CHAPTER III

METHODOLOGY

Design for manufacturability is proven design methodologies that work for any size company. Early consideration of manufacturing issues shortens product development time, minimizes development cost, and ensures a smooth transition into production for quick time market. Select processes compatible with design intent, materials and production volumes. Select materials compatible with production process and that minimize processing time and stages in the manufacturing process will be shown below.

3.1 Flowchart Design for manufacture Process

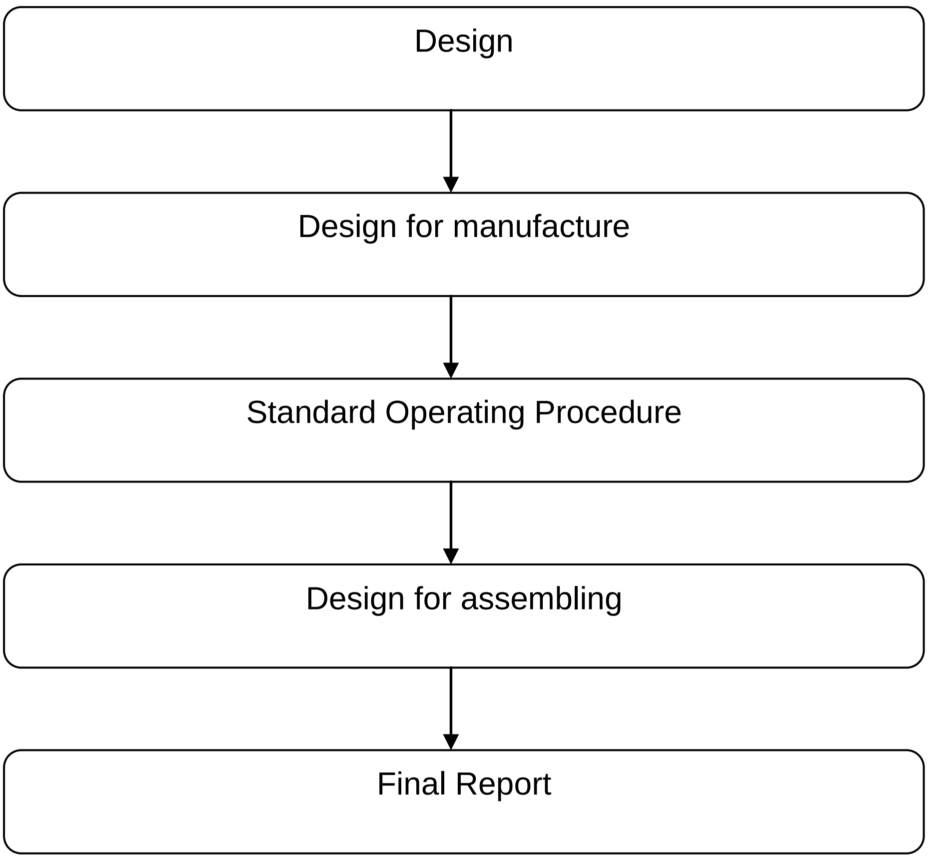


Fig. 3.1 Flowchart Process

3.2 Design

The process design of assistive device has been made by designer before. From design, I will make plan of manufacture process and how to assembling the assistive device. But first, I must determine the production cost to know how much that need to produce it cost. Design of assistive device will be shown below.

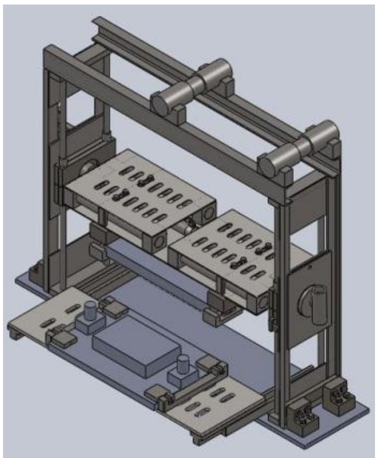


Fig. 3.2 The assistive device

3.3 Design for manufacture

The cost of a product is determined by the cost of material and production costs.

- Total Cost

$C_u = C_M + C_{plan} + \Sigma\, C_p$

Material cost consists of the purchase price and an indirect cost which is a special fee is charged for material relating to the storage and preparation.

- Material Cost

$C_M = C_{Mo} + C_{Mi}$

The cost of the production process can be broken down into the cost of preparation and equipment, the cost of machining and cutting tool costs

- Production Cost

$C_P = C_r + C_m + C_e$

Specialized equipment such as the fixture may be necessary in order to minimize non-productive time. This fixture is made in accordance with the used machine tools, machining geometry and material way.

- Fixture and Prepare Cost

  $C_r = (C_{set} + C_{fix} + C_{pr}) / n_t$

Machining costs are calculated based on the average machining time and cost of operation per piece with the ever so influenced by the rate of production speed. Cost cutting tool should be established as a separate cost component because it has direct connection with the tool life is the main variable in the machining process

- Machining Cost

  $C_m = c_m \cdot t_m$

- Tool Cost

  $C_e = c_e \cdot t_c / T$

Information:

C_u : Total Cost

C_M : Material Cost

C_{plan} : Plan production cost

C_p : Production Cost

C_{Mo} : Purchase Cost

C_{Mi} : Indirect Cost

C_r : Fixture and Prepare Cost

C_m : Machining Cost

C_e : Tool Cost

C_{set} : Setting Cost

C_{fix} : Fixture Cost

C_{pr} : Prepare NC Cost

n_t : Total Product

c_m : Machine operation cost

t_m : Machining Time

t_c : Effective Time

T : Tool Life

3.3.1 Machine operation cost (c_m)

Machine operation cost is a fee to find out how much it cost machine to produce a product. Before calculating the cost of production, then we must know the price of a machine to be used and the depreciation of the machine. So it will be cost plus the operator to determine the cost of machining. There are five machines that used to produce the product.

a) Lathe machine

To calculate the cost of the machine needs to know what the price of a machine. Table 3.1 will show how the depreciation of a machine to produce a product.

Table 3.1 Lathe machine operation cost

Variable	**Value**
Machine Cost	Rp. 60.000.000, 00
Economic Life	5 years
Interest	12 %
Lathe machine value	Rp. 60 Jt + (5 x 12 % x 60 Jt) = Rp. 96.000.000, 00
Depreciation by year	$\frac{96\ Jt}{5\ Yr}$ = Rp. 19, 2 Jt/year
Depreciation by month	$\frac{19{,}2\ Jt}{12\ Mnth}$ = Rp. 1.600.0000/month
Depreciation by day	$\frac{1{,}6\ Jt}{24\ Day}$ = Rp. 66.666/day
Depreciation by hour	$\frac{66.666\ Jt}{8\ Hr}$ = Rp. 8.333/hour
Depreciation by minute	$\frac{8.333\ Jt}{60\ min}$ = Rp 139/min

So, the Machine operation cost (c_m) for lathe machine is Rp 139/min.

b) Shaping Machine

The operation cost of shaping machine will be shown at table below.

Table 3.2 Shaping machine operation cost

Variable	Value
Machine Cost	Rp. 75.000.000, 00
Economic Life	5 years
Interest	12 %
Shaping machine value	Rp. 75 Jt + (5 x 12 % x 75 Jt) = Rp. 120.000.000, 00
Depreciation by year	$\frac{120\ Jt}{5\ Yr}$ = Rp. 24 Jt/year
Depreciation by minute	$\frac{24\ Jt}{138240\ min}$ = Rp 174/min

So, the Machine operation cost (c_m) for shaping machine is Rp 174/min.

c) Drilling Machine

The operation cost of drilling machine will be shown at table below.

Table 3.3 Drilling machine operation cost

Variable	Value
Machine Cost	Rp. 20.000.000, 00
Economic Life	5 years
Interest	12 %
Drilling machine value	Rp. 20 Jt + (5 x 12 % x 20 Jt) = Rp. 32.000.000, 00
Depreciation by year	$\frac{32\ Jt}{5\ Yr}$ = Rp. 6.400.000,00 Jt/year
Depreciation by minute	$\frac{6.4\ Jt}{138240\ min}$ = Rp 46/min

So, the Machine operation cost (c_m) for drilling machine is Rp 46/min.

d) Milling Machine

The operation cost of drilling machine will be shown at table below.

Table 3.4 Milling machine operation cost

Variable	**Value**
Machine Cost	Rp. 80.000.000, 00
Economic Life	5 years
Interest	12 %
Milling machine value	Rp. 80 Jt + (5 x 12 % x 80 Jt) = Rp. 128.000.000, 00
Depreciation by year	$\frac{128\ Jt}{5\ Yr}$ = Rp. 25,6 Jt/year
Depreciation by minute	$\frac{25{,}6\ Jt}{138240\ min}$ = Rp 185/min

So, the Machine operation cost (c_m) for milling machine is Rp 185/min

e) Cutting Machine

The operation cost of drilling machine will be shown at table below.

Table 3.5 Cutting machine operation cost

Variable	**Value**
Machine Cost	Rp. 15.000.000, 00
Economic Life	5 years
Interest	12 %
Cutting machine value	Rp. 15 Jt + (5 x 12 % x 15 Jt) = Rp. 24.000.000, 00
Depreciation by year	$\frac{24\ Jt}{5\ Yr}$ = Rp. 4,8 Jt/year
Depreciation by minute	$\frac{4{,}8\ Jt}{138240\ min}$ = Rp 35/min

So, the Machine operation cost (c_m) for cutting machine is Rp 35/min

3.3.2 Machining cost

After we know every machine operation cost then we insert machining time to have a machining cost. It will be shown at table below.

Table 3.6 Machining time from lathe and shaping machine

Lathe machine C_m **= 139/min**		**Shaping machine** C_m **= 174/min**	
No Part	**Time (t_m)**	**No Part**	**Time(t_m)**
3	6,6 min	3	1 min
6	6,6 & 2 min	6	1 min
10	1,3 & 0,3 min	7	4,05 min
11	3 & 2 min	8	5 min
14.2	5 min	12	2 min
14.3	3 & 5 min	14.1	2 min
14.4	7 & 7 min	14.2	1 min
14.5	7 min	14.4	2 min
14.6	10 min	14.7	2 min
19	3 & 8 & 8 min	15	2 min
21	4 min	16	10 min
23	3 min	21	2 min
24	4 min	23	2 min
28	4 min	24	2 min
30&31	8 & 8 min	25	6 min
32	2 & 2 min	26	2 min
33	3 & 3 min	27	2 min
$\Sigma(t_m)$= 125, 8 min		29	1 min

35	3 min
36	2 & 1 min
37	2 & 1 min
$\Sigma(t_m)$= 62,05 min	

Table 3.7 Machining time from drilling and milling machine

Drilling machine C_m = 46/min		**Milling machine C_m = 185/min**	
No Part	**Time (t_m)**	**No Part**	**Time(t_m)**
7	0,66 min	12	10 & 10 min
23	3 min	14.1	8 & 8 min
25	3 min	14.3	3 min
26	3 min	14.7	8 & 8 min
29	1 min	15	6 & 8 min
30 & 31	7 min	16	6 & 4 min
$\Sigma(t_m)$= 17,66 min		27	8 & 8 min
		$\Sigma(t_m)$= 95 min	

Table 3.8 Machining time from cutting machine

Cutting machine C_m = 35/min	
No Part	**Time (t_m)**
4	1 min
5	1 min
11	1 min
14.5	1 min
14.6	1 min

28	1 min
30 & 31	3 min
32	1 min
Σ(tm)= 10 min	

Assumption:

Operator cost: Rp 1.200.000,00/month

Rp. 104, 00 /min

1. Lathe machine cost

$C_{m\ lathe} = c_m \cdot t_m$

= (Rp. 139 + Rp 104) . 125, 8 min

= Rp. 30. 600, 00

2. Shaping machine cost

$C_{m\ shaping} = c_m \cdot t_m$

= (Rp. 174 + Rp 104) . 62,05 min

= Rp. 17. 250, 00

3. Drilling machine cost

$C_{m\ dril} = c_m \cdot t_m$

= (Rp. 46 + Rp 104) . 17,66 min

= Rp. 2. 700, 00

4. Milling machine cost

$C_{m\ mill} = c_m \cdot t_m$

= (Rp. 185 + Rp 104) . 95, min

= Rp. 27. 500, 00

5. Cutting machine cost

$C_{m\ lathe} = c_m \cdot t_m$

= (Rp. 35 + Rp 104) . 10 min

= Rp. 1.400, 00

C_m total = $C_{m\ lathe}$+ $C_{m\ shaping}$+ $C_{m\ dril}$+ $C_{m\ mill}$+ $C_{m\ lathe}$

=Rp. 30. 600+Rp. 17. 250+Rp. 2. 700+Rp. 27. 500+Rp. 1.400

=Rp. 79. 450,00

3.3.3 Fixture and prepare cost

Before we determine the total cost of the assistive device, we must know the fixture and prepare cost. The calculate of fixture and prepare cost will be shown below.

$C_r = (C_{set} + C_{fix} + C_{pr}) / n_t$ where is; $C_{set} = c_m . t_{set}$

$C_r = \frac{cm.tset}{nt}$

$= \frac{Rp\ 79.450\ .8\ min}{34}$

=Rp. 18. 700, 00

So the Production Cost is:

$C_P = C_r + C_m + C_e$

= Rp. 18. 700+Rp. 79. 450+Rp. 350.000

=Rp. 448. 150, 00

Assumption:

C_{fix} & C_{pr} is negligible because there is no fixture and NC program.

t_{set} average in 8 min

Tool Cost(C_e): Rp. 50. 000,00/5 times

So $\frac{34}{5} = 6{,}8 \approx 7 times$

And, C_e = 7 x Rp. 50.000

C_e = Rp. 350.000, 00

3.3.4 Material Cost

Every cost of material has been determined by market price. Based on survey, the cost of material will be shown at table below.

Table 3.9 material cost

No	Component	Dimension (mm)	Amount (pcs)	Weight (Kg)	Price (Rp)	Total (Rp)
1	C Light channel	102 x 51 x 50	2	15	7.100	213.000
2	Unequal angle	60 x 30 x 5	4	4	8.150	130.400
3	Plate 7 mm	350 x 200	4	2,7	12.500	135.000
4	Plate 7 mm	350 x 400	4	5	12.500	250.000
5	Plate 5 mm	550 x 400	2	7,5	12.500	187.500
6	Plate 5 mm	1200 x 400	1	16,6	12.500	207.500
7	Plate 15 mm	1200 x 400	1	48,5	12.500	606.250
8	Cylinder	400 x ø 100	2	23	15.000	690.000
9	Cylinder	1200 x ø 25	4	4,6	15.000	276.000
10	Cylinder	1320 x ø 56	3	25	15.000	1.125.000

So, the Material Cost Total (C_M) is Rp. 3.820.650, 00

3.3.5 Total Cost

After we know material cost, fixture and prepare cost and production cost then we can found how much that cost we need to manufacture the assistive device.

$$C_u = C_M + C_{plan} + \Sigma\ C_p$$

= Rp. 3.820.650 + Rp. 448. 150

= Rp. 4.268.800, 00

So, total cost is Rp. 4.268.800, 00

3.4 Standard Operation Procedure

The manufacture process that used on the Assistive device is:

1. Turning :

   The turning process is used to make some part in this tool like rod brace, connecting shaft.
2. Milling

   The milling process is used to make some part in this tool like Clamp, upper holder dies.

3. Drilling

   The drilling process is used to make some part in this tool like upper holder dies and lower holder dies.
4. Shaping

   The shaping process is used to make some part in this tool like grinding Profile and slider.
5. Cutting

   Cutting process is used to make part in two.

A part of assistive device that I choose is rod brace. Rod brace is a part to hold wire rope that lifting the up holder dies. How to make rod brace determine the operation plan below.

Table 3.10 Operation Plan of rod brace

No	Operations	Tools	Instrument	Cutting speed (V)	Feeding speed (V_f)
1	Chucking of the blank	Chuck	-		

2	Facing of the end	Side tool	Steel rule	*94, 2 m/min*	*300 mm/min*
3	Roughing	Roughing tool	Steel rule		
4	Grooving	Grooving tool	Caliper		

Determine machining time

The principles of taking time have been laid down by REFA (the former National Committee for Time Study Procedures which exists now as an association for work study procedures). The amount of time which is given for the completion of a work order is called Total Time. It is the sum total of set-up time, machining time, indirect machining time and delay time.

Set up time is the time needed for preparing the working place for the execution of a certain operation, and reducing it to its original state, this includes also the study of drawings, the time for adjusting tools out of and returning them to the store.

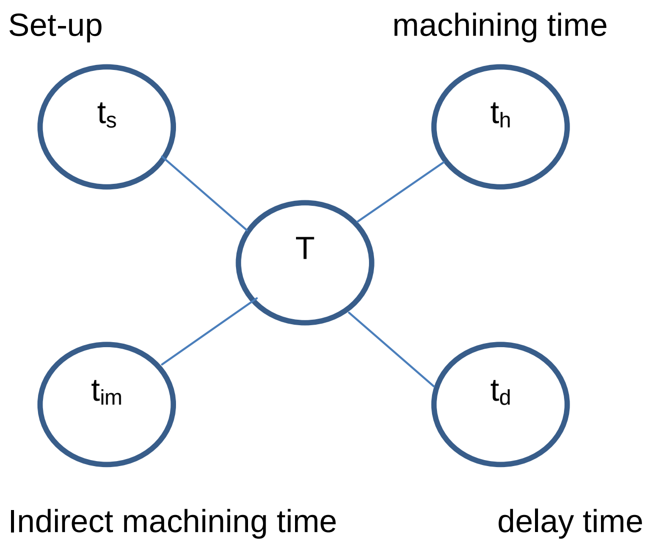


Fig. 3.3 Machining time

Indirect machining time is the time spent for operations and operational elements prior to, between, and/or concluding basic elements. Indirect machining time occurs regularly. It includes such operational elements as picking up positioning and removing work piece, measuring, tool, sharpening.

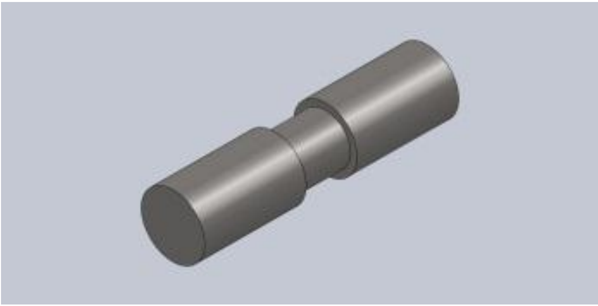
Machining time is the time during which operations are performed which contribute directly to the completion of the work order (e.g. time in which the work piece is machined, operating time of the machine, cutting time).

Delay time is the time allowed for personal needs, overcoming fatigue, and unavoidable delays. Delay time occurs irregularly. It comprises of such conditions as walking to the lavatory, rest periods, waiting for material, etc.

$$\text{Machining time} = \frac{\text{Turning length}}{\text{feed / min}}$$

$$T_h = \frac{L}{s \times n}$$

1. Rod Brace



Cut the material use cutting machine with length 400 mm and then use facing in turning process ta have diameter 100 mm. Therefore, use grooving in turning process with width 80 mm and depth 20 mm.

Turning operations

1. Facing

do = 100 mm

d1 = 80 mm

l = 400 mm

lt = 80 mm

n = 300 RPM

f = 1 mm/R

Rate of diameter:

$$đ = \frac{d0+d1}{2}$$

$$đ = \frac{100+80\ mm}{2}$$

$$đ = 90\ mm$$

Cutting speed:

$$V = \frac{\pi.d.n}{1000}$$

$$= \frac{3{,}14.100.300}{1000}$$

$$= 94{,}\ 2\ m/min$$

Feeding speed:

$$V_f = f\ .\ n$$

$$V_f = 1\ mm/R.\ 300\ RPM$$

$$V_f = 300\ mm/min$$

Machining time:

$$t_h = \frac{l}{vf}$$

$$t_h = \frac{400\ mm}{300\ mm/min}$$

$$t_h = 1{,}\ 3\ min$$

2. Make profile

Cutting speed:

$$V = \frac{\pi.d.n}{1000}$$

$$= \frac{3{,}14.90.300}{1000}$$

$$= 84{,}\ 7\ m/min$$

Feeding speed:

$$V_f = f.\ n$$

$$V_F = 1\ mm/R.\ 300\ RPM$$

$$V_f = 300\ mm/min$$

Machining time:

$$t_h = \frac{l}{vf}$$

$$t_h = \frac{80\ mm}{300\ mm/min}$$

$$t_h = 0,\ 3\ min$$

Total time:

$$T = 1,\ 3\ min + 0,\ 3\ min + 2\ min = 3,\ 6\ min$$

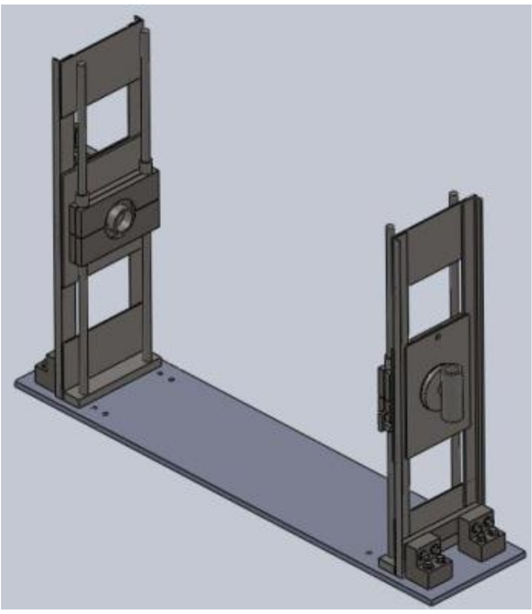
3.5 Design for assembling

The kind of welding that we used is SMAW (Shielded Metal Arc Welding). Based on the material, we choose electrodes E6011 because the yield strength of the material < 50 ksi. ASTM A36 has yield strength 36 ksi and tensile strength 58-80 ksi. We split the assembly of assistive device to 3 sections:

1. Assembly Construction
2. Assembly Up Holder Dies
3. Assembly All

1. Assembly Construction

First of the assembly is assembly construction. The step of this construction will explain below.

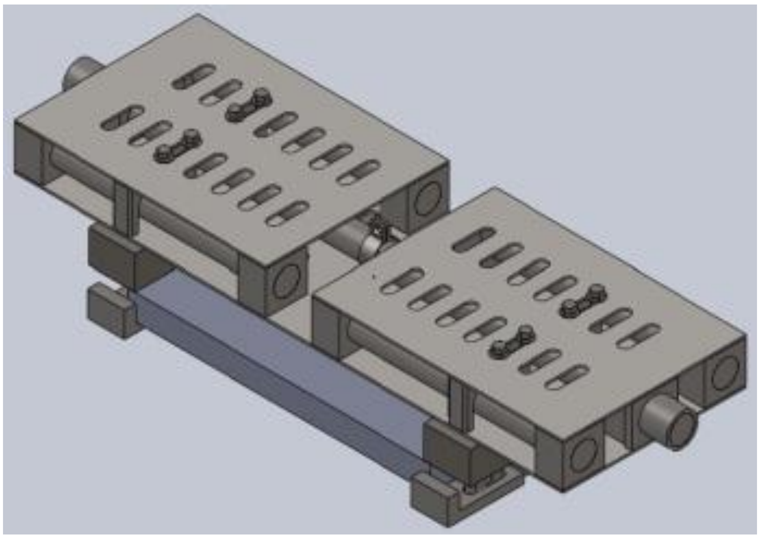


a. Welding down back wall (4) and guideline house (29) with Fillet welding

b. Welding a with L channel left and right (2)
c. Welding back wall hole (3) and back wall hole cover (6) to L channel
d. Welding the both of guideline shaft (28) to the guideline house (29)
e. Insert the lower counterweight move (30) to the guideline shaft (28)
f. Insert hole plate (33) and mouth holder (14.3) to the lower counterweight move (30)
g. Insert upper counterweight move (31)and weld
h. Welding the bushing holder (32) to the guideline shaft (28)
i. Insert control shaft (16) and ring (18) to the back wall hole (3) and back wall hole cover (6)
j. Weld top of guideline house (29) to the guideline shaft (28)

2. Assembly Up Holder Dies

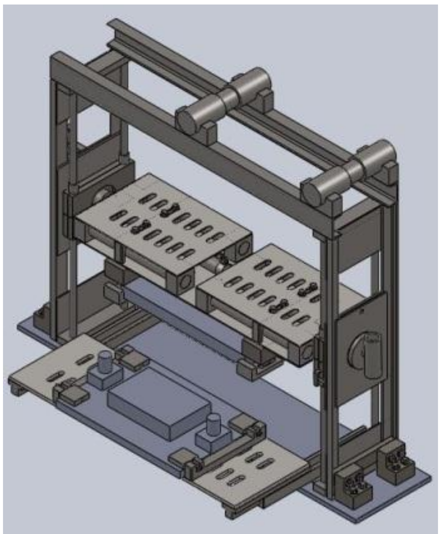
After the assembly construction has successfully, the we assembly the second component that is up holder dies. The step of assembly will explain below.



a. Weld lifter clamping shaft (14.5) to drag pillow (14.2)
b. Weld lifter connecting shaft (14.6) to drag pillow (14.2)
c. Weld turned pillow (14.4) to drag pillow (14.2)
d. Insert clamping head (15) to the shaft
e. Weld locking plate (14.7) to the drag pillow (14.2)

3. Assembly All

After the up holder dies finish to assembly then we insert to construction and we assembly all of part.



a. Install the rail table (8) to the sample table (13)
b. Weld the slider (7) to the lower locking plate (14.1)
c. Put in the slider (7) to the rail table (8)
d. Weld cross section composed (1) to the guideline house (29)
e. Weld rod brace (10) to the half pillow (11)
f. Weld step e to the cross section composed (1)