional area for different material types were determined.



Largest Force Found = F_E = 10623.3 N

6061 Aluminum

$$A = = \frac{10623.3\ N}{241.3\ x\ 10^6\ MPa} = 44.02\ mm^2$$

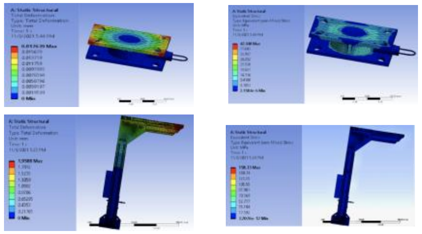
Low-Carbon Steel

$$A = \frac{10623.3\ N}{234.4\ x\ 10^6\ MPa} = 45.32\ mm^2$$

4130 Steel

$$A = \frac{10623.3\ N}{517.1\ x\ 10^6\ MPa} = 20.54\ mm^2$$

Finite element analysis was applied to the crane and turntable to determine the equivalent stresses and total deformation. FEA analysis of all subsystems showed the designs would not fail under the required load. In addition, the material will not shear at the given forces, further validating the designs.



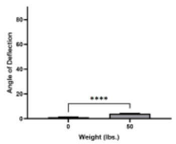
Manufacturing

The key technology used to manufacture these designs include:

- Plasma cutter
  - to cut out brackets and base pieces of the crane.
- Ferrous and Non-Ferrous grinders
  - to grind down sharp corners and edges of cut pieces.
- Drill press
  - to drill holes into the 8020 beams for the pull pins and rotary shafts
- Horizontal Bandsaw
  - to cut the 8020 beams down to the right length
- Miscellaneous Hand Tools
- Sewing Machine
  - to create the dolly straps, crane straps and modified waders

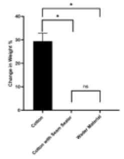
Testing and Validation

Lift testing to determine the maximum load the crane can safely hold to determine an exact load rating for the system.



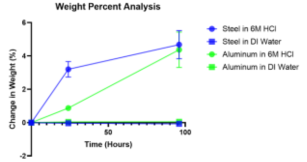
An unpaired t-test comparing the angle of deflection in the inner bracket at 40 lbs versus 0 lbs resulted in a *P value < 0.001, showing the crane does bend slightly during lifting. This is not a concern because the deflection was found to be in the elastic region, showing no permanent deformation will occur under normal use.

Waterproof testing to test waterproof properties of different materials for the waders.



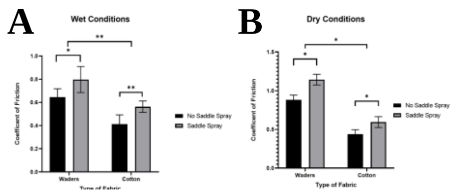
ANOVA analysis on change in weight (%) versus type of material resulted in *P < 0.001, proving the seam sealer and waders are more waterproof than traditional clothing.

Corrosion testing to simulate weather conditions in order to test different metals to determine their corrosion properties.



Significant differences between time points for each sample (row factor) with a P value = 0.0015, showing each of the samples did corrode overtime. There was statistical significance of P = 0.0101 between the steel samples and aluminum samples, showing aluminum did not lose as much weight as the steel samples.

Coefficient of friction testing to determine the significance of adding saddle spray grip to the waders material to reduce slipping.



A: Coefficient of friction versus type of fabric, with and without saddle spray, in wet conditions. P values based on paired t-tests and ANOVA are as follows: *P = 0.002 and **P = <0.0001. **B:** Coefficient of friction versus type of fabric, with and without saddle spray, in dry conditions. *P = <0.0001 for all cases.

Conclusions

The kayak team successfully achieved each of its three objectives.

- **The crane** successfully lifted the customer's kayak.
- **The transport system** successfully attached to the customer's wheelchair and moved his kayak from the truck to the water and back, reducing stress on his upper body.
- **The waterproofing system** was successfully customized to keep the customer dry when getting in and out of the kayak.

This was all achieved while keeping under the allotted budget.

Safety Considerations

The following design considerations were taken to decrease safety risks:

- Used grinder to smooth edges on metal pieces.
- PlastiDip was coated on sharp corners.
- Reduction of pinch points in design.
- Sufficient bolt tightening during manufacturing.
- Weight reduction to reduce lifting injury.
- Created user manual and troubleshooting guide.
- Foam padding on base plate to protect the truck and user.

All manufacturing was performed in a safe environment and testing was performed according to applicable standards to verify that the designs were safe. All three subsystems were validated with at least one testing protocol.

Referenced Standards

[1] "Department of Labor Logo United States department of Labor," 1926.753 - Hoisting and rigging. | Occupational Safety and Health Administration. [Online]. Available: https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.753. [Accessed: 08-Nov-2021].
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[4] "Factors of safety," Engineering ToolBox. [Online]. Available: https://www.engineeringtoolbox.com/factors-safety-fos-d_1624.html. [Accessed: 08-Nov-2021].
[5] N1020 neoprene datasheet test report - Marco Rubber. (n.d.). Retrieved November 11, 2021, from https://www.marcorubber.com/downloads/Marco-Material-Datasheet-N1020.pdf.
[6] "ASTM D2261 tearing strength of fabrics - instron." [Online]. Available: https://www.instron.com/en-us/testing-solutions/by-standard/astm/single-testing-solutions/astm-d2261?region=North%20America. [Accessed: 08-Nov-2021].
[7] Jshouse, & Jshouse. (2016, September 20). Get A grip! Get a Grip. Retrieved November 11, 2021, from https://www.srmax.com/education/blog/slip-resistance-101-coefficient-of-friction.

Acknowledgements

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