Final Project: Arm Wrestling Training Machine

MCEN 5045: Design for Manufacturability
Section No: 001

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What We Did?

A Standardized Gym Arm Wrestling Training Machine

Why We Chose To Do It?

The sport of arm wrestling is growing, more people are participating in this activity and need to be trained accordingly.

Why We Chose To Do It?

However, there is currently no standardized product on the market for the arm wrestling training.

Why We Chose To Do It?

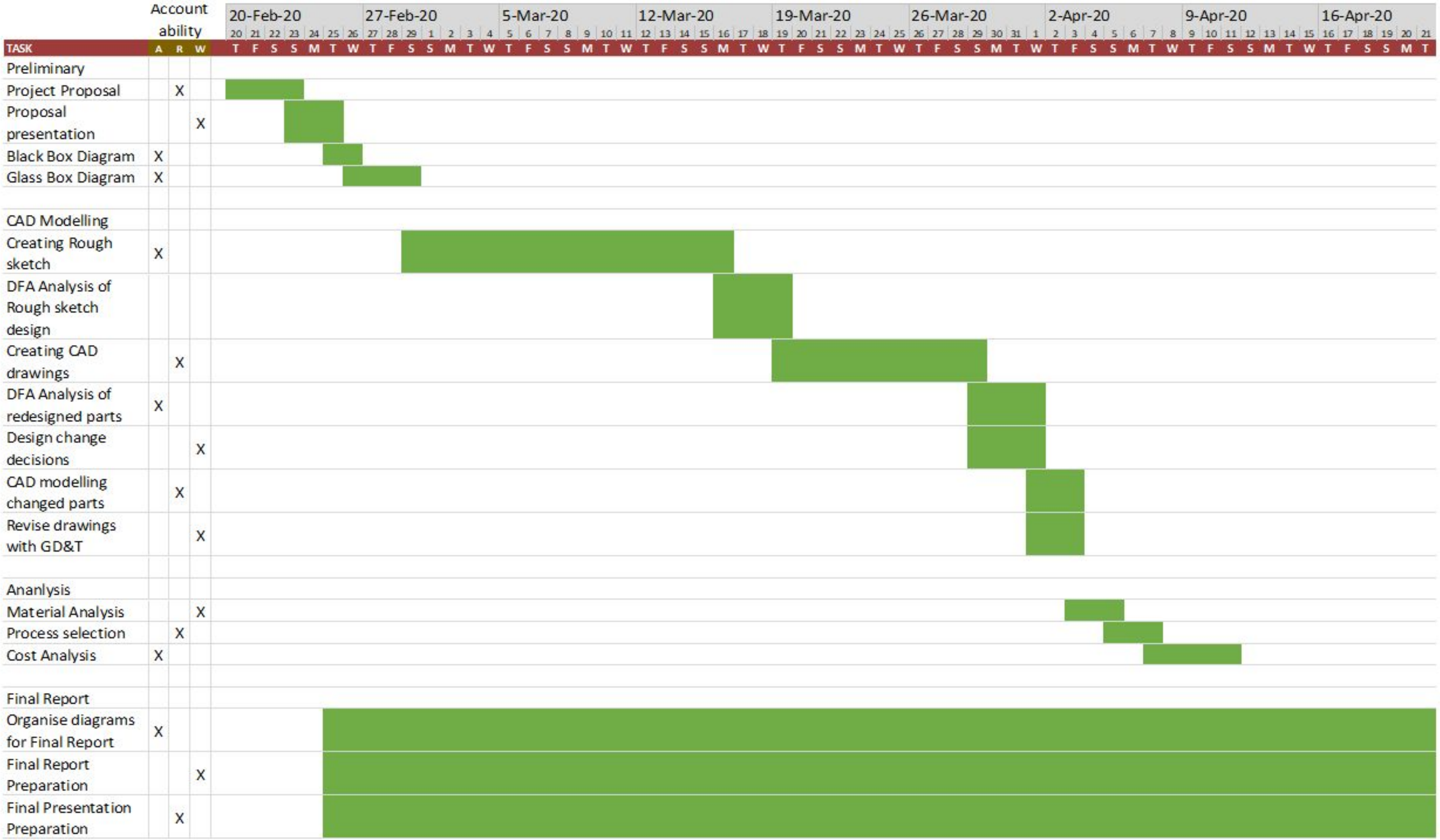
Therefore, some people build their own training machines, with different straps, variations, loading methods, etc.

Project Objective

To design a product resembling a gym machine that would be compatible to arm-wrestling training, the sport of arm-wrestling itself, and exist in the commercial gym industry. And in doing so, justification of its concept would be upheld by the engineering concepts taught throughout the course.

- Standardizing parts and equipment for assembly
- Minimized number of parts
- Training system for supination, pronation, radial and ulnar deviation, flexion, and extension

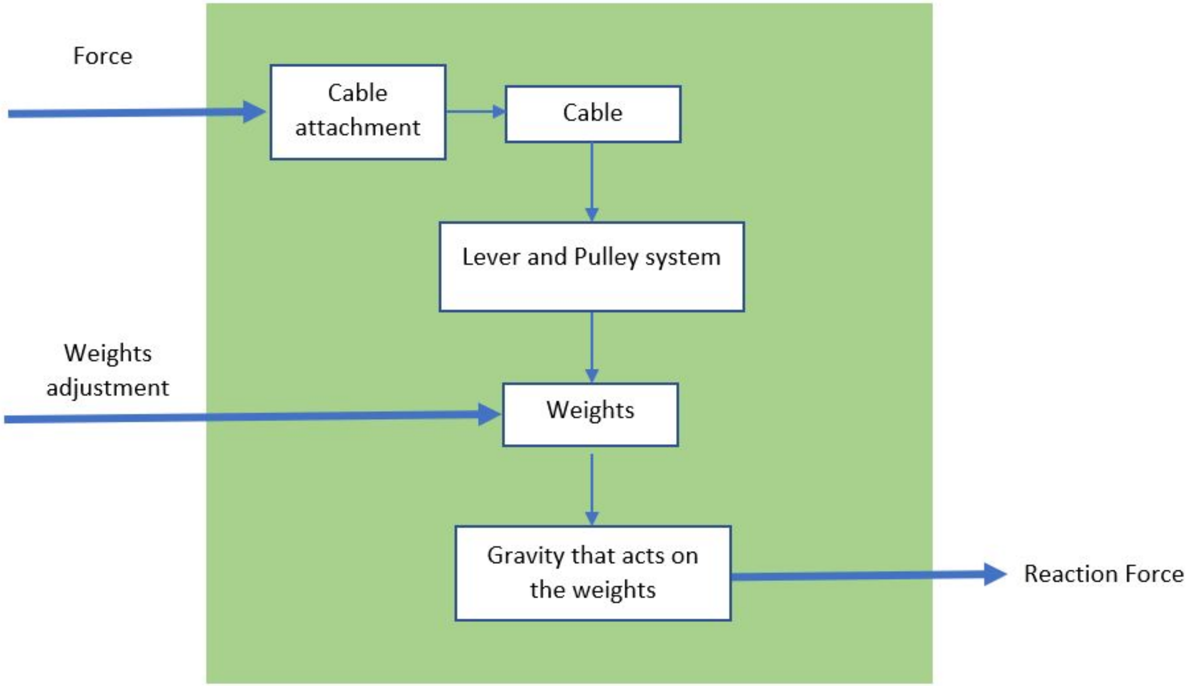
Gantt Chart



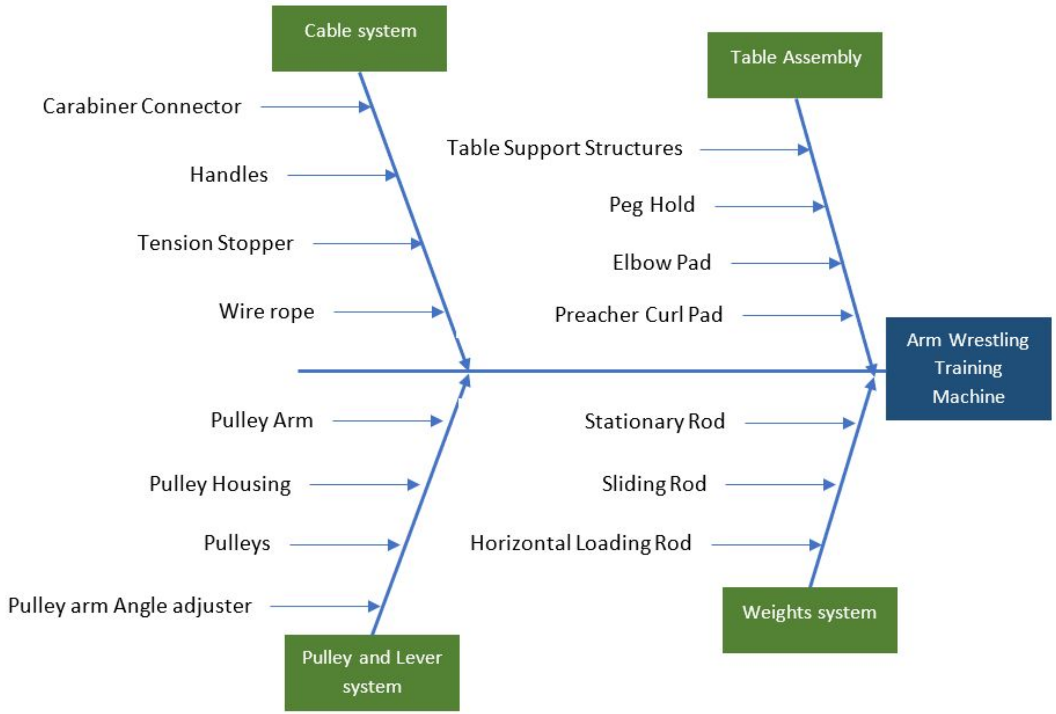
Account ability
20-Feb-20
27-Feb-20
5-Mar-20
12-Mar-20
19-Mar-20
26-Mar-20
2-Apr-20
9-Apr-20
16-Apr-20
TASK
A R W
Preliminary
Project Proposal
Proposal presentation
Black Box Diagram
Glass Box Diagram
CAD Modelling
Creating Rough sketch
DFA Analysis of Rough sketch design
Creating CAD drawings
DFA Analysis of redesigned parts
Design change decisions
CAD modelling changed parts
Revise drawings with GD&T
Ananlysis
Material Analysis
Process selection
Cost Analysis
Final Report
Organise diagrams for Final Report
Final Report Preparation
Final Presentation Preparation

BLACK BOX DIAGRAM

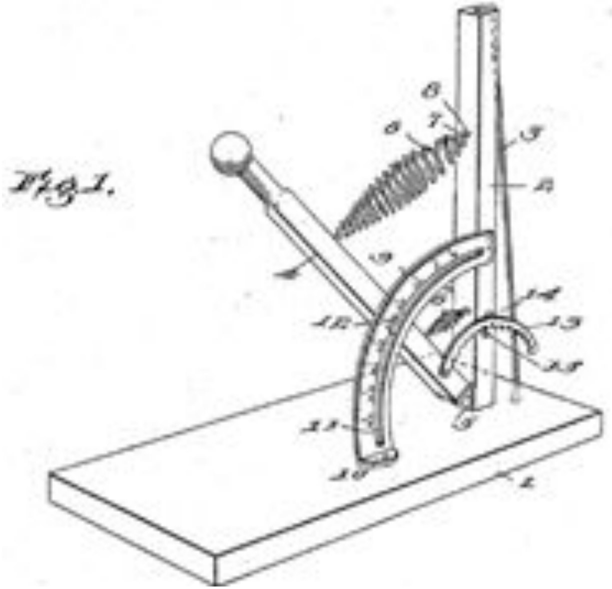
GLASS BOX DIAGRAM

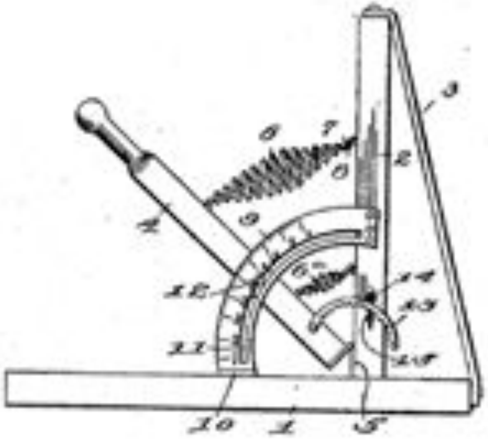


Fishbone Diagram



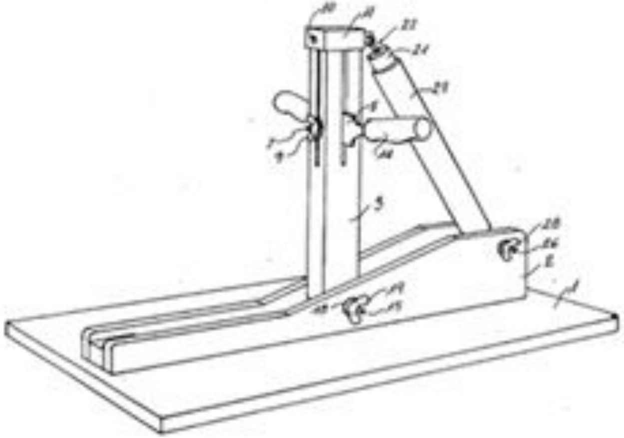
Patent Search

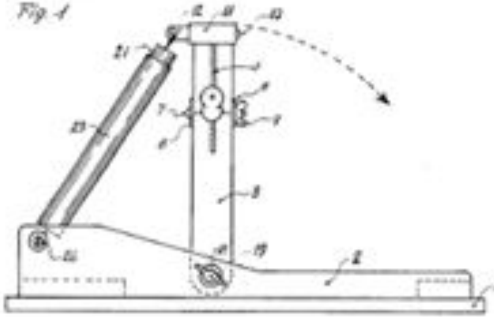


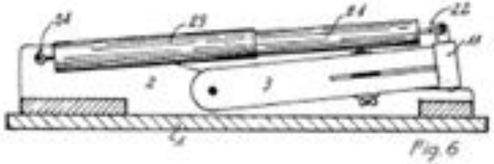


US911925, Feb 09, 1909

Patent Search

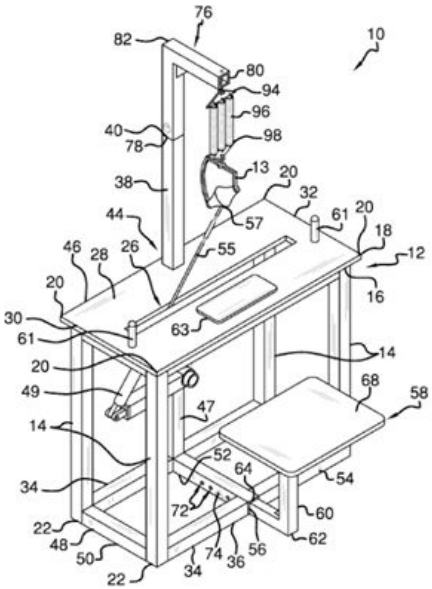


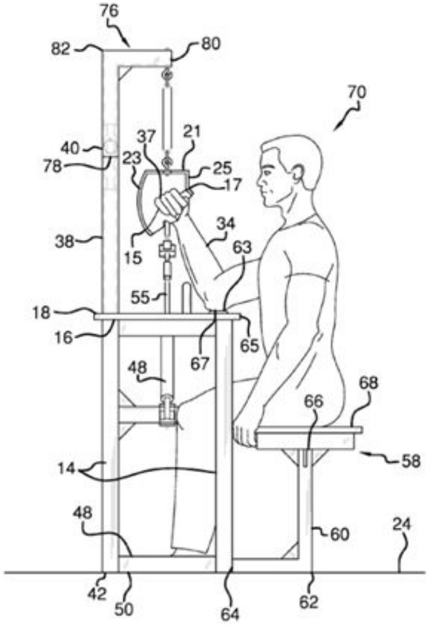




US 4129297 December 12, 1978

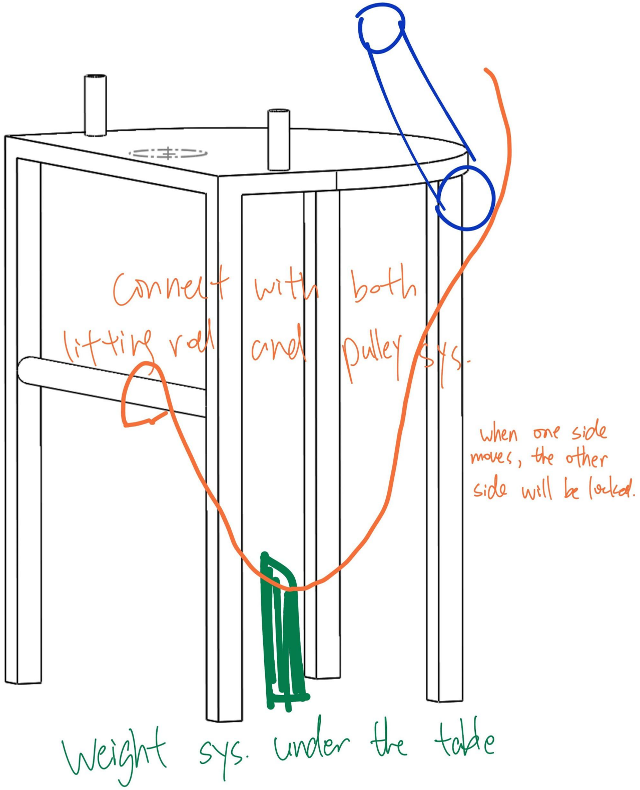
Patent Search

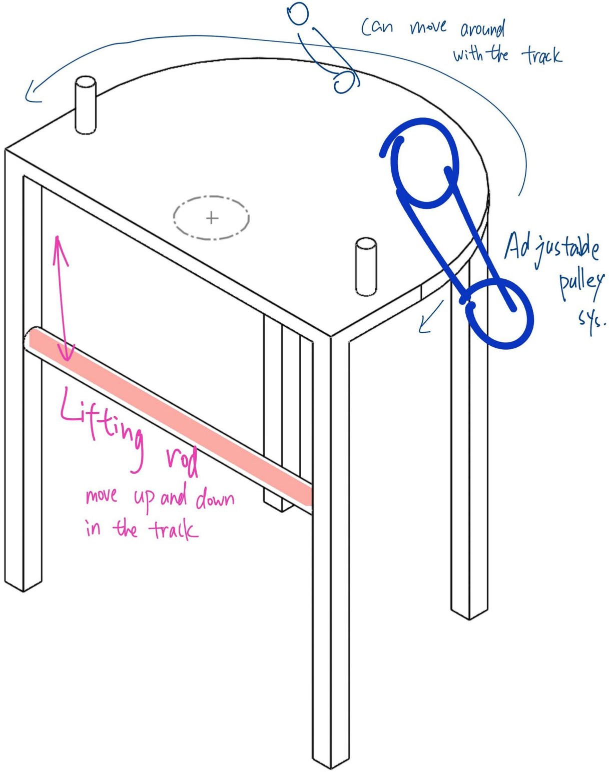




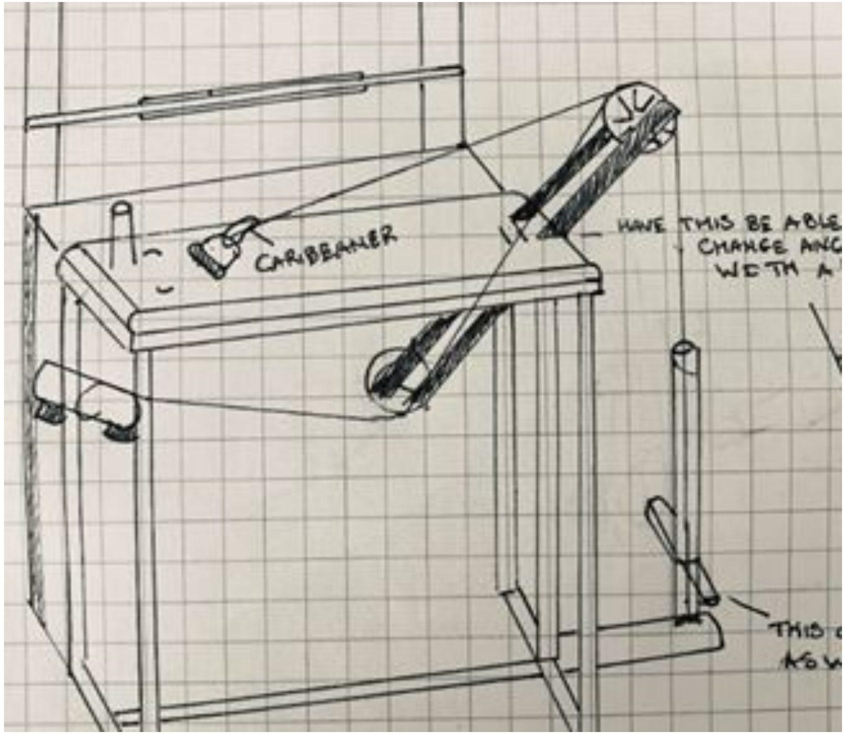
US 9314657 B2 April 19, 2016

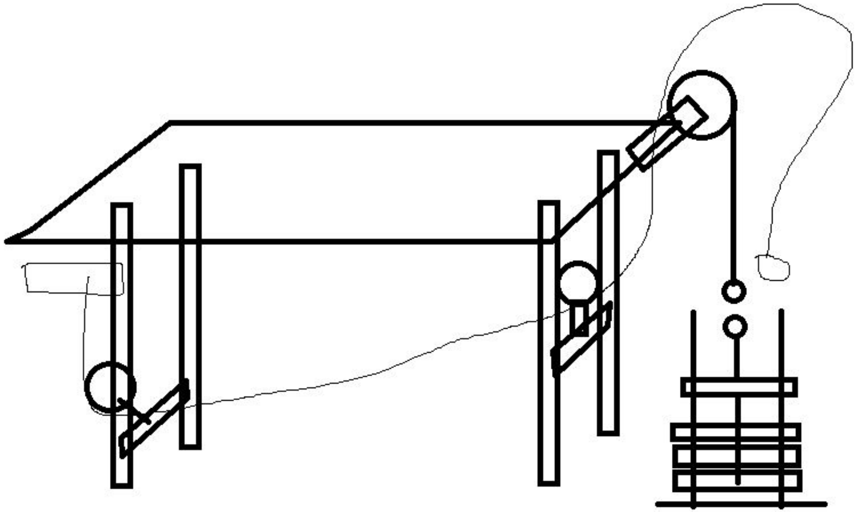
Design Idea: Hemispherical Table + Rotating Pulley Arm





Design Idea: Table with Cupping Rod Rack

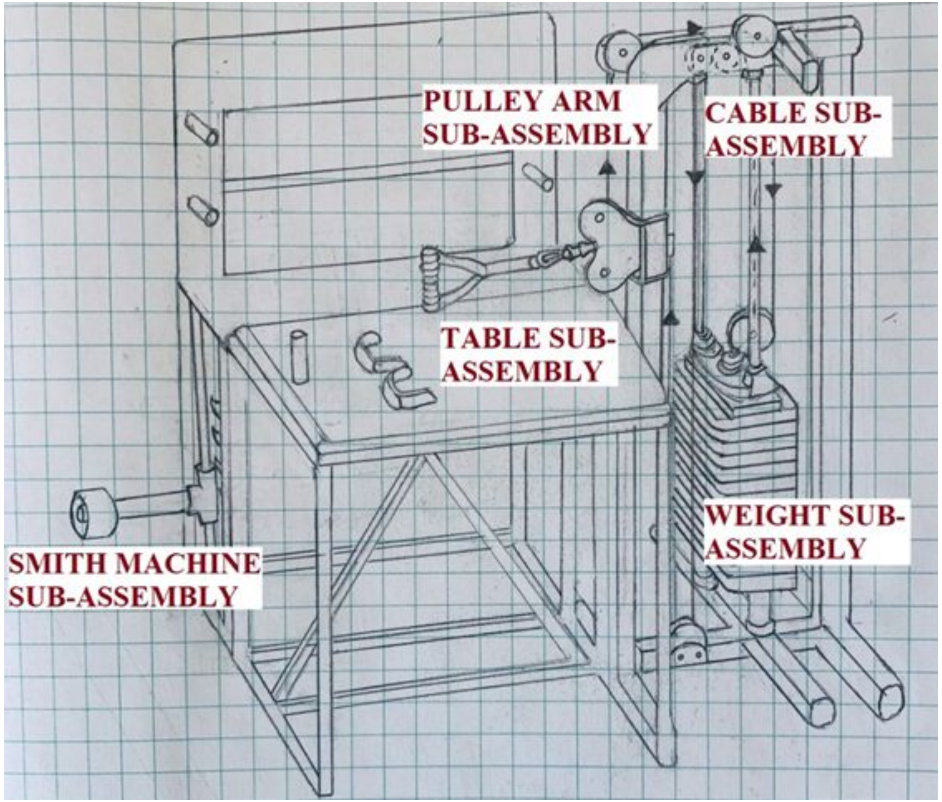




Initial Design

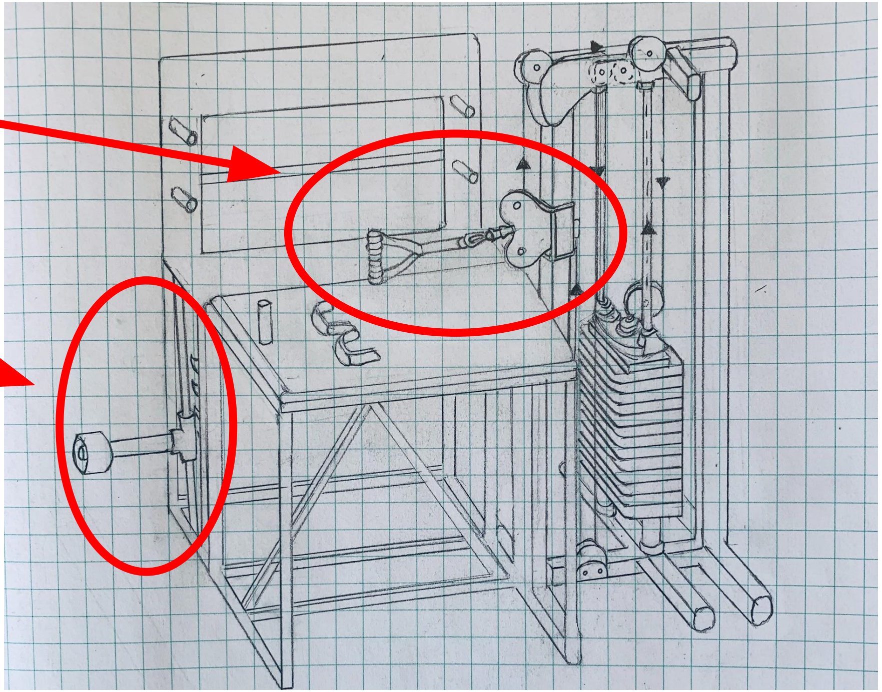
3 main sub-assemblies

- Main Body
  - Table Sub-assembly
- Smith Machine
- Weight System
  - Pulley Arm Sub-assembly
  - Cable Sub-assembly



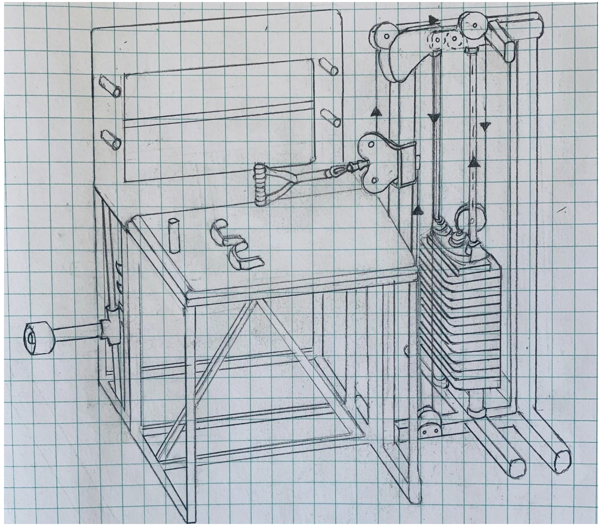
Initial Design: Functions Highlight

- Adjustable weight system
- Attached Smith Machine



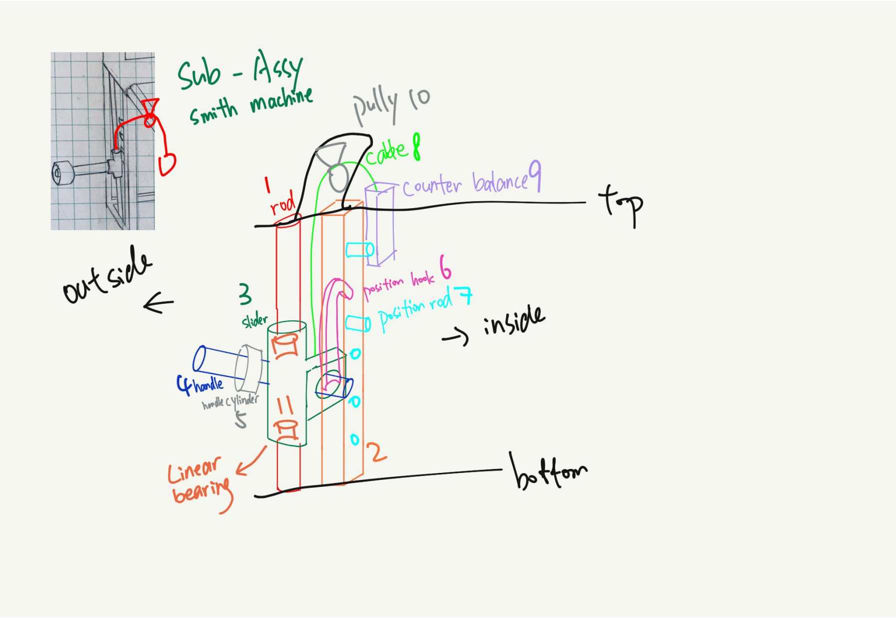
Initial Design: DFA Analysis

- DFA Complexity: 401
- Theoretical efficiency: 23.7%
- Practical efficiency: 35.8%



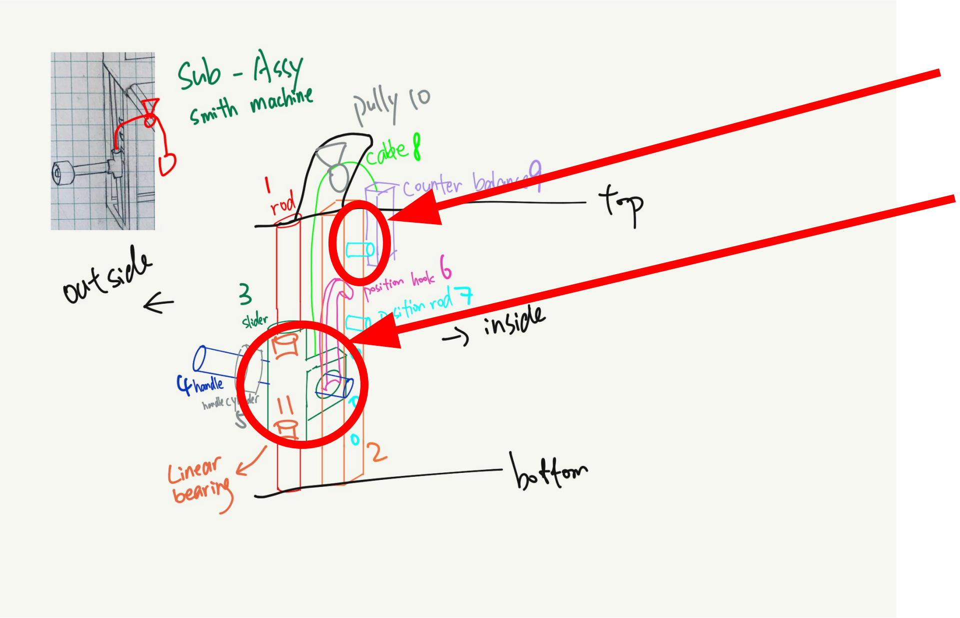
Part	Comp.		Functional Analysis / Redesign Opportunity				Proofing		Handling			Insertion				Secondary Operations				
#	Number of Parts (N_p)	Number of Interfaces (N_i)	Theoretical Minimum Part	Part Can Be Standardized (if not already standard)	Cost (Low/Medium/High)	Practical Minimum Part	Assemble Wrong Part/ Omit Part	Assemble Part Wrong Way Around	Tangle, Nest, or Stick Together	Flexible, Fragile, Sharp or Slippery	Pliers, Tweezers, or Magnifying Glass Needed	Difficult to Align/ Locate	Holding Down Required	Resistance to Insertion	Obstructed Access/ Visibility	Re-orient Workpiece	Screw, Drill, Twist, Rivet, Bend, or Crimp	Weld, Solder, or Glue	Paint, Lube, Heat, Apply Liquid or Gas	Test, Measure or Adjust
Totals	215	747	51	40	0	77	46	31	8	1	0	17	4	15	2	0	24	49	48	8
DFA Metrics	400.756		23.7%	←Theor. Effy. Pract. Effy.→		35.8%	1.51		0.18			0.75				2.53				

Initial Design: DFA Analysis



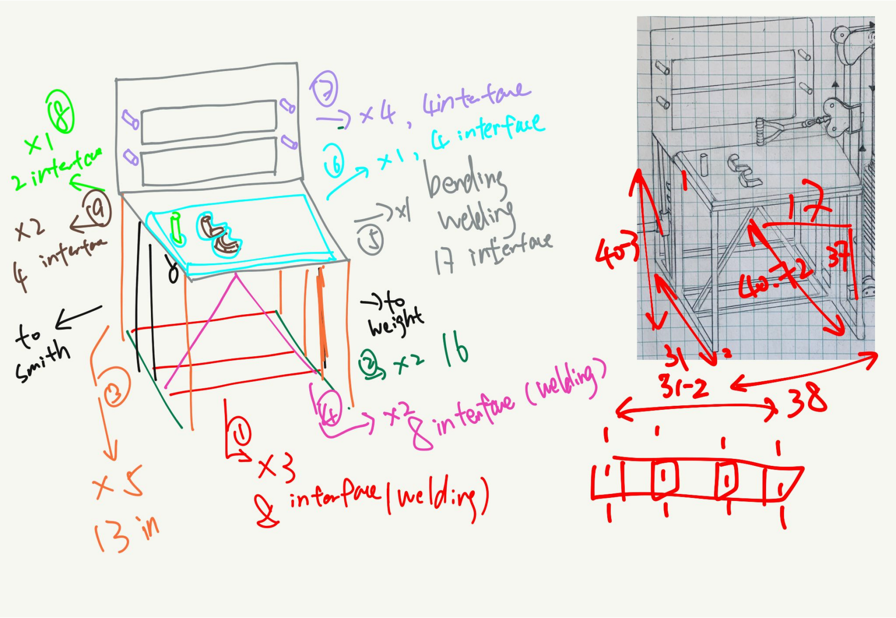
- DFA Complexity: 24
- Theoretical efficiency: 50%
- Practical efficiency: 62.5%

Initial Design: DFA Analysis



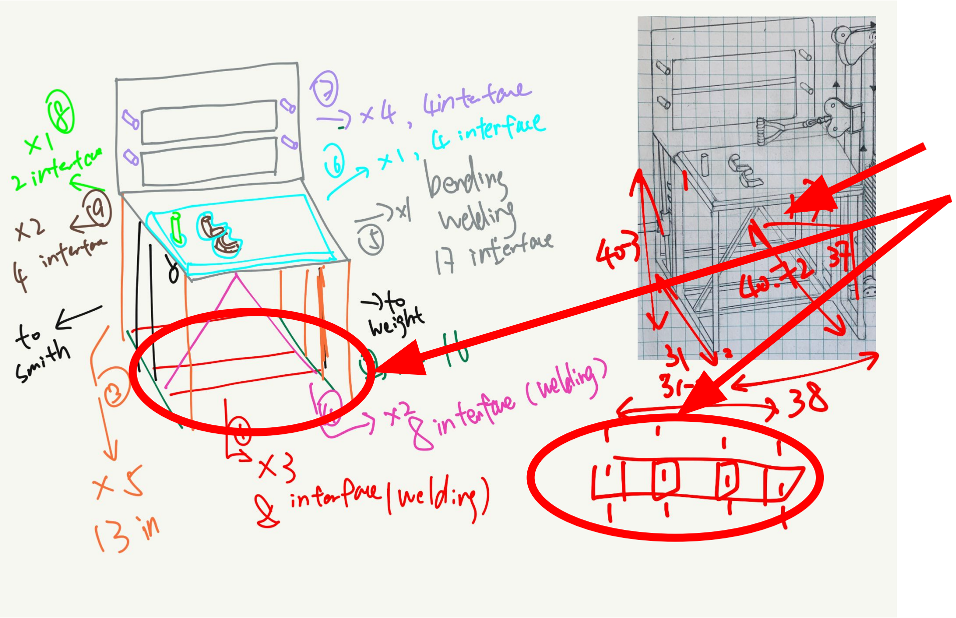
- The position rods are hard to locate.
- The slider may be assembled wrong way around.
- May use less parts.

Initial Design: DFA Analysis



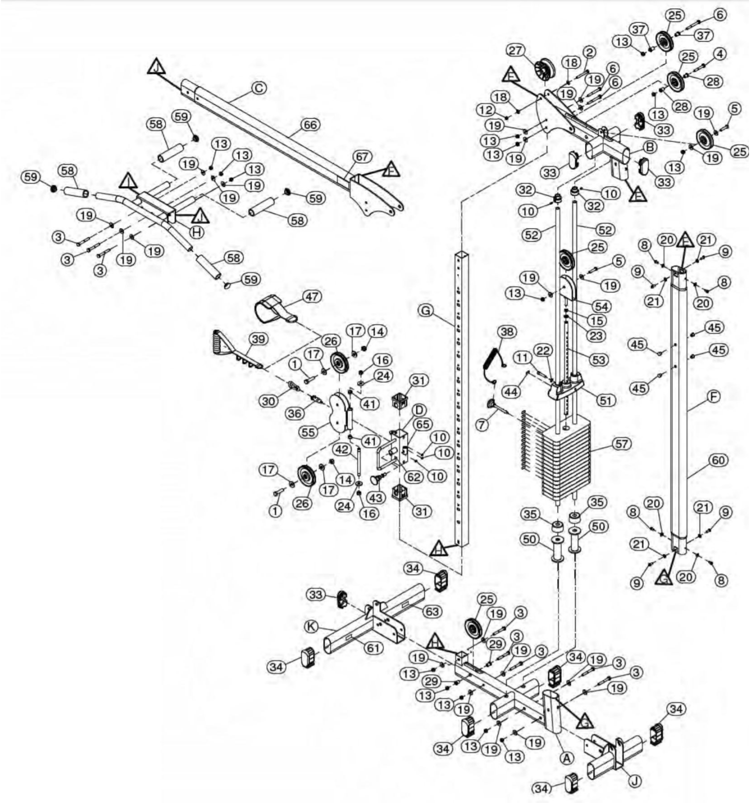
- DFA Complexity: 42
- Theoretical efficiency: 34.8%
- Practical efficiency: 39.1%

Initial Design: DFA Analysis



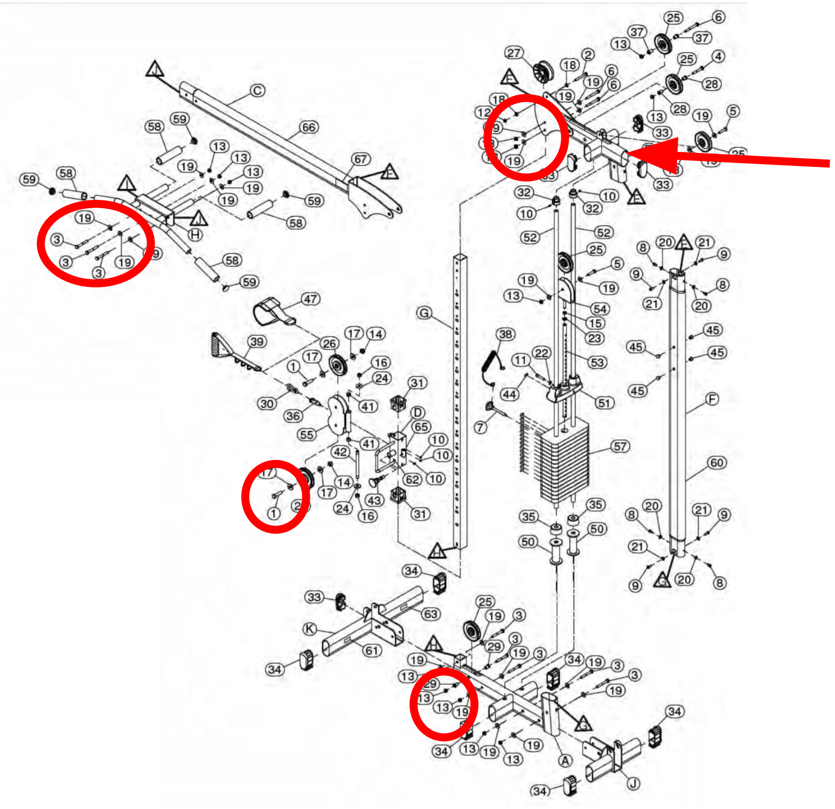
- Everything are welding together.
- Sharp edges on the diagonal bars.
- The frame bars are hard to distinguish and locate.
- Not enough functions.

Initial Design: DFA Analysis



- DFA Complexity: 334
- Theoretical efficiency: 19.9%
- Practical efficiency: 33%

Initial Design: DFA Analysis



- Too many parts (~180)
- Most of parts are not standardized.
- Too many similar parts, too easy to get wrong during assembly.

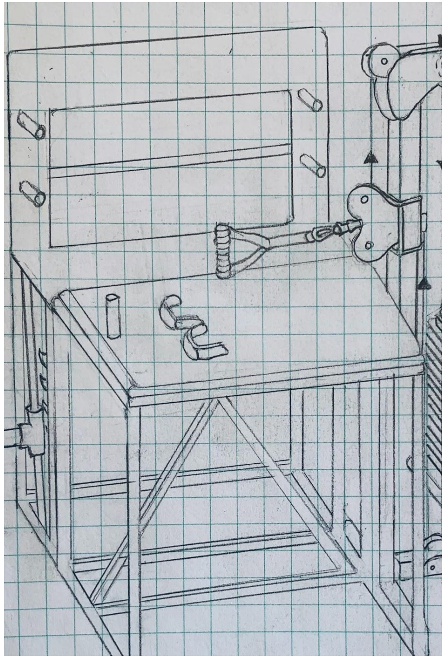
- We should redesign the whole thing.

Conclusions drawn from the DFA Analysis

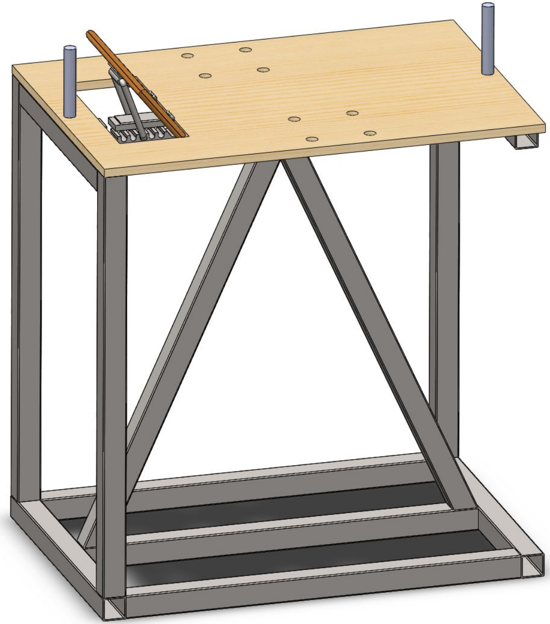
- Smith Machine
  - Reduce the number of parts
  - Add location features
- Main Body
  - Redesign the frame bars
  - Redesign the tabletop
- Weight System
  - Redesign the entire sub-assembly to reduce the complexity

Design Changes: Main Body

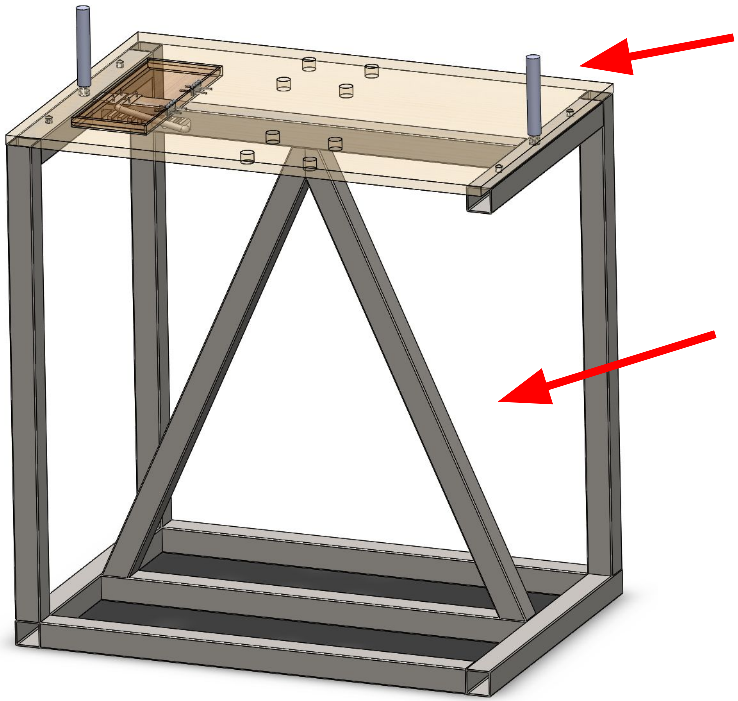
Before



After

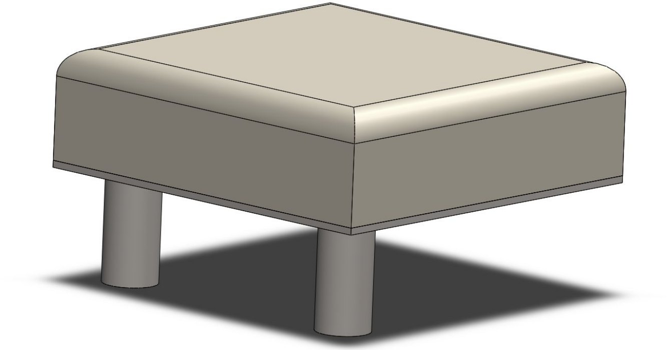


Design Changes: Main Body



- Change the shape and size of the table, use the standard size tabletop
- Simpler frame, reduced the number of parts

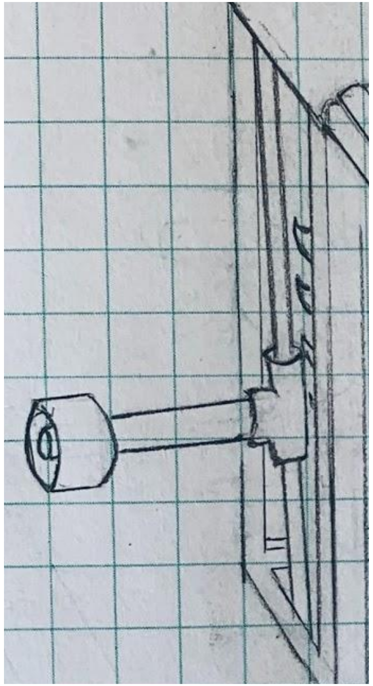
Design Changes: Elbow Pad



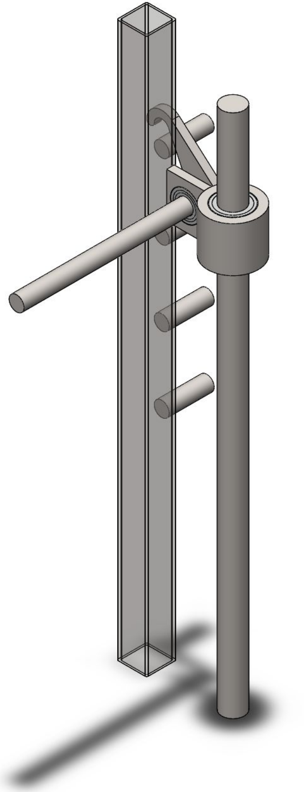
- Separated the elbow pads from the main body sub-assembly
- Using standardized Elbow Pad dimensions

Design Changes: Smith Machine

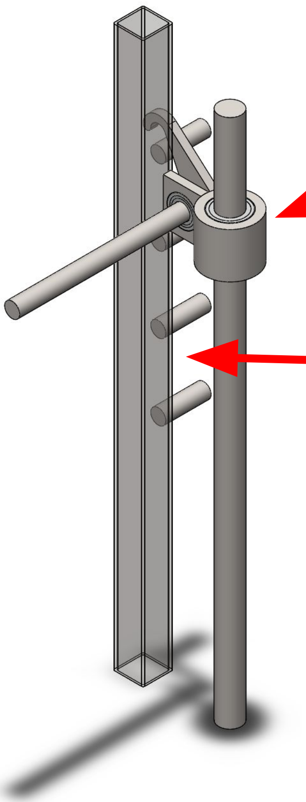
Before



After



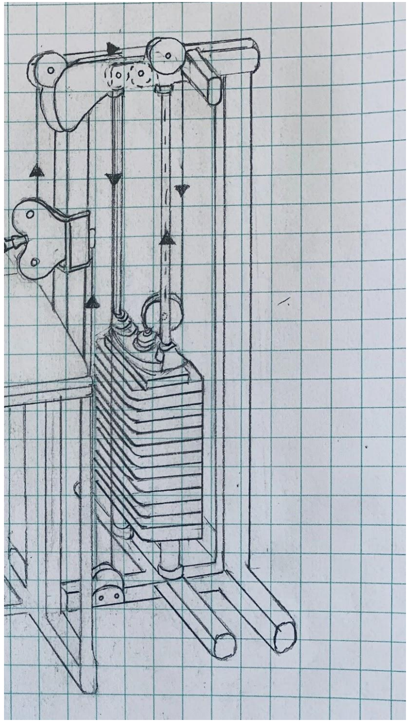
Design Changes: Smith Machine



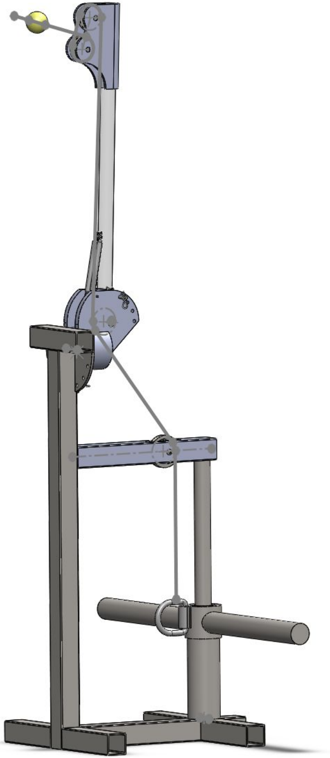
- Reduce the length of the slider and reduce the number of bearings
- Welding markers added to help locate the position rods

Design Changes: Weight System

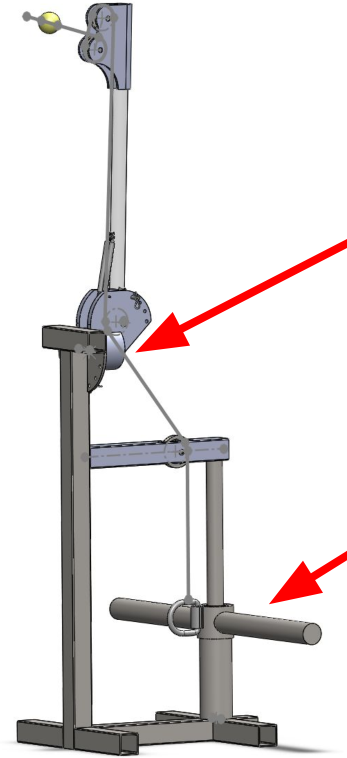
Before



After



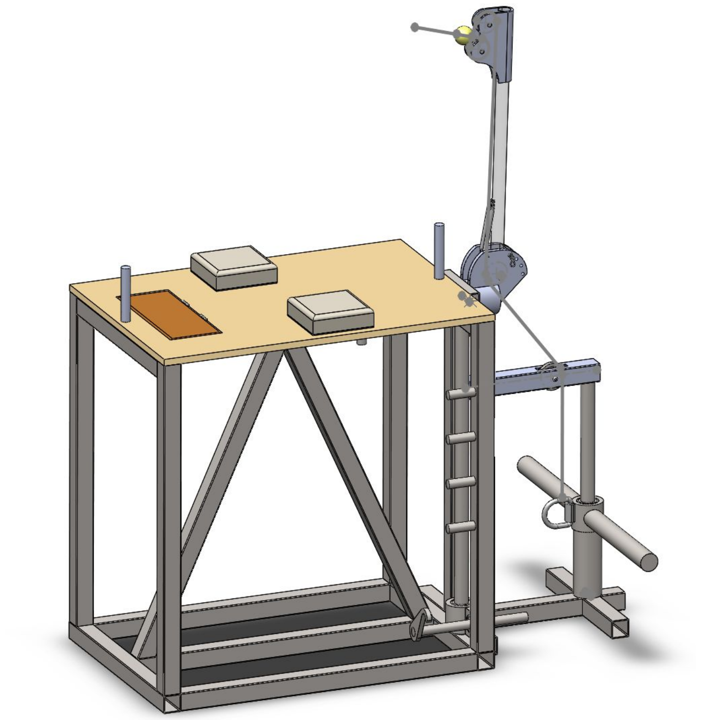
Design Changes: Weight System



- Simplified the adjustment method of the weight system

- Simplify the way of weight change, directly use standard size rod to match standard weight plates.

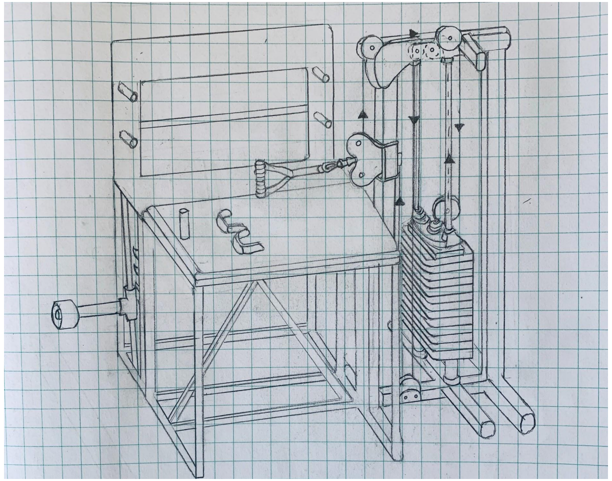
Final Design: DFA Analysis

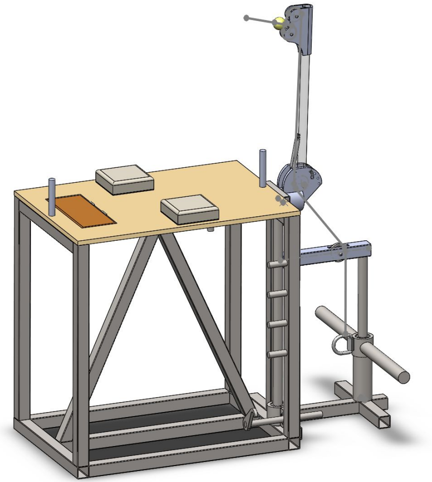


- DFA Complexity: 194
- Theoretical efficiency: 45.6%
- Practical efficiency: 58.3%

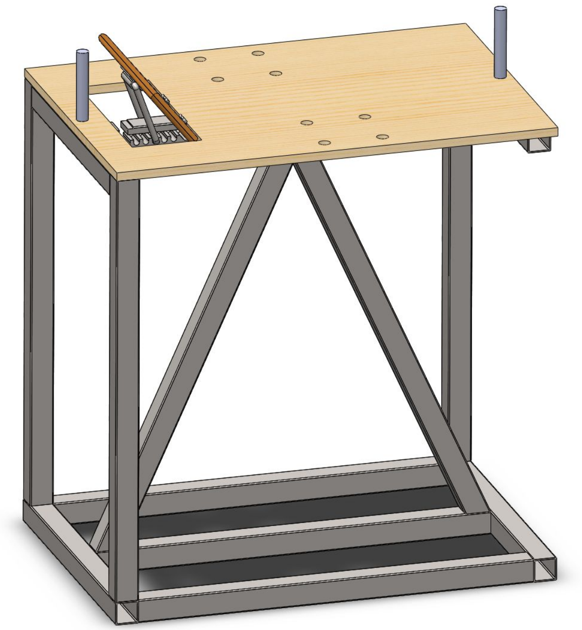
Final Design: DFA Analysis

Part	DFA Complexity	Functional Analysis / Redesign Opportunity			Error Proofing	Handling	Insertion	Secondary Operations
Design for Assembly Metrics	194.4247927	45.6%	←Theor. Effy. Pract. Effy.→	58.3%	0.11	0.02	0.45	0.91
DFA Metrics for the Initial Design	400.7555365	23.7%	←Theor. Effy. Pract. Effy.→	35.8%	1.51	0.18	1.00	2.53
Delta	206.3307438	21.9%	←Theor. Effy. Pract. Effy.→	22.5%	1.40	0.15	0.55	1.62



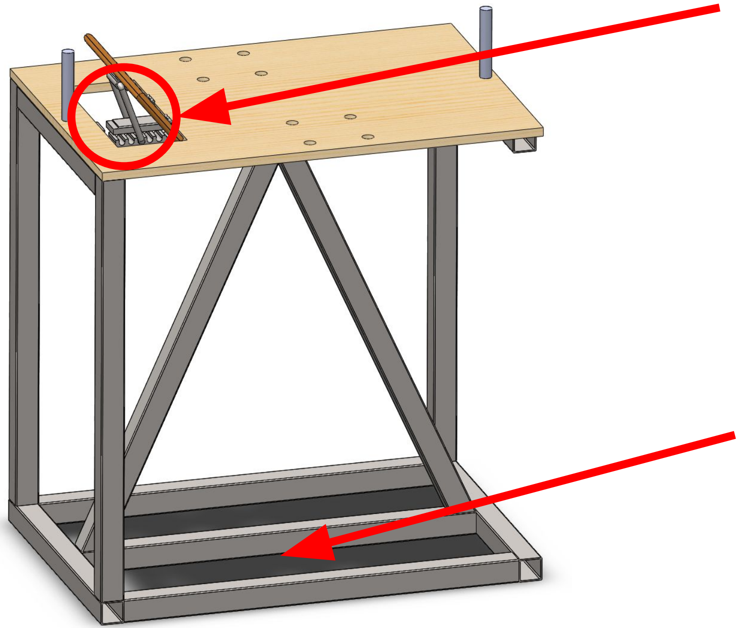


Final Design: DFA Analysis



- DFA Complexity: 78
- Theoretical efficiency: 30.8%
- Practical efficiency: 41%

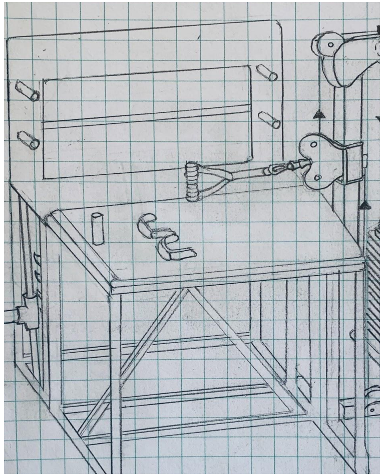
Final Design: DFA Analysis



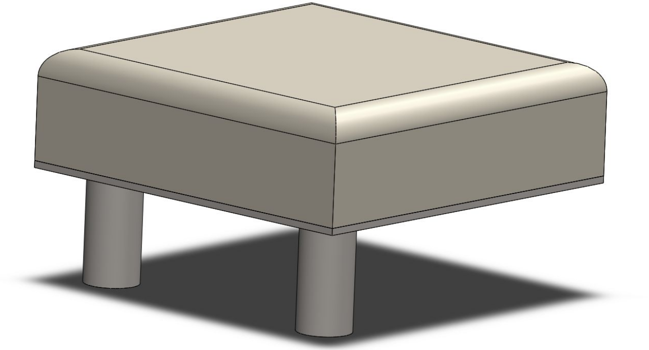
- The adjuster may be assembled wrong way around, but it won't influence using.
- Will add stickers to help distinguish between different bars; Will add welding markers for the middle frame.

Final Design: DFA Analysis

Part	DFA Complexity	Functional Analysis / Redesign Opportunity			Error Proofing	Handling	Insertion	Secondary Operations
Design for Assembly Metrics	78.49840763	30.8%	←Theor. Effy. Pract. Effy.→	41.0%	0.33	0.08	0.33	1.33
DFA Metrics for the Initial Design	41.80908992	34.8%	←Theor. Effy. Pract. Effy.→	39.1%	0.50	0.13	0.75	2.00
Delta	36.68931771	4.0%	←Theor. Effy. Pract. Effy.→	1.9%	0.17	0.04	0.42	0.67

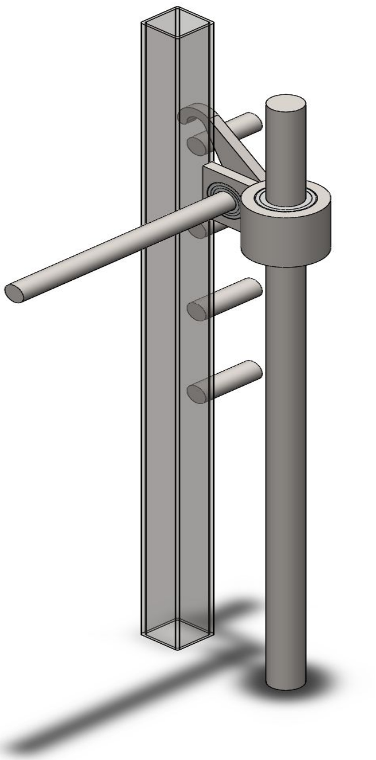


Final Design: DFA Analysis



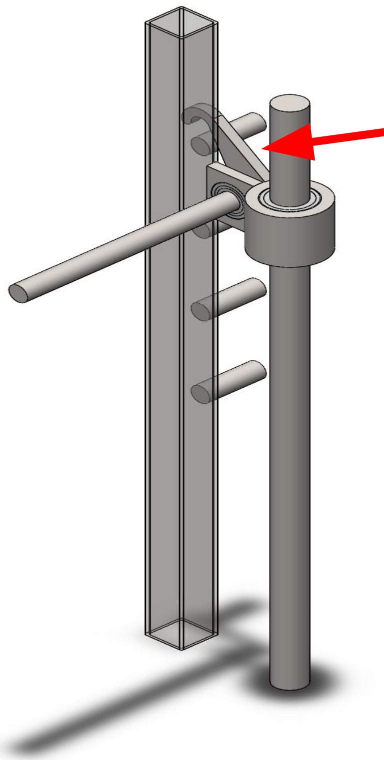
- DFA Complexity: 12
- Theoretical efficiency: 37.5%
- Practical efficiency: 37.5%

Final Design: DFA Analysis



- DFA Complexity: 18
- Theoretical efficiency: 58.3%
- Practical efficiency: 75%

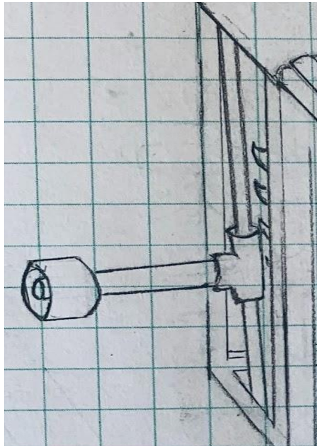
Final Design: DFA Analysis

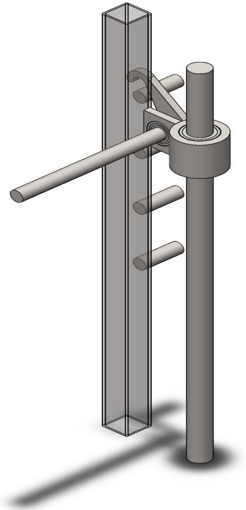


- The position hook might be assembled wrong way around, will add a sticker to mark the direction.

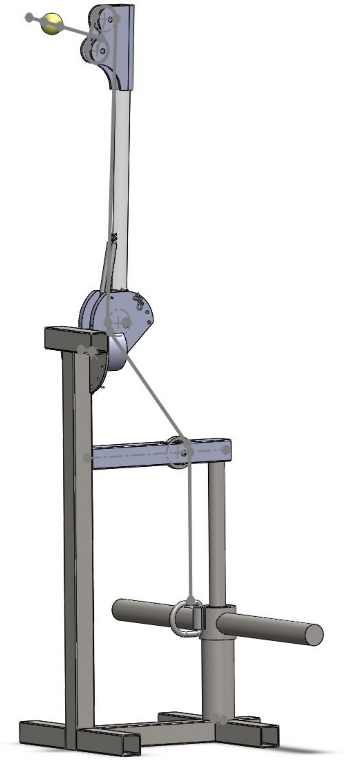
Final Design: DFA Analysis

Part	DFA Complexity	Functional Analysis / Redesign Opportunity			Error Proofing	Handling	Insertion	Secondary Operations
Design for Assembly Metrics	18	58.3%	←Theor. Effy. Pract. Effy.→	75.0%	0.14	0.00	0.57	0.86
DFA Metrics for the Initial Design	24	50.0%	←Theor. Effy. Pract. Effy.→	62.5%	0.38	0.00	1.00	3.00
Delta	6	8.3%	←Theor. Effy. Pract. Effy.→	12.5%	0.23	0.00	0.43	2.14



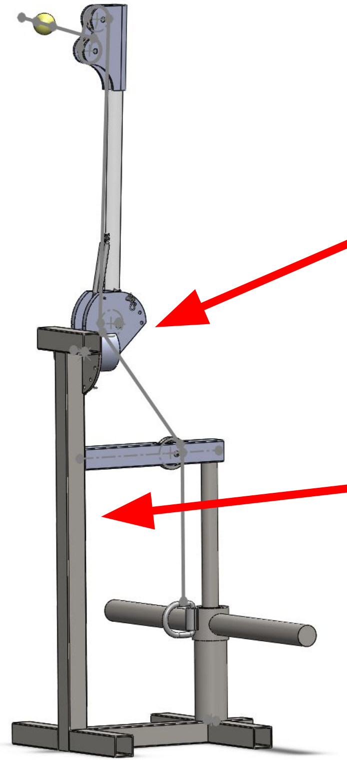


Final Design: DFA Analysis



- DFA Complexity: 84
- Theoretical efficiency: 56.8%
- Practical efficiency: 72.7%

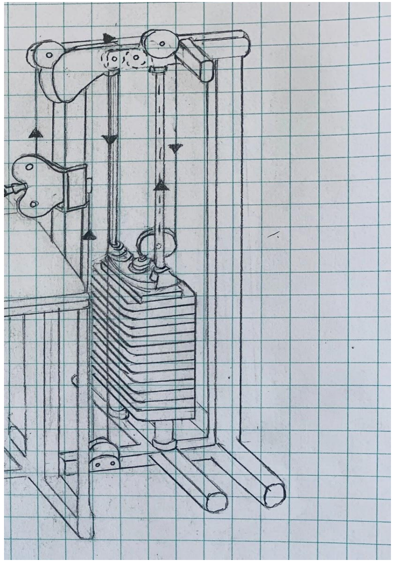
Final Design: DFA Analysis

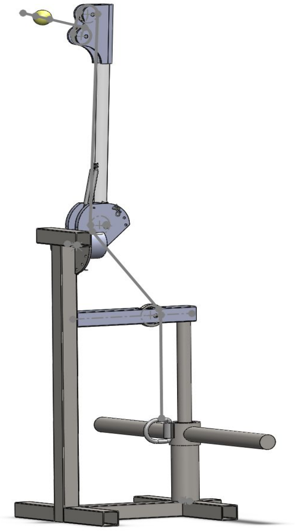


- We could use a standardized pulley arm and adjuster.
- Reduce the use of frame bars by directly connecting to the Main Body frame.

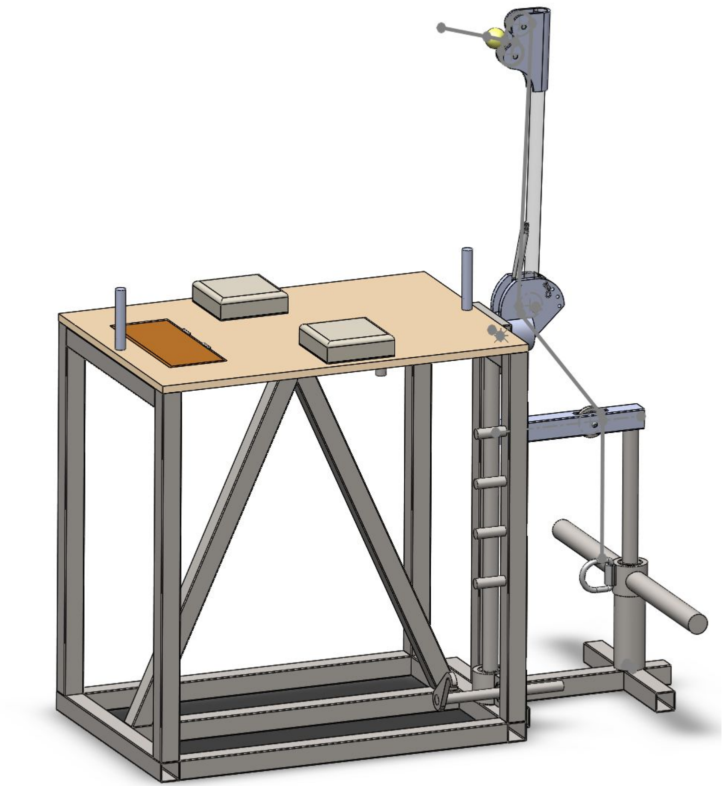
Final Design: DFA Analysis

Part	DFA Complexity	Functional Analysis / Redesign Opportunity			Error Proofing	Handling	Insertion	Secondary Operations
Design for Assembly Metrics	84.94704233	56.8%	←Theor. Effy. Pract. Effy.→	72.7%	0.00	0.00	0.44	0.72
DFA Metrics for the Initial Design	334.3052497	19.9%	←Theor. Effy. Pract. Effy.→	33.0%	2.00	0.23	1.00	2.54
Delta	249.3582074	36.9%	←Theor. Effy. Pract. Effy.→	39.7%	2.00	0.23	0.56	1.82





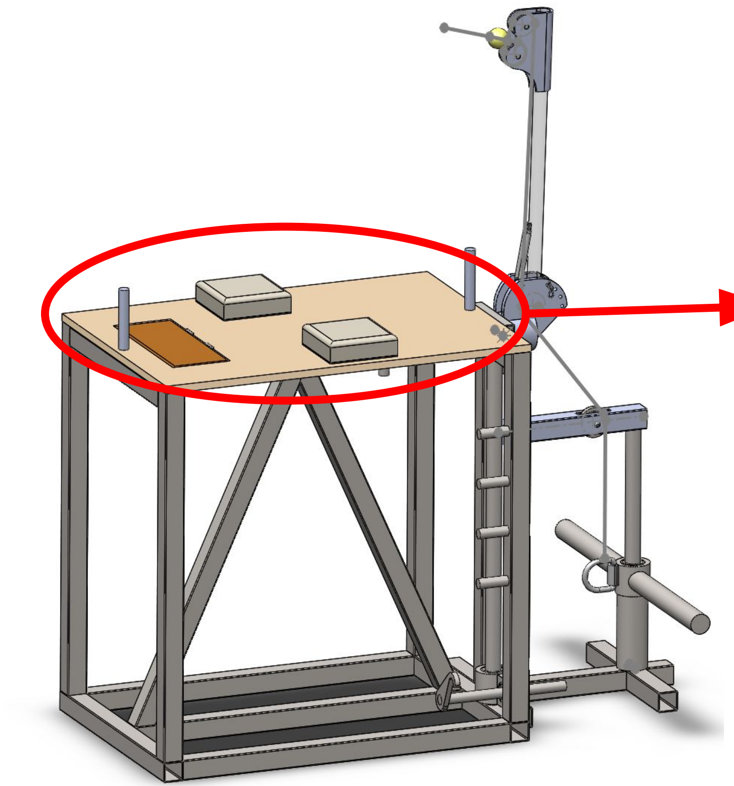
Final Design

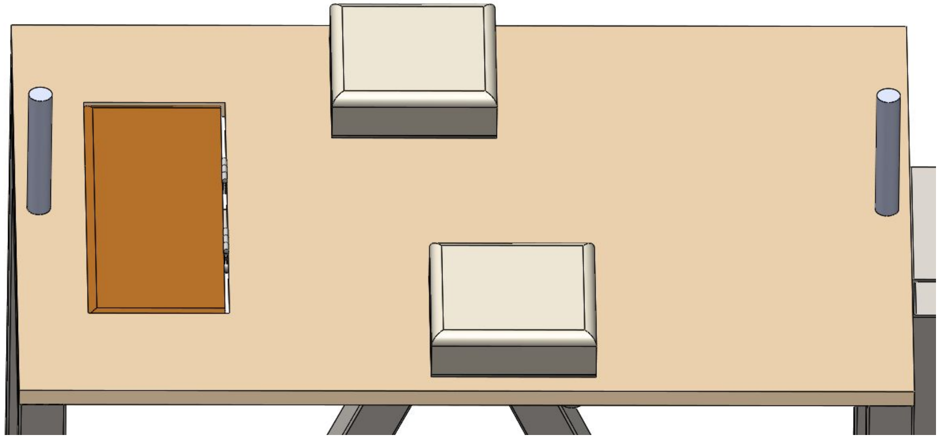


Four sub-assemblies

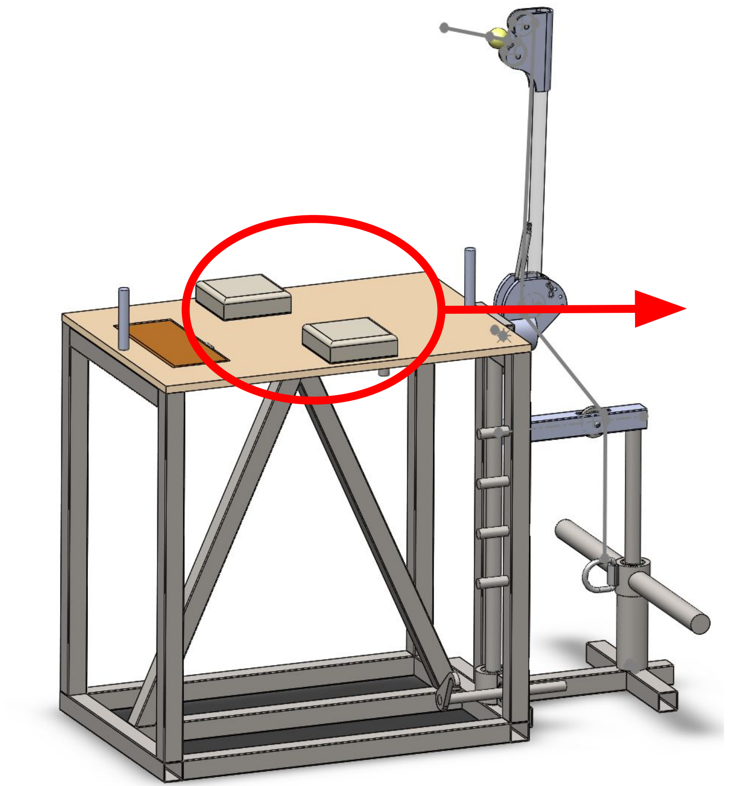
- Main Body (table)
- Elbow Pads
- Smith Machine
- Weight System

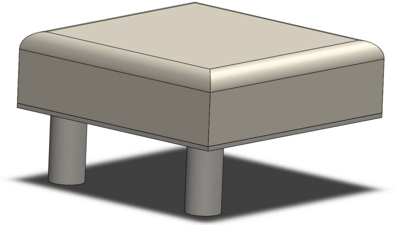
Final Design: Functions Highlight

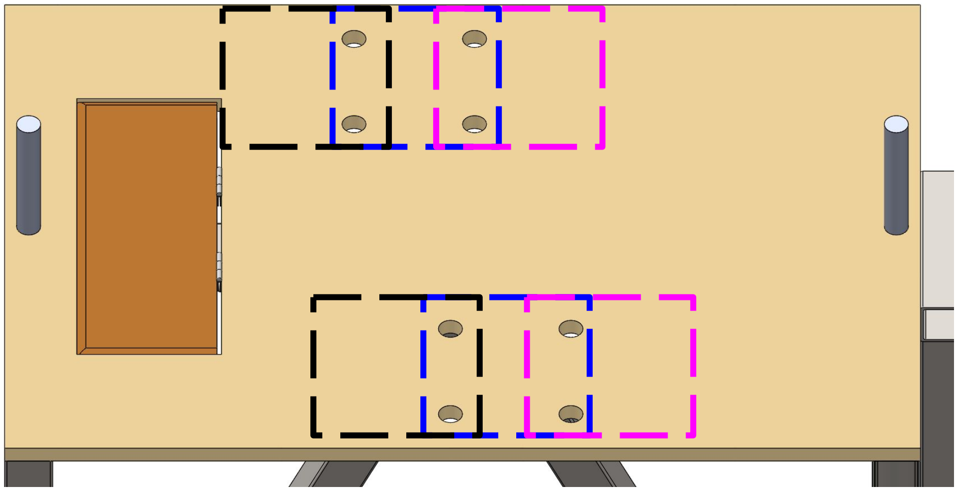




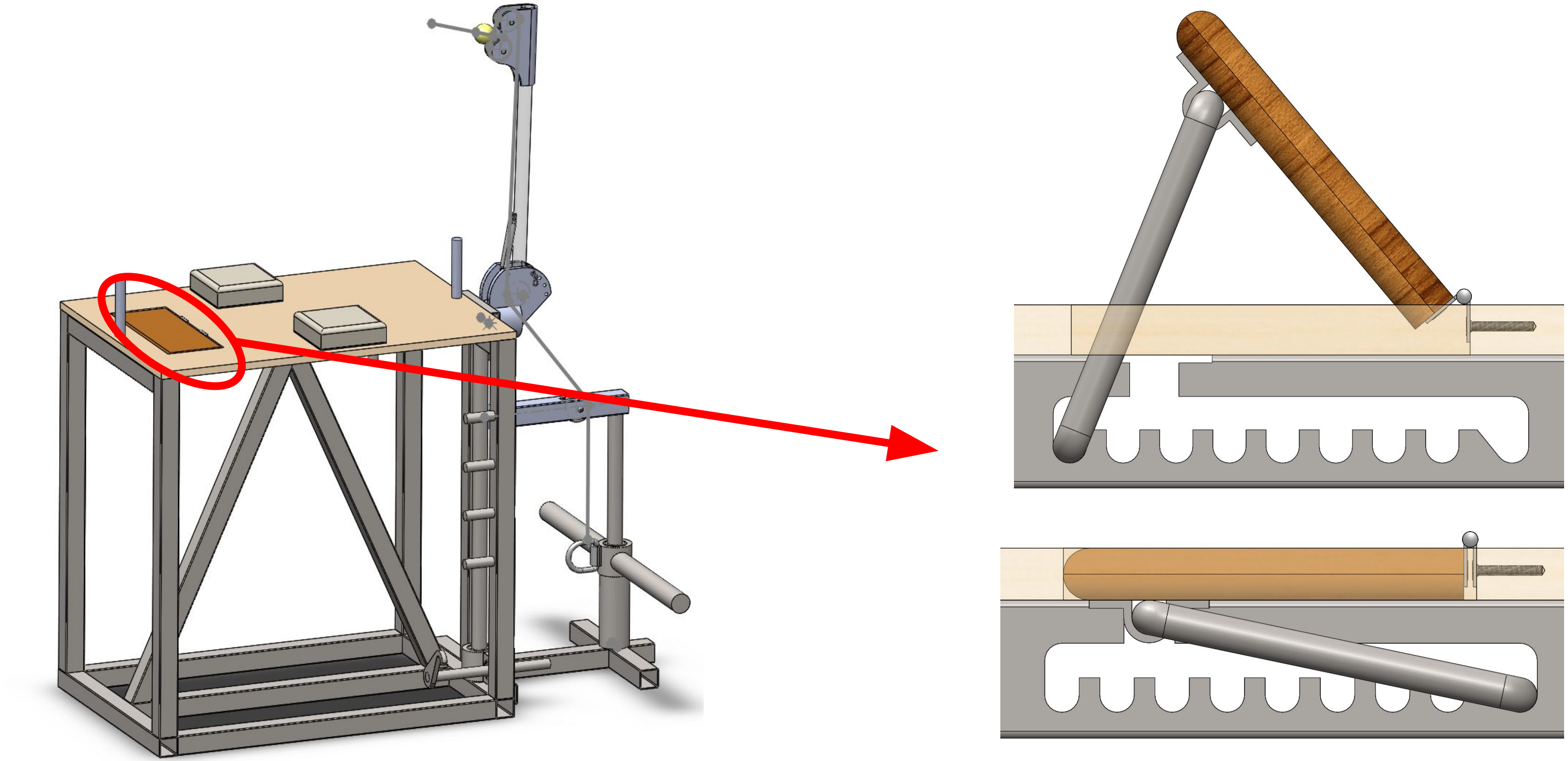
Final Design: Functions Highlight



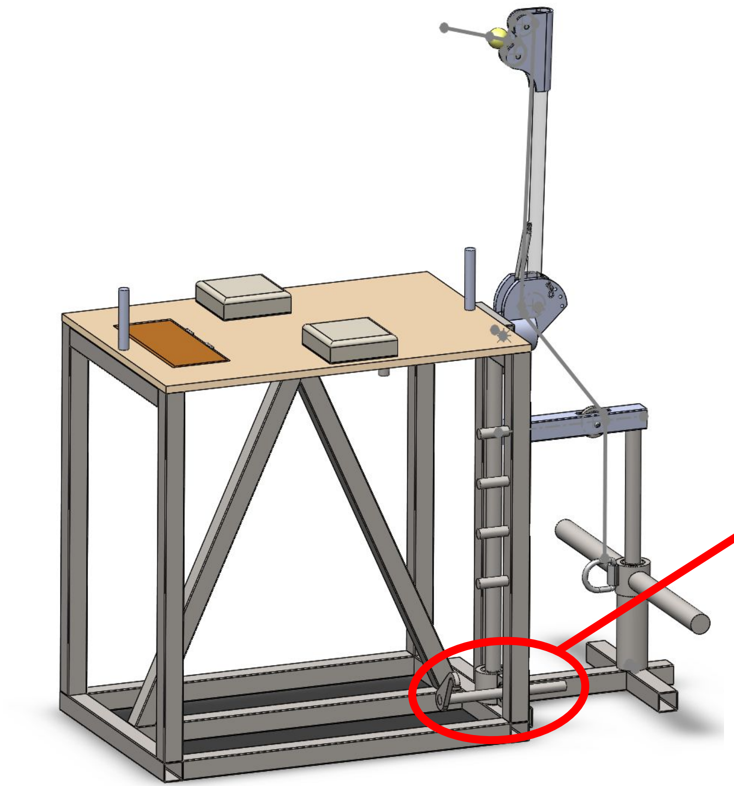


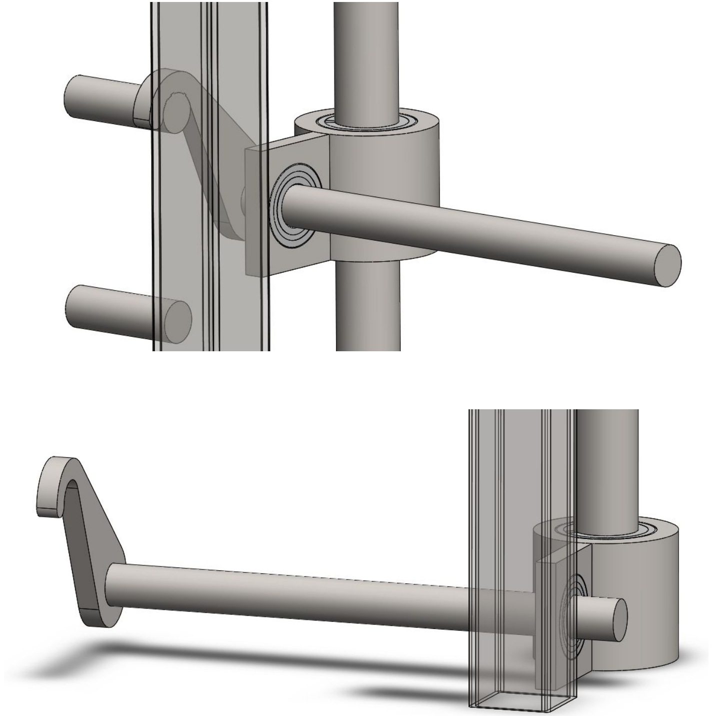


Final Design: Functions Highlight

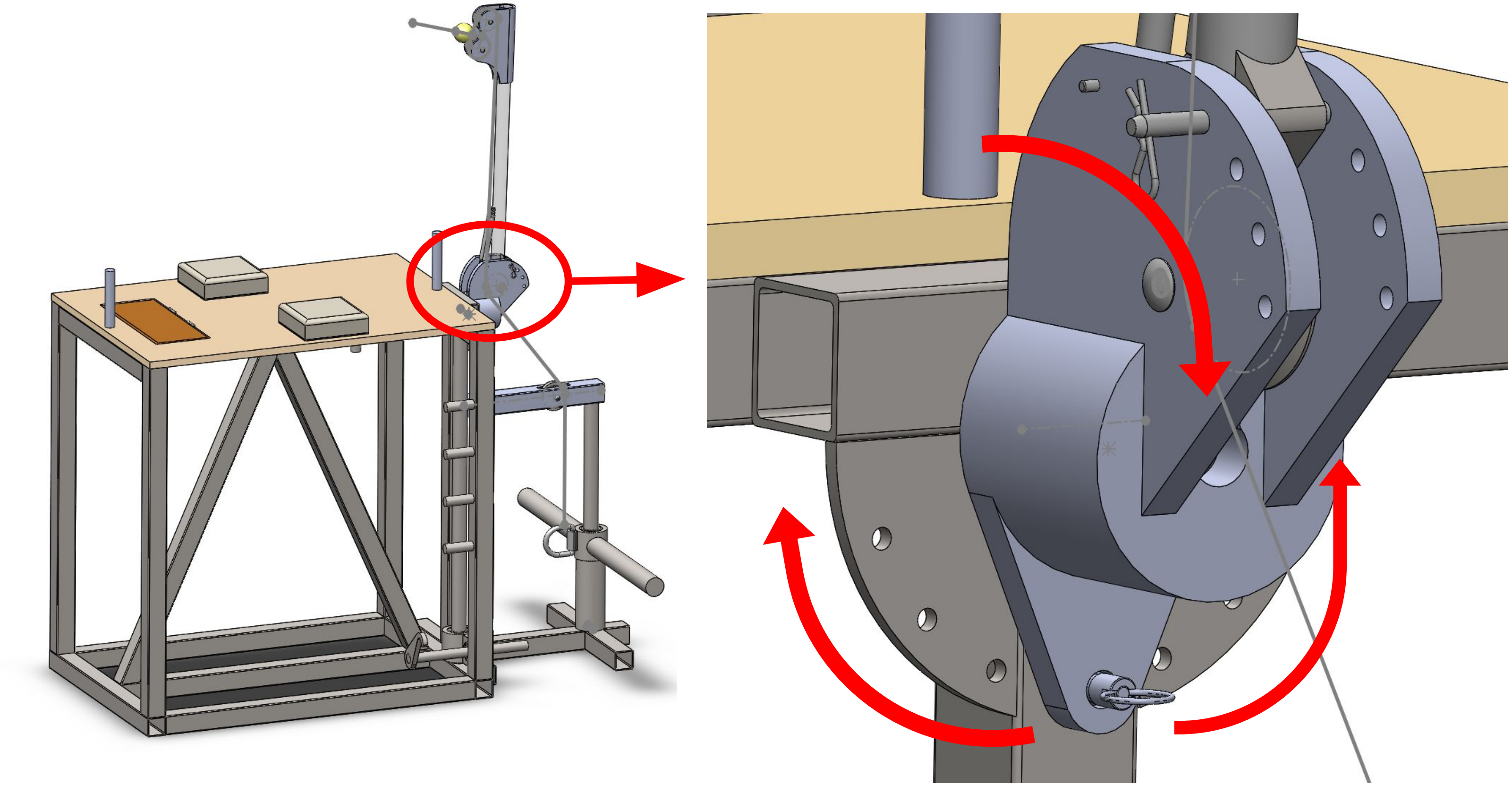


Final Design: Functions Highlight

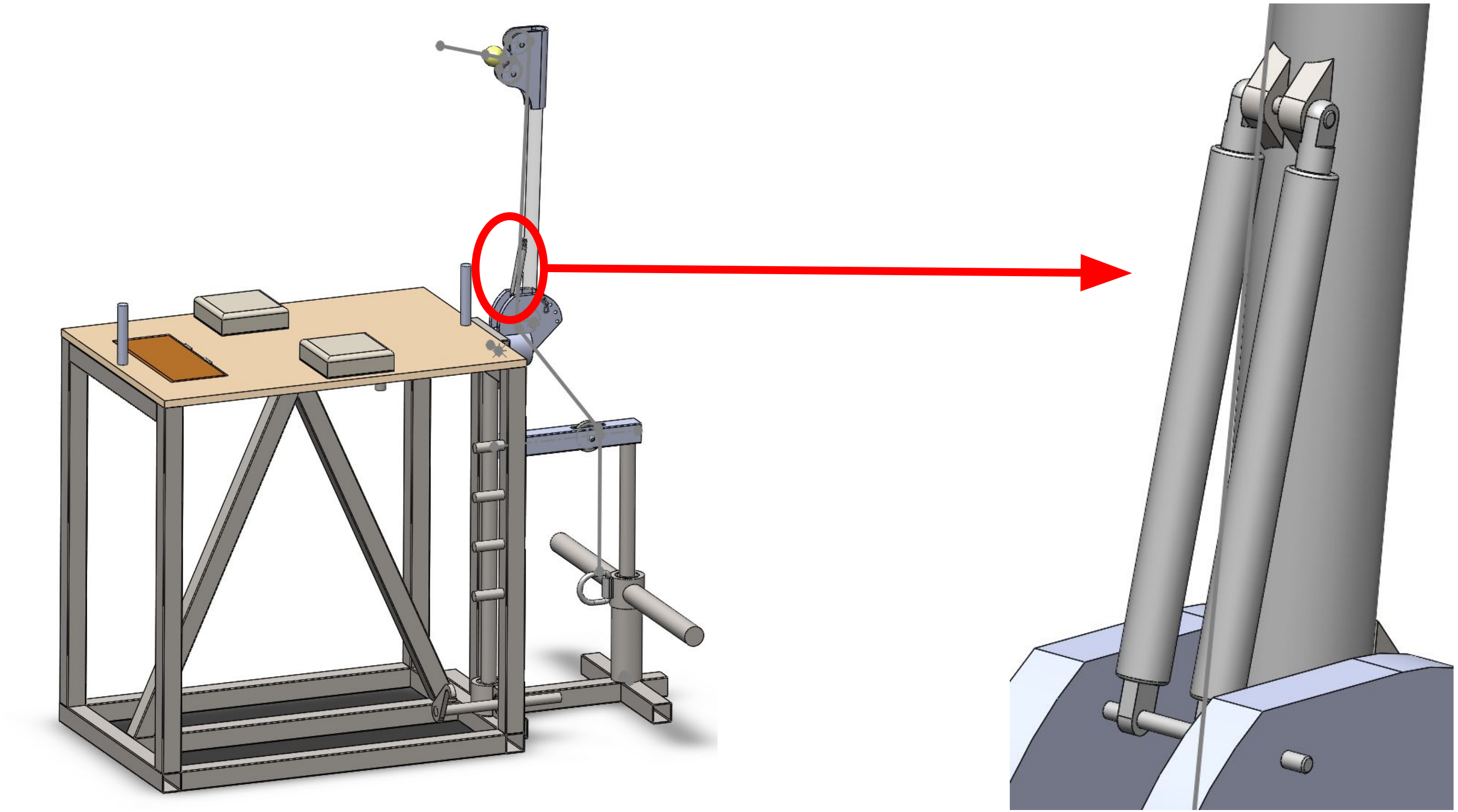




Final Design: Functions Highlight

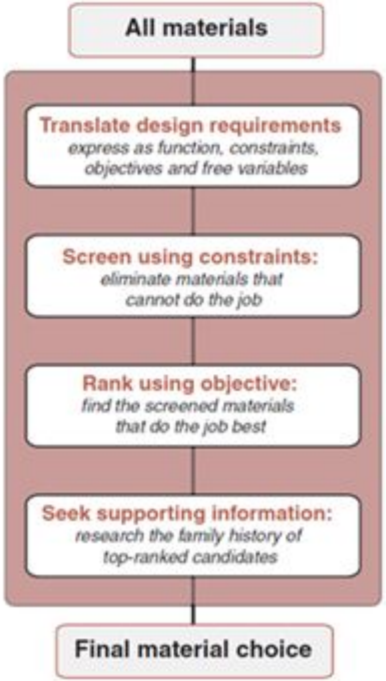


Final Design: Functions Highlight



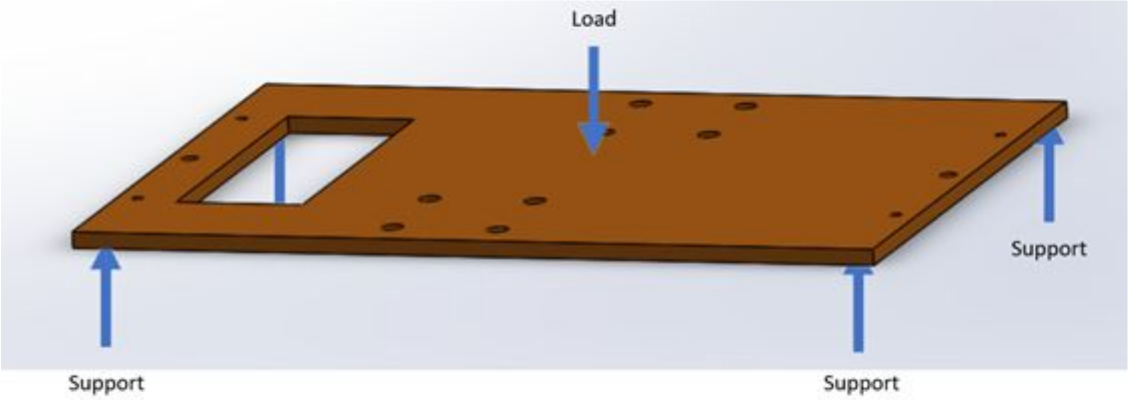
Final Design

Material Analysis



Material Analysis

Table Top



Constraints

Must have high stiffness

Must be light-weight

Low cost

High machinability

Material Analysis

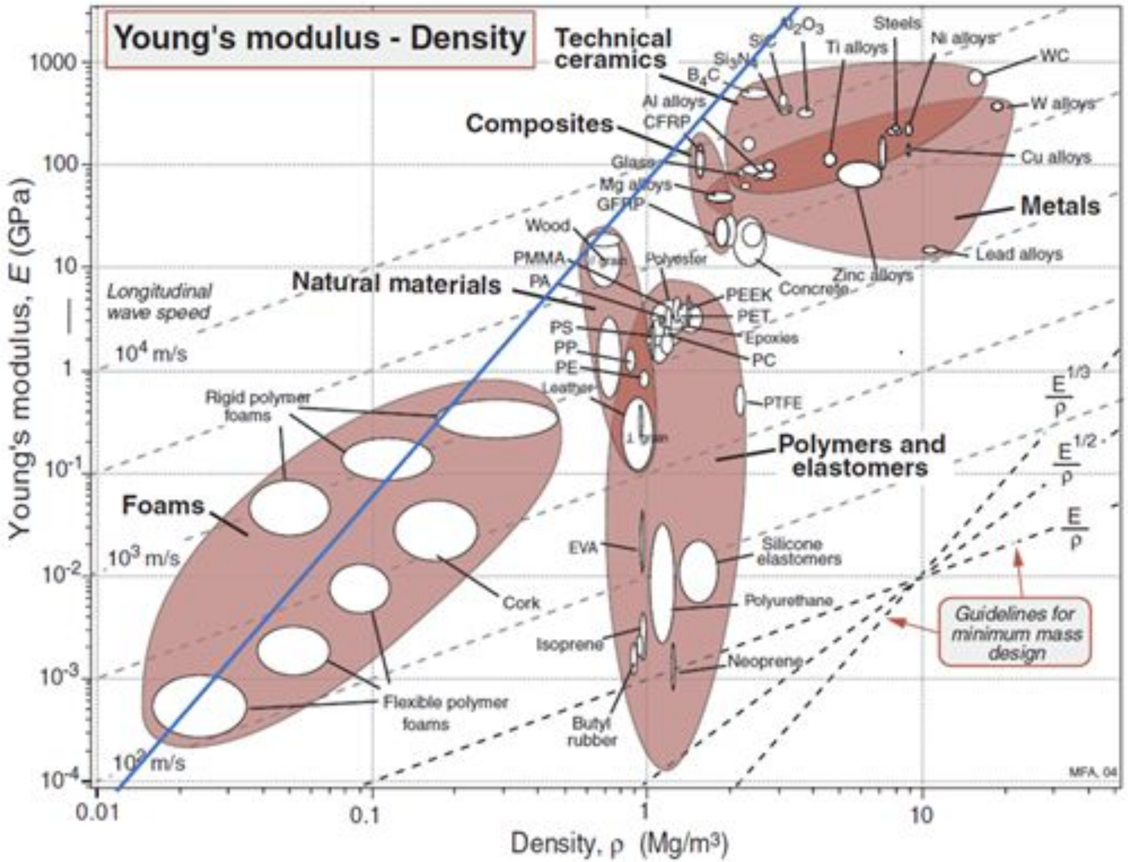
Screen Using constraints

Material performance index

$$M = \frac{\sqrt[3]{E}}{\rho}$$

Materials shortlisted

- Steel
- Aluminium
- High Density Polyethylene (HDPE)
- Ultra-High Molecular Weight Polyethylene (UHMW)
- Wood



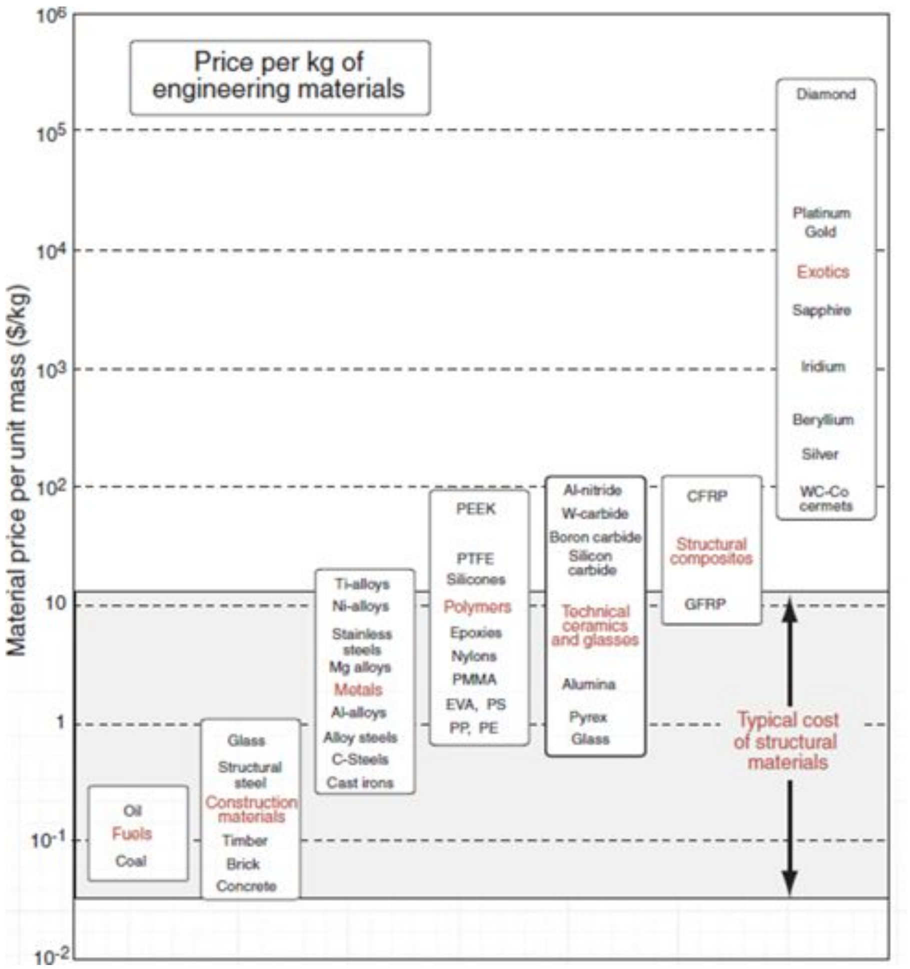
Material Analysis

Rank using objectives

1. Wood
2. HDPE
3. UHMW
4. Aluminium
5. Steel

Material Analysis

Seek supporting info



Material Analysis

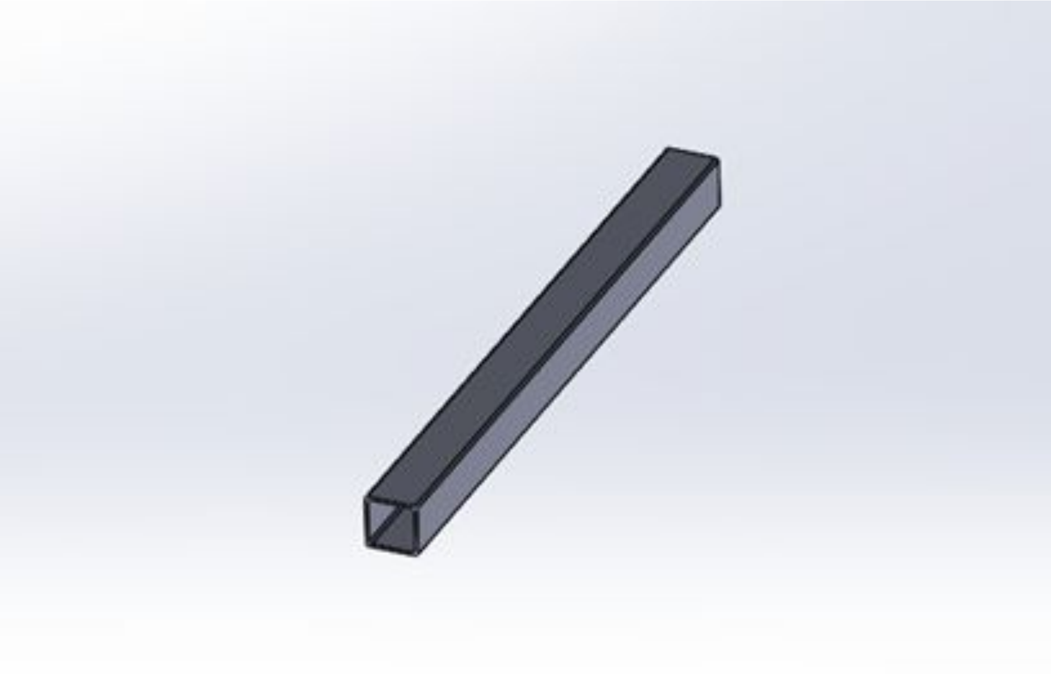
Material Selected : Wood

Material Analysis

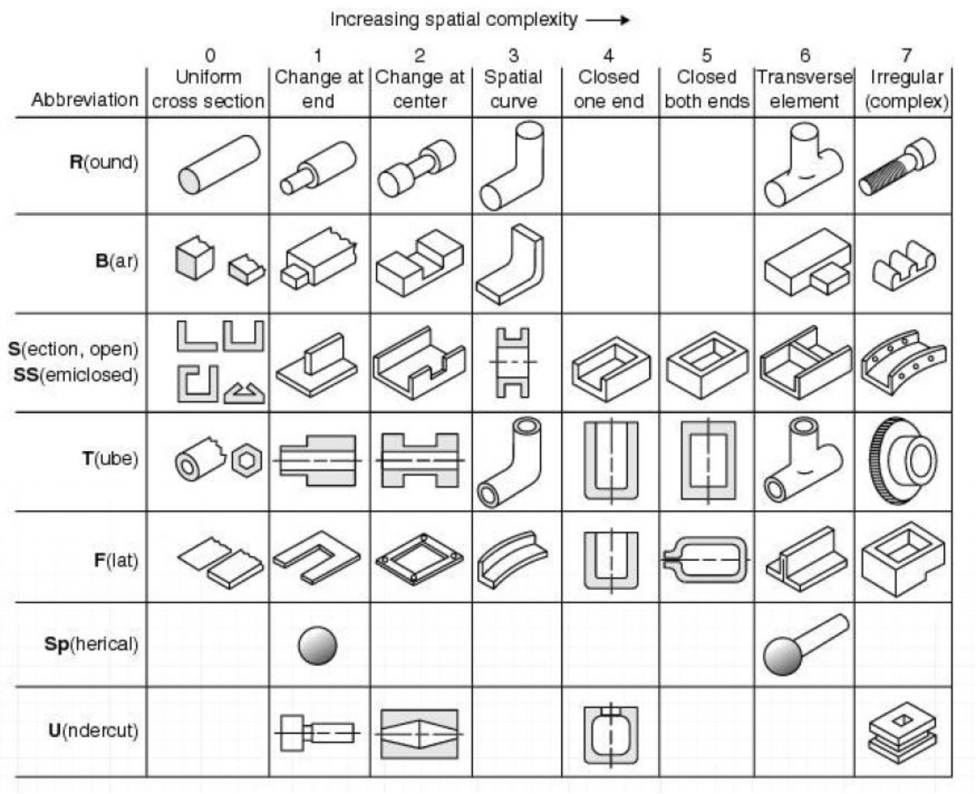
- Pulleys: Cast Iron
- Table support structures: Stainless Steel
- Pulley Arm: Low carbon Steel

Process Selection

Table Support Structures



Process Selection



Spatial Complexity: T0

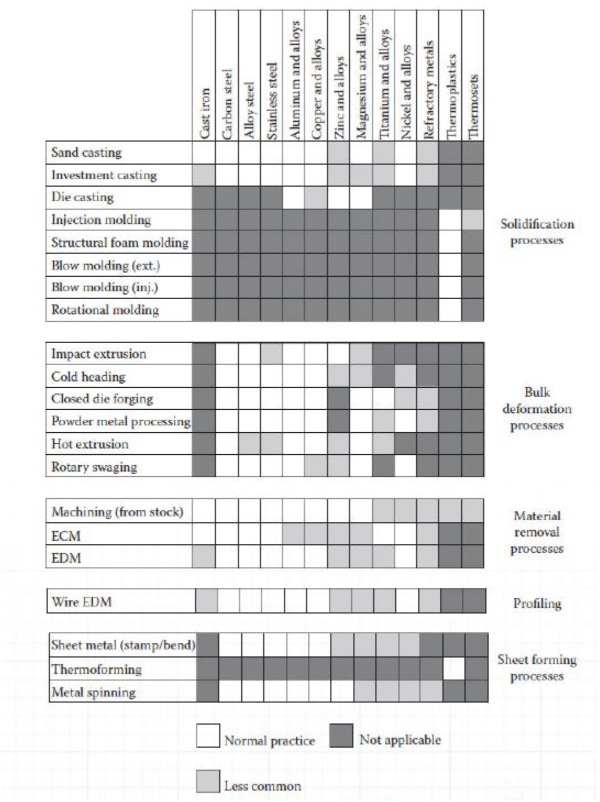
Process Selection

Ability of Manufacturing Processes to Produce Shapes

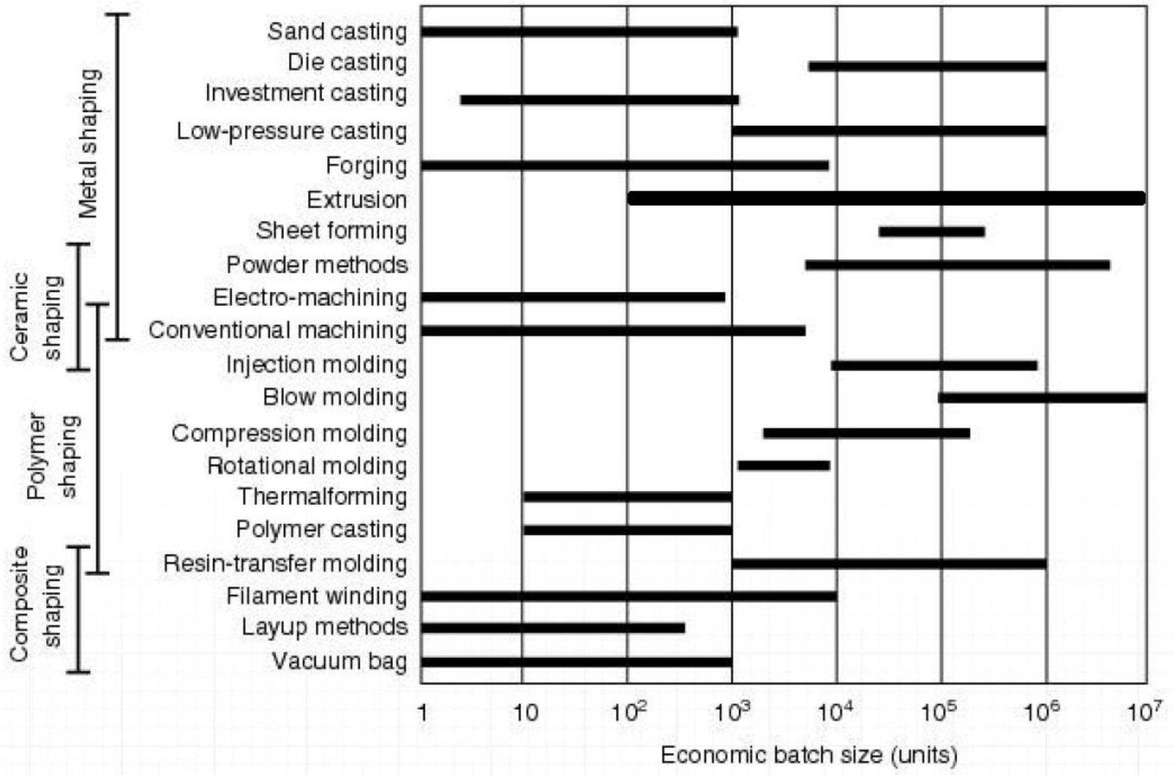
Process	Capability for Producing Shapes
Casting processes	
Sand casting	Can make all shapes
Plaster casting	Can make all shapes
Investment casting	Can make all shapes
Permanent mold	Can make all shapes except T3, T5; F5; U2, U4, U7
Die casting	Same as permanent mold casting
Deformation processes	
Open-die forging	Best for R0 to R3; all B shapes; T1; F0; Sp6
Hot impression die forging	Best for all R, B, and S shapes; T1, T2; Sp
Hot extrusion	All 0 shapes
Cold forging/cold extrusion	Same as hot die forging or extrusion
Shape drawing	All 0 shapes
Shape rolling	All 0 shapes
Sheet-metal working processes	
Blanking	F0 to F2; T7
Bending	R3; B3; S0, S3, S7; T3; F3, F6,
Stretching	F4; S7
Deep drawing	T4; F4, F7
Spinning	T1, T2, T4, T6; F4, F5
Polymer processes	
Extrusion	All 0 shapes
Injection molding	Can make all shapes with proper coring
Compression molding	All shapes except T3, T5, T6, F5, U4
Sheet thermoforming	T4, F4, F7, S5
Powder metallurgy processes	
Cold press and sinter	All shapes except S3, T2, T3, T5, T6, F3, F5, all U shapes
Hot isostatic pressing	All shapes except T5 and F5
Powder injection molding	All shapes except T5, F5, U1, U4
PM forging	Same shape restrictions as cold press and sinter
Machining processes	
Lathe turning	R0, R1, R2, R7; T0, T1, T2; Sp1, Sp6; U1, U2
Drilling	T0, T6
Milling	All B, S, SS shapes; F0 to F4; F6, F7, U7
Grinding	Same as turning and milling
Honing, lapping	R0 to R2; B0 to B2; B7; T0 to T2, T4 to T7; F0 to F2; Sp

- Sand casting
- Plaster casting
- Investment casting
- Die casting
- Hot extrusion
- Cold forging/Cold extrusion
- Shape drawing
- Permanent mold
- Shape rolling
- Lathe turning
- Honing, lapping

Process Selection

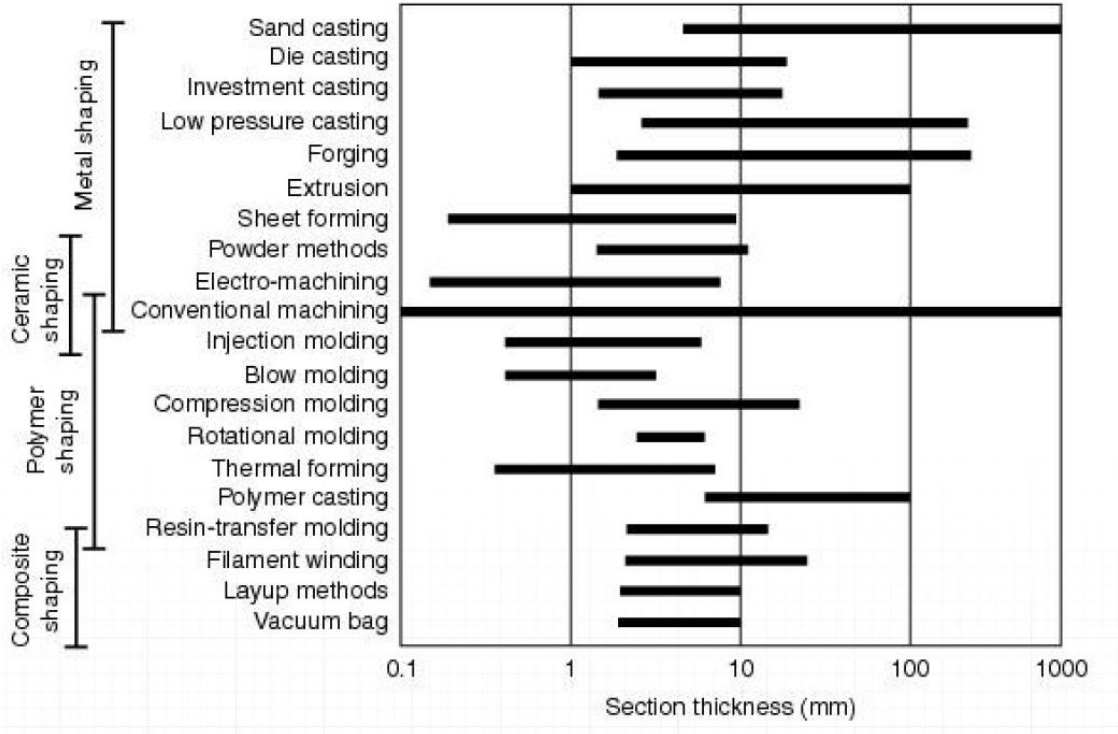


Process Selection



Process Selection

Section thickness of component: 3 mm



Process Selection

Initial Screening

Process	Carbon Steel Yes or No	Reject?	Reason for Elimination
Sand casting	Y	R	Section thickness of 3mm cannot be obtained
Plaster casting	Y	R	Not economical for higher batch sizes
Investment casting	Y	R	Not economical for higher batch sizes
Permanent mold	Y		
Die casting	N		
Hot extrusion	Y		
Cold forging/Cold extrusion	Y		
Shape drawing	Y		
Shape rolling	Y		
Lathe turning	Y	R	Not suitable for square hollow bars
Honing, lapping	Y	R	Not suitable for square hollow bars

Process Selection

Rating of Characteristics of Common Manufacturing Processes

Process	Shape	Cycle Time	Flexibility	Material Utilization	Quality	Equipment Tooling Costs	Handbook Reference
Casting							
Sand casting	3-D	2	5	2	2	1	AHB, vol. 15, p. 523
Evaporative foam	3-D	1	5	2	2	4	AHB, vol. 15, p. 637
Investment casting	3-D	2	4	4	4	3	AHB, vol. 15, p. 646
Permanent mold casting	3-D	4	2	2	3	2	AHB, vol. 15, p. 687
Pressure die casting	3-D solid	5	1	4	2	1	AHB, vol. 15, p. 713
Squeeze casting	3-D	3	1	5	4	1	AHB, vol. 15, p. 727
Centrifugal casting	3-D hollow	2	3	5	3	3	AHB, vol. 15, p. 665
Injection molding	3-D	4	1	4	3	1	EMH, vol. 2, p. 308
Reaction injection molding (RIM)	3-D	3	2	4	2	2	EMH, vol. 2, p. 344
Compression molding	3-D	3	4	4	2	3	EMH, vol. 2, p. 324
Rotational molding	3-D hollow	2	4	5	2	4	EMH, vol. 2, p. 360
Monomer casting contact molding	3-D	1	4	4	2	4	EMH, vol. 2, p. 338
Forming							
Forging, open die	3-D solid	2	4	3	2	2	AHB, vol. 14A, p. 99
Forging, hot closed die	3-D solid	4	1	3	3	2	AHB, vol. 14A, p. 111, 193
Sheet metal forming	3-D	3	1	3	4	1	AHB, vol. 14B, p. 293
Rolling	2-D	5	3	4	3	2	AHB, vol. 14A, p. 459
Extrusion	2-D	5	3	4	3	2	AHB, vol. 14A, p. 421
Superplastic forming	3-D	1	1	5	4	1	AHB, vol. 14B, p. 350
Thermoforming	3-D	3	2	3	2	3	EMH, vol. 2, p. 399
Blow molding	3-D hollow	4	2	4	4	2	EMH, vol. 2, p. 352
Pressing and sintering	3-D solid	2	2	5	2	2	AHB, vol. 7, p. 326
Isostatic pressing	3-D	1	3	5	2	1	AHB, vol. 7, p. 605
Slip casting	3-D	1	5	5	2	4	EMH, vol. 14, p. 153
Machining							
Single-point cutting	3-D	2	5	1	5	5	AHB, vol. 16
Multiple-point cutting	3-D	3	5	1	5	4	AHB, vol. 16
Grinding	3-D	2	5	1	5	4	AHB, vol. 16, p. 421
Electrical discharge machining	3-D	1	4	1	5	1	AHB, vol. 16, p. 557
Joining							
Fusion welding	All	2	5	5	2	4	AHB, vol. 6, p. 175
Brazing/soldering	All	2	5	5	3	4	AHB, vol. 6, p. 328, 349
Adhesive bonding	All	2	5	5	3	5	EMH, vol. 3
Fasteners	3-D	4	5	4	4	5	. . .
Surface treatment							
Shot peening	All	2	5	5	4	5	AHB, vol. 5, p. 126
Surface hardening	All	2	4	5	4	4	AHB, vol. 5, p. 257
CVD/PVD	All	1	5	5	4	3	AHB, vol. 5, p. 510

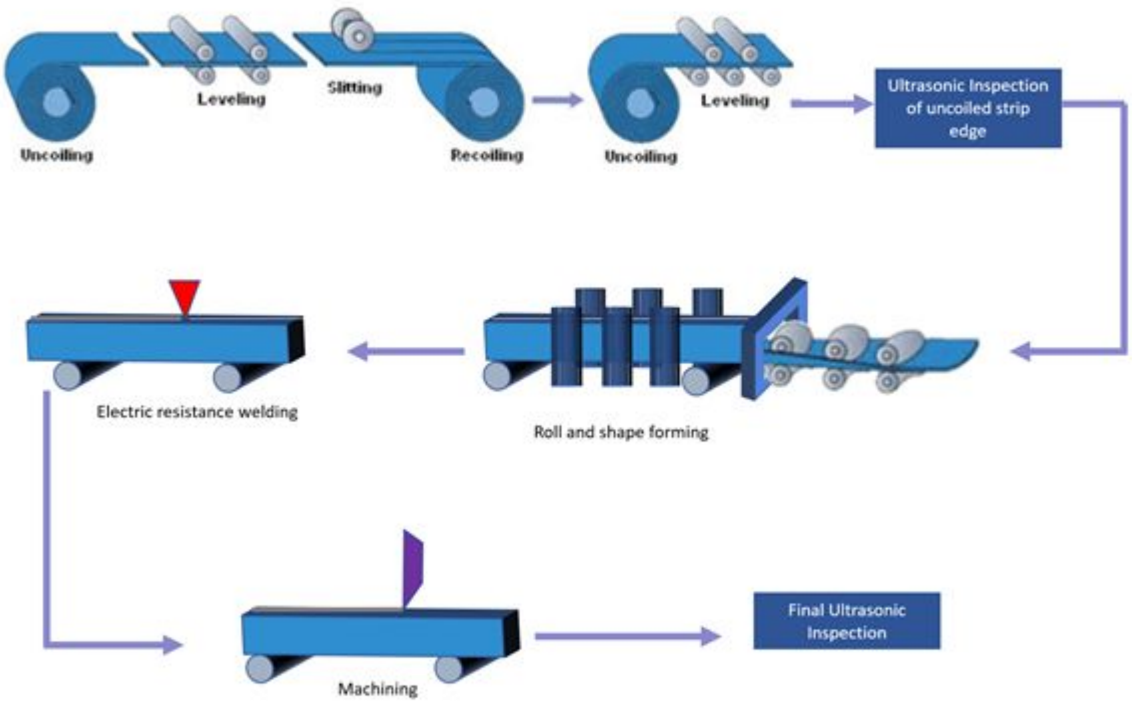
Rating scheme: 1, poorest; 5, best. From *ASM Handbook*, Vol. 20, p. 299, ASM International. Used with permission.

Process Selection

Process	Cycle Time	Process Flexibility	Material Utilisation	Quality	Equipment Tooling	Total
Permanent mold	4	2	2	3	2	**13**
Hot extrusion	5	3	4	3	2	**17**
Cold forging	3	4	3	2	2	**14**
Shape drawing	3	3	4	3	3	**16**
Shape rolling	5	3	4	3	2	**17**

Process selected: Shape Rolling & ERW

Process Selection



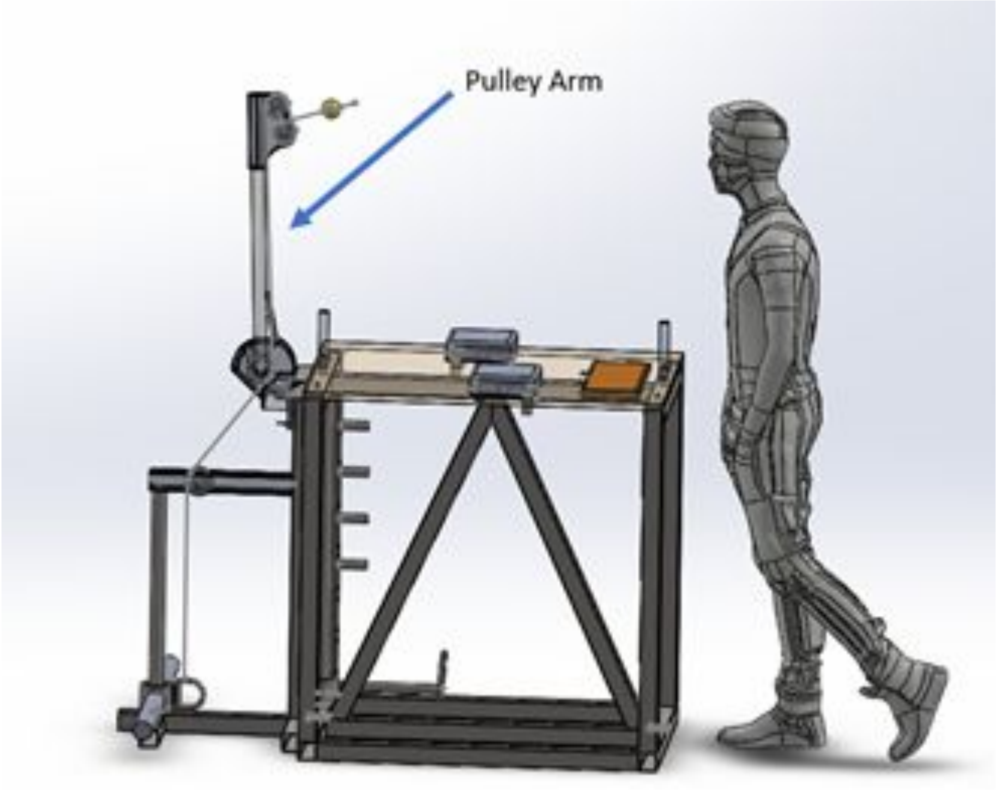
Process Selection

Part	Description	Process
6677	MAIN BODY TABLETOP	Cutting and Finishing
6661	MAIN BODY HORIZONTAL BAR WIDTH	ERW
6662	MAIN BODY HORIZONTAL BAR LENGTH	ERW
6663	MAIN BODY VERTICAL BAR HEIGHT	ERW
6664	MAIN BODY GRIPPING PEG	Cutting & Machining
6665	MAIN BODY DIAGONAL BAR	ERW
6667	MAIN BODY PREACHER CURL PAD (PCP)	Cutting and Finishing
6668	MAIN BODY UPPER HORIZONTAL BAR WIDTH	ERW
6669	MAIN BODY UPPER HORIZONTAL BAR	ERW
6670	MAIN BODY PCP ADJUSTER CONNECTOR	Cutting & Bending
6671	MAIN BODY PCP ADJUSTER	Cutting & Bending
6616	SMITH MACHINE VERITAL BAR	ERW
6626	SMITH MACHINE POSITION ROD	Cutting
6636	SMITH MACHINE ROD	Cutting
6656	SMITH MACHINE SLIDER	Hot extrusion & Machining
6676	SMITH MACHINE SLIDER BLOCK	Waterjet cutting
6686	SMITH MACHINE HANDLE	Cutting
6696	SMITH MACHINE POSITION HOOK	Waterjet cutting
6166	WEIGHT VERTICAL BAR	ERW
6266	WEIGHT HORIZONTAL BAR	ERW
6366	WEIGHT GROUND BAR	ERW
6466	WEIGHT ADJUSTMENT ROD	Cutting
6566	WEIGHT ADJUSTER PLATE	Waterjet cutting
6766	WEIGHT ADJUSTER	Casting & Machining
1166	WEIGHT LOWER PULLEY	Casting & Machining
1466	WEIGHT UPPER PULLEY	Casting & Machining
6866	WEIGHT VERTICAL STATIONARY ROD	Cutting
6966	WEIGHT VERTICAL SLIDING ROD	Hot extrusion & Machining
7066	WEIGHT HORIZONTAL LOADING ROD	Machining
7166	WEIGHT PULLEY ARM	Cutting & Machining
7266	WEIGHT PULLEY HOUSING	Waterjet cutting & Bending
7366	WEIGHT GAS SPRING CONNECTOR	Casting & Machining
7466	WEIGHT UPPER BAR	ERW
7566	WEIGHT PIN CONNECTOR	Casting & Machining
7666	WEIGHT ROPE STOPPER	Injection Molding
7766	WEIGHT VERTICAL STATIONARY ROD TUBE	Hot extrusion & Machining
6001	ELBOW PAD BOARD	Waterjet Cutting
6002	ELBOW PAD PIN	Cutting
6003	ELBOW PAD FOAM	Foam Casting

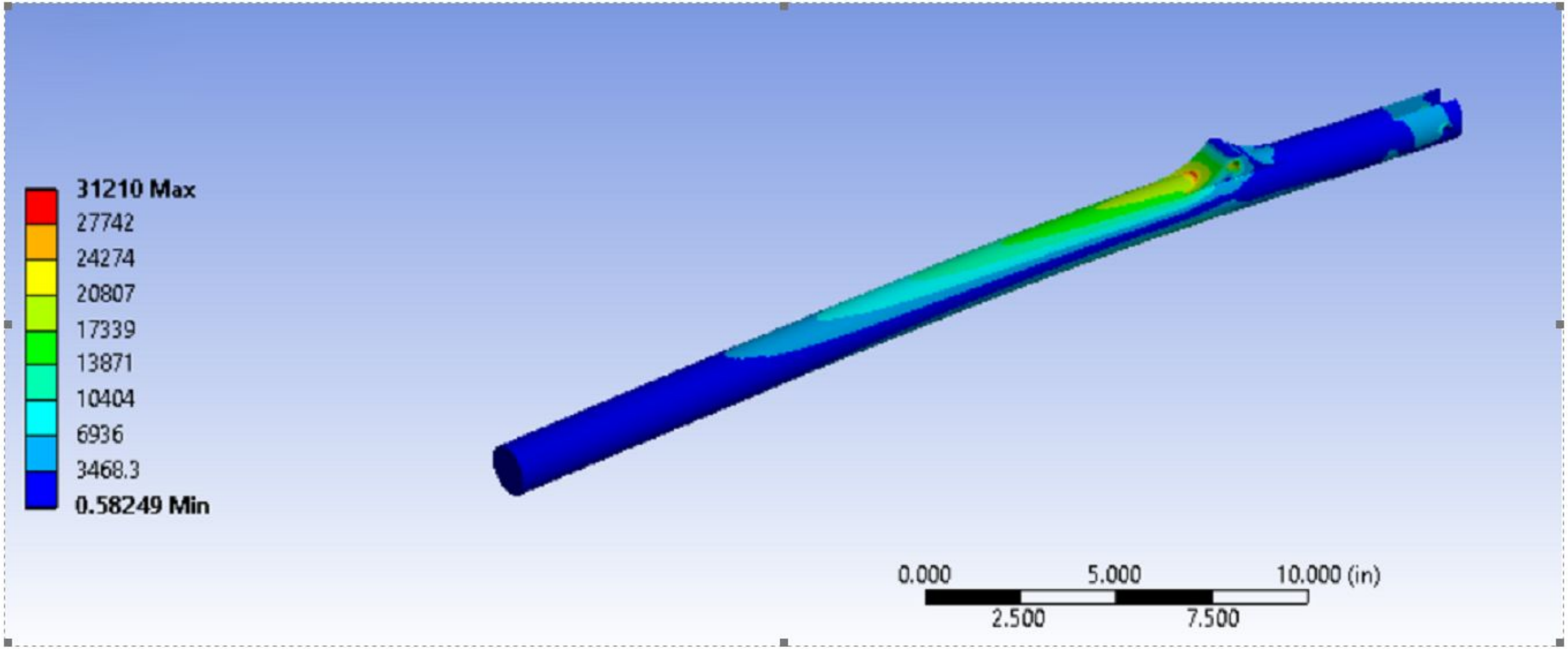
FEA Analysis

Pulley Arm

- 300 lbf



FEA Analysis



FEA Analysis

- Maximum von mises stress acting on the member = 31210 psi
- Yield stress of Low carbon steel = 53700 psi

58% of yield stress

Cost Analysis

OME

Custom Partnet

Cost to Manufacture

Breakeven Analysis

OME

Part No.	Part Description	Material	Qty	Mass (lb)	Material Rate ($/lb)	Material Cost ($)	Mfg Cost	Price
6677	TABLETOP	Teak	1	15.2	0.53	8.056	24.168	72.50
6661	HORIZONTAL BAR WIDTH	Sheet Metal	2	13.4	0.32	4.288	12.864	38.59
6662	HORIZONTAL BAR LENGTH	Sheet Metal	3	26.28	0.32	8.4096	25.2288	75.69
6663	VERTICAL BAR HEIGHT	Sheet Metal	3	28.59	0.32	9.1488	27.4464	82.34
6664	GRIPPING PEG	304 Steel	2	2.38	1.07	2.5466	7.6398	22.92
6665	DIAGONAL BAR	Sheet Metal	2	19.32	0.32	6.1824	18.5472	55.64
6667	PREACHER CURL PAD (PCP)	Teak	1	1.45	0.53	0.7685	2.3055	6.92
6668	UPPER HORIZONTAL BAR WIDTH	Sheet Metal	2	11.04	0.32	3.5328	10.5984	31.80
6669	UPPER HORIZONTAL BAR	Sheet Metal	1	13.16	0.32	4.2112	12.6336	37.90
6670	PCP ADJUSTER CONNECTOR	LCS	1	0.21	0.24	0.0504	0.1512	0.45
6671	PCP ADJUSTER	304 Steel	1	0.92	1.07	0.9844	2.9532	8.86
6616	SMITH MACHINE VERITAL ROD	Sheet Metal	1	9.53	0.32	3.0496	9.1488	27.45
6626	SMITH MACHINE POSITION ROD	Low Carbon Steel	4	2.68	0.24	0.6432	1.9296	5.79
6636	SMITH MACHINE ROD	304 Steel	1	17.88	1.07	19.1316	57.3948	172.18
6656	SMITH MACHINE SLIDER	304 Steel	1	3.92	1.07	4.1944	12.5832	37.75
6676	SMITH MACHINE SLIDER BLOCK	LCS	1	0.62	0.24	0.1488	0.4464	1.34

Part No.	Part Description	Material	Qty	Mass (lb)	Material Rate ($/lb)	Material Cost ($)	Mfg Cost	Price
6686	HANDLE	304 Steel	1	2.95	1.07	3.1565	9.469	28.41
6696	POSITION HOOK	LCS	1	0.93	0.24	0.2232	0.669	2.01
6166	WEIGHT VERTICAL BAR	Sheet Metal	1	9.53	0.32	3.0496	9.148	27.45
6266	WEIGHT HORIZONTAL BAR	Sheet Metal	5	10.3	0.32	3.296	9.888	29.66
6366	GROUND BAR	LCS	1	4.64	0.24	1.1136	3.340	10.02
6466	WEIGHT ADJUSTMENT ROD	LCS	1	0.92	0.24	0.2208	0.662	1.99
6566	WEIGHT ADJUSTER PLATE	LCS	2	1.18	0.3	0.354	1.062	3.19
6766	WEIGHT ADJUSTER	LCS	1	17.57	0.3	5.271	15.813	47.44
1166	LOWER PULLEY	LCS	2	1.014	0.3	0.3042	0.912	2.74
1466	UPPER PULLEY	LCS	2	1.08	0.3	0.324	0.972	2.92
6866	VERTICAL STATIONARY ROD	304 Steel	1	12.26	1.07	13.1182	39.354	118.06
6966	VERTICAL SLIDING ROD	304 Steel	1	3.92	1.07	4.1944	12.583	37.75
7066	HORIZONTAL LOADING ROD	304 Steel	2	27.84	1.07	29.7888	89.366	268.10
7166	PULLEY ARM	304 Steel	1	12.36	1.07	13.2252	39.675	119.03
7266	PULLEY HOUSING	Sheet Metal	1	4.51	0.32	1.4432	4.329	12.99
7366	GAS SPRING CONNECTOR	LCS	2	0.02	0.24	0.0048	0.014	0.04
7466	UPPER BAR	LCS	1	3.73	0.24	0.8952	2.685	8.06
7566	PIN CONNECTOR	LCS	1	0.13	0.24	0.0312	0.093	0.28
7666	ROPE STOPPER	ABS	1	0.13	1.5	0.195	0.585	1.76
7766	VERTICAL STATIONARY ROD TUBE	304 Steel	1	11.49	1.07	12.2943	36.882	110.65
6001	ELBOW PAD BOARD	LCS	1	1.75	0.24	0.42	1.26	3.78
6002	ELBOW PAD PIN	LCS	2	0.9	0.24	0.216	0.648	1.94
6003	ELBOW PAD FOAM	Polyurethane Foam Rigid	1	0.56	1.58	0.8848	2.654	7.96
					Total	**169.37**	**508.11**	**1524.3**

Cost Analysis

Price of OTS components

Part No.	Part Description	Specs	Qty	Price
1060	SCREW FOR HANDLE	SS Socket head	2	0.06
1061	SCREW FOR TABLETOP	Black Oxide Alloy Steel	4	0.08
1062	HINGE FOR PCP	Mortise MNT	2	1.05
1063	SCREW FOR PCP	Alloy Steel Flat Head	8	0.22
1064	SCREW FOR PCP ADJUSTER	Flat Head Phillips Screw	4	0.1
1006	LINEAR BEARING	Thomson AB1420	1	2.1
1016	BALL BEARING	6048	1	2.08
1066	SLEEVE BEARING	High Load Dry Running	1	10
1266	SCREW FOR ADJUSTER	Zinc Pated Steel Ribbed	1	0.277
1366	SPRING PIN	SS Dowell Pin	1	0.14
1566	HITCH PIN FOR PULLEY ARM	Zinc Plated Steel Ribbed	1	0.277
1766	BOLT FOR PULLEY ON ADJUSTER	SS Button Head	1	0.2
1866	LOCKNUT	High Strength Steel	2	0.04
1966	GAS SPRING	Various	2	2.77
2066	PIN FOR GAS SPRING	SS Dowell Pin	1	0.14
2166	LINEAR BEARING	Thomson A81421	1	2.1
2266	RING FOR ROPE	SS	1	.1
2366	PIN FOR UPPER PULLEY	SS Dowell Pin	2	0.28
2466	SCREW FOR LOWER PULLEY	Zinc Plated Steel Ribbed	1	0.277
2566	PIN FOR GAS SPRING	SS Dowell Pin	1	0.14
2666	WIRE ROPE	Nylon Core SS wire rope	1	1.8
			Total	24.231

OME

Manufacturing cost = $508.11
Selling price = $1548.5

Cost Analysis

Cost to manufacture method

Assumptions

- 5000 number of products to be manufactured
- 50 weeks per year operation
- 18 hours of machine operation per day in 3 shifts
- In case of components which are same in design but appears multiple times in a unit of the product, parts to be manufactured will be multiplied to the number of repeats it has in the design

Cost to manufacture method

	Material cost				Labor cost			Tooling cost				Equipment cost						Overhead cost		Total cost
Equation	$C_M = \frac{mc_m}{1-f}$				$C_L = \frac{c_w}{n'}$			$C_T = \frac{c_t k}{n}$				$C_E = \left(\frac{1}{n'}\right)\left(\frac{c_e\, n_e}{Lt_{wo}}\right) q$						$C_{OH} = \frac{c_{oh}}{n'}$		
Cost element	c_m	f	m (lb)	C_M	c_w ($/h)	n', (units/h)	C_L	c_t ($/set)	n (units)	k	C_T	c_e ($)	Number of equipment used, n_e	t_{wo} (yrs)	L	q	C_E	c_{OH} ($/h)	C_{OH}	Total unit cost = C_M+C_L+C_T+C_E+C_{OH}
6677	0.53	0.1	15.2	**8.951**	80	40	**2.000**	7000	5000	5	**7**	70000	1	5	1	0.5	**0.02778**	400	**10.000**	**27.979**
6661	0.32	0.05	13.4	**4.514**	160	700	**0.229**	100000	10000	1	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**16.459**
6662	0.32	0.05	26.28	**8.852**	160	700	**0.229**	100000	15000	1.5	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**20.797**
6663	0.32	0.05	28.59	**9.630**	160	700	**0.229**	100000	15000	1.5	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**21.575**
6664	1.07	0.1	2.38	**2.830**	160	3000	**0.053**	50000	10000	0.5	**2.5**	500000	1	5	1	0.143	**0.00076**	1200	**0.400**	**5.784**
6665	0.32	0.05	19.32	**6.508**	160	700	**0.229**	100000	10000	1	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**18.453**
6667	0.53	0.1	1.45	**0.854**	80	50	**1.600**	7000	5000	5	**7**	70000	1	5	1	0.5	**0.02222**	400	**8.000**	**17.476**
6668	0.32	0.05	11.04	**3.719**	160	700	**0.229**	100000	10000	1	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**15.664**
6669	0.32	0.05	13.16	**4.433**	160	700	**0.229**	100000	5000	0.5	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**16.378**
6670	0.24	0.05	0.21	**0.053**	20	10000	**0.002**	10000	5000	0.25	**0.5**	4000	1	8	1	0.1	**0.00000**	50	**0.005**	**0.560**
6671	1.07	0.1	0.92	**1.094**	160	3000	**0.053**	50000	5000	0.25	**2.5**	500000	1	5	1	0.143	**0.00076**	1200	**0.400**	**4.048**
6616	0.32	0.05	9.53	**3.210**	160	700	**0.229**	100000	5000	0.5	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**15.155**
6626	0.24	0.05	2.68	**0.677**	20	10000	**0.002**	10000	20000	1	**0.5**	4000	1	8	1	0.167	**0.00000**	50	**0.005**	**1.184**
6636	1.07	0.1	17.88	**21.257**	20	10000	**0.002**	10000	5000	0.25	**0.5**	4000	1	8	1	0.167	**0.00000**	50	**0.005**	**21.764**
6656	1.07	0.1	3.92	**4.660**	180	80	**2.250**	55000	5000	0.1	**1.1**	55000	1	5	1	0.33	**0.00720**	700	**8.750**	**16.768**
6676	0.24	0.05	0.62	**0.157**	20	60	**0.333**	20000	5000	0.25	**1**	100000	1	5	1	0.2	**0.01058**	90	**1.500**	**3.001**
6686	1.07	0.1	2.95	**3.507**	20	10000	**0.002**	10000	5000	0.25	**0.5**	4000	1	8	1	0.167	**0.00000**	50	**0.005**	**4.014**
6696	0.24	0.05	0.93	**0.235**	20	60	**0.333**	20000	5000	0.25	**1**	100000	1	5	1	0.2	**0.01058**	90	**1.500**	**3.079**
6166	0.32	0.05	9.53	**3.210**	160	700	**0.229**	100000	5000	0.5	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**15.155**
6266	0.32	0.05	10.3	**3.469**	160	700	**0.229**	100000	25000	2.5	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**15.414**
6366	0.24	0.05	4.64	**1.172**	160	700	**0.229**	100000	5000	0.5	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**13.117**
6466	0.24	0.05	0.92	**0.232**	20	10000	**0.002**	10000	5000	0.25	**0.5**	4000	1	8	1	0.167	**0.00000**	50	**0.005**	**0.739**

	Material cost				Labor cost			Tooling cost				Equipment cost						Overhead cost		Total cost
Equation	$C_M = \frac{mc_m}{1-f}$				$C_L = \frac{c_w}{n'}$			$C_T = \frac{c_t k}{n}$				$C_E = \left(\frac{1}{n'}\right)\left(\frac{c_e\, n_e}{Lt_{wo}}\right) q$						$C_{OH} = \frac{c_{oh}}{n'}$		
Cost element	c_m	f	m (lb)	C_M	c_w ($/h)	n', (units/h)	C_L	c_t ($/set)	n (units)	k	C_T	c_e ($)	Number of equipment used, n_e	t_{wo} (yrs)	L	q	C_E	c_{OH} ($/h)	C_{OH}	Total unit cost = C_M+C_L+C_T+C_E+C_{OH}
6566	0.3	0.05	1.18	**0.373**	20	60	**0.333**	20000	10000	0.5	**1**	100000	1	5	1	0.2	**0.01058**	90	**1.500**	**3.217**
6766	0.3	0.05	17.57	**5.548**	60	10	**6.000**	7500	5000	1	**1.5**	300000	1	6	1	0.2	**0.15873**	20	**2.000**	**15.207**
1166	0.3	0.05	1.014	**0.320**	60	20	**3.000**	7500	10000	2	**1.5**	300000	1	6	1	0.2	**0.07937**	20	**1.000**	**5.900**
1466	0.3	0.05	1.08	**0.341**	60	20	**3.000**	7500	10000	2	**1.5**	300000	1	6	1	0.2	**0.07937**	20	**1.000**	**5.920**
6866	1.07	0.1	12.26	**14.576**	20	10000	**0.002**	10000	5000	0.25	**0.5**	4000	1	8	1	0.167	**0.00000**	50	**0.005**	**15.083**
6966	1.07	0.1	3.92	**4.660**	180	80	**2.250**	55000	5000	0.1	**1.1**	55000	1	5	1	0.33	**0.00720**	700	**8.750**	**16.768**
7066	1.07	0.1	27.84	**33.099**	20	5	**4.000**	700	10000	100	**7**	180000	1	5	1	0.2	**0.22857**	200	**40.000**	**84.327**
7166	1.07	0.1	12.36	**14.695**	180	30	**6.000**	55000	5000	0.1	**1.1**	55000	1	5	1	1	**0.05820**	700	**23.333**	**45.186**
7266	0.32	0.05	4.51	**1.519**	40	100	**0.400**	25000	5000	0.25	**1.25**	150000	1	5	1	0.2	**0.00952**	180	**1.800**	**4.979**
7366	0.24	0.05	0.02	**0.005**	60	20	**3.000**	7500	10000	2	**1.5**	300000	1	6	1	0.2	**0.07937**	20	**1.000**	**5.584**
7466	0.24	0.05	3.73	**0.942**	160	700	**0.229**	100000	5000	0.5	**10**	500000	1	5	1	0.091	**0.00206**	1200	**1.714**	**12.887**
7566	0.24	0.05	0.13	**0.033**	60	20	**3.000**	7500	5000	1	**1.5**	300000	1	6	1	0.2	**0.07937**	20	**1.000**	**5.612**
7666	1.5	0.05	0.13	**0.205**	20	3000	**0.007**	7000	5000	0.5	**0.7**	150000	1	5	1	1	**0.00159**	800	**0.267**	**1.180**
7766	1.07	0.05	11.49	**12.941**	180	80	**2.250**	55000	5000	0.1	**1.1**	55000	1	5	1	0.33	**0.00720**	700	**8.750**	**25.049**
6001	0.24	0.05	1.75	**0.442**	20	60	**0.333**	20000	5000	0.25	**1**	100000	1	5	1	0.2	**0.01058**	90	**1.500**	**3.286**
6002	0.24	0.05	0.9	**0.227**	20	10000	**0.002**	10000	10000	0.5	**0.5**	4000	1	8	1	0.167	**0.00000**	50	**0.005**	**0.734**
6003	1.58	0.1	0.56	**0.983**	80	100	**0.800**	800	5000	1	**0.16**	10000	1	10	1	1	**0.00159**	100	**1.000**	**2.945**
																				528.426

Cost Analysis

Cost to manufacture method

Manufacturing cost = 528.426

Cost Analysis

Break even analysis

Break even point - 650

Part	G&A Expenses	Factory Expenses	Sales & OH	Depreciation	Total Fixed Cost per month, f ($)	Labor cost	Material cost	Total Variable cost per unit, v ($/Unit)	Break-even target (Units)	Selling price ($/unit)
6677	10000	800	1200	4666.67	**16666.67**	1.60	8.95	**10.55**	**650**	**36.192**
6661	10000	4800	1200	33333.33	**49333.33**	3.20	4.51	**7.71**	**1300**	**45.662**
6662	10000	7200	1200	33333.33	**51733.33**	3.20	8.85	**12.05**	**1950**	**38.582**
6663	10000	7200	1200	33333.33	**51733.33**	3.20	9.63	**12.83**	**1950**	**39.360**
6664	10000	2400	1200	33333.33	**46933.33**	3.20	2.83	**6.03**	**1300**	**42.132**
6665	10000	4800	1200	33333.33	**49333.33**	3.20	6.51	**9.71**	**1300**	**47.657**
6667	10000	800	1200	4666.67	**16666.67**	1.60	0.85	**2.45**	**650**	**28.095**
6668	10000	4800	1200	33333.33	**49333.33**	3.20	3.72	**6.92**	**1300**	**44.867**
6669	10000	2400	1200	33333.33	**46933.33**	3.20	4.43	**7.63**	**650**	**79.838**
6670	10000	100	1200	266.67	**11566.67**	0.40	0.05	**0.45**	**650**	**18.248**
6671	10000	100	1200	33333.33	**44633.33**	3.20	1.09	**4.29**	**650**	**72.960**
6616	10000	2400	1200	33333.33	**46933.33**	3.20	3.21	**6.41**	**650**	**78.615**
6626	10000	200	1200	266.67	**11666.67**	0.40	0.68	**1.08**	**2600**	**5.564**
6636	10000	50	1200	266.67	**11516.67**	0.40	21.26	**21.66**	**650**	**39.375**
6656	10000	2400	1200	3666.67	**17266.67**	3.60	4.66	**8.26**	**650**	**34.825**
6676	10000	90	1200	6666.67	**17956.67**	0.40	0.16	**0.56**	**650**	**28.182**
6686	10000	50	1200	266.67	**11516.67**	0.40	3.51	**3.91**	**650**	**21.625**
6696	10000	90	1200	6666.67	**17956.67**	0.40	0.23	**0.63**	**650**	**28.261**
6166	10000	2400	1200	33333.33	**46933.33**	3.20	3.21	**6.41**	**650**	**78.615**
6266	10000	12000	1200	33333.33	**56533.33**	3.20	3.47	**6.67**	**3250**	**24.064**
6366	10000	2400	1200	33333.33	**46933.33**	3.20	1.17	**4.37**	**650**	**76.577**
6466	10000	50	1200	266.67	**11516.67**	0.40	0.23	**0.63**	**650**	**18.350**
6566	10000	180	1200	6666.67	**18046.67**	0.40	0.37	**0.77**	**1300**	**14.655**
6766	10000	2500	1200	20000.00	**33700.00**	1.20	5.55	**6.75**	**650**	**58.595**
1166	10000	5000	1200	20000.00	**36200.00**	1.20	0.32	**1.52**	**1300**	**29.366**
1466	10000	5000	1200	20000.00	**36200.00**	1.20	0.34	**1.54**	**1300**	**29.387**
6866	10000	50	1200	266.67	**11516.67**	0.40	14.58	**14.98**	**650**	**32.694**
6966	10000	2400	1200	3666.67	**17266.67**	3.60	4.66	**8.26**	**650**	**34.825**
7066	10000	2000	1200	12000.00	**25200.00**	0.40	33.10	**33.50**	**1300**	**52.883**
7166	10000	700	1200	3666.67	**15566.67**	3.60	14.69	**18.29**	**650**	**42.243**
7266	10000	180	1200	10000.00	**21380.00**	0.80	1.52	**2.32**	**650**	**35.211**
7366	10000	5000	1200	20000.00	**36200.00**	1.20	0.01	**1.21**	**1300**	**29.051**
7466	10000	2400	1200	33333.33	**46933.33**	3.20	0.94	**4.14**	**650**	**76.347**
7566	10000	2500	1200	20000.00	**33700.00**	1.20	0.03	**1.23**	**650**	**53.079**
7666	10000	900	1200	10000.00	**22100.00**	0.40	0.21	**0.61**	**650**	**34.605**
7766	10000	2400	1200	3666.67	**17266.67**	3.60	12.94	**16.54**	**650**	**43.105**
6001	10000	90	1200	6666.67	**17956.67**	0.40	0.44	**0.84**	**650**	**28.468**
6002	10000	100	1200	266.67	**11566.67**	0.40	0.23	**0.63**	**1300**	**9.525**
6003	10000	300	1200	666.67	**12166.67**	1.60	0.98	**2.58**	**650**	**21.301**
										1552.990

Cost Analysis

Break even analysis

Selling price including OTS parts = $1577.221

Cost Analysis

Cost comparison

	Estimation Technique	Estimated value
Manufacturing cost	OME	508.11
	Cost to Manufacture	528.426
Selling price	OME	1548.561
	Break Even Analysis	1577.221

Conclusion

- Project objective met

- Appropriate justification product’s manufacturability
- DFA metrics improved significantly
- Marketability
- Future work


Thank You!
Questions?