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Conceptual Design Of Pneumatic Sheet Metal Cutter

Dhruv B Solanki[1], Harshil J Acharya[2]

[1]B.E. Student, Department of Mechanical Engineering, Vishwakarma Government Engineering College, Ahmedabad, Gujarat, India
[2]B.E. Student, Department of Mechanical Engineering, Vishwakarma Government Engineering College, Ahmedabad, Gujarat, India

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Abstract - *From the decade's scissors are being used for simple sheet metal cutting with manual operating so there are several chances for getting waste materials because of many factors like unappropriated dimensions, improper cutting etc... nowadays there are many alternatives for this operations like hydraulics operated, pneumatic operated even plasma cutting is also an option for the same.*

Here is a paper, in which we are going to take deep knowledge in pneumatic operated system with their component and force calculations. Other systems like hydraulics are also have been used but can only be used for heavy metal cutting and it is very much expensive. Here main advantage of pneumatic sheet metal cutting machine is to increase production rate with decreasing human efforts.

***Key Words*: pneumatic cutter, hydraulic, sheet metal, control valve, controller**

1.INTRODUCTION

When it comes to automation in industries, pneumatic and hydraulic performs the rudimentary role in the development. So here we will be discussing about the pneumatic operated sheet metal cutter in which we have studied about the essential requirements for the working of the machine and tried to do some possible changes that can make the machine self-working and can mitigate the labour work of the human being. Here in this paper we will also have a look on the machines that can also be used for the same purpose but we will focus on the point that why pneumatic applications are the best for the operations of the same concept. Pneumatic applications are playing pivotal role in the development of the world of technology. And it is also offering the best advantages that makes it one of the most essential point to consider for the research work.

2.LITERATURE REVIEW

There is plethora of methods that can be used by an industry for metal cutting operations or such any other operations. But industries generally prefer the method that is more economical and having more advantages which can be proved more beneficial for the growth of the industry. Many researchers are working on the pneumatic based applications for improving it's efficiency and to provide it to the real time working world for the advancement and better production. Innovators are also trying to change the shape and size of the pneumatic based sheet metal cutter by which the performance of the machine can be more beneficial for the operators.

There are several other machines that can be the alternative of pneumatic based sheet metal cutter. The list of such machines are as given below: -

Types of cutting machines:

2.1 Pneumatic operated

2.2 Hydraulic operated

2.3 Rack and pinion operated

2.4 Plasma cutting machine

Let's discuss above methods of the cutting operations in brief:

2.1 PNEUMATIC OPERATED MACHINE: -

the name of this machine is suggesting the principle on which this machine works which is pneumatic. Term that we used above in the main line "PNEUMATIC" Came from the Greek word "PNEUMA" which means 'WIND'. Which means it is working on the concept of compressed air and with that high air pressure and piston movement the cutting operation can be done.

There are few examples of such operations that are: -

1.pneumatic based cutter

2.pneumatic cleaner etc...

2.2 HYDRAULIC OPERATED MACHINE: -

Mostly hydraulic application are used where the high pressure/force is in need rather then the speed of working machine. Hydraulics are also crucial part of the industrial applications.

Most operations that can be carried out by the hydraulics are-

1. Hydraulic press

2. hydraulic lift etc...

2.3 RACK AND PINION OPERATED MACHINE: -

As name suggested this cutting machine is based on the working principle of the rack and pinion which are the important parts of any mechanism.

By the rotation of gears and pinions this cutter performs the operation.

2.4 PLASMA CUTTING MACHINE: -

Plasma cutting is a process that cuts through electrically conductive materials by means of an accelerated jet of hot plasma. Plasma cutting is used for typical materials such as steel, aluminum.

Plasma cutting is often used in fabrication, automotive application, industrial construction and scrapping operations.

Due to high cost plasma torches were only found in professional welding applications

Safety: proper eye protection is required in such cutting applications to prevent eye damage called "Arc eye".

3. MAIN COMPONENTS: -

Main components that can be used in the pneumatic based sheet metal cutter are as below:

3.1 DOUBLE ACTING PNEUMATIC CYLINDER-

As the name suggests this kind of cylinders are having two ports. One placed at piston side and another at rod side. During the forward motion of the cylinder compressed air will be driven from the compressor admitted to the piston side and while rod side is connected to the exhaust. vice versa happens for the return motion of the cylinder. [1]

Generally, Air leaving from a compressor is hot, dirty, and wet—which can damage and shorten the life of other equipments, such as valves and cylinders. So it must have to be filtered, regulated and lubricated, for that FRL unit has been used.

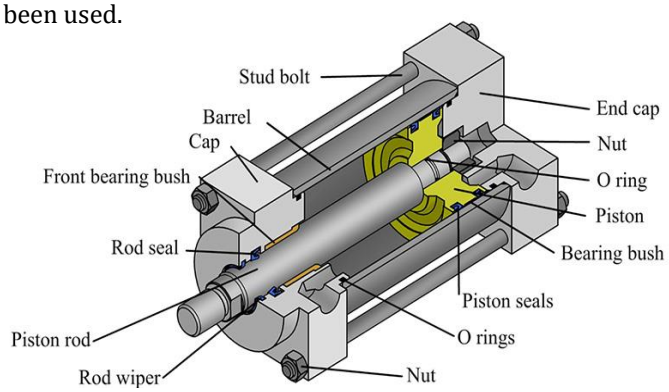

Fig -1: Double Acting Pneumatic Cylinder

3.2 AIR COMPRESSOR-

An air compressor is a pneumatic device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air and air compressor forces more and more air into a storage tank, increasing the pressure. When the tank's pressure reaches its engineered upper limit, the air compressor shuts off. The compressed air, then, is held in the tank until called into use. The energy contained in the compressed air can be used for a variety of applications, utilizing the kinetic energy of the air as it is released and the tank depressurizes. When tank pressure reaches its lower limit, the air compressor turns on again and re-pressurizes the tank. An air Compressor must be differentiated from a pump because it works for any gas/air, while pumps work on a liquid. [2]

Air compressor selection depends on many factors such as

- average air consumption of the system
- Free air delivery
- Air receiver capacity
- Power supply etc.

Fig -2: Air Compressor

3.3 DIRECTION CONTROL VALVES-

Directional control valves are one of the most fundamental parts in hydraulic machinery as well as in 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.

Directional control valves can be classified according to-

- number of ports
- number of positions
- Type of spool.

Example: A 5/2 directional control valve would have five ports and two spool positions.

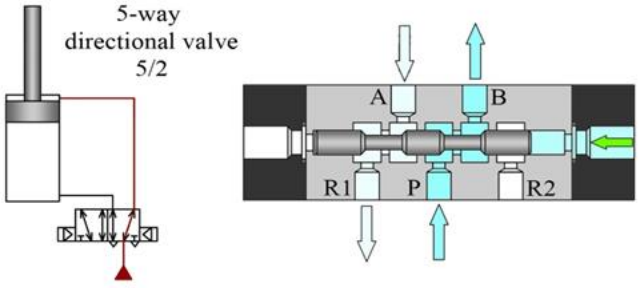

Fig -3: Direction Control Valve

3.4 AVAILABLE MATERIALS FOR SHEET METAL-

First of all, sheet metal is formed from metal after overcoming industrial process in which metal pieces turned into thin sheets, flat pieces can be cut and bent easily into variety of shapes. foils are the example of the extremely thin metal sheets.

3.4.1 STAINLESS STEEL-

The three most common stainless steel grades available in sheet metal are 304, 316, and 410.

- Grade 304 is the most common of the three grades. It offers good corrosion resistance while maintaining formability and weldability. Available finishes are #2B, #3, and #4.
- Grade 316 possesses more corrosion resistance and strength at elevated temperatures than 304. It is commonly used for pumps, valves, chemical equipment, and marine applications. Available finishes are #2B, #3, and #4
- Grade 410 is a heat treatable stainless steel, but it has a lower corrosion resistance than the other grades. It is commonly used for cutlery. The only available finish is dull.
- Grade 430 is popular grade, low-cost alternative to series 300's grades. This is used when high corrosion resistance is not a primary criterion. Common grade for appliance products, often with a brushed finish. [3]

3.4.2 ALUMINIUM-

The four most common aluminum grades available as sheet metal are 1100-H14, 3003-H14, 5052-H32, and 6061-T6.

4. INNOVATIVE ATTACHMENT-

Before applying this innovative attachment operator had to manually work for the time delay processes for an example: - if there is a sheet of length 10cm and worker wants to cut it in 5 parts of 2cm then Operator has the control the process manually with batch of 2cm for 5 times but this can be reduced by this attachment which is described in detailed in below segment.

4.1 PICOBOO ONE CONTROLLER-

Picoboo one is economical yet influential support controller, this is the first time when this kind of programming controller is being used in pneumatic cutter machines. This controller has plenty of attention-grabbing features such as it has the recording option. this controller can record actuation of cylinder up to one minute and actuates accordingly, after recording it person only needs to push green button which is shown in figure and system works same as per our recorded actuation. So this function can be very much useful to make process Self working and mitigates human efforts.

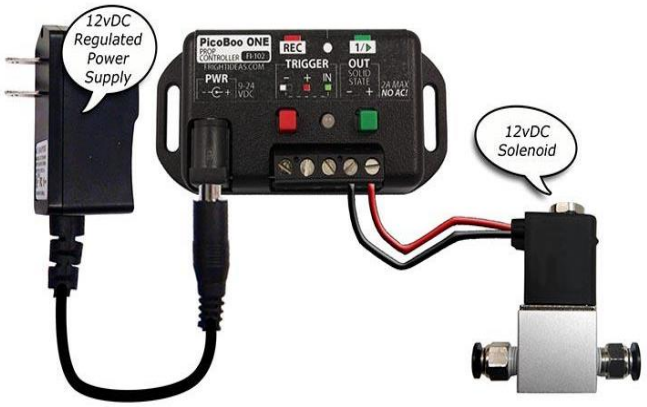

Fig -4.1: Connecting Way of Picoboo One Controller

PicoBoo ONE has implemented write-protection function so you don't have to worry about accidentally erasing or changing your program. One can see connecting way of this controller in given figure also same can be happened to 24v DC valve. [4]

Fig -4.2: Protection Feature of Picoboo One Controller

5. CONSTRUCTION

For construction detail, as we can see in the above figures in which we have designed it in two softwares

AUTOCAD which we have used for drafting purpose so that we can go through all the 3 views of the design. We have presented the third angle view here in orthographic view of the design

About lower stand: -

In the design we can see that this pneumatic sheet metal cutter is supported by the strong cube shaped lower stand.

in which we are having two slots which we can use to set the tools that are essential for work.

About upper stand: -

Upper stand of the design is fixed with the lower stand so that vibrations can be reduced as much as possible during the performance. And it has a structure like shelter which protects the bed on which the sheet will be placed so that amount of unwanted contaminants during the operation can be reduced. Which may enhance the work quality. In addition, we can say that it also offers the enough space for the movement of the piston hence piston can move freely. We can set the tool with the piston rod end as shown in the figure for cutting operations.

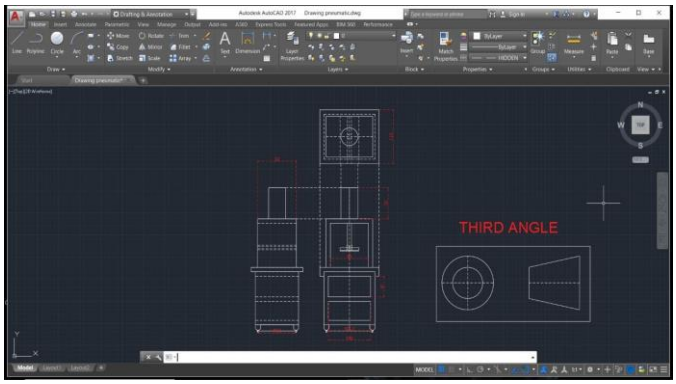

Fig -5.1: Orthographic View of the Pneumatic Sheet Metal Cutter.

NX SIEMENS which is a 3D modeling software so we have used it to show 3D view of the pneumatic sheet metal cutter.

Fig -5.2: 3D View of the Pneumatic Sheet Metal Cutter.

6. CALCULATIONS: -

here in this section of paper we will be discussing about some force calculation formulas that are essential to take in amount for the cutting operations and we will also focus on the theory based calculation of the pneumatic cylinder.

CALCULATIONS FOR SHEET METAL CUTTING FORCE: -

Here for the calculation of force required for sheet metal we will focus on two types of sheet metals as given below: -

- **For mild steel: -** formula to calculate the force required is,
  F= (L) × (t) × (Tmax)

Where:
L stands for= length of cut (mm)
t stands for= thickness (mm)
Tmax stands for= maximum shear strength (N/mm^2)
By applying above equation and putting corresponding values as per the equation one can get the cutting force required for cutting operation.
For example: - if we take the values such as
Length of cut L = 30 mm
Thickness t = 0.5 mm
Maximum shear strength Tmax = 60N/mm^2
Force required to perform the cutting operation is
F = 30 × 0.5 × 60
= 900 N
Here we have calculated the force which is totally based on theory so the value of actual force required for the start of the operation can be more (around 120% -140%.) Than we calculated.

- **For Stainless steel: -** formula to calculate the force required is
  F= (L) × (t) × (Tmax)

Where:
L stands for= length of cut (mm)
t stands for= thickness (mm)
Tmax stands for= maximum shear strength (N/mm2)
By applying above equation and putting corresponding values as per the equation one can get the cutting force required for cutting operation.
For example: - if we take the values such as
Length of cut L = 25 mm
Thickness t = 0.5 mm
Maximum shear strength Tmax = 30N/mm2
Force required to perform the cutting operation is
F = 25 × 0.5 × 30
= 375 N
Here we have calculated the force which is totally based on theory so the value of actual force required for the start of the operation can be more (around 120% -140%.) Than we calculated.

CALCULATION FOR PNEUMATIC CYLINDER THURST: -

Parameters that are essential for the calculation of pneumatic cylinder are as follows: -
D = diameter of piston or bore diameter
d = diameter of piston rod
F = force in N
V = velocity in m/s
A = area in m^2
Q = discharge in m^3/s
P = power in watts
p = pressure in N/m^2 [5]

packing friction: - the minimum amount of force which is required to move the piston in cylinder with the condition where there is no any load is called packing friction.
Net force required = working load + packing friction

SOME FORMULAS FOR THE CALCULATION: -

There are two types of motions should be in consideration for the calculation of pneumatic cylinder are

1. Forward/extension motion and
2.backward/retraction.

1. **For forward motion of piston: -**

Force developed F = p × A
Velocity of piston V = rate of flow/effective area
Power input to cylinder P = pressure × rate of flow
Power output of cylinder P = force × velocity of piston
[if packing friction is not considered then (Pin) = (Pout) which means efficiency of cylinder is 100%]
When packing friction (FN) is considered then
Net force developed becomes (F)net = (P × A) - FN
So efficiency of cylinder = Pout/Pin

2. **For backward motion of piston: -**

Force developed F = p × (A – a)
Velocity of piston V = rate of flow/effective area
Power input to cylinder P = pressure × rate of flow
Power output of cylinder P = force × velocity of piston
When packing friction (FN) is considered then
Net force developed becomes (F)net = (P × (A – a)) - FN
So efficiency of cylinder = Pout/Pin

As we have calculated the force required for cutting operation for sheet metal then from that calculation we can get the diameter of the pneumatic cylinder. [6]

For example: - as we got the force of 900 N for mild steel then from this force we can get the diameter of the cylinder required to generate this force. For that let's assume the pressure from the air compressor is 10 bar then.

As per the formula of force required (as per the calculation of mild steel): -

$F = p \times A$

$F = \pi/4\ d^2\ p$

So, $900 = \pi/4 \times d^2 \times 10/10$

$d = \sqrt{(900 \times 4/\pi)}$, $\therefore d = 67.8 \sim 70$ mm

Similarly, we can calculate for the stainless steel we can find the diameter of the cylinder as per given below: -

F = π/4 d^2p

So, $375 = \pi/4 \times d^2 \times 10/10$

$d = \sqrt{(375 \times 4/\pi)}$, $\therefore d = 43.52 \sim 44$ mm

This is how we can get the values from the equations given above and can apply the formulas to find the force required to perform the cutting operation for sheet metal and to find the diameter of the pneumatic cylinder.

7. CONCLUSIONS: -

After reading many articles about various cutting methods and as we have discussed above in this paper about other cutting methods as well. So we can conclude that pneumatic based systems are way too economical compared to other cutting methods. And the sheet metal cutting is one of the major processes of manufacturing. So it can be beneficial for small scale industries and workshop users who cannot afford the expensive methods for the cutting operations. Pneumatic systems are more faster in operation then hydraulic based systems. Pneumatic based systems are also being used in the field of robotics and automation. After going through the whole research work we can say that there are several aspects on which work can be done on this conceptual design but our motto of the research was to mitigate the human efforts while working with the pneumatic system. And as it is explicated above that we have used one innovative attachment which can make the work of the operator easier than before.

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BIOGRAPHIES

Dhruv B Solanki
B.E, Mechanical
Student

Harshil J Acharya
B.E, Mechanical
Student