International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Design Calculations, CAD Modelling and Analysis of Plastic Scrubber / Bullet Assembly Machine

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Abstract: ***This paper will discuss in detail the design procedure and simulation results of the plastic bullet assembly machine. This machine is manufactured so as to reduce the production time and cost, to enhance overall production, to reduce man power and man fatigue. The machine works on the principle of a simple press machine which uses compressed air for its operation. A chuck with an indexer is provides for the 120^0 rotation of bullet while manufacturing. This has as a result increased precession and accuracy of the production.***

Keywords: Chuck, adon block and rail, pneumatic cylinder, bullet/scrubber, DCV (Tandem Centre), ANSYS, simulation

1. Introduction

There are certain components in day to day life which are used extensively and have to be kept with utmost care and with good maintenance so that they can be used further smoothly. Hence for the cleaning purpose of materials with narrow cross section there are some special types of components used. One such material is a Condenser. Normally the Condenser having length of about 2-3 meter can be cleaned manually. But with the length of about 15-20 meters there comes a difficulty of cleaning effectively. Hence with the growing technology in the modern age a special type of cleaning element is used for the cleaning of condenser tubes.

This element is known as a 'Scrubber' or 'A Bullet'. Now this bullet is having the periphery such that when it is been passed through the tube with the help of water jet then it goes on cleaning the tube. The scaling property comes into existence accordingly and with the help of about 20-25 times cycle the proper cleaning is done.

1.1 Making of bullet / scrubber

Presently, the bullets are manufactured manually. The PVC rod is placed in a hollow tube. The brass flange is placed on the rod and is forced pushed with the help of a hammer. The next flange is placed with an angle 120 degree and is again forced into the rod. The same procedure is repeated for the third flange. Following this manual procedure for assembly of bullets, about 100 bullets are manufactured in a day. Though less force is required, it becomes a tedious job for the workers to do hammering. To eliminate this disadvantage and also enhance the production, the idea of creating a bullet assembly machine came into existence.

The Bullet is being fitted with the copper flanges which are three in number and they have been fitted with an angle of 120 degrees so that when the flanges are mounted together then their straight vision makes an angle of 360 degrees that is a circle.

Figure 1: Scrubber Bullet

2 Design calculations of assembly machine

2.1 Design calculations for pneumatic cylinder

Diameter of the Cylinder:
The cylinder thrust is a function of:
- F= Cylinder thrust in Kg.
- D= Diameter of meter piston in cm.
- d= Diameter of piston rod in cm.
- p= Operating air pressure in "bar".
- fr= frictional resistance in kg.

Double acting in forward stroke:
F = {π/4x D2 x P}
Required forward stroke force = 3*9.81 = 29.43 N
Approximately required design force = 30 N
Available operating pressure 10 KPa

D =$\sqrt{F*4/\pi*P}$
= $\sqrt{30*4\pi*10*100}$
= 0.06180*1000
D = 61.80 mm.

ii) Diameter of the cylinder rod

The required force in return stroke is 28 N because here we don't need to push the flanges inside the PVC rod
F = {π/4 x (D2 –d2) x P}

28 = {π/4 x (0.0632-d2) x 10 x 1000}
d = 20.06 mm.

iii) Air Consumption:
Theoretical air consumption calculations: Let
D = Diameter of piston in cm.
d = piston rod diameter.
L = stroke in cm.
P = Air pressure in bar
Free air consumption in liters for forward stroke
C = ¼*{πx D x (P+1) x L} / 1000
= 0.074m3/sec
Free air consumption in liters for return stroke
C = ¼*{πx (D –d) x (P+1) x L} / 1000
=0.050 m3/sec

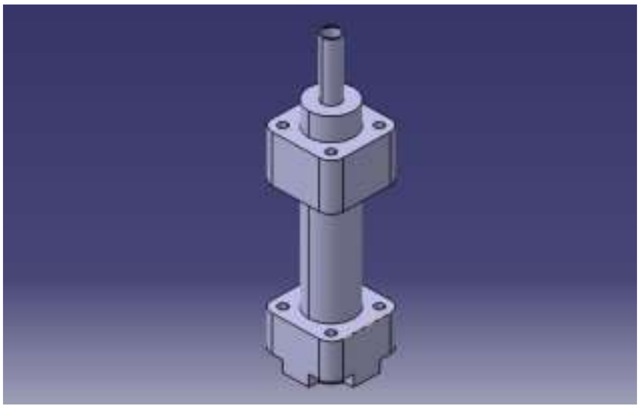


Figure 2: Catia Model OF Pneumatic Cylinder

Air Cylinder - Pressure/Force Diagram

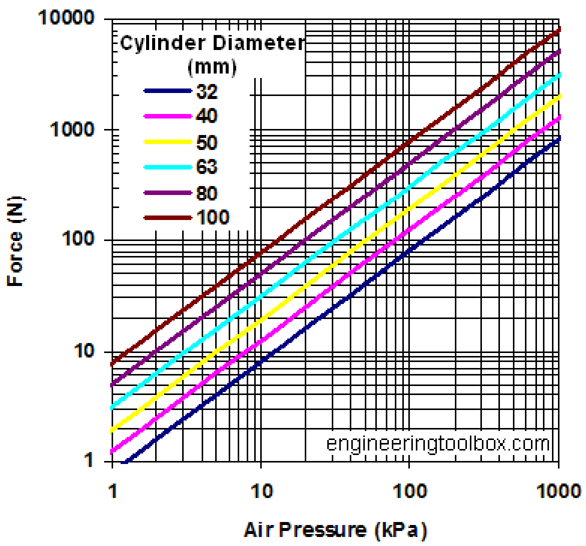


Figure 3: Standard graph for pressure calculation

The above graph is a standard chart which is used for determining the air pressure inside the cylinder, cylinder bore diameter and force. The abscissa represents the air pressure in KPa and ordinate represents force in N. The bore diameters are given by the colour lines. Knowing any two of the three parameters we can find the third. In this case I have calculated the diameter of bore and required force is known hence could find the air pressure that is needed.

Hence looking in the cyan line i.e. 63 bore diameter and horizontal line that represents force 30 N we get the intersection at point which corresponds to 10 KPa on abscissa. Hence operating pressure shall be 10 KPa.

Table 1: Cylinder specifications

Stroke	100mm/ 3.9"
Screw Shaft Diameter	16.7mm/ 3/8"
Thread Hole Diameter	11mm/ 7/16"
Overall Size	7.5 x7.5 x 25cm / 2.9" x 2.9" x 9.8"(L*W*H)
Material	Aluminium Alloy
Weight	1521g
Package Content	1 x Air Cylinder
Acting Mode	Double
Rod Type	Single
Working Medium	Air
Max Pressure	0.1-9 MPa
Bore	63mm/ 2.5

2.2 Design of Frame

2.2.1. Selection of Material:

To provide support to the structure the material should have high shear strength. The weight of the assembly machine is divided on the base plate and the frame of the machine. Hence the frame carries equal weight that is been taken by the base plate. Therefore, the strength is of great importance for the long lasting working of the machine.

The best recommended material to provide bending strength and shear strength is Mild
Steel (Plain Carbon Steel)

Table 2: standard table to calculate self-weight of frame

Size mm	Weight kg/m	Size mm	Weight kg/m
20 x 20 x 1.60	0.870	90 x 90 x 3.20	8.510
30 x 30 x 1.60	1.380	90 x 90 x 3.60	9.680
30 x 30 x 2.60	2.100	90 x 90 x 4.50	11.900
40 x 40 x 1.60	1.880	90 x 90 x 5.56	14.600
40 x 40 x 2.60	2.920	90 x 90 x 7.10	16.100
40 x 40 x 2.90	3.320	90 x 90 x 8.80	21.900
40 x 40 x 3.20	3.490	90 x 90 x 10.0	24.833
40 x 40 x 4.00	4.410	100 x 100 x 3.20	9.520
50 x 50 x 1.60	2.380	100 x 100 x 4.00	12.000
50 x 50 x 2.60	3.730	100 x 100 x 5.00	14.700
50 x 50 x 2.90	4.230	100 x 100 x 6.30	18.300

2.2.2. Working length required is 0.45 m

Calculating weight using the table 2
Weight of square tube
=14.70*0.45=6.615 kg
= 64.89 N = 65 N

2.2.3 Calculation

Total force acting on frame will be
Weight of cylinder =1.521*9.81= 14.9N=17N
Force of stroke=160N
Weight of L plates=17.09*2=35 N
Weight of square plate= 65 N
Weight of indexing mechanism and fixtures + adon and rail= 2*9.81= 19.62 N= 20 N
Total weight=297 N= 300 N
Material =55 C8=sut=780 Mpa
A=.2*.2=.04 m2
Total force that can be applied=1560
Fos =1560/280= 5.2

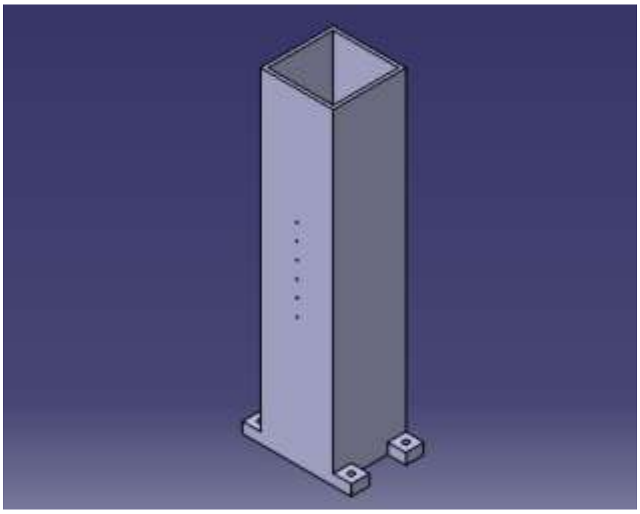


Figure 4: Catia model of frame

2.2.4 Analysis of Frame

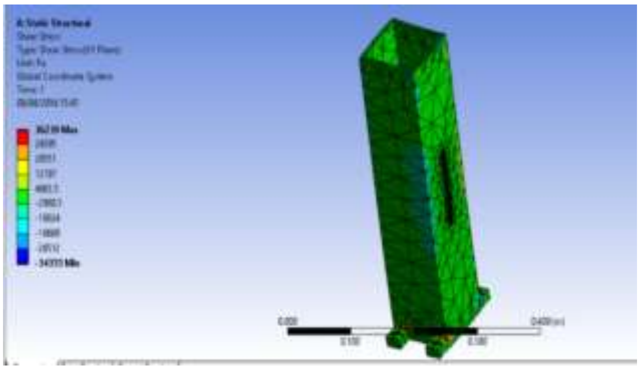


Figure 5: Shear Stress Analysis of frame

ANSYS software has been used for the analysis.

In this force is exerted at the edge of the tube due to the cyclic strokes during the operation. Hence considering the loads, the frame is tested it in shear.

Maximum shear stresses are generated at the nodal ends near the bolts and edges.

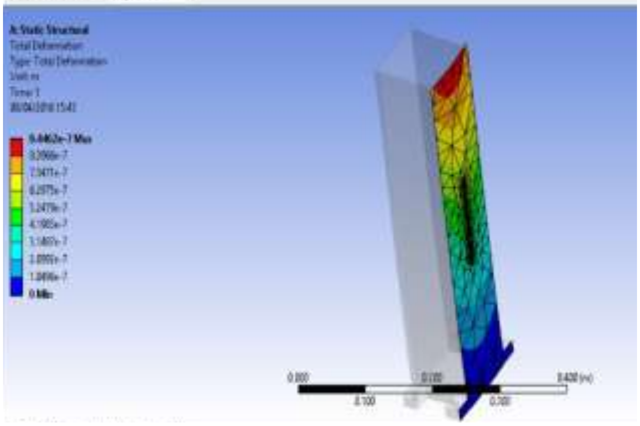


Figure 6: Deformation Analysis of frame

In this the force is exerted perpendicular to the cross-section of the square tube. These forces are compressive in nature. The frame is fixed at the bottom by bolts and the length is 450 mm there is buckling of the tube. The stress concentration is at the uppermost point and the maximum stresses are generated here.

Maximum shear stress = 36239 Pa
Minimum shear stress= -34355 Pa
Maximum deformation= 9.44*10-4 mm
Minimum deformation= 0 mm

2.3 Design of L plate (Bottom)

2.3.1 Dimensions and Selection of material

Taking thickness of the required plate to be 10 mm.

As the weight on bottom plate will be more than that of the above plate. Hence design and check for the bottom plate is done.

Table 3: Standard table for calculating weight of M.S.L-plate

Size mm	Thickness mm	Weight per Metre Length kg	Size mm	Thickness mm	Weight per Metre Length kg
20 x 20	3.0	0.9	70 x 70	5.0	5.3
	4.0	1.1		6.0	6.3
30 x 30	3.0	1.4		8.0	8.3
	4.0	1.8		10.0	10.2
	5.0	2.2	80 x 80	5.0	6.0
40 x 40	3.0	1.8		6.0	8.0
	4.0	2.4		8.0	10.0
	5.0	3.0		10.0	12.0
	6.0	3.5	90 x 90	6.0	8.2
50 x 50	3.0	2.3		8.0	10.8
	4.0	3.0		10.0	13.4
	5.0	3.8		12.0	15.4
	6.0	4.5	100 x 100	6.0	9.2
60 x 60	5.0	4.5		8.0	12.1
	6.0	5.4		10.0	14.9
	8.0	7.0		12.0	17.7
	10.0	8.6		14.0	18.5

Weight calculation: for 100*100*10 weight =14.9 kg/m
Weight in kg=14.9*0.110=1.639 kg
Weight of two L plates=1.639*2=3.278 kg
Weight in N= 3.278*9.81=32.08 N= 35 N

The center hole is provided for the indexing mechanism to fit in. The two taping of 6mm are provided for the smaller L plate to be provided. The spring force of the indexer will be on this plate.

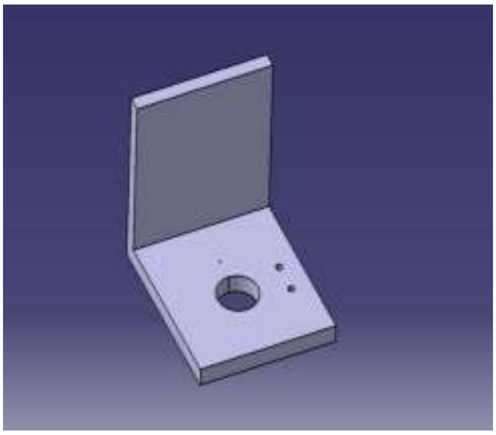


Figure 7: Catia model of bottom L- Plate

2.3.2 Dimensions of L plate

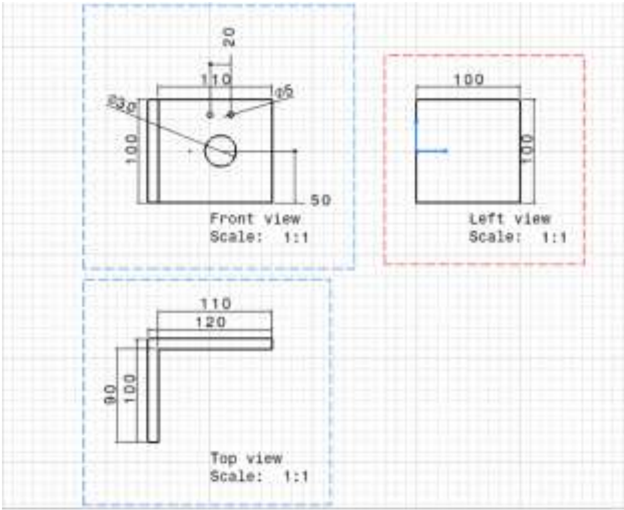


Figure 8: Drafted Part of bottom L-Plate

2.3.3. Checking Safety for L-Plate (Bottom)

Total force acting on frame will be:
Weight of cylinder =17 N
Force of stroke=160N
Weight of L plates=17.08*2=35 N
Total weight=509N
Selecting 100*100 square plate
Load carrying capacity =800N
FOS (factor of safety) =800/509=1.57
As the bottom plate is safe so will be the upper plate.

2.3.4 Analysis of L-Plate

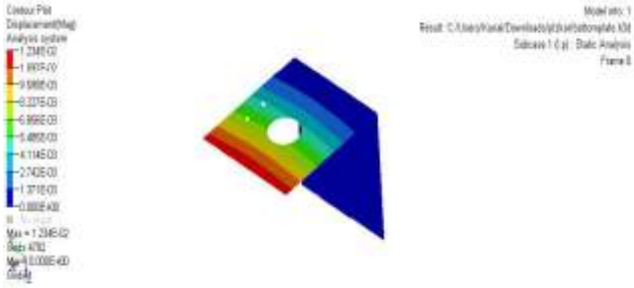


Figure 9: Deformation Analysis Bottom Plate

Force is exerted at the center of L-plate so there is a chances of bending. Analysis has been done considering it as cantilever beam. In this plate maximum deformation is seen at free end and minimum at the fixed end.

Maximum Deformation =1.234*10-2 mm
Minimum = 0 mm

2.4 Design of L-plate (upper)

2.4.1 Dimensions of upper L plate

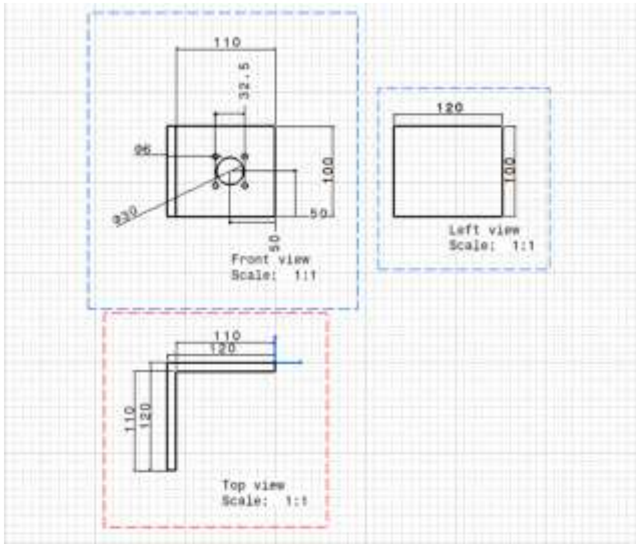


Figure 10: Drafted Part of upper L-Plate

There are holes in the center for the mounting of the cylinder. Pneumatic cylinder of 63 bore is to fit on the plate hence the mounting holes are made accordingly.

2.4.2 Analysis of Upper L plate

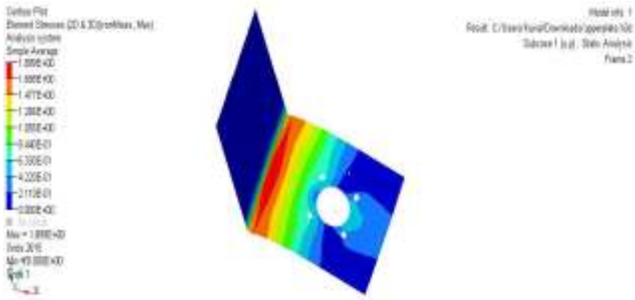


Figure 11: Stress Analysis of upper L plate

Force is exerted at the center of L-plate so there is a chance of bending. Analysis is done considering it as cantilever beam. In this plate maximum bending stress generated at welded joint of plate and minimum at free end.

Maximum stress =1.899 Pa.
Minimum stress=0 Pa

2.5 Design of Base Plate:

2.5.1Dimensions of Base Plate

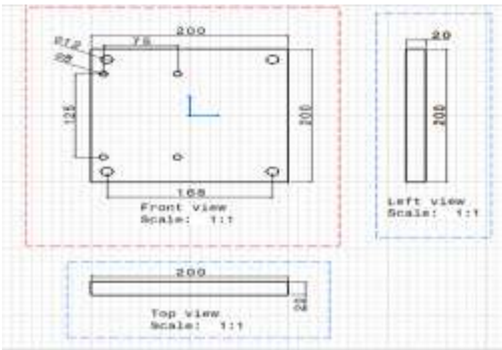


Figure 12: Drafted part of Base plate

2.5.2 Design Calculation and Selection of material

Material: Plain carbon steel (45c8) Dimension of Base Plate:
Length=200 mm
Width =200 mm
Thickness=20 mm
Load carrying capacity=800 N
Total applied load =Cyclic load +Self weight
=120 N+300 N = 420 N

$$\text{Factor of safety} = \frac{\text{load Carrying capacity}}{\text{total applied load}} = \frac{800}{420} = 1.904$$

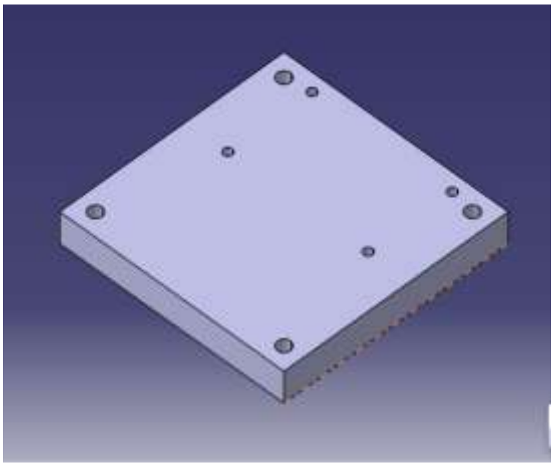


Figure 13: Catia part of base plate

2.6 Adon Block

2.6.1Design of Adon Block

Table 4: Type of Adon block and Series

Series	Assembly Height	Load	Square Tap Hole	Flange		
				Tap hole	Drilled hole	combination
WE	Low	Heavy	WEH-CA	-	-	WEW-CC

Accuracy

The accuracy of the WE series can be classified into 5 classes: normal(C), high (H), precision (P), super precision (SP), and ultra-precision (UP). Choose the class by referencing the accuracy of selected equipment. As we are selecting WE series for linear guide ways so we are considering properties related to WE series only.

2.6.2Construction

The WE series features equal load ratings in the radial, reverse radial and the lateral direction with contact points at 45 degrees. This along with the wide rail, allows the guide way to be rated for high loads, moments and rigidity. By design, it has a self-aligning capacity that can absorb most installation errors and can meet high accuracy standards. The ability to use a single rail and to have the low profile with a low center of gravity is ideal where space is limited and/or high moments are required.

2.6.3 Construction of WE Series

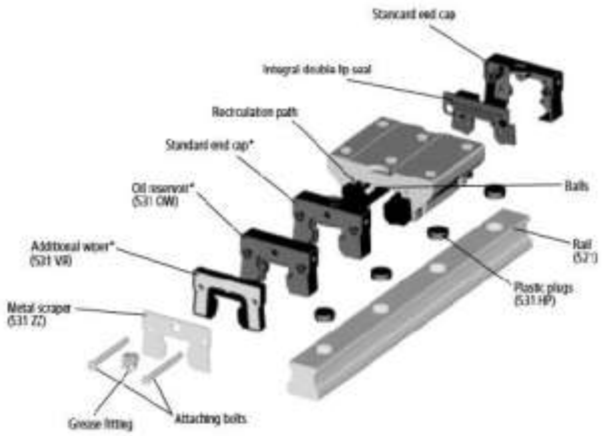


Figure 14: Constructional detail of Adon block and Rail

2.6.4 Different Parameters of Rail:

Rolling circulation system: Block, rail, end cap and retainer
Lubrication system: Grease nipple and piping Joint
Dust protection system: End seal, bottom seal, cap and scraper
Model Number of WE Series

WE series linear guide ways are classified into non-interchangeable and interchangeable.

The sizes of these two types are the same as one another. The main difference is that the interchangeable type of blocks and rails can be freely exchanged and they can maintain P-class accuracy. Because of strict dimensional control, the interchangeable type linear guide ways are a wise choice for customers when rails do not need to be matched for an axis. The model number of the WE series identifies the size, type, accuracy class, preload class, etc.

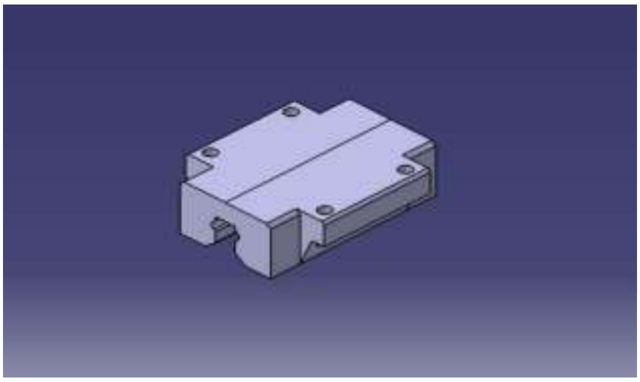


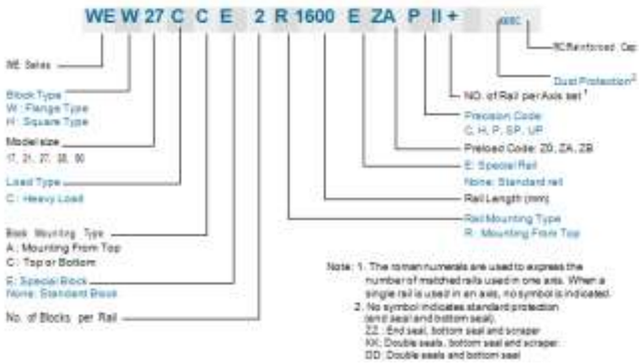
Figure 15: Catia model of Adon Block

Table 5: Adon Block Rail Tolerance

Type	WE-17,21					WE-27,35				
Accuracy classes	Normal (C)	High (H)	Precision (P)	Super precision (SP)	Ultra-precision (UP)	Normal (C)	High (H)	Precision (P)	Super precision (SP)	Ultra-precision (UP)
Dimensional tolerance of height 'H'	±0.1	±0.03	0-0.03	0-0.015	0-0.008	±0.001	±0.04	0-0.04	0-0.02	0-0.01
Dimensional tolerance of width 'N'	±.1	±0.03	0-0.03	0-0.015	0-0.008	±0.001	±0.04	0-0.04	0-0.02	0-0.01
Variation of height 'H'	0.02	0.01	0.008	0.004	0.003	.02	0.015	0.007	0.005	0.003
Variation of width 'N'	0.02	0.01	0.008	0.004	0.003	.03	0.015	0.007	0.005	0.003

Model No: -WEH20CA
Dimension of assembly:
H=20mm
H1=4mm
N=10mm

Table 6: Nomenclature of adon Block



2.7 Design of Rail

HIWIN offers a number of standard rail lengths. Standard rail lengths feature end mounting hole placements set to predetermined values (E). For non-standard rail lengths, be sure to specify the E-value to be no greater than 1/2 the pitch (P) dimension.

An E-value greater than this will result in unstable rail ends.

3.7.1 Calculations for design of rail

L= $(n-1)\times P+2\times E$
L: Total length of rail (mm)
n: Number of mounting holes
P: Distance between any two holes (mm)
E: Distance from the center of the last hole to the edge (mm)

Table 6: Standard Rail dimension

Item	WER17	WER21	WER27	WER35	WER50
Standard length, L(n)	110 (3)	130 (3)	220 (4)	280 (4)	280 (4)
	190 (5)	230 (5)	280 (5)	440 (6)	440 (6)
	310 (8)	380 (8)	340 (6)	600 (8)	600 (8)
	390 (10)	480 (10)	460 (8)	760 (10)	760 (10)
	470 (12)	580 (12)	640 (11)	1000 (13)	1000 (13)
	550 (14)	780 (16)	820 (14)	1640 (21)	1640 (21)
	-	-	1000 (17)	2040 (26)	2040 (26)
	-	-	1240 (21)	2520 (32)	2520 (32)
	-	-	1600 (27)	3000 (38)	3000 (38)
Pitch(P)	40	50	60	80	80
Distance to End (Es)	15	15	20	20	20
Max std length	4000 (100)	4000 (80)	4000 (67)	3960 (50)	3960 (50)
Max length	4000	4000	4000	4000	4000

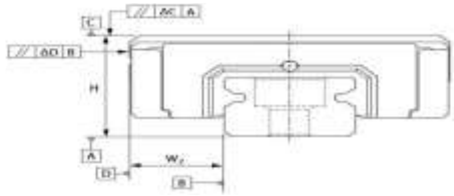


Figure 16: Catia model of Adon Block

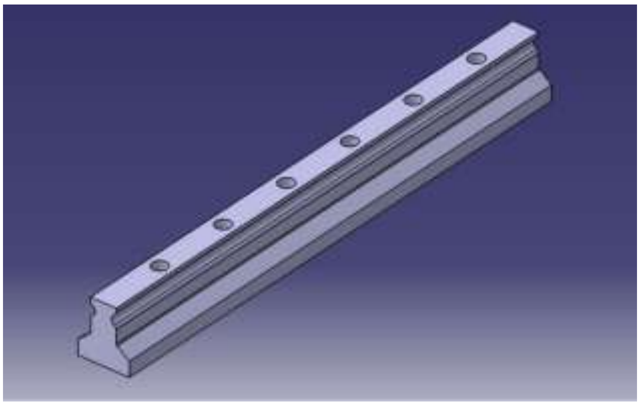


Figure 17: Catia model of Rail

SIZE mm	WEIGHT kg/m	SIZE mm	WEIGHT kg/m
20 x 20 x 1.60	0.870	90 x 90 x 3.20	8.510
30 x 30 x 1.60	1.380	90 x 90 x 3.60	9.680
30 x 30 x 2.60	2.100	90 x 90 x 4.50	11.900
40 x 40 x 1.60	1.880	90 x 90 x 5.56	14.600
40 x 40 x 2.60	2.920	90 x 90 x 7.10	16.100
40 x 40 x 2.90	3.320	90 x 90 x 8.80	21.900
40 x 40 x 3.20	3.490	90 x 90 x 10.0	24.833
40 x 40 x 4.00	4.410	100 x 100 x 3.20	9.520
50 x 50 x 1.60	2.380	100 x 100 x 4.00	12.000
50 x 50 x 2.60	3.730	100 x 100 x 5.00	14.700
50 x 50 x 2.90	4.230	100 x 100 x 6.30	18.300

2.8 Chuck:

In the project three jaw chuck is selected which is a type of drill chuck. The purpose of using this type of chuck is the time saving goal which is necessary in the optimization process. This chuck can be easily operated with the help of our hand and a key the procedure is simple. The chuck is being used for holding the non-ferrous materials like the copper, bronze, aluminum, titanium, plastics, and stone.

2.9 Indexing Mechanism:

The assembly machine has an indexing mechanism which is having a dimple on the three sides known as dimple. The dimples are set in such a way that the when the head is being rotated it should be locked at 120 degrees. The indexing mechanism is having a dye at the top which is has same shape as that of the flange. The flange could be kept accurately on the dye. Indexing mechanism which is shown in figure 18 has a protruding end which is the starting end. This protruding end is made with the purpose of having a lock when it is kept on the L-plate as a base. How it is being kept and taken to be operated is the part where a hollow circular part is mounted from the bottom side which is against the gravity and hence with the help of this the holding position is secured accordingly. Now the position of the part is fixed with the help of the key which is fitted for the purpose. With the help of the key the part is secured to be at one position and does not slide due to the influence of the gravity. Further there are dimples on the side of the base of the dye now the question arises that how these dimples are worked out so that we can get the necessary output? The answer relies in the shape of dimple which is circular and can be locked by the lock nut.

The other concerned part is of the locking nut. The locking nut is used for the locking with the help of the dimple. The dimple is circular section which is used with a certain depth such that when the locking nut is placed into the circular section then the locking should be tight and proper. The degree which I have given is due to the reason of the setting of the flange accordingly. The Setting of the flange should be accurate because the ultimate purpose of the flange is to clean a circular cross section. Hence the locking nut is always kept in tension with the help of the compression spring and locked by a pin which is inserted in the other end of the locking nut. Accordingly, the locking nut is having a holder on the other side which is used by the operator. Thus the locking nut provides a useful output for holding the head and hence the indexing mechanism is made.

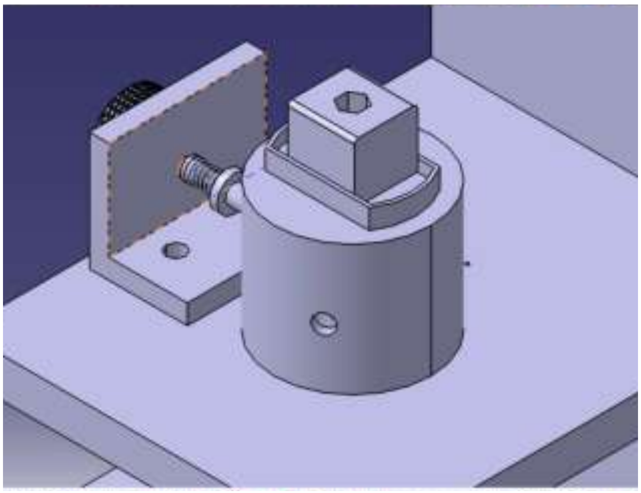


Figure 18: Catia part of assembly indexing mechanism

The other important aspect of the indexing mechanism is the surface of the dye. The surface of the dye should be hexagonal the reason behind keeping it hexagonal is the purpose of the dye to hold the PVC rod which has to be assembled. The dye is having the shape which is manufactured with the help of a wire cutting machine. The wire cutting machine can be used accordingly with the end cause of providing an accurate hole for the assembling purpose.

Hence in this way the indexing mechanism is the small part of the assembling machine but it proves to be an important part of our indexing machine.

2.10 Guide plate (for the adon block)

Dimensions and material selection

L plate for adon is required as to connect it to the cylinder rod. The rod is at 38 mm from the tube. As the rod needs stability during its stroke and that the PVC rod should not bend, so the L plate is provided. The thickness of the plate is not an issue as the load is not much on it and it is only to be used for supporting the alignment.
We take thickness=3mm
Material = mild steel

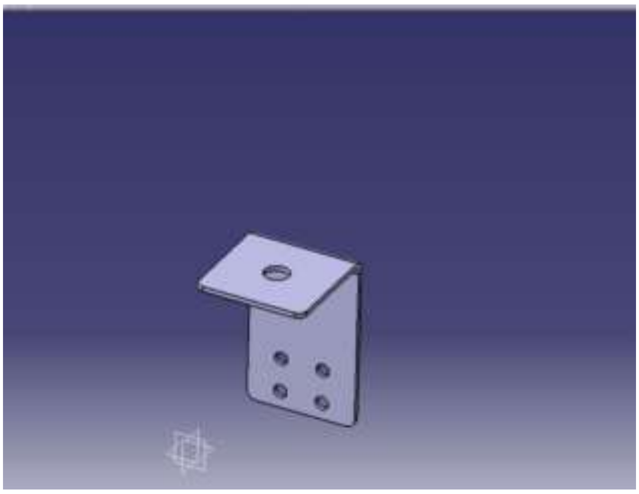


Figure 19: catia model of Guide Plate

Rests of the dimensions are as per the requirements of the assembly.

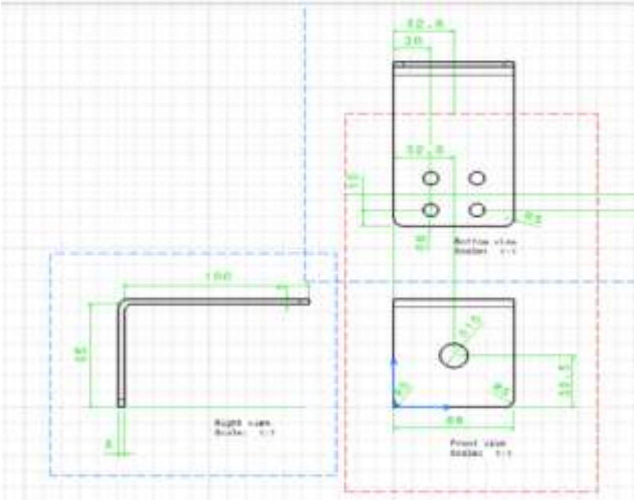


Figure 20: Drafted part of Guide Plate

2.11 Dowel pin

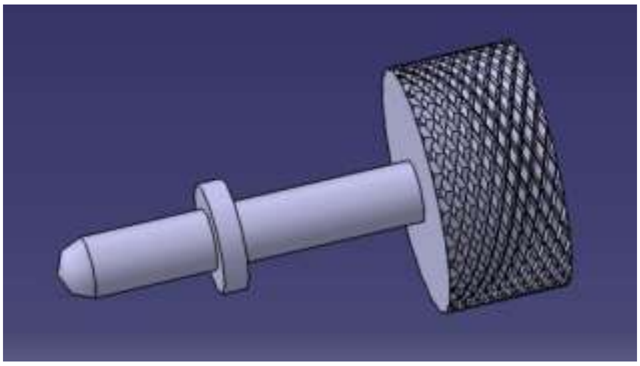


Figure 21: Catia part of dowel pin used for locking

The dowel pin is attached with a spring in middle between the fix flange and the knurled end. When in normal working the spring is in compression and hence it maintains the required force to lock itself inside the dimple. When the next indexing degree is to be achieved the operator pulls back the pin which compresses the spring further and then he rotates and releases the pin. Due to the spring force it gets locked in the next dimple that is provided on the circumference of the indexer.

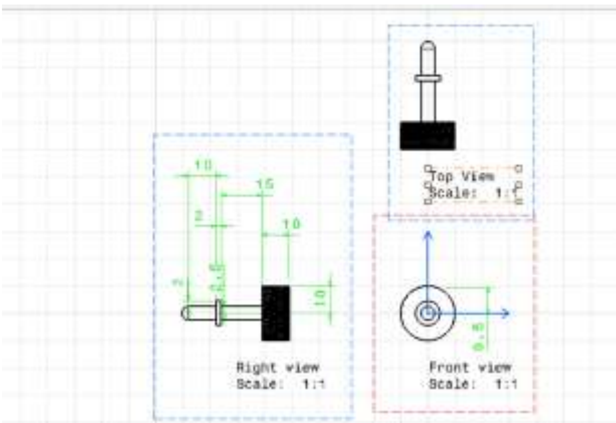


Figure 22: Drafted part drawing of dowel pin

2.12 Spring

A compression spring is used because a force that has to be constantly acting on the spring is needed. Compression spring – is designed to operate with a compression load, so the spring gets shorter as the load is applied to it.

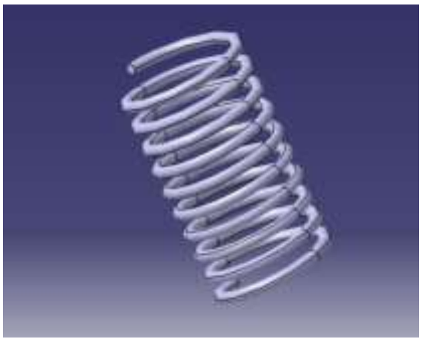


Figure 23: Drafted part drawing of dowel pin

2.13 Plate for indexing

L-plate is used to support the dowel pin and spring. The pin is inserted inside the spring and locked by flange at one end and l plate at other. As there negligible forces acting on this plate we need not check it for safety.

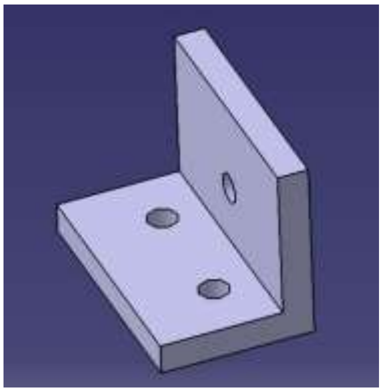


Figure 24: Catia model of indexing support plate.

The material used is mild steel
Thickness of the plate is 5 mm

As it is needed to hold the dowel pin there is a centre hole of diameter 5mm

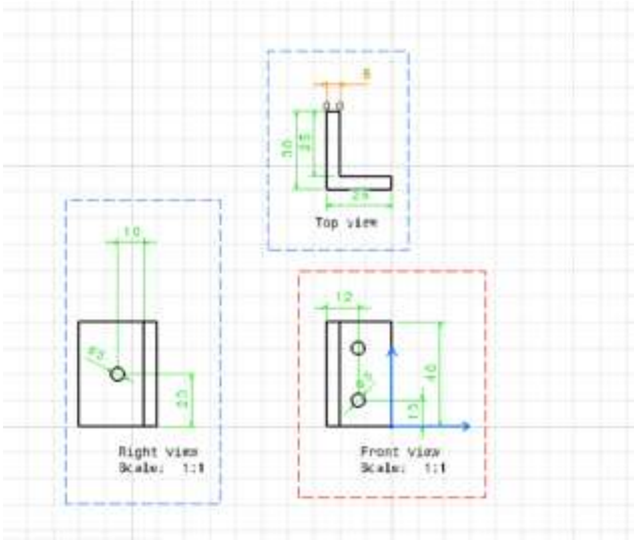


Figure 25: Drafted part of support plate.

Figure 26: Filters, Regulators, And Lubricators F.R.L unit

3. Selection of FRL unit and DCV

3.1 Filters, Regulators, And Lubricators (FRL's) Unit

Pneumatic actuators and controls perform more reliably and efficiently, and have a longer life, when the air is prepared for your specific application. These easy-to-use FRLs are specifically engineered to give you increased airflow from a modular system.

3.1.1. Pneumatic filter

Condensation during the compression of air and water vapor can cause particles of pipe scale and other contaminants in the pipes. These particles need to be removed before they reach the pneumatic equipment, such as valves and cylinders. Particles can damage and clog small orifices in the equipment unless they are filtered out. Filters separate the water droplets and particles from the air before they reach your pneumatic equipment.

3.1.2. Pressure regulator

A pressure regulator is a valve that automatically cuts off the flow of a liquid or gas at a certain pressure. Regulators are used to allow high-pressure fluid supply lines or tanks to be reduced to safe and/or usable pressures for various applications. Gas pressure regulators are used to regulate gas pressure and are not used for measuring flow rates. Flow meters, Rota meters or Mass Flow Controllers are used to accurately regulate gas flow rates.

3.1.3 Pneumatic lubricator

A pneumatic lubricator injects an aerosolized stream of oil into an airline to provide lubrication to the internal working parts of pneumatic tools, and to other devices such as actuating cylinders, valves and motors.

3.1.4 Connection of FRL Units:

The FRL's are of modular design and are preassembled. It utilizes spacers and brackets to make mounting and connection of different configurations. If there is a need to rearrange or re-assemble the FRL units use the following procedures:

i. Put the FRL units to be joined together side by side, insert a proper size spacer (with gaskets pre-installed) in between the units. Align and butt the units together. Join and fasten the units together using the front and back special purpose mounting brackets. Tighten the screws on the front and back brackets until the units are aligned and tightly joined together.

ii. When the FRL units are used independently, remove the screws on the mounting bracket and separate the FRL units.

3.2 Direction Control Valve with Tandem Centre:

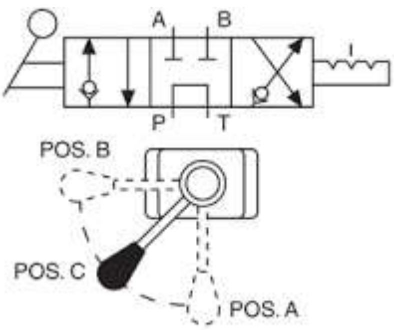


Figure 27: Basic working of DCV

Directional control valves are one of the most fundamental parts in hydraulic machinery as well as pneumatic machinery. They allow fluid flow into different paths from one or more sources. They usually consist of a spool inside a cylinder which is mechanically or electrically controlled. The movement of the spool restricts or permits the flow, thus it controls the fluid flow.

Selected DCV:

4 ways 3 position DCV:

4. Assembly of dowel pin

Spring is attached as shown in the figure 18 and hence it is always under compression. This is because of which the proper force is exerted on the indexer so that the pin and the indexing mechanism is constrained during the rest of the operation. The round edge is provided on the dowel pin so as to avoid friction and to have smooth sliding of the pin inside the groove. The spring is so chosen that the operator does not have to apply much force to pull the pin back. The supporting plate is mounted on the lower L-splate on which the indexer is placed. The die is mounted on top of the indexer hence as the indexer rotates so as die rotates hence the accurate degree rotation is achieved. Knob is attached at one end so as to incorporate easy operating conditions. The pulling of the dowel pin is enables easy unlocking.

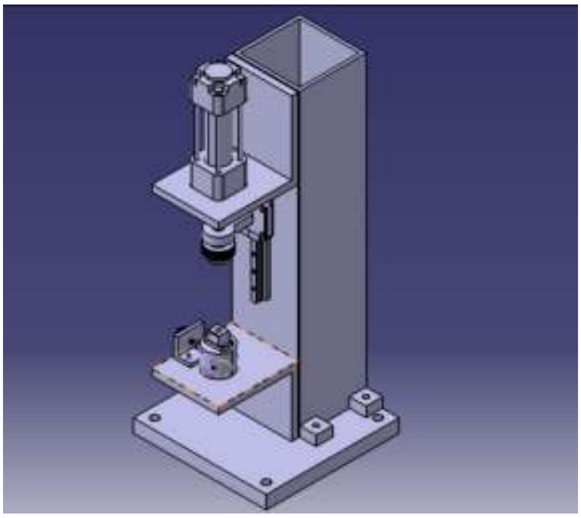


Figure 28: Catia model of assembly machine

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Author Profile

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