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Design and Development Pneumatic Operated Washer Making Machine

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Abstract

This research article presents the advanced method design and development of pneumatic operated washer making machine. The pneumatic system has gained a large amount of importance in last few decades. This project work mainly includes the main components of designs of pneumatic operated washer making machine such as: design of cylinder, selection of direction control valve, and selection of tube, design of aluminum sheet, plastic sheet, tar felt sheet and pneumatic circuit design. Design analysis also done by using CATIA software. Fabrication and implementation includes: fabrication of frame and components. This importance is due to its accuracy and cost. Due to ease of operation, handiness, and expediency in operating the pneumatic system has made us to design and fabricate this unit as our project. This pneumatic operated washer making machine unit, as we hope that it can be operated easily with partially skilled operators also. The pneumatic operated washer making machine has an advantage of working in low shear strength pressure, that is even a shear strength of 72 N/mm^2 is enough for operating the unit. Different types of pneumatic operated washer making machines as requirement can be thus got. According to the work material the operating shear strength can be varied.

Keywords: *Pneumatic operation, washer machine, fabrication, shear strength, CATIA software, design and development*

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INTRODUCTION

The main function of pneumatic press is to punch thin sheet metals or nonmetals using pneumatic power. In this project, authors used punching process and bending process for simple application and using the foot operated valve instead of hand operated lever so single man can perform the operation of machine like punching easily.

In today's practical and cost-conscious world, sheet-metal parts have already replaced many expensive cast, forged, and machined products. The reason is obviously the relative economy of operation, easier implementation for mass-production, as well as greater control on the technical parameters. In almost all of the sheet metal operations punching or pressing operation is the major or primary operation in the process operation series. Automation, this operation results in reduced lead time and also can decrease human attempt. Automation can be defined as the "technology related with application of electrical, mechanical, electronic and computer-based integrated systems to operate and control production process". There are many reasons for automating the process. The reason may be to reduce manufacturing lead time, to increase labour productivity or to improve the worker safety, etc.

Sheet metals are frequently employed for industrial and end user parts because of its high capacity for being bent and formed into complex shapes. Galvanized iron, tin plates, copper, brass, zinc, aluminium etc. metals are regularly utilized. Sheet metal parts include automotive industry, agricultural machinery parts, and aerospace applications as well as consumer equipments. Choice of sheet metal forming operation depends on the selection of a material with sufficient formability, suitable tooling and design of part, the surface state of the sheet material, right use of lubricants, and the manufacturing conditions such as the speed of the forming operation and the forces applied, etc., sheet metal forming processes includes: Shearing, Bending, Drawing and Squeezing.

By this research paper we get information about punching operation of sheet metal. Punching or pressing process is one of the most important and necessary processing step in sheet metal industry. By automating this process one can have a greater control over the process.

PUNCHING PROCESS

The press is the punching machine tool devised to punch blank of sheet by be applicable to mechanical force or pressure. The presses are absolutely meant for mass production and they represent the fastest, best and more proficient way to form a metal into a finished punched product. In manual or conventional methods of pressing the disadvantages are [1]:

- Angular misalignment of the sheet
- Higher material handling time and manufacturing lead times
- Reduced safety for the worker

After referring this paper, we get information about pneumatic system and component included in the system like,

- Directional control valve
- Double acting pneumatic cylinder
- Punch and die
- Flow control valve
- Compressor

We study working of pneumatic system and future scope in pneumatic system. The pneumatic press tool has an advantage of working in low pressure, that is even a pressure of 6 bar is enough for operating the unit [2].

From this, authors able to study designing process, selection of material and force requirement.

In this project work, the selected material is mild steel, because it is readily available in the market, economical for use and is available in standard sizes. Its mechanical properties are good, i.e., it is easily machinable, has moderate factor of safety. It also has high tensile strength and low coefficient of thermal expansion. The sheet metals which I have assumed to be punched are aluminium and plastic as I have designed the machine keeping these two as reference [3].

Therefore the selected material is aluminium for sheet metal material, thickness 0.5 mm, diameter of hole to be punched (d) is 10 mm, maximum shear strength of aluminium (T) is 30 N/mm^2.

From these researchesrs able to study case study of compound die and working of compound die is as follows:

Working of Compound Die

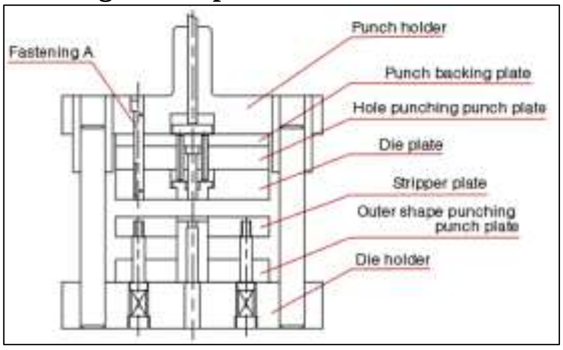

Fig. 1: *Compound punching die structure-1*

Figure 1 depicts the die as it appears during various stages of its cycle. The pressure plate-II is shown with metal strip nested in position on the die block, i.e., pressure plate-II hold that strip over die block. The press ram is descending. The drawing and cutting punch just contacted with metal strip. Cutting action takes place. The press ram continues to descend drawing action is initiated and proceeds as shown. Further descent will cause the outer edge of the draw around the draw die radius. The pressure plate-I just hold the cup. This pressure plate-I acts as a guide for cutting punches-II. The drawing operation is complete. Punching of 105 mm start as soon as the drawing operation is completed. During the upstroke, the ejector plate will eject the draw piece from the die [4].

From this paper researchers able to study different manufacturing processes and strip layout of the sheet used to cut washer.

Economical stock utilization should always be in mind while designing strip layout. The goal should be at least 60 percent utilization. In preparing the strip layout the distance between the two points of blanks and the edge of strip should not be less than the sheet thickness [5].

Definition of Problem

- Now days, in industrial sector heavy and bulky machines used to washer making.
- Available machines having less efficiency with high initial cost.
- Industry require highly trained worker to run machine.
- Time required to produce washer is more.

Objectives

- Studying current machines used to make washers in industries.
- Studying cutting forces and properties of materials.
- Design and fabricate a machine.
- Taking test of machine.
- Calculate payback time of designed machine.

EXPERIMENTAL METHODOLOGY

Problem Analysis

- Now days, in industrial sector heavy and bulky machines used to washer making. So, authors use pneumatic machine to cut the washer.
- Available machines having less efficiency with high initial cost. Pneumatic machines have low cost as compared to mechanical operated machine.
- First industry requires highly trained worker to run machine. But for this machine no any highly trained worker is required. Anyone can work on this machine.
- First in industry time required to produce washer is more. By using this machine we can save time.

Selection of Sheet

Generally, for computation and estimation functions shear strength is considered as 80% of tensile strength. In most of the cases, the shear and tensile strengths for most materials are not similar. Shear strength for the materials are given below:

- Aluminium is about 50% of its tensile strength
- Cold roll steel is around 80% of its tensile strength
- Stainless steel is in the region of 90% of its tensile strength

Selection of Material

To prepare any machine part,
The type of material should be properly selected considering design and safety. These selection of material for engineering application is given by the following factors:
Availability of material

- Suitability of the material for the application of the product,
- Suitability of the material for the desired working conditions,
- Cost of the materials. The machine is basically made up of mild steel.

The reasons for the selection are:

- Mild steel is easily available in market,
- It is economical to use,
- It is available in standard sizes,
- It has good mechanical properties i.e., good machinability and mechanical strength,
- It has modest factor of safety, since high factor of safety results in redundant wastage of material and heavy assortment. Low factor of safety results in preventable risk of failure,
- It has high tensile strength,
- Low coefficient of thermal expansion. The materials of the sheets to be punched are taken as aluminum and plastic as they are replacing many metals in the present scenario because of their distinguished properties and features.

In this case the selected material is the mild steel, because it is readily accessible in the market, economical for use and is existing in standard sizes. Its mechanical properties are good i.e., it is easily machinable, has modest factor of safety. Mild steel also has high tensile strength and low coefficient of thermal expansion. The sheet metals, what assumed to be punched are aluminium and plastic as designed the machine keeping these two as orientation.

RESULTS AND ANALYSIS

Component Design

Design of Cylinder

Design a cylinder to cut washer of 25 mm OD, 10 mm ID and 0.5 mm thickness of material having shear strength of aluminium is 30 N/mm^2. Operating with 8 bar pneumatic system.

Cutting force required= π d t σ_c

where, d is the diameter of washer, t is the thickness of sheet, σ_c is the shear strength of material.

Now, f = π (25+10) × 0.5 x 30 = 1649.33 = 168 kg

Force applied by piston ≥ required cutting force

Now,

F = force applied by piston = P × A

Where, P is the pressure applied by compressor, A is the cross sectional area of cylinder

$F = 8 \times 10^5 \times \pi/4 \times D^2$

Diameter of cylinder D = 0.05 m = 50 mm

Selection of Direction Control Valve

This formula and chart will give the C_v (Valve flow) required for operating a given air cylinder at a specific time period.

$$C_v = \frac{\text{Area x Stroke x A x } C_f}{\text{Time x 29}}$$

Where, Area is the π x Radius ^{2} or see Table 2 below i.e., 7.79 sq.in

Stroke is the Cylinder Travel (in.) i.e., 3.94 in

A is the Pressure Drop Constant (Table 1) i.e., 0.041

C_f is the Compression Factor (Table 1) i.e., 8.5

Time in seconds, i.e., 1 sec

NOTE: Use "A" Constant at 5 PSI P for most applications. For critical applications use "A" at 2 PSI P. A 10 PSI P will save money and mounting space.

$$c_v = \frac{7.79 \times 3.94 \times 0.041 \times 8.5}{1 \times 29} = 0.368$$

Selection of Tube

First we find the discharge of the cylinder,

We have the formula for discharge,

$$Q_c = \frac{volume}{time} = \frac{A \times l}{t}$$

$$Q_c = \frac{\frac{\pi}{4} \times 0.08^2 \times 0.1}{2}$$

$Q_c = 2.513 \times 10^{-4} m^3/s$

Discharge of tube is,

$Q_t = A \times v$

Where, A is the area of the tube in m^2, v is the velocity of air in m/s

We consider velocity of the air is 5 m/s

$\therefore 2.513 \times 10^{-4} = \pi r^2 \times 5$

$\therefore r^2 = \frac{2.513 \times 10^{-4}}{5 \times \pi}$

$\therefore r = 3.999 \times 10^{-4}$ m

$\therefore r = 3.999$ mm $\cong 4$ mm

$\therefore d = 8$ mm

∴ We select tube having 8 mm diameter.

Sample Calculation for Various Materials

*Sample calculation for aluminum sheet***:** Here is a sample calculation to calculate the punching force required for different thickness of aluminum sheet (Table 1).

- Total length of cut, L =110 mm.
- If sheet thickness, t = 0.5 mm
- Maximum tensile strength of aluminum, T_{max} = 30 N/mm^2
- Total cutting force = L × t × T_{max}
- Total cutting force = 35 × 0.5 × 30
- Total cutting force = 1650 N
- Stripping force = 15% of the cutting force= 247.5 N
- Press force = Cutting force + Stripping force = 1650 N + 247.5 N = 1897.5 N

Table 1: *Press Force Calculations for Aluminium Sheet of Different Thickness.*

Total length of cut (L) n mm	110	110	110	110
Al sheet thickness (t) in mm	0.5	0.6	0.7	0.8
T_{max} of Aluminum in N/mm^2	30	30	30	30
Total cutting force (in N)	1650	1980	2310	2640
Stripping force (in N) = 15% of cutting force	247.5	297	346.5	396
Press force (in N) =	1897.5	2277	2656.5	3036

Table 2: *Press Force Calculations for Plastic Sheet of Different Thickness.*

Total length of cut (L) n mm	110	110	110	110
Al sheet thickness (t) in mm	1.0	1.2	1.4	1.6
T_{max} of Aluminium in N/mm^2	15	15	15	15
Total cutting force (in N)	1650	1980	2310	2640
Stripping force (in N) = 15% of cutting force	247.5	297	346.5	396
Press force (in N)	1897.5	2277	2656	3036

Sample calculation for plastic sheet: Here is a sample calculation to calculate the punching force required for different thickness of plastic sheet (Table 2).

- Total length of cut L = 110 mm.
- If sheet thickness, t = 1 mm.
- Maximum tensile strength of plastic, T_{max} = 15 N/mm^2
- Total cutting force= 1650 N
- Stripping force = 247.5 N
- Press force = Cutting force + Stripping force= 1650 + 247.5 N =1897.5 N

Table 3: *Press Force Calculations for Tar Felt Sheet of Different Thickness.*

Total length of cut (L) n mm	110	110	110	110
Al sheet thickness (t) in mm	1	1.5	2	2.5
T_{max} of Aluminium in N/mm^2	8	8	8	8
Total cutting force (in N)	880	1320	1760	2200
Stripping force (in N) = 15% of cutting force	132	198	264	330
Press force (in N)	1012	1518	2024	2530

Sample calculation for tar felt sheet: Here is a sample calculation to calculate the punching force required for different thickness of tar felt sheet (Table 3).

- Total length of cut L = 110 mm, If sheet thickness, t = 1 mm.
- Maximum tensile strength of plastic, T_{max}= 8 N/mm^2
- Total cutting force= 880 N, Stripping force = 132 N, Press force = 1012 N

Fabrication and Implementation

Fabrication of Frame

We use mild steel to fabricate our frame of model, as mild steel is easily available in market. It fulfills our all requirements.
Properties of mild steel are,
Yield strength = 247 Mpa
Tensile strength = 841 Mpa
Poisson's ratio = 0.3

Joint

We use arc welding to join two parts of frame. In some cases bolt joins are used where necessary.

Proposed Machine

Design proposed machine in design software CATIA (Figure 2).

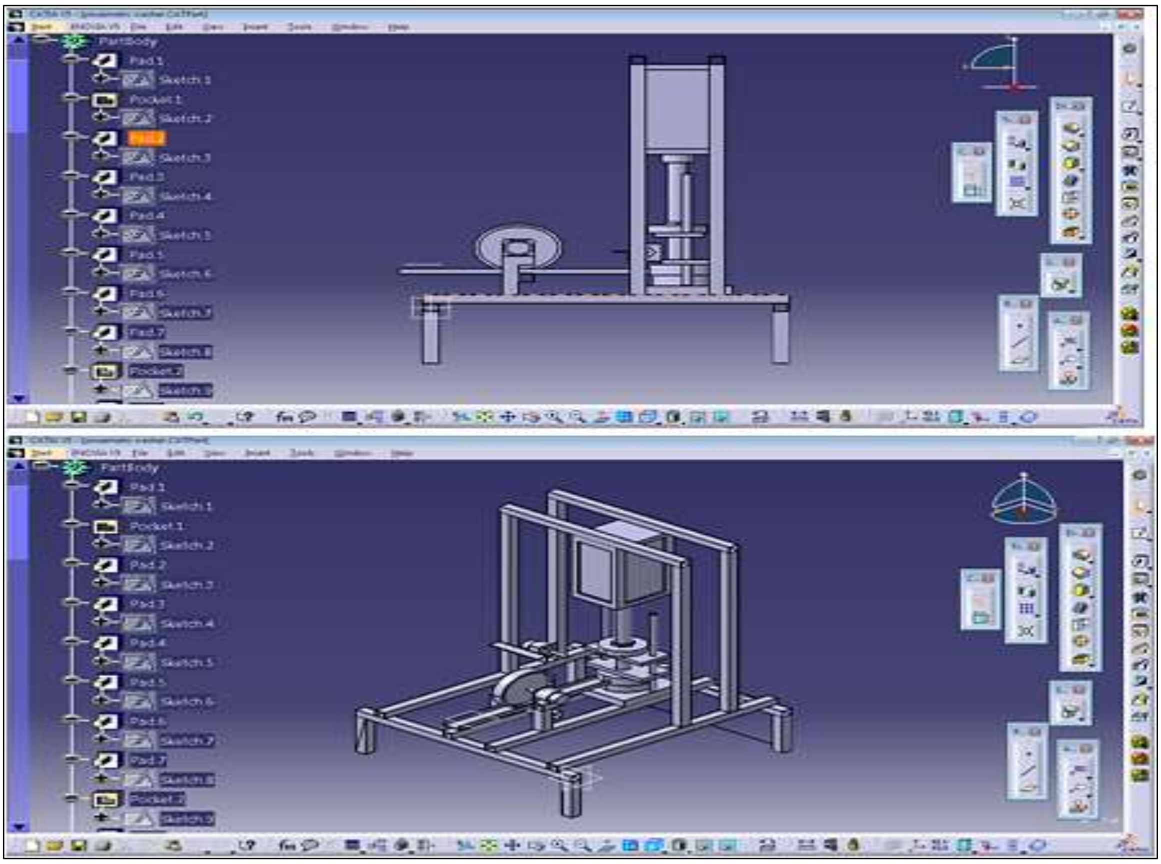

Fig. 2: *Proposed Machine.*

Description of Machine

The Pneumatic washer machine is made up of a variety of components. It consists of pressure regulator, pneumatic cylinder, solenoid/direction control valves, flow control valves, compressor and mounting table. Pneumatic automation components are broadly used as sealing material organized beyond rubber composites. For efficient and trouble free working of these seals, they need to be oiled or lubricated to reduce friction and corrosion. To lubricate compressed air actuated equipment, the most efficient and economical method is to inject the lubricant in to the compressed air that powers this equipment. Solenoid/Direction control valve is used to control the direction of the air.

Working Principle

The compressed air from the compressor at the pressure of 8 to 12 bar is passed through a pipe connected to the directional control valve with one input. The directional control valve is actuated with Control Timing Unit. The directional control valve has two outputs and one input. The air entering into the input goes out through the two outputs when the timing control unit is actuated. Because of the elevated air pressure at the bottom of the piston, the air pressure below the piston is in excess of the pressure above the piston. Therefore, this moves the piston rod upwards which in addition moves up the effort arm, pivoted by control unit. This force acting is bypassed on to punch which also moves downwards. The punch is also, guided by a punch guide which is fixed in such a way that the punch is clearly guided to the die. The materials are in between the punch and die. So as the punch descends down, the material is sheared to the required profile of the punch and the blank is moved downwards through the die clearance.

Working of Machine

The compressed air from the compressor at the pressure of 8 to 10 bar is passed through a pipe connected to the valve with one input. The valve has two outputs pressure below the piston is more than the pressure above the piston. So, this moves the piston rod from BDC to TDC. This force acting is passed on to punch which also moves downwards.

When the piston is at the extreme point of the stroke length, the exhaust valve is opened and the air is exhausted through it and when valve is released the pressurized air comes in at the TDC of the piston and it pushes the piston from TDC to BDC.

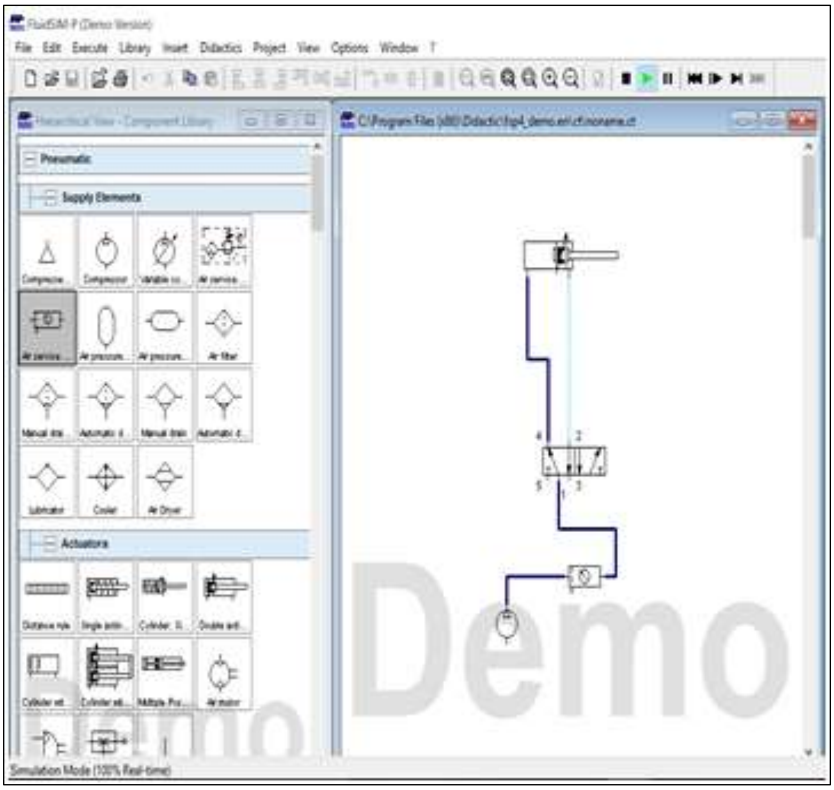

Fig. 3: *Pneumatic Circuit Working Stroke (Forward).*

So the one side of the air is pulled downwards and the other side is lifted upwards. So the punch is therefore, pulled upwards from the die. Now the piston reaches the BDC of the required stroke length. Now the material is fed and the next stroke of the piston is made ready.

Working Stroke (forward)
In forward stroke compressed air is passing to the cylinder and it actuates to downwards to cut washer (Figure 3).

Working Stroke (backward)
In reverse stroke compressed air is pass to the cylinder and it actuates to upwards to generate electricity by using motors (Figure 4).

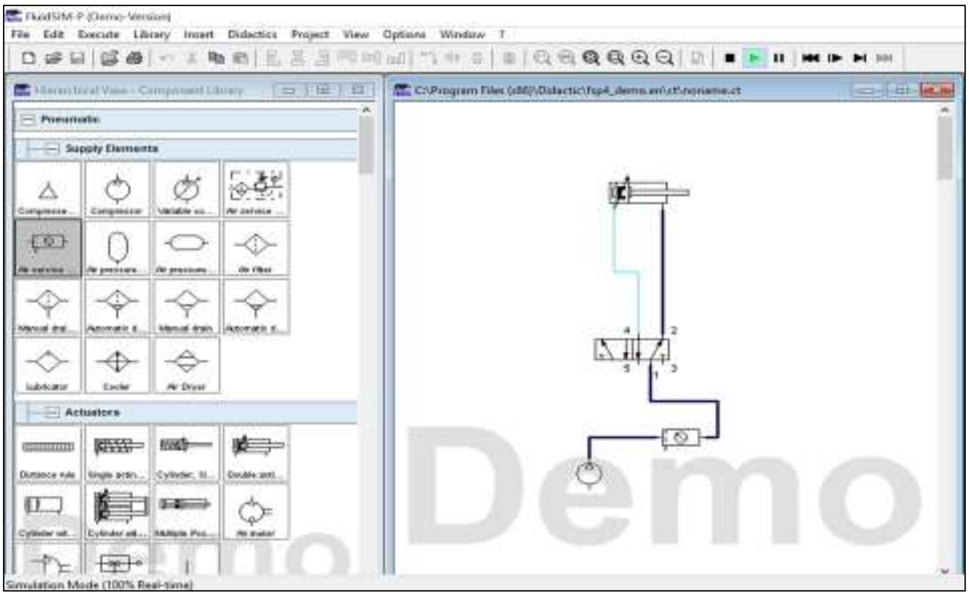

Fig. 4: *Pneumatic Circuit Working Stroke (backward).*

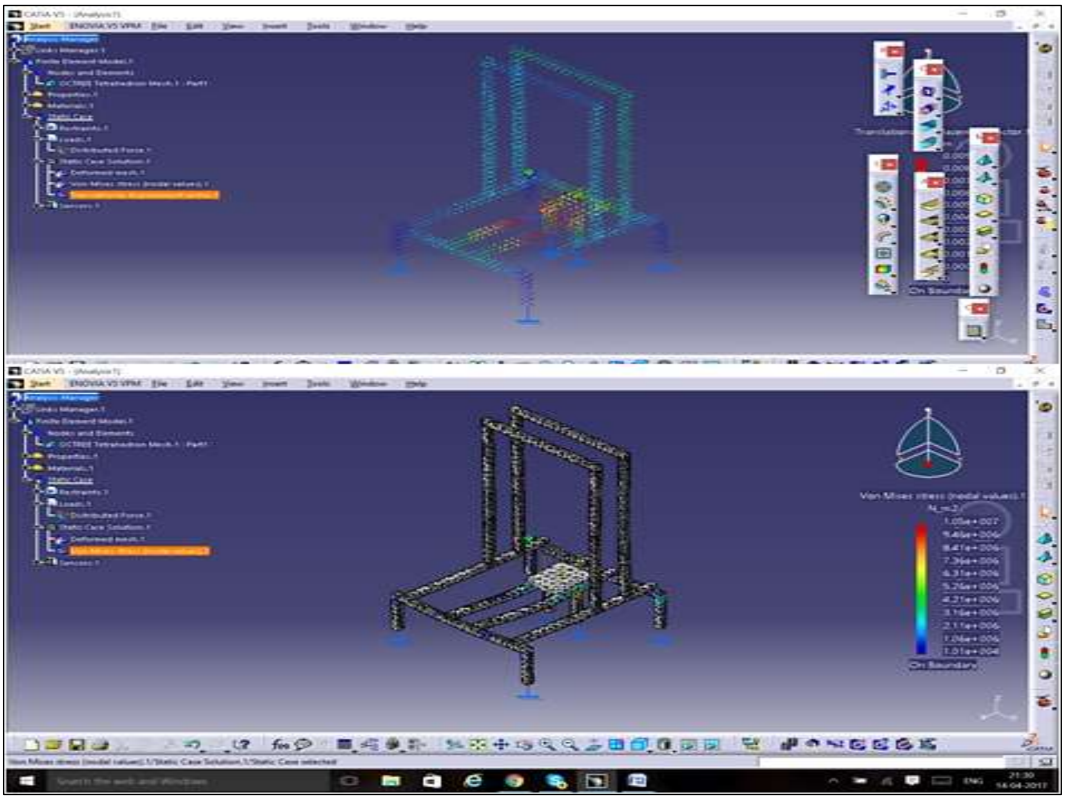

Fig. 5: *Transitional Displacement as per Von Misses Stress Criteria. We Check Stress on Frame Structure by using CATIA Software. For Load 1730 N Our Frame is Safe.*

Fig. 6: *Photographs of Washer Machine.*

Authors designed a pneumatic washer, is of lower cost as compared to market. Our pneumatic press is useful to do metal punching. Simple operations like bending; punching can be performed using this press. This is extremely helpful and supportive to do miniature works at our Institute (Figure 5, 6).

For this project, we can use any material having shear strength up to 72 N/mm^2.

For this we list of materials which have shear strength up to 72 N/mm^2.

The below given Table 4 gives the shear strength of several materials.

Table 4: *Result Analysis.*

Material	T_{max} in N/mm^2
German silver (2–20% Ni, 45–75% Cu)	300–20
Tin	30–40
Lead	20–30
Aluminium 99% pure	20–120
Hard board	70–90
Paper and card board	20–50
Mica	20–50
Plywood	20–40
Leather	7
Soft rubber	7
Hard rubber	20–60
Celluloid	40–60
Tar felt sheet	10

Advantages

- No extra skill is required for operating this system.
- This machine can run continuously for longer period.
- Simple construction than the mechanical and hydraulic presses.
- Compared to hydraulic and mechanical presses pneumatic press is economical.
- By this machine we can get more output by applying less effort.
- This machine is environment friendly.
- Convenient to assemble and disassemble.
- Reduce human efforts and time.
- Limitations.
- Stroke length is fixed.
- Force developed is very less as compared to hydraulic machine.
- There is limit on the thickness of sheet metal.

Future Scope

- Automation of pneumatic press.
- Improvements in pneumatic press by adding components like timers, silencers etc.
- Whole system can run by using solar power.
- The air releasing to atmosphere can be used again for working of cylinder.

CONCLUSION

The following major conclusions were drawn from the Design and Development

Pneumatic Operated Washer Making Machine. From the above calculation and results authors find shear strength for constant thickness and force,

By reverse calculation

Shear Force, $F = P \times A = 8 \times 10^5 \text{ x } \pi/4 \times (0.08)^2 = 4021.23$ N

Now we find shear strength,

$4000 = \pi \times 35 \times 0.5 \times$ (shear Force) = 72 N/mm^2

From this project we can conclude that, we can use any material for washer making with 0.5 mm thickness, internal dia.10 mm, outer dia. 25 mm and shear strength 72 N/mm^2.

Pneumatically operated washer making machine which is developed here is well suitable and appropriate for small scale and medium sized industries. Based on the shear strength provided on the punch face the punching force is reduced approximately in the range of 25% to 60% by this means thereby increasing tool life and reducing tool machining cost successively. Therefore, with this force reduction we are able to easily punch sheets of thickness equal to 2.25 mm for plastic sheet having tensile strength approximately 72 N/mm^2.

And up to 1.5 mm of aluminium sheet having tensile strength 72 N/mm^2.

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