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Mechanical Lift Assist Hoist

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Introduction

Description & Motivation

At North Start Casteel, the manufacturing of truck hitches weighing roughly 40lbs involves employees bending over and lifting them throughout the day. Currently, employees at North Star are being injured and unable to attain higher manufacturing speeds due to individual physical limitations. A type of lift to carry and hold castings could increase efficiency and reduce the toll on the workers. By increasing how quickly the workers can finish the hitches, profits would increase, benefitting North Star.

The general design of the project will follow a rotating I-Beam, mounted on the wall behind the workbench. It will allow an electric hoist to roll on a trolley along the length of the beam. The electric hoist will have a pneumatic gripper mounted to the end, containing all the controls for the user. This will allow the user to easily operate the hoist and gripper from the same place, rather than wasting time between two control panels.

Function Statement

A device is needed that will lift and hold a variety of metal castings.

Requirements

- Lift 60lbs
- Attach/detach to casting in less than 15sec
- Rotates at least 180 degrees
- Can endure 8 hours of continual operation daily
- Traverse a distance of 10ft in an arc
- Capable of reaching the ground
- Capable of lifting up to 6ft high
- Can lift a casting 3 feet in 15 seconds

Success Criteria

The Lift reduces the time to clean a part and creates a more comfortable work environment for the employees.

Scope

The scope for this involves the grasping mechanism and how it will attach to an appropriate lift. It will also require a system to traverse a distance on rollers. The grasping mechanism will be a pneumatic gripper, attached to an electric hoist.

Benchmark

The benchmark is the current effectiveness of North Star employees without any assistance. A second benchmark would be another lift preforming a similar purpose.

Success of the Project

If this system improves speed and reduces the physical toll on the employees, it will be considered successful.

Design and Analyses

Approach

A rotating I-beam assembly with a rolling cable lift, capable of lifting parts from a bin and then rotating to a work station and separate finished bin. This assembly is required to lift parts up to 40lbs, which defines the design in several ways. A load of 40lbs requires a specific gripping force. In analysis A10, a standard gripper jaw was used to calculate the required gripping force. This gripper ended up resulting in a required gripping force of 250lbs, making it unreasonable. In light of this, a new gripper jaw was designed to apply the griping force at an upward angle, rather than downward. This lowered the gripping force to roughly 35lbs, which is much more reasonable. This analysis can be viewed in appendix A11. The designed gripper can be seen in drawing 10-0004.

Additionally, the assembly must be able to grasp the part within 15seconds, and sooner is better. This led the team to use a pneumatic gripping system in order for a quick and easy to use system. An analysis critical to this was the bore size of the pneumatic cylinder. This analysis can be seen in appendix A12. It resulted in a bore size of 19mm. This bore size will be able to lift the required load without slipping and includes a factor of safety because the calculations were done with a smooth steel on cast iron coefficient of friction, and the steel gripper will be textured in the manufacturing process to increase that value.

Performance Predictions

The assist hoist is predicted to increase the worker efficiency by 10% on average. This is predicted by considering the exhaustion of the employees to be prevented, allowing them to continue at a quicker pace while maintaining a comfortable working environment. Additionally, it is predicted that back injuries will be reduced as a benefit of this project.

Scope of testing and Evaluation

Testing will be done primarily at NorthStar Casteel in Vancouver WA. This testing will include weld testing to ensure enough load capabilities. Testing will be done on the pneumatic griper in Hogue hall at CWU by using known weights and varying pressure.

Testing methods will evaluate shear failure, buckling failure, excessive strain/deflection, gripping force, and grasping speed.

List of Analyses

The Analyses below can be found in the respective place in Appendix A.

A1. Weight of hallow beam

This analysis was intended to calculate the weight, and its effect on the total loading on the structure. This beam design has been replaced due to optimization recommended by Professor Ted Bramble.

A2. Maximum deflection of beam

This analysis solves the maximum deflection of the original support beam when loaded to its maximum. It was found that the deflection was 0.22in, and after changing the beam design, geometry was increased to reduce this deflection and increase the safety factor.

A3. Maximum shear stress in beam

This analysis calculated the maximum shear and moment in order to ensure that the beam dimensions were enough to withstand the loading. It found that a maximum of only 100.7 psi was being applied in shear, which was well below the materials yield point. This concluded that shear failure is not a concern for this geometry.

A4. Maximum moment and Shear stress in cantilever Beam

This analysis was to determine the maximum stresses in the beam after it was determined to be supported in a cantilever style. The maximum moment ended up being 180lb*ft, which is used to dimension the cantilever beam.

A5. Geometry specification due to buckling

This analysis was to determine the critical buckling load of the vertical support column when using a .25in wall thickness. This thickness was assumed and then verified with a calculation, indicating that this wall thickness is well above the required thickness to prevent buckling

A6. Required bolt diameter for mounting

This analysis is required in order to determine the bolt thickness required to avoid a shear failure under max loading. This analysis determined a bolt with a diameter of 0.5in diameter would be enough, and since this analysis, an additional two bolts were added per mount, giving an additional factor of safety for a minimal cost increase.

A7. Max Shear and Moment for simply supported beam

This analysis describes the maximum shear and moment under max loading, if the beam was simply supported. This analysis resulted in a maximum normal stress of 651psi, which is not a concern for the steel used in its construction.

A8. Required gripping force (if applied Horizontally)

This analysis describes what the gripping force would have to be if applied in a horizontal fashion. This led to a required gripping force of 83lbs, which was unnecessarily high. This analysis was to determine if a horizontal gripper would be better than an angular gripper for this application. It yielded that the angular gripper is a better option for this design.

A9. Required gripping force if applied in upward direction

This analysis evaluated the gripping force if the force was applied in an upward direction, using custom jaws to direct that force. The custom jaws were designed to apply the force at an upward 45-degree angle, and therefore lowered the required gripping force to 35lbs, which was much more realistic for the gripper available from Bimba.

A10. Required friction force to hold part

This analysis found the friction force needed per jaw to keep hold of the part and found that with a smooth steel jaw the grip will be enough. In manufacturing, the jaws will still be textured in order to increase the safety factor and make the project more versatile if they decide to use it for additional parts in the future.

A11. Required bore size to output sufficient gripping force (standard gripper)

This analysis assumed a standard gripper jaw was being used and solved for the required bore size that would be required. The bore size ended up at nearly 2 inches, which is not available commercially from the sources available. In order to utilize a smaller bore size, custom jaws were designed and then evaluated in analysis A12.

A12. Required bore size to output enough gripping force (custom gripper)

In this analysis, the custom jaws were evaluated to determine the required bore size. The new bore size was .75inches, or 19 mm. This bore size is available and makes the griping force cap-able of significantly higher values.

Device description

An I-beam will be attached to the existing structure, and a roller assembly as shown in drawing 10-0003 will be affixed to this beam. This will allow a hoist with a pneumatic griper to roll freely between the workspace and the bins that the part comes from and goes to. The pneumatic gripper with have 3 pivoting grips to firmly grasp the variety of parts that are going to be manipulated. The grips will be made of a steel to ensure durability and effectiveness.

Methods

Calculations

This project spans several engineering disciplines, but relies significantly on statics, strength of materials, and pneumatics. These areas are explored in the analyses in appendix A and have yielded the parameters given in this design.

The project will involve calculations regarding the required loading. These calculations involve shear stress, bending stress, buckling, and maximum deflection. The equations are as follows:

Shear Stress: P/A

Bending Stress: MC/I

Buckling: (pi*EA)/(L/r)^2

Maximum Deflection: (-PL^3)/(48EI)

There will also be calculations required for the pneumatic gripper mechanism for grasping the cast parts. These calculations will include gripping force, required coefficient of friction, and bore size.

Gripping Force: From Manufacturer specifications, as shown below

Technical Data

Engineering Specifications

Bore Size (mm)			6	10	16	20	25	32
Fluid			Air (Clean/Dry)					
Pressure Range	Double Acting	6mm	28 to 100 PSI (0.15 to 0.7 MPa)					
		10mm to 32mm	22 to 100 PSI (0.1 to 0.7 MPa)					
	Single Acting	6mm	50 to 100 PSI (0.3 to 0.7 MPa)					
		10mm to 32mm	36 to 100 PSI (0.25 to 0.7 MPa)					
Temperature Range			-4 °F to 160 °F (-20 °C to 70 °C)					
Lubrication			Cylinder: Not Required Jaws: Grease Regularly					
Cushion Type			Bumper					
Integrated Flow Control			Not Available	Standard - Flow Control in Closing Direction				
Maximum Frequency			180 cycles per minute					
Port Size			M3x0.5		M5x0.8			
Sensor Switch Compatibility[1]	Reed Switch		MCS1-H	MCS1-G				
	Solid State Switch		MDS1-H	MDS1-G				
Includes			Magnet					

[1] See pages 104-107 for switch specifications

Gripping Force and Stroke

1 MPa = 145.04 PSI
1 N-cm = 0.089 lb-in

Model		Double Acting (MHFY)					
Bore Size (mm)		6	10	16	20	25	32
Gripping Moment[2], M_g (N-cm)	Closing[3]	7.4 x P	17.6 x P	90 x P	152 x P	304 x P	637 x P
	Opening[3]	10.6 x P	29.4 x P	129 x P	252 x P	473 x P	904 x P
Maximum Recommended Length to Gripping Point[4] (mm)		30	30	40	60	70	85
Opening Angle[3]		30° +3/-0					
Closing Angle[3]		10° +0/-3					

Model		Single Acting Normally Open (MHFTY)					
Bore Size (mm)		6	10	16	20	25	32
Gripping Moment[2], M_g (N-cm)	Closing[3]	5.7 x P	11.8 x P	71.2 x P	122.4 x P	252 x P	589 x P
	Opening[3]	-	-	-	-	-	-
Maximum Recommended Length to Gripping Point[4] (mm)		30	30	40	60	70	85
Opening Angle[3]		30° +3/-0					
Closing Angle[3]		10° +0/-3					

Note: P = Operating Pressure (MPa)
[2] See figure 3 on page 102.
[3] See figure 4 on page 102.
[4] See figure 5 on page 102.

Coefficient of friction: P/N

Bore size: Based on required force, defined by manufacturer

Optimization

Optimizations for this project will be handled in a few ways. One of the most significant will be the time required to grip the part. The faster this can happen, the more efficient the worker will be. Additionally, minimizing geometry will aid in a lesser cost, as it will use less material.

The grippers were manufactured by using an additive process, rather than a machining method. This cut down on manufacturing time and saved material. The grippers were cast at NorthStar in Seattle, based on the pans that were 3D printed at CWU. The material was chosen to be mild steel, as some machining was still necessary after the cast part was removed from its mold. The machining required was in order to mount the jaws to the gripper assembly. A slot was cut into the end and then two holes were drilled to align with the holes in the gripper assembly. The mild steel will still have enough properties to support the design load and operate properly, over a long life.

Modifications

Due to an issue faced with manufacturing, the gripper material had to changed from steel to aluminum. This change of material also required a redesign of the grippers in order to maintain proper stress. The change of material was due to a lack of demand or mild steel alloy at NorthStar. Aluminum was suggested due to this. Gripper jaws were both made 50% wider to accommodate this change. An additional concern with the use of aluminum in place of steel was the potential for deformation. The uneven surface of the cast products has the potential to gash and scrape the aluminum jaws. This concern was brought to the mentors at NorthStar. It was decided that the use of aluminum will be sufficient for a prototype, and that steel would be arranged if the prototype is successful.

Benchmarks

Current Method

Currently at NorthStar, employees lift each part by hand and have no sort of assistance. It takes roughly 20 seconds to move the hitch from the bin to the workbench. That number also increases at the day goes on and the employees begin to get fatigued. By increasing the ease of lifting the part, it is the goal of the project to increase the production speed in an overarching effect. This will allow the workers to maintain a comfortable working pace, without overexerting themselves unnecessarily.

Separate Potential Solution

Another potential proposed solution is a device produced by a company named ergonomic Partners. They provide 'zero gravity' lift assist options. These devices are generally custom made, and significantly more expensive than alternative solutions. The articulation of the grippers on these are not as tailored toward the applications intended in this situation. The project designed in this report will yield a gripper that will be easily used for the castings being manufactured by NorthStar. To summarize, the Ergonomic partner solution would be sufficient, however it would be less effective and more expensive.

Construction

This section will describe the device in its entirety, as well as a description of the device drawings found in Appendix B.

Full Assembly

The design consists of an I-beam supported by a solid wall mounted square column. The column will be affixed to the wall by two steel hinges. The hinges are mounted by 6 bolts each. The I Beam will support the rest of the assembly, and has a maximum load of 500lbs, well above the actual load in practice. The trolley will slide onto the bottom flange of the I-beam and roll freely along the length of it. It will be an unpowered trolley and move simply by pulling force. This trolley includes a lower mounting hook, that will attach to an electric hoist. The electric hoist will be powered with wire ran along the length of the I-beam with enough slack to give unrestricted motion. A pneumatic gripping device attached to the end of the hoist will have two separate custom jaws mounted to it, one with two arms, and the other with only one. The purpose of the two-arm jaws it to prevent any rotational motion that could allow the part to slip free of the gripper. The controls for both the hoist and gripper will be located on the gripper mount that connects it to the hoist. This will allow for easy operation and reduce the impact of a learning curve when new employees begin to use this system.

Manufacturing

The two custom manufactured parts are the single and double gripper jaws. In order to machine these, two methods were considered.

1. Using the CNC mill would allow for manufacturing of these parts. A lack of CNC training means that assistance would be required for this method, and learning to code the CNC would mean this would take longer than wanted.
2. Another option for manufacturing would be to cast these parts, and then clean then up by grinding. This is a valid approach because of the fairly low tolerance required for the gripper jaws. This method could not be done at the CWU campus, and would be performed at Northstar's Seattle location, where they have a functional foundry.

After evaluating the options, the team decided to have the part cast at Northstar's Seattle plant because of the accessibility to a foundry setting, and the low cost because scrap metal could be used. The team will 3-D print a model of the part, slightly enlarged to account for shrinkage, to provide to Northstar as a pattern to make the needed molds.

List of Drawings

All listed drawings can be found under Appendix B, in their respective designations

B1. 10-0001

Drawing showing the full assembly, including all of the following drawings in their appropriate locations.

B2. 10-0002

Drawing showing the pneumatic gripper, as well at the mounting fingers and gripper jaws together.

B3. 10-0003

Drawing showing the roller trolley that will be affixed to the I-beam support in the final assembly.

B4. 20-0001

Drawing of the custom single arm gripper, with a cutout to mount to the pneumatic gripper.

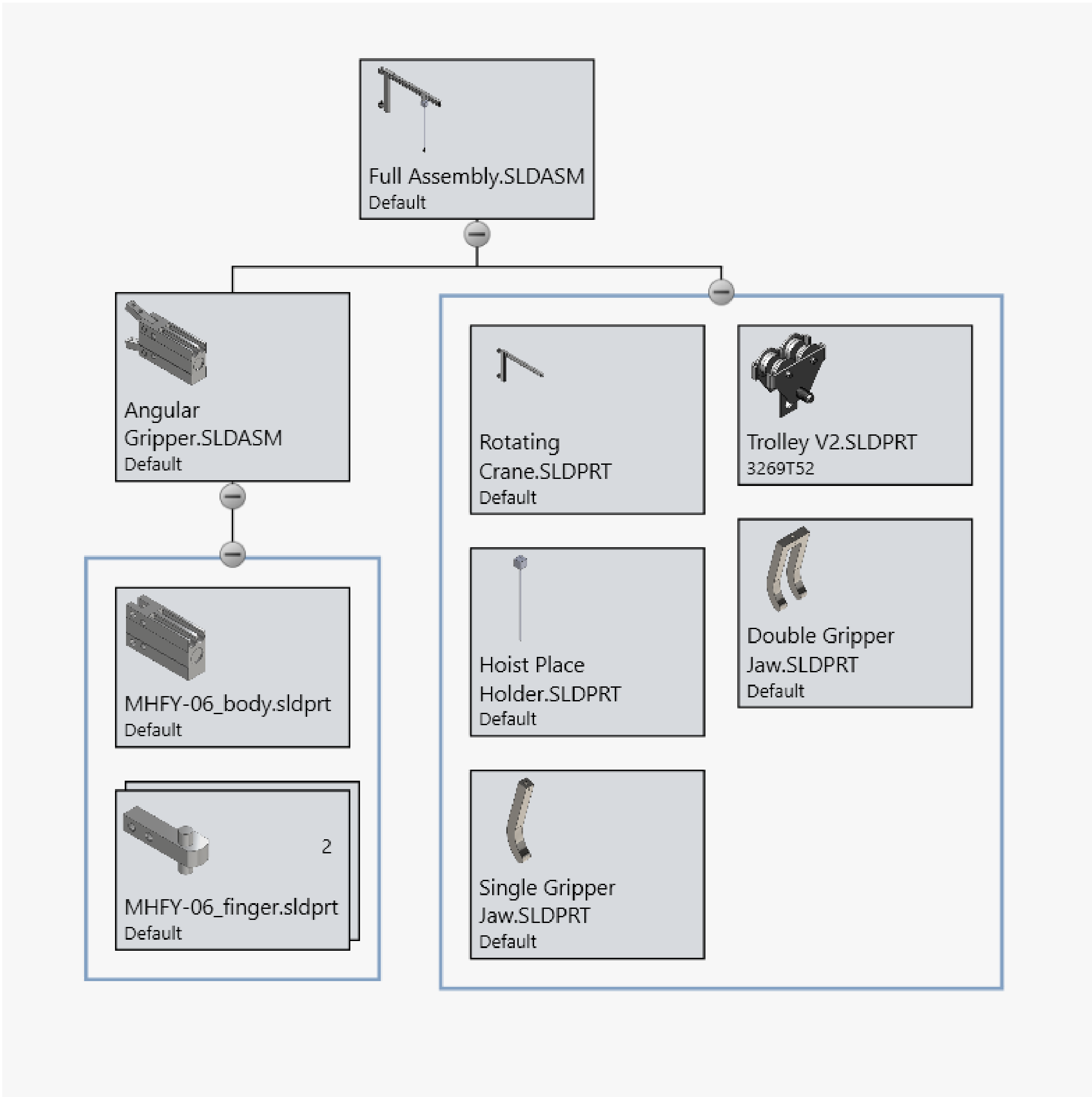
B5. 20-0002

Drawing of a modified gripper arm to have two arms. Two arms are necessary to prevent rotation of the part when being moved after gripped.

B6. 55-0001

Drawing depicting the rotating support beam, independent of any other parts.

Drawing Tree



Sub Assembly Descriptions

Pneumatic Gripper

The pneumatic gripper assembly consists of the aluminum gripper body, pneumatic cylinder, mounting arms, and machined jaws. The aluminum body houses the cylinder. It also has two connections for pressurized air due to the double action nature of the gripper. Attached to the cylinder is the two mounting arms needed to transmit the force of the cylinder. The custom machined jaws connect to the mounting arms, as an extension of them. This sub assembly will attach to the end of the electric hoist in the full assembly.

Roller Trolley

The roller trolley will be purchased from McMaster-Carr. The trolley consists of four wheels, a primary housing, and wheel bumper guards. As part of the main housing, a hook for connecting to the hoist is available. The wheel guards are intended to protect the wheels in the event of rolling it into the end of the I-beam.

Beam Support

The beam style support assembly consists of a solid square column and a cantilever I-beam. The Horizontal Beam will be mounted to the wall by two heavy duty hinges with 180 degrees of rotation. This will allow the I-beam to swing out to lift the castings from the appropriate bins. The I-beam is defined as a 4-inch-wide, 6.25-inch-high, and an 8-foot length size. This will allow for adequate reach and will accommodate the roller trolley that was chosen. The I-beam also has two perpendicular plates near each end to prevent the trolley from rolling off the end. Each wall mounted hinge will be affixed by 6 bolts in the pattern shown in drawing 20-0005.

Testing Method

In order to test the gripping mechanism, the sample hitch provided by NorthStar will be clamped by the grippers and held for an extended period of time. This testing will take place in Hogue. In order to test the pneumatic system with a known pressure.

Additional testing will be conducted at the NorthStar facility in Vancouver. This testing will be non-destructive. The welds of the primary structure will be tested visually by inspection by a qualified individual. The load will be applied to the structure once assembled, and deflections will be noted. Analyses have been conducted to predict proper deflection, and any variance from this would be cause for deeper inspection.

The efficiency of the new system will also be determined. By using data provided by NorthStar regarding how many parts can be finished per day per person without the assistance device, the team will compare the new number of parts that can be finished per day per person. This will allow if the lift has achieved its goal of increasing productivity. A learning curve will likely be present, and that will have to be kept in mind when evaluating this data. By excluding the first week of data, and ensuring the same employee is evaluated for consistency this can be negated.

The employees using the lift will also be asked to answer a few questions regarding their use of the lift. They will be asked the following questions:

1. Do you feel like there is less strain on your body after a full day's work compared to before the lift was installed?
2. Do you believe the lift is helping you to accomplish your daily tasks more efficiently?
3. Is the lift easily operable, and consistent?
4. Do you believe the addition of the lift was a benefit to you?

The hoist was tested by NorthStar employees in Vancouver to verify the requirements of lift speed of 16ft/min and a maximum load of 60lbs. A sample casting weighing 62lbs was attached to the hoist and it was lifted 3 feet from the ground. This process was timed to determine a lift speed. 16ft/min was used as the required lift speed due to the fact that it is the industry standard for this weight class. When testing, the time was recorded for six trials to ensure an accurate test. The times were consistent and only differed by a maximum of 0.39s. This variance was between 11.76s and 11.37s. This is an acceptable amount of variance for this test, and the team concluded that the results are viable. The testing determined that the lift speed was approximately 15.6ft/min. This is slightly lower than the 16ft/min that was expected because the hoist that was used was a used hoist. It was chosen to use this hoist to save on the budget. No issues were encountered during this test. The only complication organizing this test was timing, as an employee of NorthStar had to find a time when the hoist was not in use to be able to test it. Due to this, the test took several days to complete in its entirety.

Budget

NorthStar will be funding this project if approved. The following is a detailed budget of the required parts to make this project successful.

Part	Cost	Source
Wall mounted I-Beam support system	$935.48	McMaster-Carr
Electric Hoist with 50% work/ 50% rest rating	$2,089.63	McMaster-Carr
Manual Hoist trolley	$149.04	McMaster-Carr
Pneumatic gripper assembly	$257.01	Bimba
Single gripper jaw	$50.00	Cast
Double gripper jaw	$50.00	Cast
Mounting bolts	24.27	Home Depot
Total:	$3,531.16	

During manufacturing of this project, a hoist was found that NorthStar had already owned. This hoist was enough for the purposes needed, and saved NorthStar money. Additional changed to the budget include that the manufacturing process for the gripper jaws was changed. The jaws were originally going to be machined from a block of raw material. It because clear that having these parts cast would be more efficient. This means that the pattern needed to be created via 3D printing. This was a minimal cost, and the casting took place at NorthStar in Seattle. A second set of Jaws was created in order to accommodate different sized parts, effectively doubling the material used and increasing cost. The gripper Jaws were estimated to be $50 each, for two jaws, resulting in a total cost of $100. The 3D prints cost roughly $5 per print, for four prints. The casting done at NorthStar was done with scrap metal they had and was not needed to be purchased. This means that the cost was $20 for all, and the use of existing materials NorthStar had acquired.

Testing did not require the use of any additional budget expenditures, as all testing equipment and facility was provided by NorthStar. The testing only required basic measuring devices such as a stopwatch, scale, tape measure, and an employee to conduct the test. None of these needed to be purchased, and the employee was able to complete it within a reasonable amount of time to avoid any additional cost to NorthStar. Originally, a separate measurement device was discussed to measure the exact gripping force, but due to the cost of the device the team decided to use an alternative approach to collect adequate results.

Angular Grippers

MFD's Angular Grippers are robust, double acting or single acting grippers. An integrated variable flow valve allows for easy convenience to adjust the speed of opening and closing the gripping jaw. To help with installation, most grippers can be mounted from three different sides. Reed and solid state switches that fit into the side grooves are available separately.

- Bore Sizes: 6, 10, 16, 20, 25, 32mm
- Pressure Range on 6mm Bores: 22-100 PSI on double acting; 45-100 PSI on single acting
- Pressure Range on other bores: 15-100 PSI on double acting; 36-100 PSI on single acting
- Maximum Frequency: 180 cycles per minute
- M3x0.5 and M5x0.8 ports available
- All "in-stock" items ship the same day

Configuration Options

3D Preview | Dimensions | Download

Bore Size
25 ▼

Model
MHFY - Double Acting ▼

Select 'Generate 3D' below
to build a 3D Preview.

Configured Part Number

MHFY25

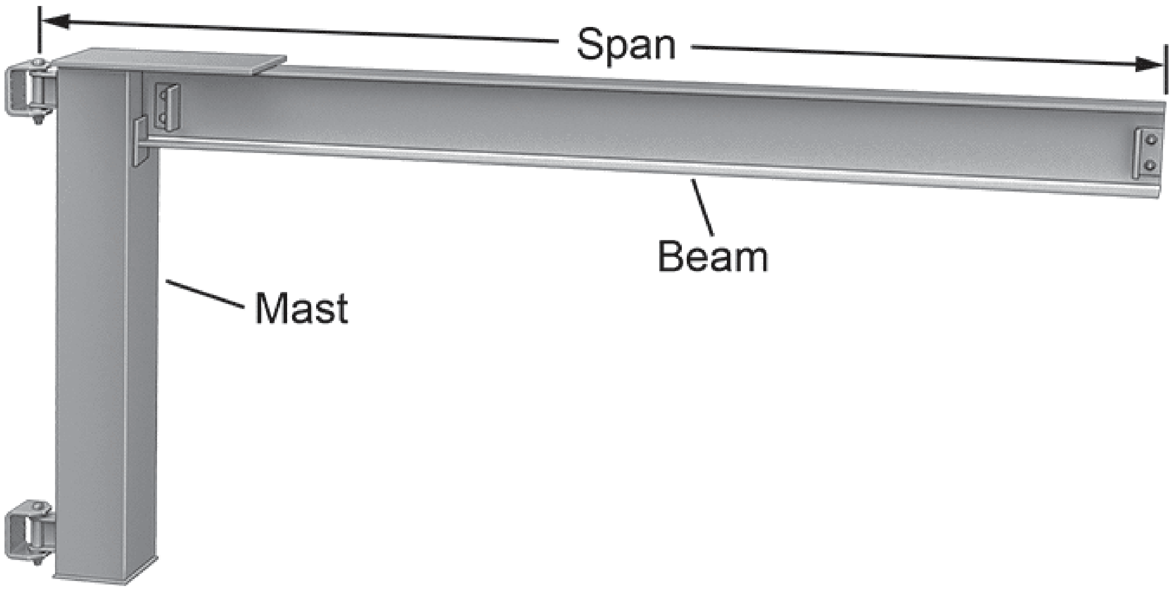
Generate 3D

powered by CADENAS PARTsolutions®

Part Number	MOQ	Estimated Ship Date	Price
MHFY25	1		* $257.01 each
* 15.5% Tariff Surcharge included in this product's pricing			**$257.01 total**

Column-Mount Rotating Crane

180 Degree Rotation with 8 Feet Span, 500 lbs. Capacity



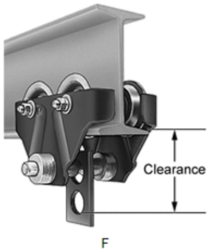
Each

ADD TO ORDER

In stock
$935.48 Each
3729T65

Application	For Lifting
Mobility	Stationary
Mounting Location	Column
Rotation	180°
Span	8 ft.
Capacity	
tons	1/4
lbs.	500
Thrust/Pull Force	1,290 lbs.
Overall Height	4'9"
Beam	
Width	4"
Height	6 1/4"
Style	Open Track
Material	Yellow Painted Steel

Hoist Trolleys



Transport hook-mount hoists along a beam. Trolleys **with mounting bar and eye** allow you to remove the mounting eye and use the mounting bar for applications that require lower clearance.

Trolleys **with spacing washers** can accommodate a range of beam widths; add or remove the washers to fit.

Wheel bumpers protect wheels from collisions with other equipment on your beam.

Warning: Never use to lift people or items over people.

CAD For technical drawings and 3-D models, click on a part number.

With Mounting Bar and Eye

	Capacity		For Beam											
	tons	lbs.	Shape	Wd.	Min. Ht.	Clearance	Min. Curve Radius	Wheel Material	Eye Dia.	Bar Thick.	Adjustment Type	Features		Each
Steel														
F	1/2	1,000	Flat, Tapered	2 3/4"-4 1/2"	4"	2", 6"	24"	Cast Iron	1 1/2"	3/8"	Spacing Washers	Wheel Bumpers	3269T52	$149.04

CM Lodestar NH Electric Chain Hoist

30 Mins./hour, 275 lb. Capacity, 32 fpm

Voltage (Power Source)
✓ 120V AC (Plug In)

Lift Length, ft.
✓ 10

Each

ADD TO ORDER

In stock
$2,089.63 Each
3316T962

Application	For Lifting
Hoist Type	Chain
Operation Type	Button
Mount Type	Hook
Duty Cycle	50% Lifting/Lowering, 50% Rest
Maximum Continuous Run Time	30 min.
Capacity	
tons	1/8
lbs.	270
Lifting Speed	32 fpm
Clearance	14"
Hook Opening Width	1"
Plug Type	Three Prong
Electrical Phase	Single
Brake Type	Electromagnetic
Body	
Width	18 3/4"
Depth	8 3/4"
Body Material	Aluminum
Chain Material	Steel
Hook Material	Steel
Manufacturer	CM
Manufacturer Series	Lodestar NH

Robtec >

5/8 in. x 8 in. Zinc-Plated Grade 5 Hex Bolt (4-Pack)

Write the first Review Ask the first question

$8.09

Save up to $100 on your qualifying purchase.
Apply for a Home Depot Consumer Card

Overview

These Grade 5 cap screws are blue zinc plated and are recommended for medium duty bolting applications. The grade 5 bolt is compatible with grade 5 and grade 8 mating nuts and washers of the same thread pitch and diameter. ... See Full Description

Schedule

The Gantt chart for this project can be found in Appendix E and outlines the timeline for this project. The Gantt chart identifies the different tasks that need to be accomplished as well as the estimated time to complete them. The milestones are denoted with diamonds to show when they need to be completed, and the X's on the timeline represent current progress toward the individual task. It is estimated that the total project will take 158.5hrs, with 75 of them being finished at this time.

The schedule is lined up in a way that the individual part manufacturing and assembly will be finished by the end of winter, so that spring can be devoted to testing and optimizing the design to work in the best way that it can. The schedule also allows for flexibility in the event of unforeseen complications that may arrive.

The schedule was delayed in part due to an inability to manually machine the gripper jaws, as per the team's original plan. A CNC option was offered, however due to a lack of experience the team decided to have the jaws cast. This meant that a pattern was needed, and this was created by 3D printing the SolidWorks parts. These parts will remain loose and will be cast using a green sand mold. After being cast, the parts will still need to be machined, in order to accommodate the mounting slot to attach them to the pneumatic gripper purchased from Bimba.

An unexpected change regarding the gripper jaw material was made. This change meant that a last minute re design was required. A new model was made and printed. This model was then shipped to Seattle to be cast. Unfortunately, all of this had set the project behind by two weeks, due to printing and shipping times. The new pattern was shipped to NorthStar to be cast on 03/16/2020.

Testing went according to schedule with modification to adjust for the modified testing logistics due to limited travel. There was concern from the team due to the fact that no testing was able to be completed by team members, however with the help of NorthStar's employees the testing phase was able to be successfully completed within the desired timeline. By planning ahead and sending testing procedures several days in advance, the team was able to clarify testing procedures before testing was to be completed to avoid delays. The data provided was able to be processed and analyzed within a day of receiving it from NorthStar. This allowed for all testing facets to be completed in a timely manner, in order to be presented to applicable parties when needed.

Discussion

This design has evolved over the course of its development. It shifted from an over mounted cross beam to a mounted rotating support. The beam stayed as an I-beam to accommodate the pull trolley for the electric hoist. This allows for another degree of motion, making it a more flexible setup.

The pneumatic gripping mechanism had to undergo a change as well. Originally, calculations were done to find the required gripping force for standard straight gripping jaw. This calculation resulted in a value unreasonably high. In order to create a lower required gripping force, the jaws were designed to increase the gripping arm length and to apply the force in an upward direction, rather than downward.

When manufacturing the gripper jaws, originally traditional machining methods were intended. This unfortunately was not a viable option due to the geometry and tolerances of the part. A CNC mill option was recommended, however because of the limited time and lack of training regarding CNC coding, the team decided it would be better to have it cast. Patterns were created by 3D printing, and those patterns were supplied to NorthStar's Seattle plant to undergo manufacturing. The cast part was to be cast with a mild steel so that it could still be machined afterwards, in order to mill the mounting slot seen in the drawings. Mild steel was chosen because the other option available, a proprietary manganese steel, would not be easily machinable.

After attempting to cast the grippers, NorthStar ran into a problem with a mild steel alloy availability. In order to cast with any given alloy, a minimum of 1500lbs must be met for the heat. The demand for a mild steel was not met, so it was recommended that the team used an aluminum to cast the grippers. In order for the jaws to be successful the jaws needed to be modified dimensionally. The grippers were made to be 50% wider, with a larger fillet and slight draft. The fillet and draft were added in order for the pattern to be easily removed from the sand after a mold was made. Without these features, patterns generally get stuck and it makes the casting process more difficult and less successful. The additional width was required to maintain the safety factor implemented into these parts. Due to the fact that the aluminum is not as rigid as steel, deflection had to be evaluated with more regard.

The team did have some concerns regarding the use of aluminum instead of steel for this part. The primary concern was due to the fact that this would make the gripper material significantly softer than the gripped part. The gripped parts are cast with a specific manganese steel that is desired because of its strength and durability in industrial applications. Additionally, these parts are not smooth and may have sharp points and corners. These sharp points and corners are a cause for concern due to the fact that they could deform the aluminum and reduce its life. When gripping it, these points will cause divots and gashes on the inside of the material. While this will not have sudden effects, it is suspected that it will lead to a reduced life span of the gripper and could potentially allow the part to slip from its grasp. These concerns were expressed to a mentor at NorthStar and were put to ease because this will only be a prototype. If successful, the jaws will be replaced with steel when the demand is appropriate to do so.

The actual pattern was used with the use of a removable ram-up block to put behind the curvature of the gripper. This block matched up with the part and was able to prevent it from bending and cracking when sand is packed in on top of it. The pattern is then flipped, and these blocks are removed in order for the other side to be packed full of sand. Additionally, a wooden board was made to match up with the pattern in order to define the center split of the sand mold. This split is not flat, which is why a custom board was required.

The testing of the pneumatic gripper was successful with minimal issues. It was tested in several stages. First the hoist was tested for maximum load and lift speed. Then gripping strength was tested. It was tested with two methods. First the gripper was tested by simply lifting the intended castings and ensuring that it worked as expected. After the success of this test, the gripper was tested with a force sensor to measure how many pounds of force the gripper was exerting in the horizontal direction. All tests were conducted by NorthStar employees with directions the team provided to them. The employee acquires appropriate data and reports it to the team for analysis.

During testing no major problems were encountered to achieve success. The three tests conducted verified success criteria for all requirements. Test one verified that the deflection was within an appropriate range, and that the system would support the maximum load required. Test two verified the lift speed reported by the manufacturer for the hoist being used. This resulted in a value slightly lower than expected, but still enough for its application. Test three determined the mobility of the hoist trolley and rotating support beam. It determined that the hoist was able to reach all necessary places without any adjustment. The testing was completed within the desired timeline. Modifications will be made in the future to optimize the design further, however the design is successful in solving the problem initially presented to the team by NorthStar.

Conclusion

This project will be a success for the following reasons:

Cost

The cost of the majority of this project will be covered by NorthStar if approved. This project is funded by NorthStar as it will benefit them, and they will own the mechanism once it is created. The client has requested that the budget is submitted before it is approved, however if edits need to be made, they can be. This will ensure that the project will be completed in a reasonable amount of time without concern for funding acquisition.

Time

The time required to construct the project is outlined under the schedule heading of this report and detailed in the Gantt chart in Appendix E. Time has been allocated to finish the project ahead of schedule, and if any unforeseen complications arise, there is enough time to navigate around it. With the support of the NorthStar employees, this project will have enough man hours put toward it to make it a reality.

Motivation

Both NorthStar and the team are motivated to complete this project. NorthStar requires a solution to the employee welfare and production speed. The success of this project will solve these problems, and allow NorthStar to gain additional profits, making it a priority in their business. For the team, the success of this project represents a significant part of their degree and Capstone class. The team is motivated to aid NorthStar additionally in order to build good rapport with the business for future potential collaborations that may arise.

Acknowledgement

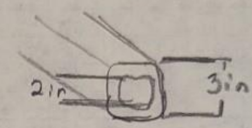
The Team would like to give thanks to the follow people for their continued support of this projects. Kurt Gray, President of NorthStar, has been a significant factor in the success of this project. His continual support and input have helped shape the project into a successful solution to their problem. Additionally, Kurt Gray has been the primary source for project funding, making this project possible. Professor Ted Bramble, Matt Burvee, Dr. Craig Johnson, Dr. John Choi, and Professor Charles Pringle have all be significant aids in this project as well with guidance for analyses and potential solutions. The input given by these advisors had helped create a more efficient solution for the client than could have been possible without.

CWU facilities were used for the creation and testing of this project. This project was made possible by CWU's machine shop and education spaces.

Appendix A: Analyses

Jacob VanBlaricom 10/24/19

Given: hollow steel bar, square
dimensions as shown
6 ft long
A-36 steel



Assume: Homogeneous
constant cross section

Find: cross section Area
weight of beam

Solution:

$A = d^2 - D^2$

$= (3\,in)^2 - (2\,in)^2$

$= 5\,in^2$

$V = AL$

$= (5\,in^2)(6 \cdot 12\,in)$

$= 360\,in^3$

density from matweb: $.284\,lb/in^3$

$m = \rho V$

$= 0.284\,lb/in^3 \cdot 360\,in^3$

$m = 102.2\,lb$

$W = mg$

$= 102.2\,lb \cdot 32.2\,ft/s^2$

$W = 3291\,lb_f$

A 1

Jacob VanBlaricom | 11/1/19

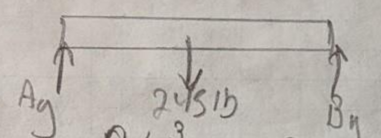
Given: A-36 steel
S3x7.5 I beam - 6 foot

Find: Max deflection of beam

Assume: Isentropic
Max beam load = 245 lbs
homogeneous

Method: 1.) FBD
2.) Find I
3.) deflection

Solution:



$I = 2.93\,in^4$
$E = 29\,msi$

$$y_{max} = \frac{-PL^3}{48EI} = \frac{-245\,lb \cdot 72^3\,in}{48(29\,msi)(2.93\,in^4)}$$

$$y_{max} = -22 \cdot 10^{-3}\,inches$$

$= 0.022\,in$

A 2

Jacob VanBlaricom | 10/29/19

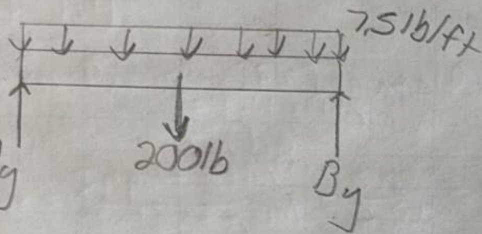
Given: A-36 steel
S 3 x 7.5 I beam - ~~6ft~~ long

Find: Max shear stresses

Assume: Max load = 100 lb_f
homogeneous
hoist weight = 100 lb_f

Method: 1.) FBD
2.) equilibrium
3.) symmetry
4.) stress

Solution:

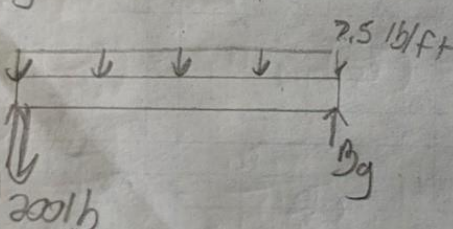


$\Sigma F_y = 0$

$0 = A_y + B_y - 200 - (7.5 \cdot 6)$

$A_y + B_y = 245$

$A_y = B_y = 122.5 \, lb_f$



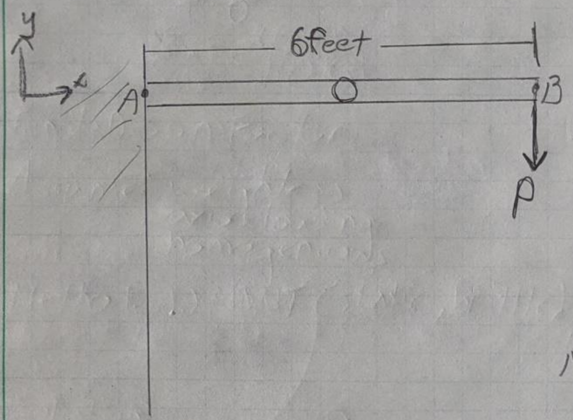
$\circlearrowleft + \Sigma M_{B_y} = (A_y \cdot 6) - (200 \cdot 6) - (45 \cdot 3)$

$A_y = 222.5 \, lb$

$\tau_{max} = \frac{P}{A} = \frac{222.5 \, lb}{2.21 \, in^2} = 100.7 \, psi$

A 3

Jacob VanBlaricom | 10/16/19



Given: P = 30lbs

A is fixed support

Assume: homogeneous

isentropic

weightless

Find: Max moment

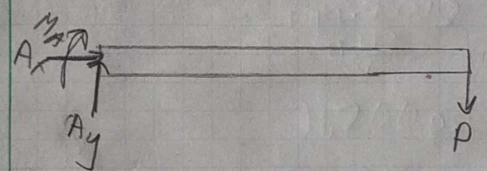
Max shear stress

Method: 1.) FBD

2.) Equilibrium

3.) V & M

Solution:



$\rightarrow \Sigma F_x = 0$

$A_x = 0$

$\uparrow \Sigma F_y = 0$

$A_y - P = 0$

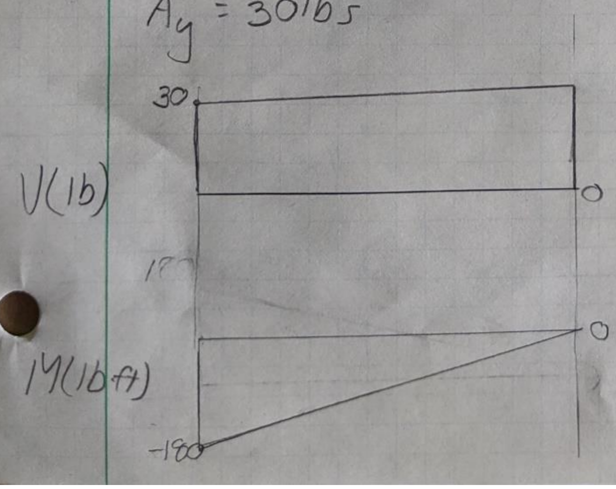
$A_y = 30lbs$

$\circlearrowleft \Sigma M_A = 0$

$M_A - (P \cdot 6ft) = 0$

$M_A = 30lb \cdot 6ft$

$M_A = -180lb \cdot ft$ ccw



A 4

Jacob VanBlaricom | 11/08/19

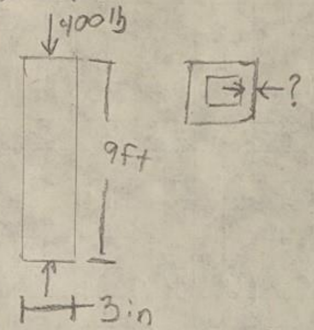
Given: A-36 steel
9-ft long square beam
400 lb load

Find: thickness required to prevent buckling

Assume: homogeneous, isentropic, axial loading, fixed ends

Method: 1.) FBD
2.) assume cross section
3.) caucnlate I

Solution:



Assume euler

$P_{cr} = \frac{\pi^2 E A}{\left(\frac{KL}{r}\right)^2}$

$E = 29 msi$

$k = .65$

$L = 9ft$

use thickness of .25 in

$A = 2.9 in^2$

$400 = \frac{\pi^2 (29 \cdot 10^6) 2.9}{\left(\frac{.65 \cdot 108}{r}\right)^2} \Rightarrow \left(\frac{.65 \cdot 108}{r}\right)^2 = 2.075 \cdot 10^6$

$r = 48.73 \cdot 10^{-3}$

$r = \sqrt{\frac{I}{A}}$

$48.73 \cdot 10^{-3} = \sqrt{\frac{I}{2.9}}$

$I = 6.887 \cdot 10^{-3}$

$I = \frac{BH^3}{12} - \frac{bh^3}{12}$

$B = H \quad b = h$

$I = \frac{B^4}{12} - \frac{b^4}{12}$

$6.887 \cdot 10^{-3} = \frac{3^4}{12} - \frac{b^4}{12}$

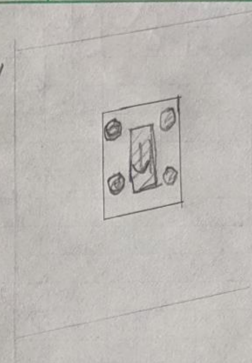
$b = 2.999 in$ ✓

A 5

Jacob VanBlaricam | 10/17/19

Given: Shear force = 30 lb
18-8 stainless steel - AISI 304

Find: appropriate bolt diameter



Assume: homogeneous
static loading
we will use 4 bolts
weightless beam

Method: 1.) FBD
2.) Material properties
3.) stress

Solution:

· AISI 304 stainless steel
$\sigma_y = 31.2\ ksi$
$\sigma_u = 73.2\ ksi$
$E = 28.5\ ksi$

$+\uparrow \Sigma F_y = 0$
$R_y = 30\ lb$

$\sigma = \frac{P}{A} < \sigma_y$

$31.2\ ksi = \frac{30\ lb}{4A}$

$A = 240.38 \cdot 10^{-6}\ in^2$ ← Area per bolt

$A = \frac{\pi}{4} D^2$

$240.38 = \frac{\pi}{4} D^2$

$D = 17.49 \cdot 10^{-3}\ in$

A 6

Jacob VanBlaricom | 10/24/19

Given: Dimensions as shown

Assume: homogeneous
isentropic
No forces in x

Method: 1.) FBD
2.) Equilibrium
3.) V & M

Find: Max shear and moment

Solution:

(see previous analysis) — $W = 3291\,lb$

$\frac{W}{L} = \frac{3291\,lb}{6\,ft} = 548.5\,lb/ft$

$\Sigma F_y = -3291 - (100 \cdot 32.2) + R_A + R_B = 0$

$R_A + R_B = 3291 + 3220$

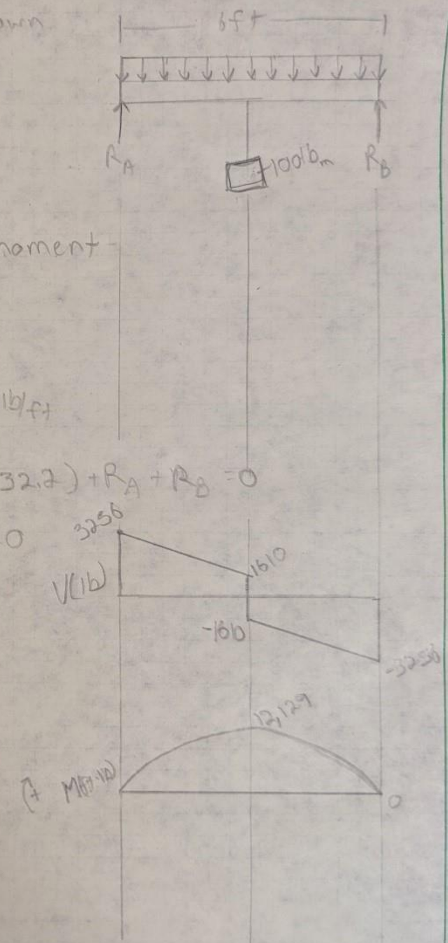
$2(R_{A/B}) = 6511\,lb$

$R_{A/B} = 3256\,lb$

$\sigma_{max} = \frac{P_{max}}{A}$

$\sigma = \frac{3256\,lb}{5\,in^2}$

$\boxed{\sigma = 651.2\,psi}$



A 7

Jacob VanBlaricom | 12/2/19

Given: required friction per arm is 25lb,

Find: required gripping force

Assume: Clean environment

$\mu_s = .3$ - steel on cast iron

Method: 1.) FBD

2.) friction force

Solution:

$f_s = 25lb = \mu_s N$

N = gripping force horizontally applied

$25lb = .3N$

$N = 83.3lb$ — Too high

$\uparrow f_s(2) = \mu_s N$

$\downarrow$

50lb

A 8

Jacob VanBlaricom

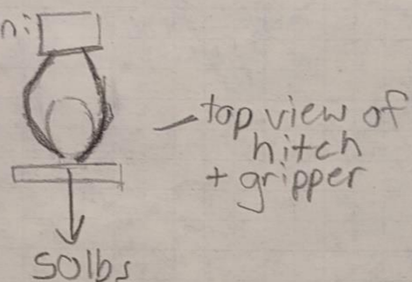
Given: Gripping force of 12lbs, 50lb load

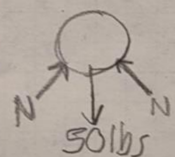
Find: Force acting on Jaws

Assume: no slip conditions
Force acting at 45°

Method: 1.) FBD
2.) equilibrium

Solution:





$\Sigma F_y = 0$

$0 = 2(N \sin 45) - 50$

$N = 35.36 \text{ lbs}$

* need to increase gripping force.

A 9

Jacob VanBlaricom

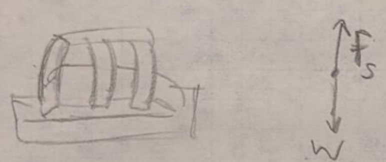
Given: 50lb part
three 1/2in grippers

Find: required friction force

Assume: contact area of 1/4 in by 1/2 in per gripper

Method: 1.) FBD
2.) equilibrium

Solution:



$W = 50lb$

$\Sigma F_y = 0$

$0 = -50lb + f_s$

$f_s = 50lb$

$f_s/\text{gripper} = 16.67lb$

A 10

Jacob VanBlaricom

Given: $\mu_s = .3$, smooth steel gripper

Find: required bore size

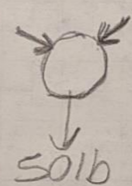
Assume: dry and clean gripper, 80psi system

Method: 1.) FBD

2.) equilibrium

3.) pneumatic force

Solution:



$\Sigma F_y = 0$ (N·.3)

$0 = f_s - 50lb - N\sin 30$

$50 = .3N - N\sin 30$

$50 = N(.3 - \sin 30)$

$N = 250$

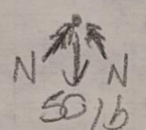
$F = P \cdot A$

$250 = 80psi \cdot \frac{\pi}{4} d^2$

$d = 1.99in$

Jacob VanBlaricom | 12/2/19

Given: required gripping force of 35.36 lbs
Find: required bore size.
Assume: clean conditions, 80 psi system
Method: 1.) FBD
2.) equilibrium
3.) bore size
Solution:



* gripping force of 35.36 lbs

$F = P \cdot A$

$35.36 lb = 80 \, lb/in^2 \cdot A$

$A = .442 \, in^2$

$\frac{\pi}{4} d^2 = A$

$.442 \, in^2 = \frac{\pi}{4} d^2$

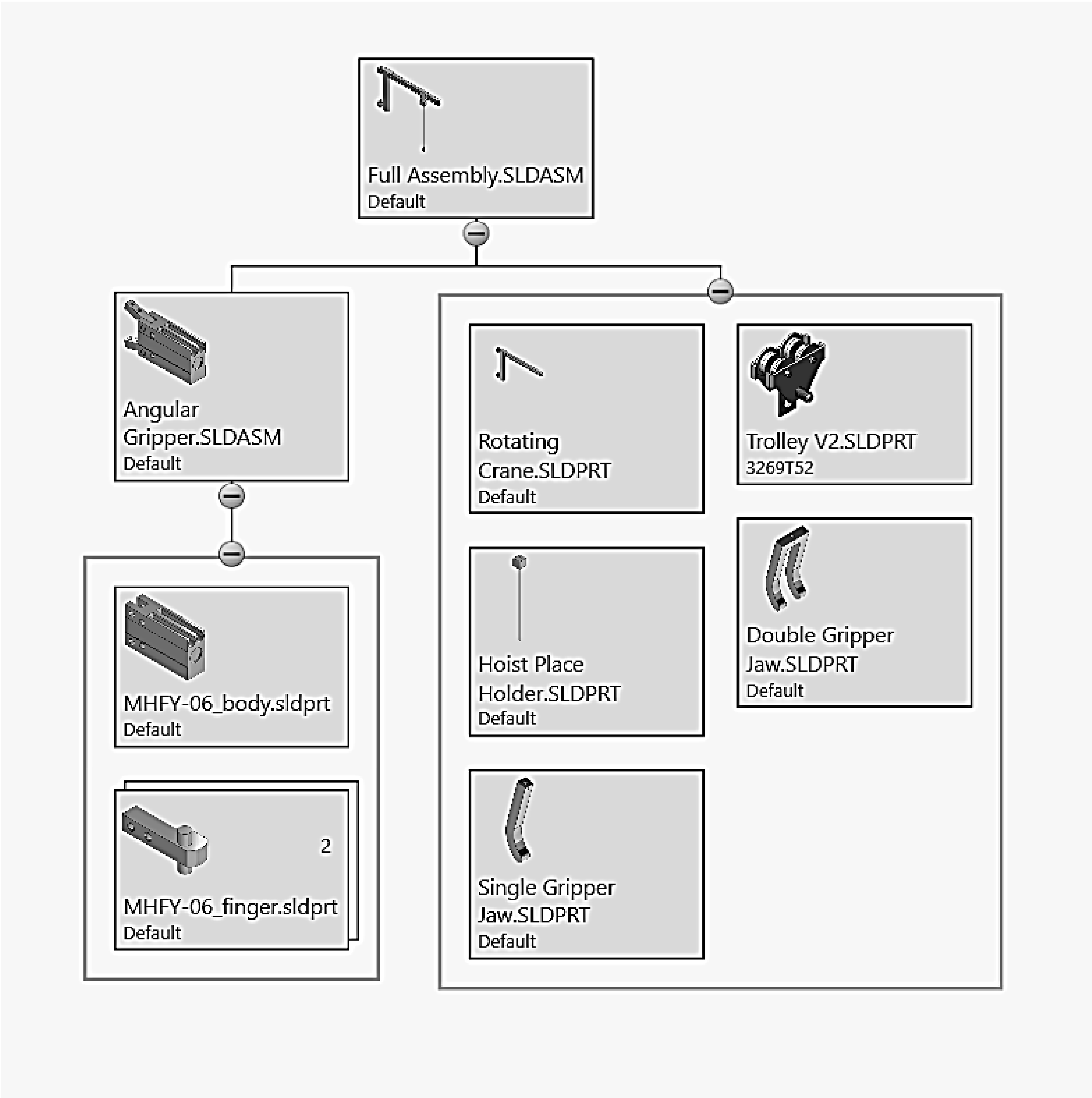
$d = .75 \, in$

$1 \, in = 25.4 \, mm$

$.75 \, in \cdot 25.4 \, mm/in =$ **19.05 mm bore**

Appendix B: Drawings

Drawing tree



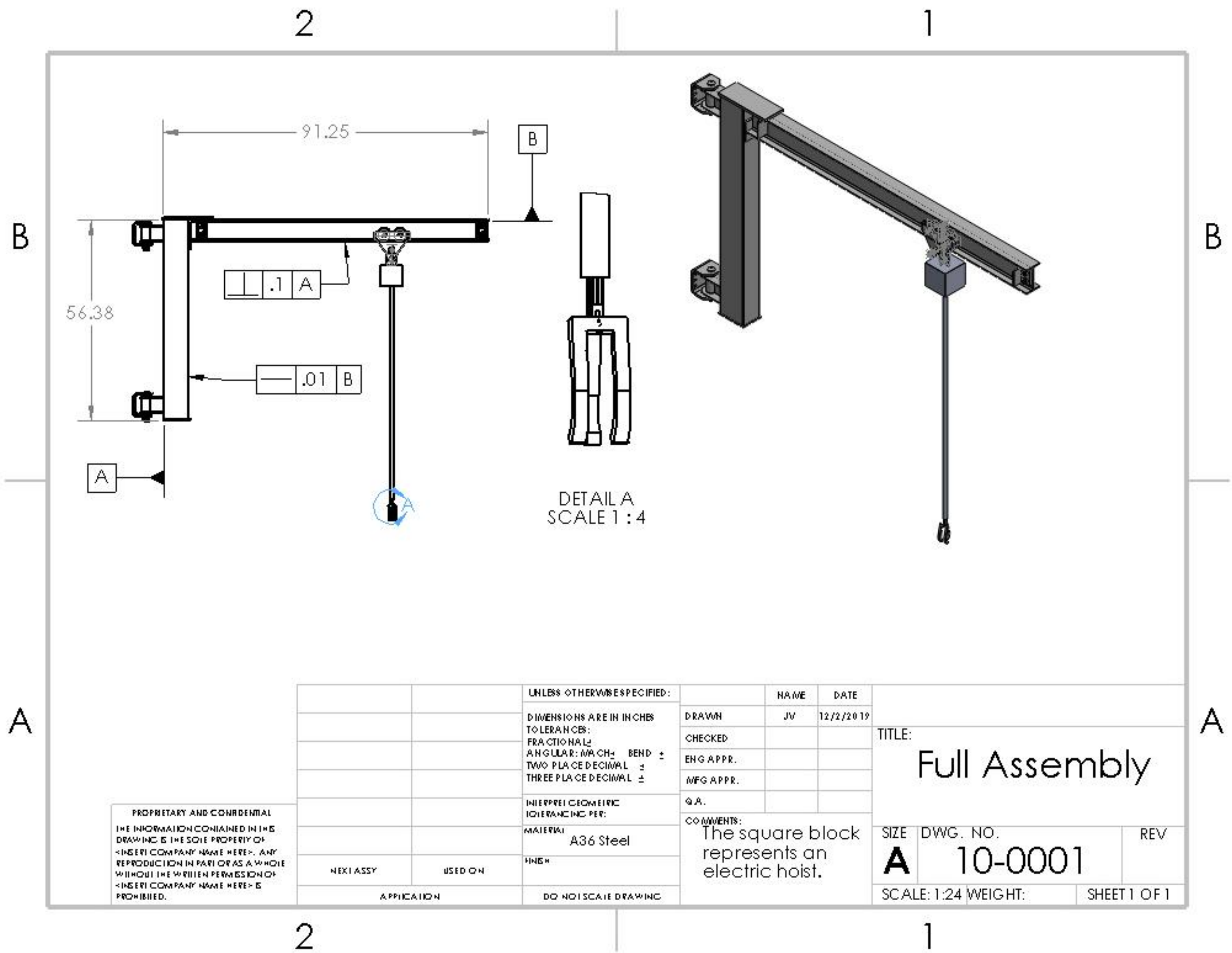


Figure 2 10-0001

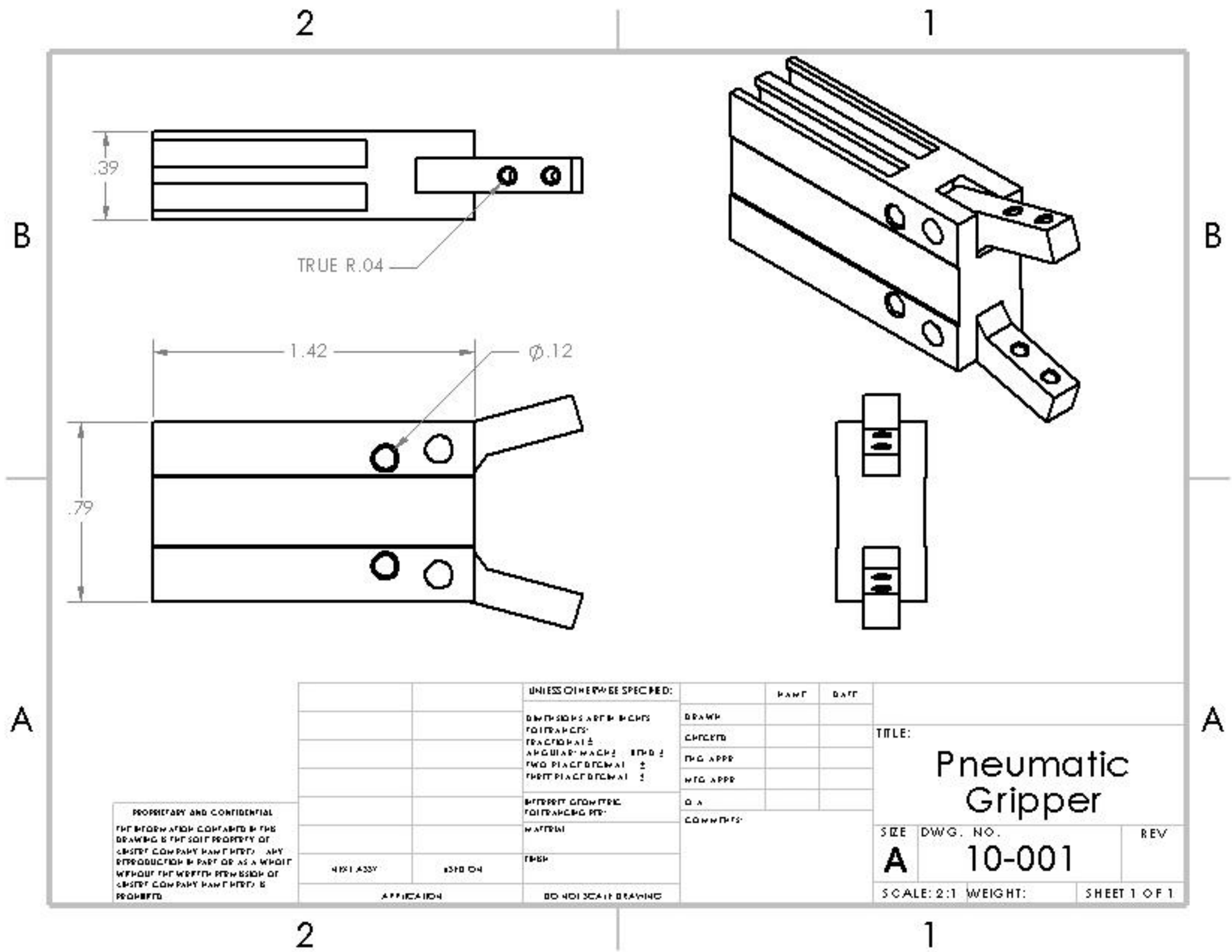


Figure 3 10-0002

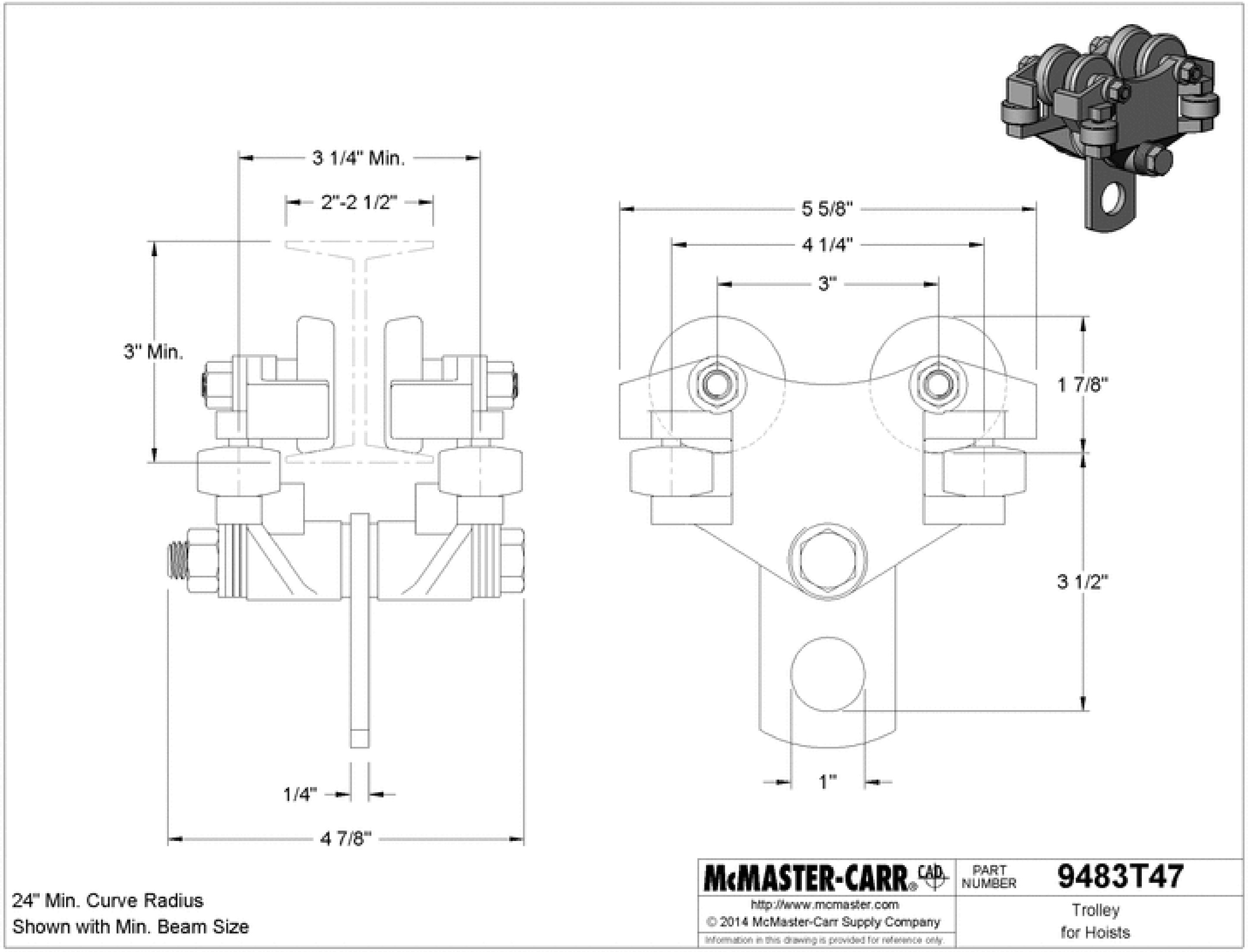


Figure 4 10-0003

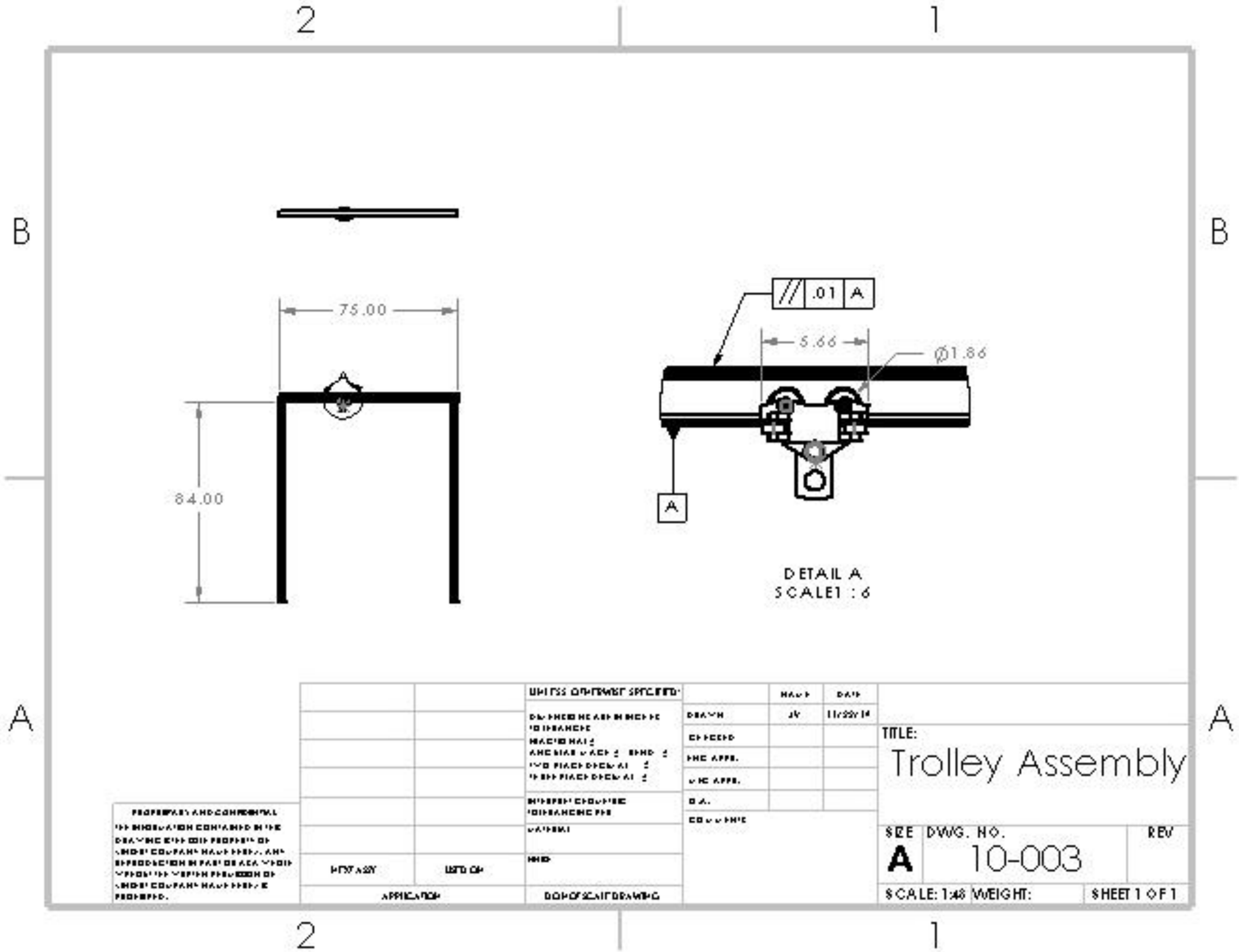


Figure 5 10-0003

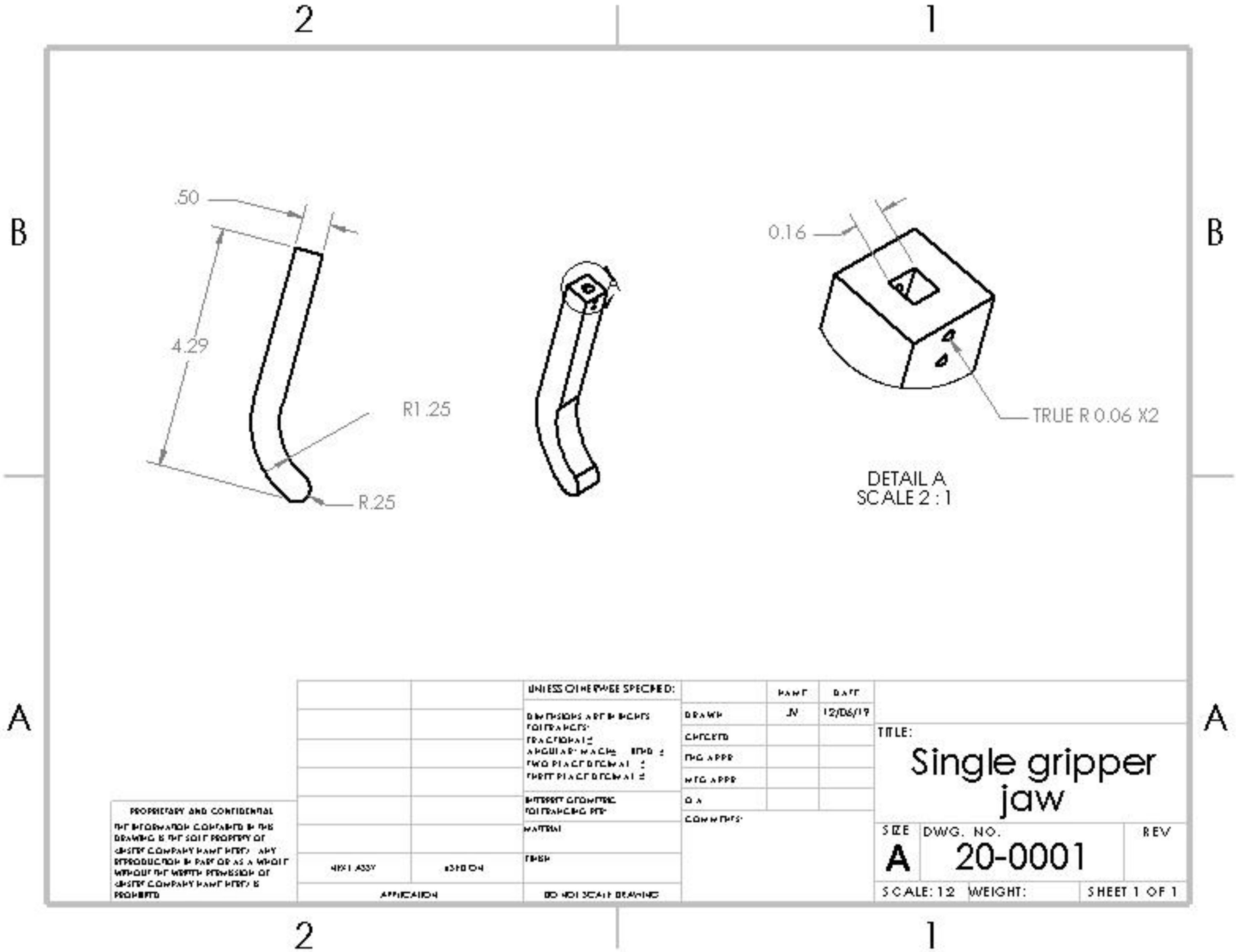


Figure 6 20-0001

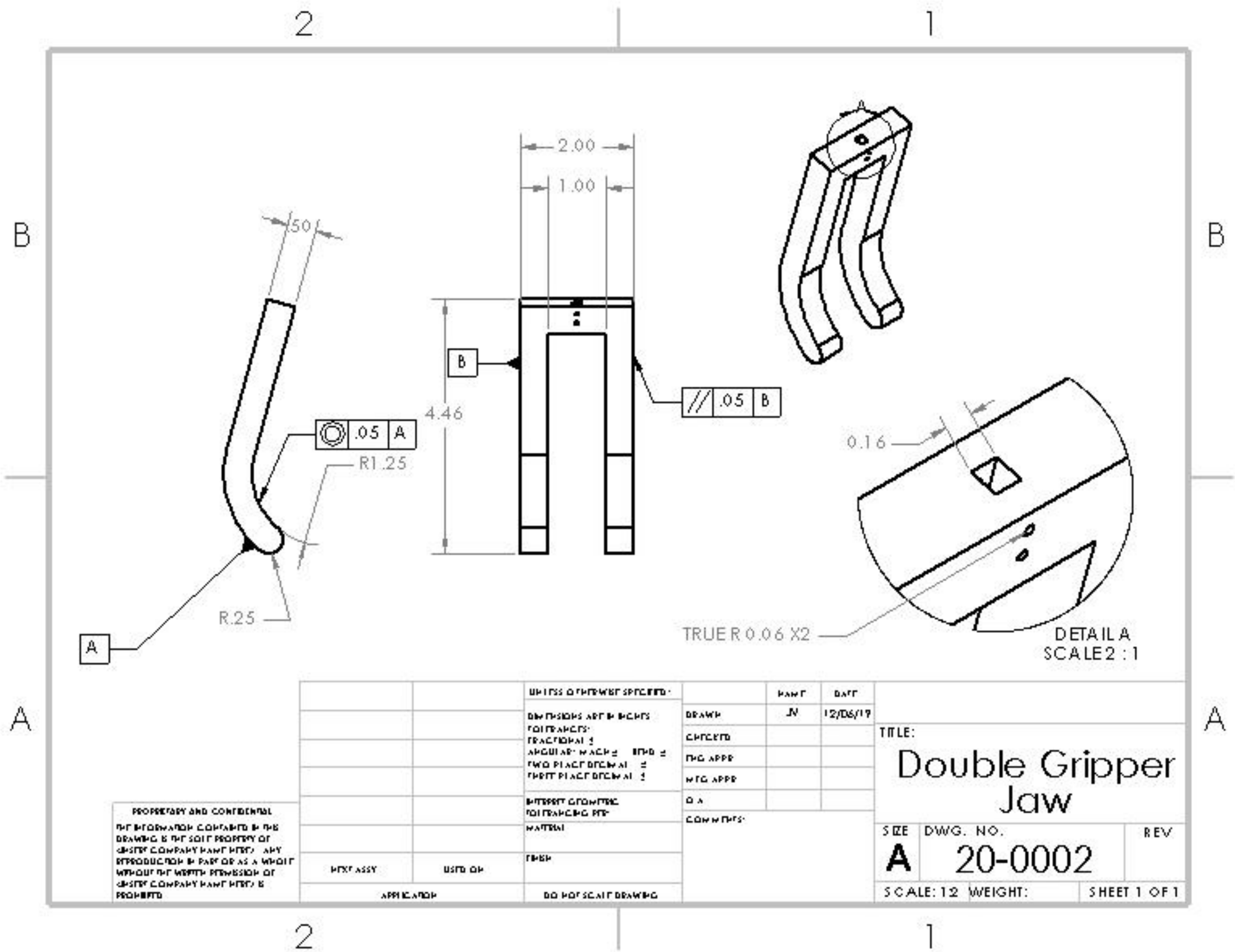


Figure 7 20-0002

Appendix C: Parts List

Parts required:

- Wall mounted I-Beam support system
- Electric Hoist with 50% work/ 50% rest rating
- Manual Hoist trolley
- Pneumatic gripper assembly
- Single gripper arm
- Double gripper arm

The above parts will be purchased from online vendors with the exception of the gripper arms. The gripper jaw arms will be cast at NorthStar, and the patterns for these will be created at CWU by the team. The online vendors used were McMaster-Carr and Bimba. Additional mounting equipment such as nuts and bolts will be purchased from home depot when needed.

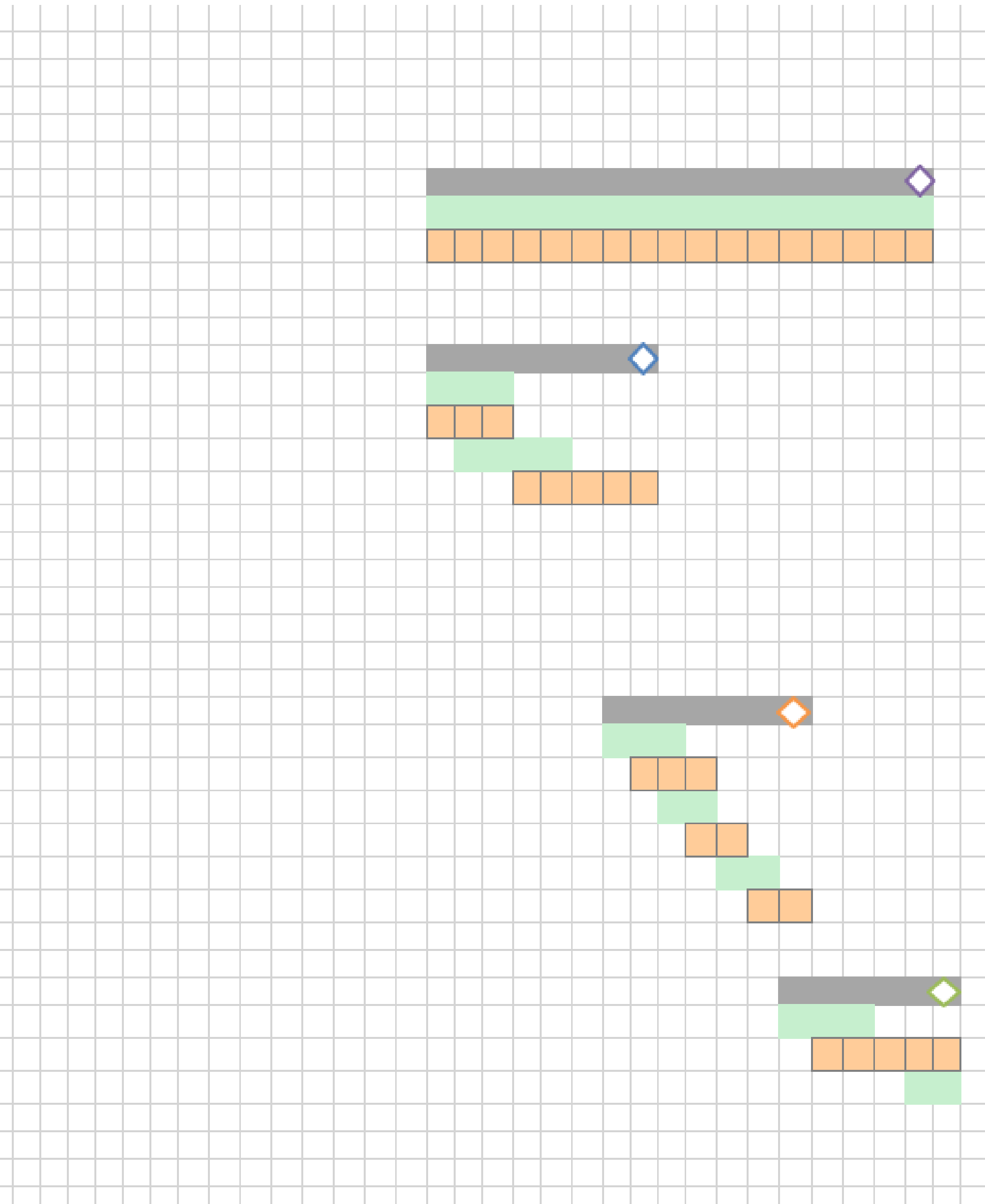
Appendix D: Budget

Part	Cost	Source
Wall mounted I-Beam support system	$935.48	McMaster-Carr
Electric Hoist with 50% work/ 50% rest rating	$2,089.63	McMaster-Carr
Manual Hoist trolley	$149.04	McMaster-Carr
Pneumatic gripper assembly	$257.01	Bimba
Single gripper jaw	$50.00	Cast
Double gripper jaw	$50.00	Cast
Mounting bolts	24.27	Home Depot
Total:	$3,531.16	

Appendix E: Gantt Chart

TASK: ID	Description	Est. (hrs)	Actual (hrs)	%Comp.	S	October	November	Dec	January	February	March	April	May	June
1	Proposal*													
1a	Outline	2	1			X X X	X							
1b	Intro	2	3			X X	X X							
1c	Methods	3	2			X	X X							
1d	Analysis	3	4				X X							
1e	Discussion	3	2				X X X							
1f	Parts and Budget	3	2				X X X							
1g	Drawings	12	12				X X X	X						
1h	Schedule	3	3				X X	X						
1i	Summary & Appx	2.5	2				X X	X						
	subtotal:	33.5	31											
2	Analyses													
2a	Heat Trans=>Geo	2	0				X X							
2b	Stress Anal=>Geo	20	20				X	X X	X X X					
2c	Power Anal=>Geo	4	2				X X							
2d	Kinematic => Geo	2	6				X X X							
2e	Tolerance => Geo	4	2						X X X					
	subtotal:	32	30											
3	Documentation													
3a	Website	10	0											
3b	Support Beam Drawing	2	2				X X X X							
3c	Hoist Drawing	2	1				X X X	X						
3d	Trolley drawing (modification)	1	4				X X	X X						
3e	Gripper drawing	2	3				X	X X	X					
3f	Single Jaw Drawing	2	2					X X	X X					
3g	double Jaw drawing	2	2											
3h		0	0											
3i		0	0											

3j		0	0
3k		0	0
3l		0	0
3m		0	0
	subtotal:	21	14
4	Proposal Mods		
4a	Optimizations	8	0
4b	Client requests	4	0
4c		0	0
	subtotal:	12	0
7	Part Construction		
7a	Trolley assembly	6	0
7b	Jaw connection	3	0
7c	Jaw manufacturing	5	0
7d	Pneumatic mount machining	4	0
7e		0	0
7f		0	0
7g		0	0
7h		0	0
7i		0	0
	subtotal:	18	0
9	Device Construct		
9a	Beam Support Mount	8	0
9b	Trolley connection	4	0
9c	Hoist attachment	3	0
9d	Electric connection for hoist	4	0
9e	pneumatic connection for gripper	4	0
9f	controller installation	2	0
	subtotal:	25	0
10	Device Evaluation		
10a	Visual Inspection	4	0
10b	Load inspection	2	0
10c	Effectiveness Analysis	2	0
10d		0	0
10e		0	0
10f		0	0
10g		0	0



10h		0	0	
10i		0	0	
10h		0	0	
	subtotal:	8	0	
11	<u>495 Deliverables</u>			
11a	Get Report Guide	0	0	
11b	Make Rep Outline	0	0	
11c	Write Report	0	0	
11d	Make Slide Outline	3	0	
11e	Create Presentation	6	0	
11f	Make CD Deliv. List	0	0	
11e	Write 495 CD parts	0	0	
11f	Update Website	0	0	
11g	Project CD*	0	0	
	subtotal:	9	0	
	Total Est. Hours=	158.5	75	=Total Actual Hrs
Labor	100	15850		
Note:	Deliverables*			
	Draft Proposal			
	Analyses Mod			
	Document Mods			
	Final Proposal			
	Part Construction			
	Device Construct			
	Device Evaluation			
	495 Deliverables			

Appendix F: Expertise and Resources

Kurt Gray has been a good source of industry knowledge for this project. Additionally, Tim Craig and Travis Lambert have been of help when seeking advice with regard to pattern design. The input from NorthStar has aided the design significantly. CWU mentors Craig Johnson, Charles Pringle, John Choi, and Ted Bramble have also been a source for aid in designing this project. Dr. Craig Johnsons experience in foundry settings has been particularly helpful, as well as Professor Ted Brambles knowledge of pneumatics. The resources that the team utilized at CWU are; the CAD software installed in computer labs, and machine shop, materials lab materials and space, 3D printing capabilities, and other general education workspaces.

Appendix G: Testing report

Introduction:

Requirements

- Lift 60lbs
- Attach/detach to casting in less than 15sec
- Rotates at least 180 degrees
- Can endure 8 hours of continual operation daily
- Traverse a distance of 10ft in an arc
- Capable of reaching the ground
- Capable of lifting up to 6ft high
- Can lift a casting 3 feet in 15 seconds

Parameters of interest

The parameters of interest for each requirement are as follows. The parameter of interest for the weight requirement is the deflection of the beam and the grip force. The parameter of interest with lifting and attaching to the casting is time. The parameter of interest for all other requirements are physical measurements and were tested qualitatively.

Predicted performance

It was predicted that the deflection of the beam would be unnoticeable, and that the gripper would hold together at the maximum weight. These calculations can be seen in Appendix A of the Senior Project Report. The values for these calculations are a gripping force of 35.4 lbs and a deflection of 0.02in. The rotating beam design, with hoist trolley led to appropriate degrees of movement to meet all of the motion-based requirements. The hoist used was rated to lift with a rate that meets the requirement and with the workload needed.

Data Acquisition

All data was collected by NorthStar employees and reported to the team digitally due to an inability to travel at this time. The data was collected using smartphone timers, tape measure's, photograph, and qualitative judgement. The deflection was measured using photographs, just to verify that it was not a noticeable amount of movement. The lift speed and clasping speed were measured using a smartphone timer. Degrees of movement were measured using a tape measure, to verify it is at the appropriate height and that it can reach all necessary bins. The employees were in direct contact with the team to ensure that testing procedures were clear, and data was being collected appropriately. Testing the gripping strength was difficult as proper force measuring devices were not readily available. In order to test gripping strength, several castings of varying weight were lifted to verify gripping strength is enough.

Schedule

The testing all went according to an improvised schedule due to changes caused by a pandemic that limited travel. Employees were tasked with completing testing and were able to do so withing the week instructions were received. All testing was finished by 05/11/2020 and reported to the team. The team was able to analyze and compile all data by 05/15/2020. This allowed the team to report it on time to all parties.

Method/Approach

Resources

Resources utilized by the team for testing were provided by NorthStar. These resources include a facility to conduct tests in, employees to conduct tests, measuring equipment (tape measure/timer/scales), and mentors to help analyze data. Data gathered by the employees was transmitted to the team after following specific instruction given by the team.

Test procedure overview

The first test was intended to determine that the gripping force exerted is sufficient for the use of this device. The device will be used to grip the cast part, as intended, and then lifted 4 feet from the ground. The tester will verify physically that the part is firmly grasped and will not slip out under any reasonable force. The only resources needed will be the device and a sample cast part from NorthStar's manufacturing line. This was repeated with different castings of varying weight.

The second test was intended to determine lift speed of the hoist. The hoist was loaded with a casting weighing 62 lbs and lift time was timed using a smartphone timer. The distance it traversed was also measured to calculate lift speed. This data was reported to the team for calculations.

The third test was intended to measure the distance the hoist was able to move an object and was measured in several different ways. The distance between far left and right reach was measured to find how far it could reach in either direction. The lift height was also measured, and the rolling hoist was moved to its extremes to ensure it could reach far enough out to be successful.

All tests were conducted at the NorthStar facility in Vancouver.

Operational limitations

Because of travel limitations, testing was limited due to an inability for the team to be there themselves. All instructions were given to NorthStar employees. Additionally, no equipment was available to accurately measure gripping force, so the team used a set of varying weight castings to ensure that the gripper would be sufficient for loads even higher than the norm.

Precision and accuracy discussion

Precision of each time measurement was +-0.01 by means of the timer used. However, the reaction time of the user to operate the timer lowers the precision to +-0.1. Any length Measurement was made by a tape measure with a precision of +-1/32. The measurements were taken by the same person for each test, and several trials were made for each test to ensure accuracy was upheld to provide accurate results.

Data storage/manipulation/analysis

Data was sent to the team via email and text message. This data was analyzed using Microsoft excel and visual inspection. Data is stored on the team’s computer, as well as in google drive as a backup.

Data presentation

Data for these tests is presented as tables to be most effective. Gripping strength and lifting speed data is presented as tables in this report. Other tests are not represented in this way as they are more qualitative than quantitative. No data is available for these tests, and thus not tables are necessary. This data will be displayed in this report, as well as on the associated senior project website.

Test Procedure:

Summary/Overview, Test 1

This test is intended to determine that the gripping force exerted is sufficient for the use of this device. The device will be used to grip the cast part, as intended, and then lifted 4 feet from the ground. The tester will verify physically that the part is firmly grasped and will not slip out under any reasonable force. This test will be conducted at the NorthStar facility in Vancouver and will take 30minutes to perform. The only resources needed will be the device and a sample cast part from NorthStar's manufacturing line. Listed are specific steps to accomplish test.

1. Align cast part with open gripper while at its lowest point (on the ground)
2. Activate pneumatic gripper to close on part
3. Slowly raise hoist, while monitoring part stability
4. After raising to about 4 feet, exert force by hand in various directions to ensure a good grasp
5. Lower and release the part
6. Examine the part and gripper jaws to verify no permanent damage was done to either
7. Repeat with 4 increasing weight castings, up to 110lbs

Discussion

The risk associated with this test is that the part could fall from the gripper, and thus appropriate PPE must be worn. Additionally, there is a risk of pinching with the gripper itself, so hands should be kept clear of the gripper when in operation. The testing itself was completed without issue. At the highest weight, of 106lbs, the part was reported to be less stable, and the grip was not strong enough to rely on for normal use.

Summary/Overview, Test 2

This test is intended to determine that the lift speed is sufficient. The requirement is based on the industry standard of 16 ft/min. The casting will be connected to the hoist, and then lifted a set height of 3ft. An employee will time how long it takes to reach that height and record it for the team. This will be repeated for accuracy. This test will take 30 minutes to complete. Resources required are a timer, and tape measure. Listed below are steps to complete test.

1. Attach casting between 40 and 60 lbs to the hoist
2. Allow casting to rest on ground, while maintaining tension in chain
3. Lift casting roughly 3 feet
4. Record time and measure actual height
5. Repeat 5 times

Discussion

The risk associated with this test is a dropping risk, if the part were attached in an unsecure manner. Additionally, if someone is touching the chain there would be a pinch risk as well. Due to this, steel toe boots should be worn, and the chain should not be touched while in operation. This test was completed without issue. The team found the list speed to be just below 16 ft/min, but this is still fast enough for the applications intended.

Summary/Overview, Test 3

The purpose of this test was to verify mobility of the hoist assembly. The requirement is due to the placement of bins and workbench in the facility. An employee will move the hoist to each extreme position and measure the distances between them to verify the hoist has appropriate reach to be successful. This is a qualitative test, as it will either reach the required distance or not. It will take 30 minutes to complete this test. The only resource requires is a tape measure. Listed below are the steps to complete this test.

1. Move hoist trolley to most outward location
2. Rotate hoist beam to the far left
3. Mark location of beam by lowering chain to touch ground
4. Rotate hoist bean to far right
5. Mark location of beam by lowering chain to touch ground
6. Rotate beam to center location
7. Mark location of beam by lowering chain to touch ground
8. Measure distance between marks to determine mobility of hoist

Discussion

The risk associated with this test is just based on operating the hoist. Appropriate training and PPE should be implemented. This test was completed without issue, and expected results were found. The hoist was able to reach all necessary positions easily.

Deliverables: (describe specific parameters and other outcomes)

Test 1

Below are the results from test 1. It is the weight of each tested casting, as well as a description of the grip stability.

Casting Weight (lbs)	Grip Stability
40	No Movement, stable
54	No Movement, stable
62	No Movement, stable
86	Slight movement, stable
104	Some movement, unstable

These results indicate that the gripping system should not exceed 80lbs of load, which meets the requirement of 60lbs. No displacement was visible at any of these loads.

Test 2

The second test yielded the results listed below for lift speed and time.

Trial	Time (s)	Rate (ft/s)	Rate (ft/min)		Reported
1	11.53	0.260	15.611		16 ft/min
2	11.76	0.255	15.306		
3	11.51	0.261	15.639		Weight (lbs)
4	11.56	0.260	15.571		62
5	11.37	0.264	15.831		
6	11.55	0.260	15.584		Lift dist (ft)
Average	11.55	0.260	15.590		3

The lift speed of 15.6 ft/min is lower than the predicted value of 16 ft/min however it is still sufficient for this project. The requirement of lifting 3 feet in 15 seconds was met.

Conclusion

Each of the tests were successful and they all met their appropriate success criteria. Test one met the max load and deflection criteria. Test two met the lift time criteria. Test three met the motion criteria of maximum reach and maneuverability. These tests were comprehensive of the requirements set in the senior project engineering report and no modifications is needed to meet these requirements.

Appendix H: Resume

Jacob VanBlaricom

MET Student- Central Washington University

Contact

- (360) 713-7333
- Jacobvan1998@gmail.com
- 312 W Helena Ave, Unit 1
  Ellensburg, WA 98926

Personal Objective

My goal is to reach a point in my career where I can benefit the public in a significant way.

Technical Skills

- Communication between customers and coworkers
- Experience with diverse customers, regarding background and age
- Decision making experience
- Leadership and delegation of tasks
- Ability to meet deadlines efficiently

Strengths

- Problem solver with innovative solutions
- Adaptive when problems arise
- Independently driven
- Collaborative team member
- Can accommodate irate customers, and bring them to a point of calm understanding

Education

Hudson's Bay High School
High honors graduate

Central Washington University
Spring 2020 Graduation-Mechanical Engineering

Experience

CWU Bookstore- Technology Sales and IT
11/2017-Present

Office Depot- Technology Sales and Services
09/2016-02/2019

Office Depot- Customer Service Manager
06/2016-09/2016

Office Max- Technology Sales and Services
08/2014-06/2016

Qualifications

- Certified SolidWorks Associate (CSWA)
- AutoCAD proficient
- Trained on Machining equipment
- Certified in Microsoft office professional suite
- Extensive experience with electronics and computer systems repair

References

Rose Mahaney
Customer Service Manager at Office Depot
(509) 654-8045

Andy Werner
Store Manager at Office Depot
(509) 494-9397

Chandra Hill
CWU Bookstore Technology Manager
(509) 306-0524

Appendix J: Job Hazard Analysis

JOB HAZARD ANALYSIS

Assembly of Electric Hoist

Prepared by: Jacob VanBlaricom	Reviewed by: Approved by:

Location of Task:	NorthStar Casteel
Required Equipment / Training for Task:	Hoist Operation Training, Grinding Training, List Training
Reference Materials as appropriate:	ASTM A36-A391 for Welding, https://ehs.berkeley.edu

Personal Protective Equipment (PPE) Required
(Check the box for required PPE and list any additional/specific PPE to be used in “Controls” section)

Gloves	Dust Mask	Eye Protection	Welding Mask	Appropriate Footwear	Hearing Protection	Protective Clothing
☒	☒	☒	☒	☒	☒	☒

Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.

TASK DESCRIPTION	HAZARDS	CONTROLS
Close off welding area.	Flashing	Close welding curtain to shield outsiders from flashing.
Prepare for arc welding.	Inhalation of fumes Flashing Sparks Slag splatter	Turn on exhaust fan and timer. Wear welding hood. Wear welding jacket, apron, gloves, work shoes. Wear welding jacket, apron, gloves, work shoes.
Turn on power and unwrap wire.	Tripping	Take care to keep wire untangled and free from under feet.
Insert arc welding rod in handle.	Pinch to fingers	Keep fingers away from pinch points.
Strike arc.	Flashing, sparks, slag splatter	Wear welding hood, welding jacket, apron, gloves, work shoes.
Allow material to cool on workbench.	Burn to hands or fingers	Wear glove.

		Chalk mark welded area "Hot"
Remove remainder of arc welding rod (if any) from handle, set aside on workbench to cool.	Burn to hands or fingers	Chalk mark welded area "Hot"
Wrap wire.	Tripping	Take care to keep wire untangled and free from under feet.
Use chipping hammer to remove excess slag.	Eye damage by flying debris from hammer strikes Injuring fingers with hammer	Wear safety glasses. Use caution to avoid striking fingers or hands with hammer.
Check cord integrity.	Hand cut from cut wires.	Wear leather gloves. Inspect slowly.
Check grinding wheel tightness.	Hand injury from inadvertent starting	Do not plug in the machine until inspection is complete.
Verify the guard is tight and appropriate for the job.	Foot injury from dropping the tool	Rest the tool on the bench. Wear steel-toed shoes.
Verify the appropriate handle location.	Foot injury from dropping the tool	(See controls for Task 4.)
Make sure the materials being ground are adequately secured and positioned correctly.	Injuries associated with the work propelled by the grinder and/or landing on you	Verify the work is adequately secured by trying to dislodge it with a gloved hand (the work weight may secure it enough). Wear steel-toed shoes.
Plug-in the grinder.	Eye and skin damage from projectiles.	Check the trigger switch to insure it is off.
Begin grinding.	Eye injuries from projectiles and sparks Skin damage from sparks and projectiles Hearing loss Ergonomic considerations.	Wear safety glasses/goggles and a face shield. Wear leather gloves, long sleeved shirt, long pants, or leather welding guards. Wear ear plugs. Change position from time to time. Wear vibration resistant gloves. Wear the appropriate respirator based on the content of the metal and its coatings. Contact

	Inhalation of toxic or irritant fume or particulate	EH&S (2-3073) for evaluation and exposure assessment. Use local or dilution ventilation to direct or collect fumes and/or particulate
Lifting heavy object. Saving yourself from injury is more important than avoiding damage to what you're lifting.	Back injury Foot injury from dropping heavy object	Bend knees to lessen pressure on the lower back. Use legs as the source of power to lift object. Solicit the help of others or employ tools if object is too heavy to be lifted by one person. Get a secure hold on object. Wear gloves to aid in a secure grip. Wear steel-toed shoes, or similar.
Transporting heavy object.	Back injury Slipping on wet or slick floor	See above for more information. Evaluate condition of floor along path from origin to destination. Do not move heavy loads until floor is dry.
Setting heavy object down.	Foot injury from dropping heavy object Back injury	Do not drop object. See above for more information. See above for more information.

JHA Information Sourced From "https://ehs.berkeley.edu"