Useful Robot Team 2: Arm and Attachments

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INTRODUCTION

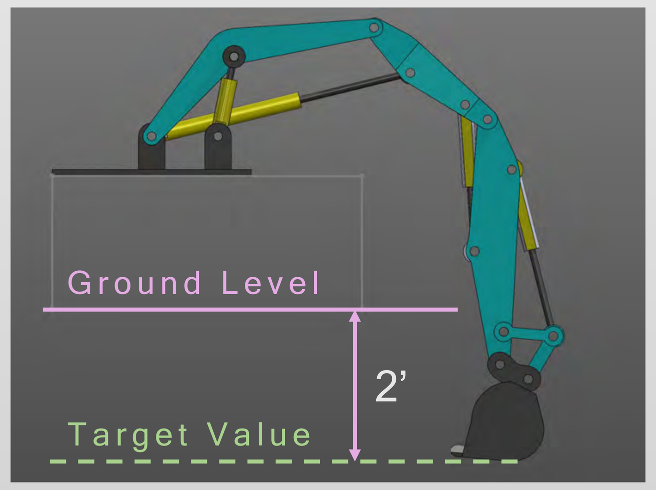
The construction industry accounts for 37% of greenhouse gas emissions. To reduce this, electric-powered machinery is being adopted. However, current models support only one attachment and are limited to construction sites due to their large size. The goal is to design an arm with attachments compatible with a chassis (courtesy of Team 1), constructing only the Boom and Arm 1. The robot is electrically powered, hydraulically actuated, and supports both bucket and fork attachments.

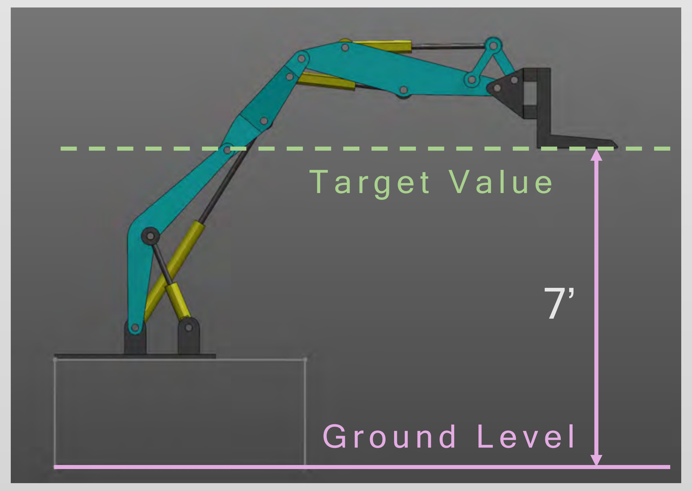
PROJECT SCOPE

The goal of this project is to design & manufacture the Boom and Arm 1 of the complete Final Arm Assembly. This includes designing the Arm to match specifications & constructing the first two segments. This scope also includes selecting & utilizing the hydraulic cylinders, which actuate the associated parts, and the joints, which connect the segments together.

INITIAL CONCEPT TESTING

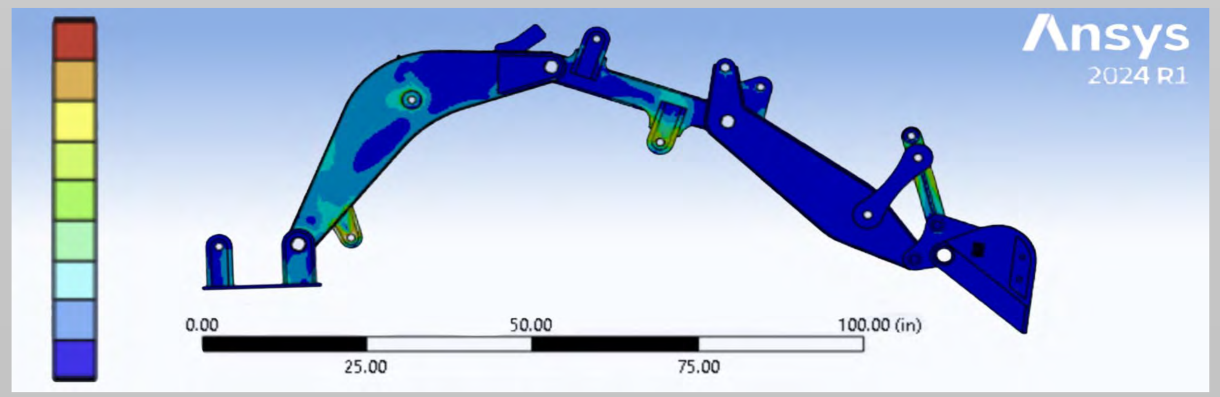
Initial concept testing of the project involved testing various kinematic models to see the range of section lengths that could accommodate the design requirements best. These kinematic models were used to initially analyze the best lengths for each arm. Afterwards, more comprehensive designs were made to maximize the lift height and reach while also minimizing the lengths to decrease cost of materials. Final concept testing results produced the basic design shape and hydraulic cylinder options for each section.

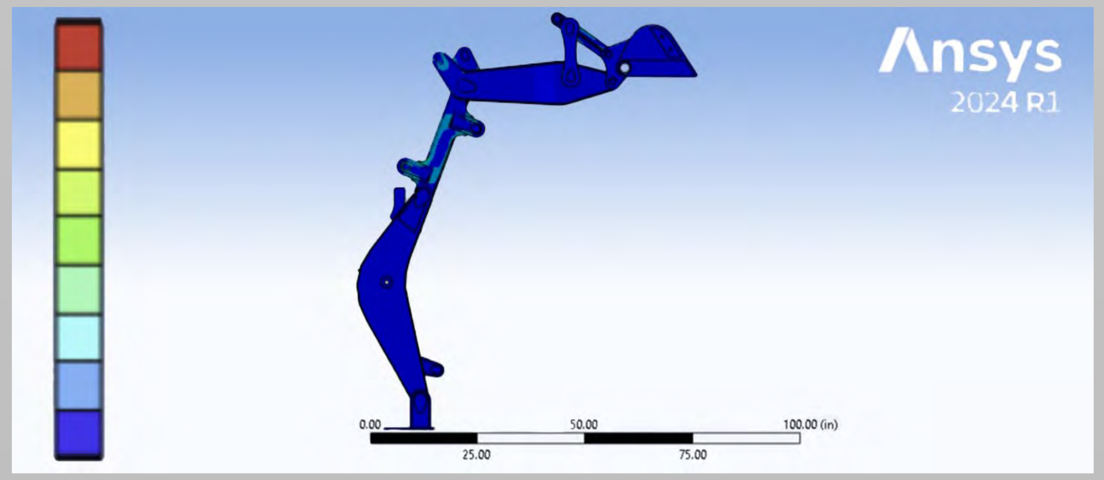




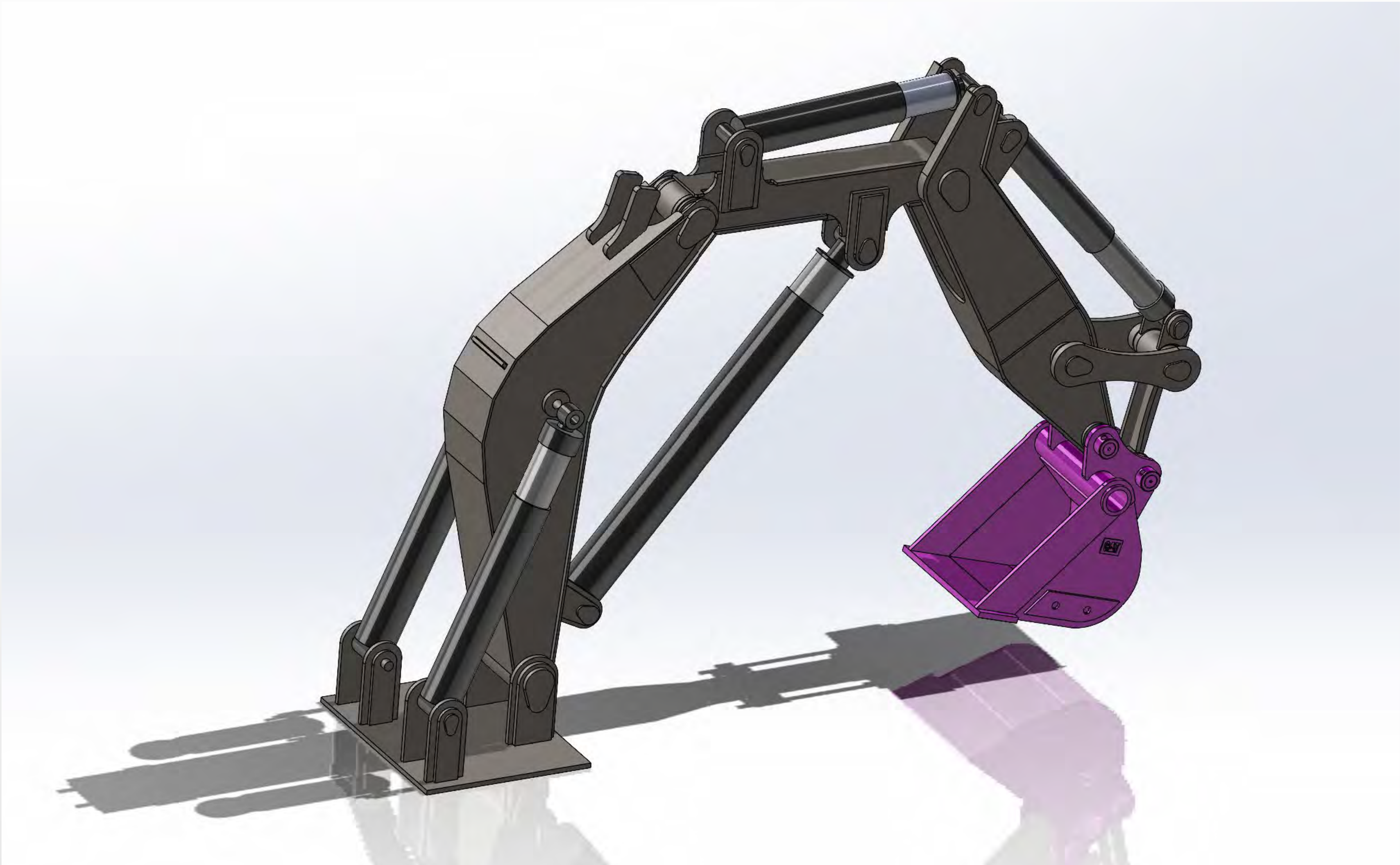
FINITE ELEMENT ANALYSIS

A Finite Element Analysis was developed in Ansys to predict the stresses & deformations the arm assembly would have to endure, which empowered us to strengthen our design to meet design criteria. The images below depict the stress (above set of images) that the Attachment Assembly will undergo in the highest stress positions: full extension (above) & highest lift (below). The color scale is calibrated such that red is the yield stress.



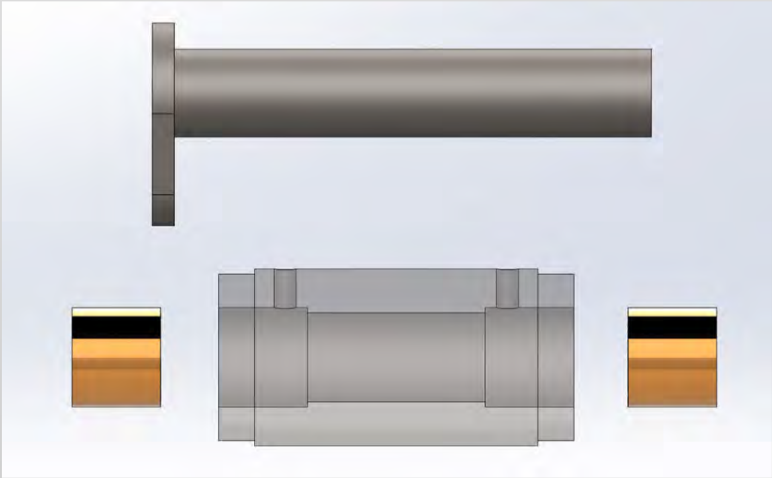


ARM ASSEMBLY DESIGN



The Final Arm Assembly is made up of 130 total parts consisting of steel plates, hydraulic cylinders, joint subassemblies, a linkage system, and a forklift/bucket attachment. The design sections include the Boom, Arm 1, Arm 2, and a Linkage System compatible to both an excavator bucket and a forklift. The design meets all the metrics, proven through a Kinematic Model and Finite Element Analysis.

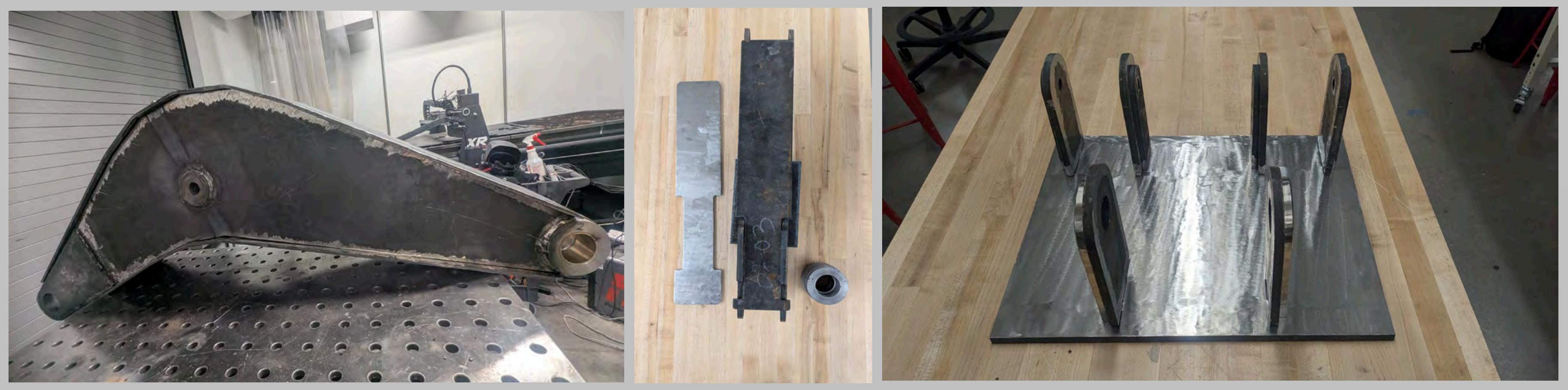
JOINT SUBASSEMBLY DESIGN



The joint subassembly consists of two bronze bearings, a thick-walled steel tube, and a steel flag pin. Part lengths vary by section requirements. The outer diameter of the bearings are press-fitted onto the tube, with an inner diameter providing a clearance fit for the pin. Beyond the bearings, the steel tube's inner diameter is a medium fit for the pin. These tolerances were used during the manufacturing process on the lathe.

RESULTS

Req #	Requirement	Target Value	Achieved Value
1	Forklift lift capacity	2500 lbs	2000 lbs
2	Forklift lift height	7 ft	10 ft
3	Excavator bucket volume	1.25 ft^3	2.7 ft^3
4	Excavator dig depth	2 ft	5.5 ft
5	Excavator lift capacity	93 lbs	93 lbs
6	Size of platforms and implements	< 90 ft^3	60 ft^3



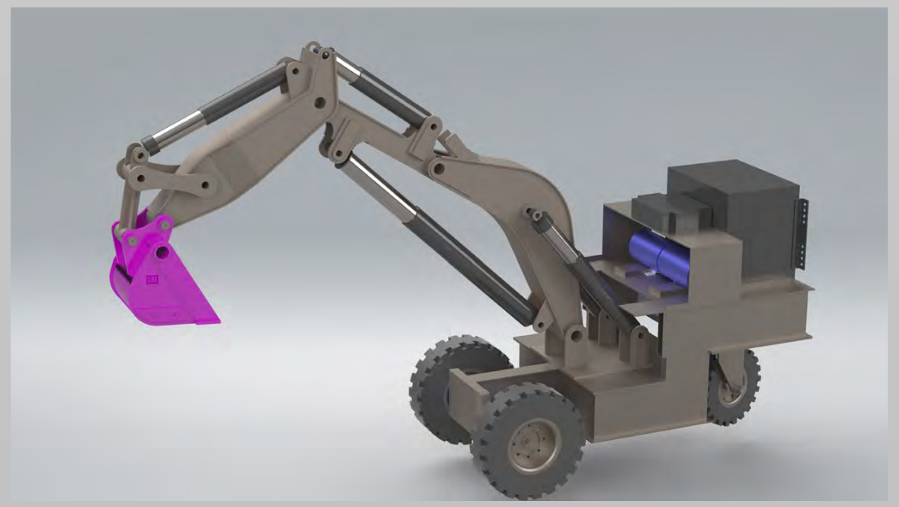
Images of the Boom (left), Arm 1 (middle) & Attachment Plate (right), as of 4/10/2025

MANUFACTURING PROCESS

Manufacturing began by cutting all required assembly cut files from the steel sheet metal using either the plasma cutter or mill. Afterwards, the boom's top and bottom plates were bent to design specifications using the bending machine. Then, joint subassemblies including the thick-walled tubes, bearings, and pins were machined on the lathe into the correct range of dimensions depending on the tolerance requirements. After the cutting, bending, and lathing process, the plates were prepared for welding using a grinding tool to the remove mill scale on the welding areas. Finally, the welding process was started to finish the required assembly.

NEXT STEPS

Next steps for the Useful Robot project is completing the manufacturing process for Arm 2, the Linkage System, and a full integration between the Arm and Chassis designs. An image of the integration is shown below. Future design teams will be tasked with physically testing and improving the design based off those tests, as well as design optimization & automation.



CONCLUSION

The Final Arm Design meets the design requirements. proven by the Kinematic Model and the Finite Element Analysis. The physical assembly of the Final Arm Design was started, completing the Boom, Arm 1 & Attachment Plate by Design Day Spring 2025.