CONSTRUCTION AND PERFORMANCE TEST OF A PNEUMATIC SHEET METAL CUTTING MACHINE

A Thesis
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Abstract

This project focuses on the design and development of a pneumatic sheet metal cutting machine capable of cutting metal sheets up to a thickness of 2 mm. Above thickness of 2.5 mm sheet cutting status is unsuccessful because of lower cutting blade hardness & sharpness. The main goal is to create an efficient, cost effective and safety alternative to conventional cutting methods such as manual shears or electrical powered cutters. Pneumatic systems offer significant advantages, such as reduce energy consumption and lower operational cost, making the machine suitable for small-scale industries and workshop where high-end CNC or hydraulic may be too expensive.

Chapter 1

Introduction

1.1 Introduction:

The sheet-cutting machine is the heart of sheet metal industries. In some industries, a hand sheet cutter is used which is operated manually. In these machines, we are using a pneumatic cylinder for sheet metal cutting. These machines should be easy to operate and maintain also. Hence, we are introducing a pneumatic sheet metal cutting machine which will reduce manufacturing costs and minimize industrial labour problems which is the biggest headache for humans. The main objective of our project is to perform job-holding operations effectively with less humane efforts by using a machine with pneumatic power. This will also reduce the time required for metal cutting. By using these machines, we can increase the production rate and automatically the industry will be in profit. Automation plays an important role in mass production. Automation can be achieved through the pneumatic form. The main advantage of the pneumatic system is economically cheap and easy to handle. The manufacturing operation is being atomized for the following reasons.

1.2 Objective of the study:

- To improve industrial production, by using machines that make the cutting process easy.
- To optimize material usage by ensuring precise cuts, leading to minimum wastage of sheet material.
- To minimize cost and operation time.
- To reduce the risk of occurrence of an accident or an injury need to develop this system.
- To cut the sheet metal easily with unexperienced Operator.

Chapter 2

Literature Review

2.1 Introduction:

In cutting operation as or blade descends upon the metal, the pressure exerted by the blade first causes the plastic deformation of the metal, since the clearance between to blade is very small. The plastic deformation takes place in a localized area and the metal adjacent to the cutting edges of the blade edges becomes highly stressed, with courses the facture to start on both sides of the sheet as the deformation progresses and the sheet is shear. Types of cutting machines:

- Pneumatically operated
- Hydraulically operated
- Rack and pinion operated
- Spring operated

2.2 Different Types of Cutting Machines

2.2.1 Pneumatically operated:

Here is the advancement of the header which is carried out in the upward and downward direction using the pneumatic double-acting piston and cylinder unit arrangement along with the foot-operated direction control valve. In this type of machine high-pressure air is used as the working fluid for the transfer of power and the motion.

2.2.2 Hydraulically operated:

Here the lowering and raising of the header which is carried over using the hydraulic Piston and cylinder arrangement. To actuate the piston and cylinder, the oil is allowed. To enter the cylinder for the front or back side of the piston. But the oil is comparatively cost layer and it is leakage may cause so many problems.

2.2.3 Rack and pinion operated:

Here the lowering and raising of the header are carried out manually using the rack and pinion arrangement. In this case, the required pressure is applied manually using direct hand pressure on the rack using pinion and leaver arrangement. Since the machine is robust and requires large pressure, it is not suitable.

2.2.4 Spring operated:

The working of a spring-operated machine is similar to a rack and pinion-operated machine but differs it in construction. Here the lowering and the rising of the heating handle are carried out manually and it requires too much pressure for its operation also their possibility to having damage to the work piece if not handled carefully.

Chapter 3

Methodology

3.1 Data Analysis

3.1.1 Cylinder Thrust:

Cylinder thrust for double acting in the forward stroke. Then, the Cylinder thrust for double acting in return stroke –

$F = (\pi /4) \times D^2 \times P$

Where,

D = Diameter of the bore in mm.

P = Pressure in the bar. (1 bar = 0.1 N/mm^2)

3.1.2 Theoretical Air Consumption:

$C = \{(\pi /4) \times D^2 \times (P + 1) \times L\}/1000$, Where,

P= pressure in bar

D= the diameter of the bore in cm

L= length of stroke in cm.

Theoretical Air Consumption of our pneumatic machine was C = 22.85 litres.

3.1.3 Sheet Metal Cutting Force:

Cutting force = $L \times S \times Tmax$, stripping force =10% -20% of cutting force

L = Length of the periphery to be cut in mm

S = Sheet thickness in mm

$Tmax$ = Shear strength in N/mm $Tmax$ = 80% of tensile strength After putting corresponding values according to the equation we can get that the aggregated cutting force.

3.2 Project Drawing:

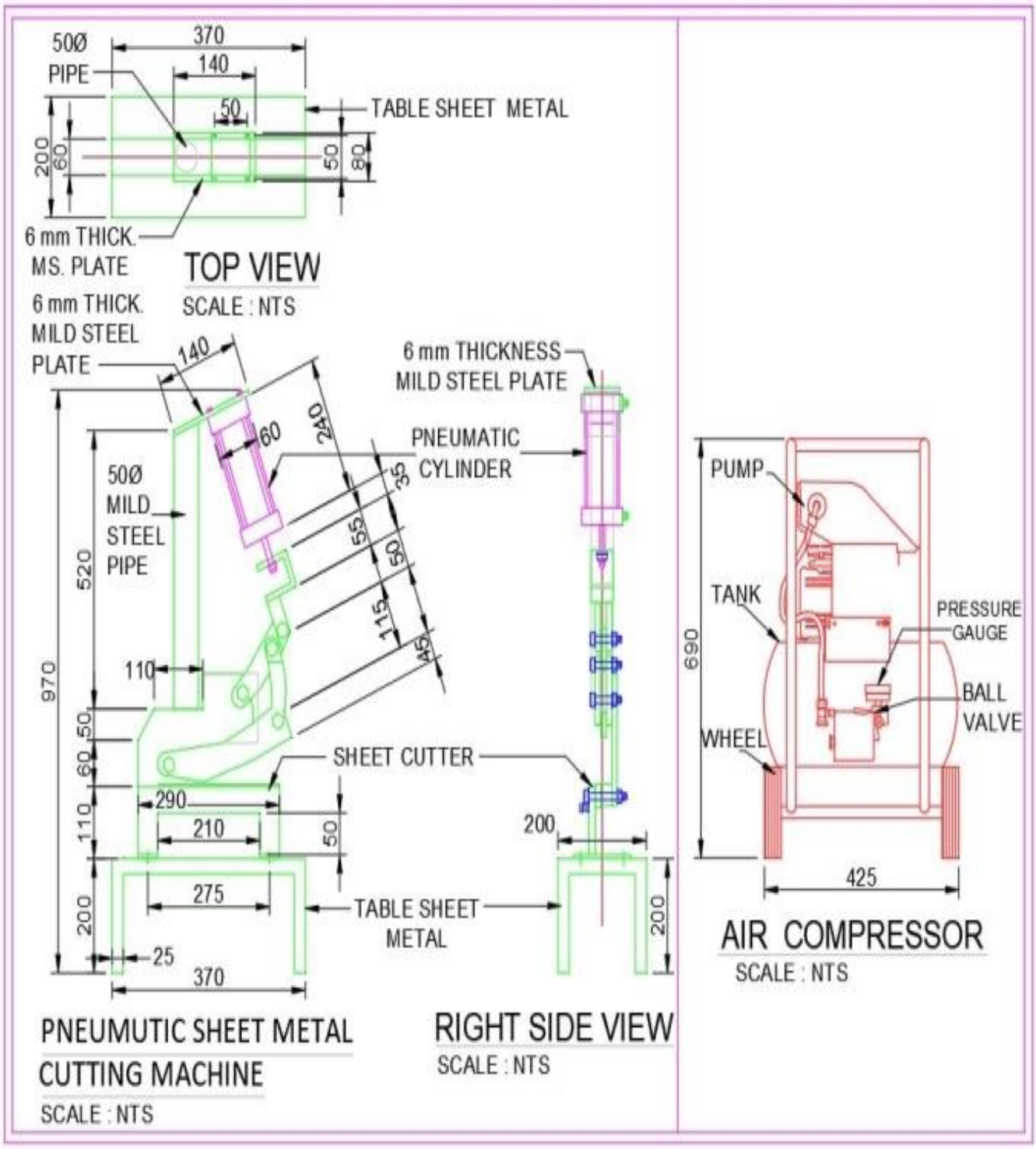


Figure: 3.1 Project Drawing

3.2.1 Project Image:

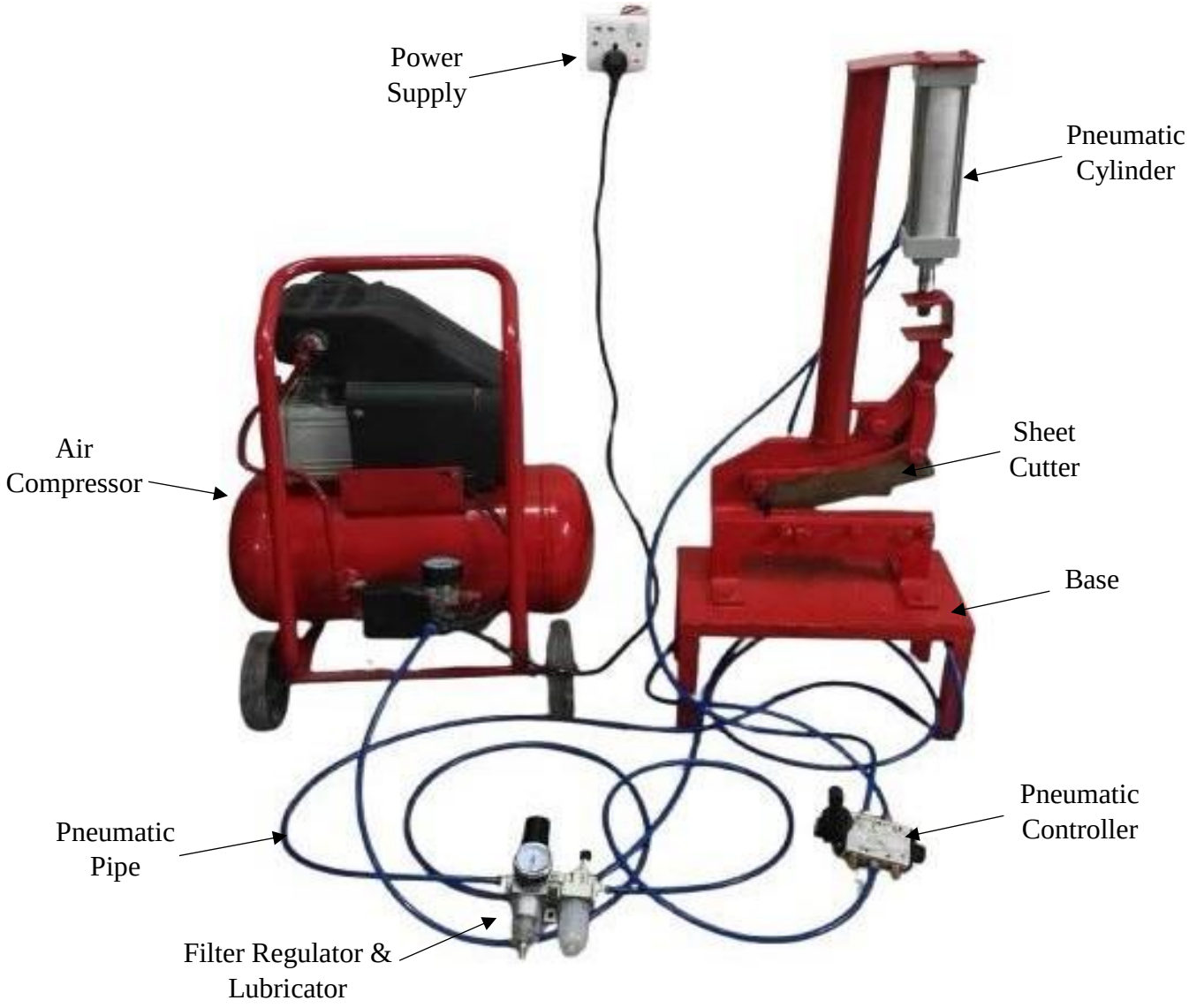


Figure: 3.2 Pneumatic Sheet Metal Cutting Machine.

3.3 Working procedure of the Pneumatic Sheet Metal:

The most common cutting processes are performed by applying a shear force and are therefore sometimes referred to as shearing processes. Cutting processes are those in which a piece of sheet metal is separated by applying a great enough force to cause the material to fail. When a great enough shearing force is applied, the shear stress in the material will exceed the ultimate shear strength, and the material will fail and separate at the cut location. This shearing force is applied by two tools, one above and one below the sheet. Whether these tools are a punch and die or upper and lower blades, the tool above the sheet delivers a quick downward blow to the sheet metal that rests over the lower tool. A small clearance is present between the edges of the upper and lower tools, which facilitates the fracture of the material. The effects of shearing on the material change as the cut progresses and are visible on the edge of the sheared material. When the punch or blade impacts the sheet, the clearance between the tools allows the sheet to plastically deform and "roll over" the edge. As the tool penetrates the sheet further, the shearing results in a vertical burnished zone of material, finally, the shear stress is too great and the material fractures at an angle with a small burr formed at the edge. The height of these portions of the cut depends on several factors, including the sharpness of the tools and the clearance between the tools. The pneumatic machine includes a table with support arms to hold the sheet, stops or guides to secure the sheet, upper and lower straight-edge blades, and a gauging device to precisely position the sheet. The table also includes the two-way directional valve. The two-way directional valve is connected to the compressor. The compressor has a piston for a movable member. The piston is connected to a crankshaft, which is in turn connected to a prime mover (electric motor, internal combustion engine).

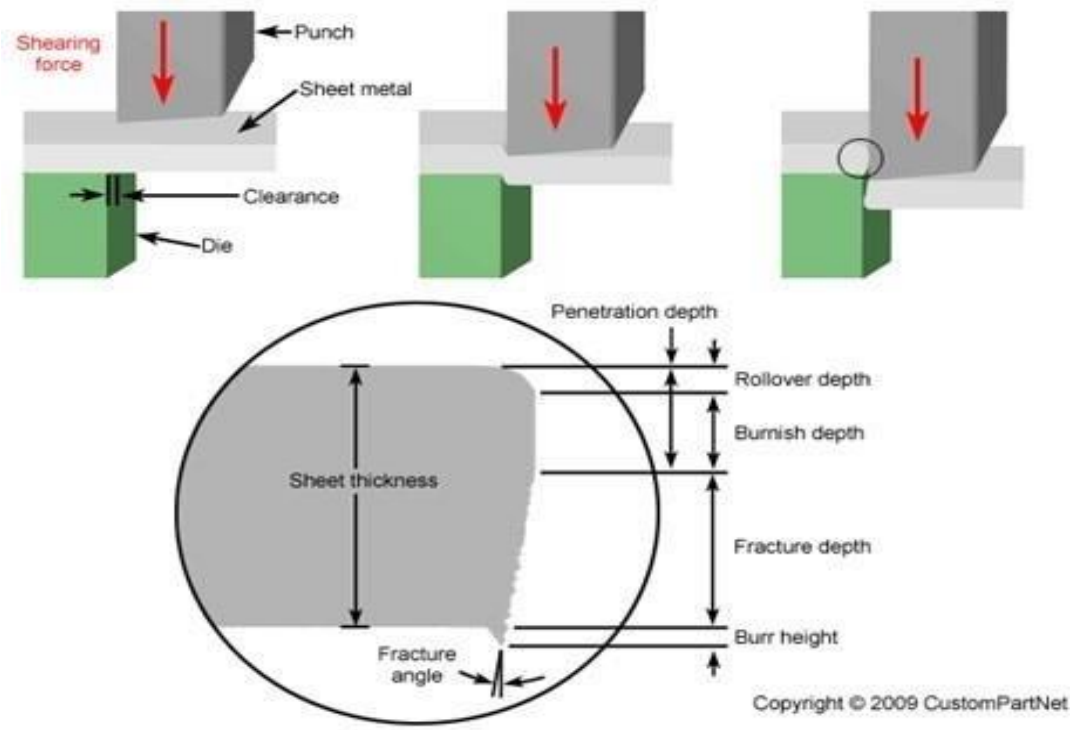


Figure: 3.3 Working procedure of the Pneumatic Sheet metal cutting machine

At inlet and outlet ports, valves allow air to enter and exit the chamber. When the Compressor is switched ON, the compressed air flows to the inlet of the pneumatic cylinder. The sheet is placed between the upper and the lower blade. The lower blade remains stationary while the upper blade is forced downward. The upper blade is slightly offset from the lower blade, approximately 5 – 10% of the sheet thickness. Also, the upper blade is usually angled so that the cut progresses from one end to the other, thus reducing the required force. When the pneumatic hand-operated lever is moved forward, the piston starts moving in the forward direction. The upper blade is then forced against the sheet, cutting the material. When the pneumatic hand-operated lever is moved backward, the upper blade will come to its original position (i.e., the upper blade will move upwards). After the material is cut, adjust the pneumatic hand lever to the mid position (i.e., normal position), and then the compressor is switched OFF.

3.3.1 Working Flow Chart

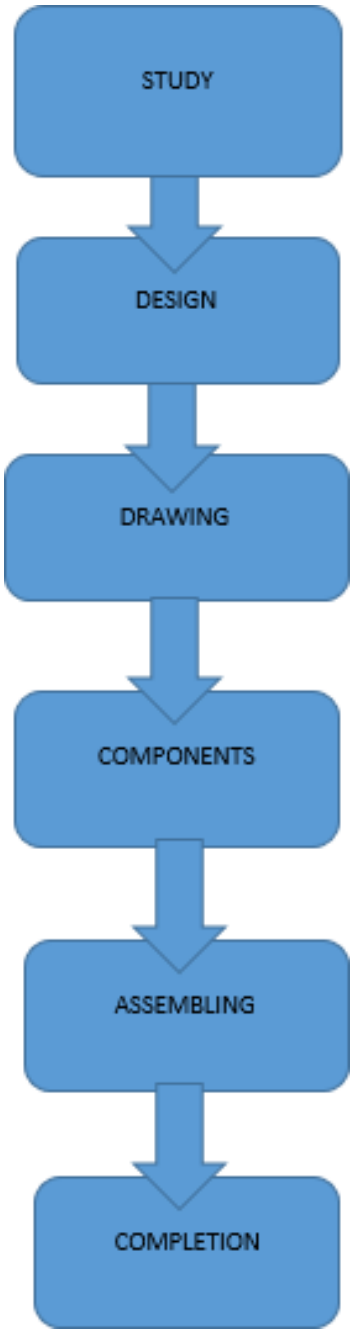


Figure: 3.4 Working Flow Chart

3.3.2 Pneumatic Transmission of Energy:

The reason for using pneumatics, or any other type of energy transmission on a machine, is to perform work. The accomplishment of work requires the application of kinetic energy to a resisting object resulting in the object moving through a distance. In a pneumatic system, energy is stored in a potential state in the form of compressed air. Working energy (kinetic energy and pressure) results in a pneumatic system when the compressed air is allowed to expand. For example, a tank is charged to 100 psi with compressed air. When the valve at the tank outlet is opened, the air inside the tank expands until the pressure inside the tank equals the atmospheric pressure. Air expansion takes the form of airflow. A positive displacement compressor consists of a movable member inside a housing. The compressor has a piston for a movable member. The piston is connected to a crankshaft, which is in turn connected to a prime mover (electric motor, internal combustion engine). At inlet and outlet ports, valves allow air to enter and exit the chamber.

3.3.3 Control of Pneumatic Energy:

Working energy transmitted pneumatically must be directed and under complete control at all times. If not under control, useful work will not be done and machinery or machine operators might be harmed. One of the advantages of transmitting energy pneumatically is that energy can be controlled relatively easily by using valves.

3.3.4 Control of Pressure:

Pressure in a pneumatic system must be controlled at two points - after the compressor and after the air receiver tank. Control of pressure is required after the compressor as a safety for the system. Control of pressure after an air receiver tank is necessary so that an actuator receives a steady pressure source without wasting energy.

3.3.5 Control of Pressure after a Compressor:

In a pneumatic system, energy delivered by a compressor is not generally used immediately but is stored as potential energy in an air receiver tank in the form of compressed air. In most instances, a compressor is designed into a system so that it operates intermittently. A compressor is a device that usually delivers compressed air to a receiver tank until high pressure is reached. Then it is shut down. When air pressure in the tank decreases, the compressor cuts in and Recharges the tank. Intermittent compressor operation in this manner is a power-saving benefit for the system. A common way of sensing tank pressure and controlling actuation and de-actuation of relatively small (2-15 HP) compressors, is with a pressure switch.

3.3.6 Construction:

The pneumatic sheet metal cutting is supported by a table includes with support arms to hold the sheet. The table also includes the two-way directional control valve. The two-way directional control valve is also known as the solenoid control valve. We used a two-way directional control valve that is connected to the compressor by an air pipe. The compressor has a piston for a movable member. The piston is connected to a crankshaft, which is in turn connected to a prime mover. At inlet and outlet ports, valves allow air to enter and exit the chamber. When the compressor is switched ON, the compressed air flows to the inlet of the pneumatic cylinder. The sheet is placed between the upper and the lower blade. The lower blade remains stationary while the upper blade is forced downward. The upper blade is slightly offset from the lower blade, approximately 5 – 10% of the sheet thickness Also, the upper blade is usually angled so that the cut progresses from one end to the other, thus reducing the required force. When the pneumatic hand-operated solenoid valve is moved forward, the piston starts moving in the forward direction. The upper blade is then forced

Against the sheet, cutting the material. When the pneumatic hand-operated lever is moved backward, the upper blade will come to its original position (i.e., the upper blade will move upwards). After the material is cut, adjust the pneumatic hand-operated solenoid valve to the mid position (i.e., normal position), and then the compressor is switched off.

3.4 Equipment list with working principle:

3.4.1 Air Compressor:

An air compressor is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When tank pressure reaches its upper limit the air compressor shuts off. The compressed air, then, is held in the tank until called into use.



Figure: 3.5 Air Compressor

3.4.2 Pneumatic Cylinder:

A double-acting cylinder is a cylinder in which the working fluid acts alternately on both sides of the piston. To connect the piston in a double-acting cylinder to an external mechanism, such as a crankshaft a hole must be provided in one end of the cylinder for the piston rod, and this is fitted with a gland or "stuffing box" to prevent escape of the working fluid. Double-acting cylinders are common in steam engines but unusual in other engine types.

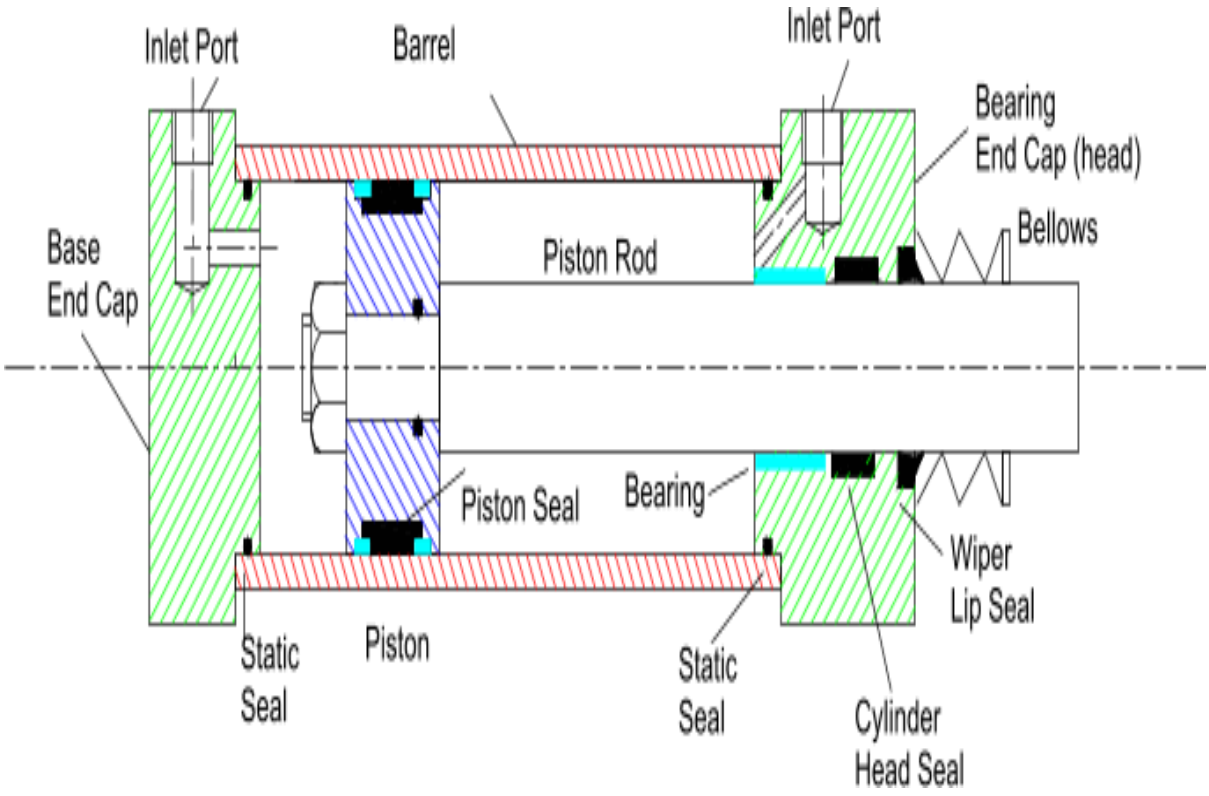


Figure: 3.6 Pneumatic Cylinder

3.4.3 Double-acting cylinder:

Double-acting cylinders (DAC) use the force of air to move in both extend and retract strokes. They have two ports to allow air in, one for outstroke and one for in-stroke. Stroke length for this design is not limited, however, the piston rod is more vulnerable to buckling and bending. Addition calculations should be performed as well by using the design data handbook using some relations between cylinder and pressure we can accurately find out the bending and buckling of the tie rod.

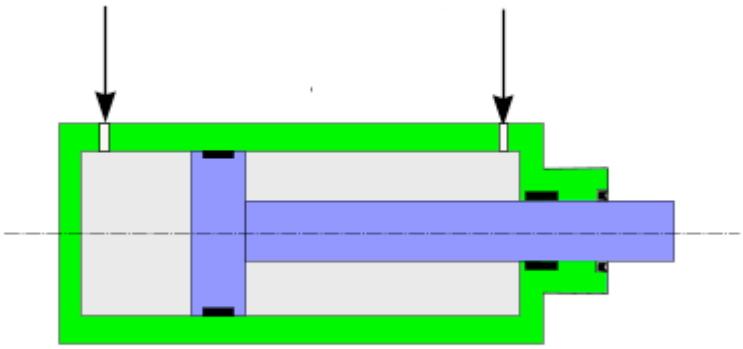


Figure: 3.7 Double-acting cylinder

3.4.4 Pneumatic valve:

A Pneumatic valve is an electromechanically operated valve. The valve is controlled by an electric current through a Pneumatic. In the case of a two-port valve, the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports. Multiple Pneumatic valves can be placed together on a manifold. Pneumatic valves are the most frequently used control elements in fluidics. The pull-type Pneumatic is one in which the plunger is pulled when the Pneumatic is energized.

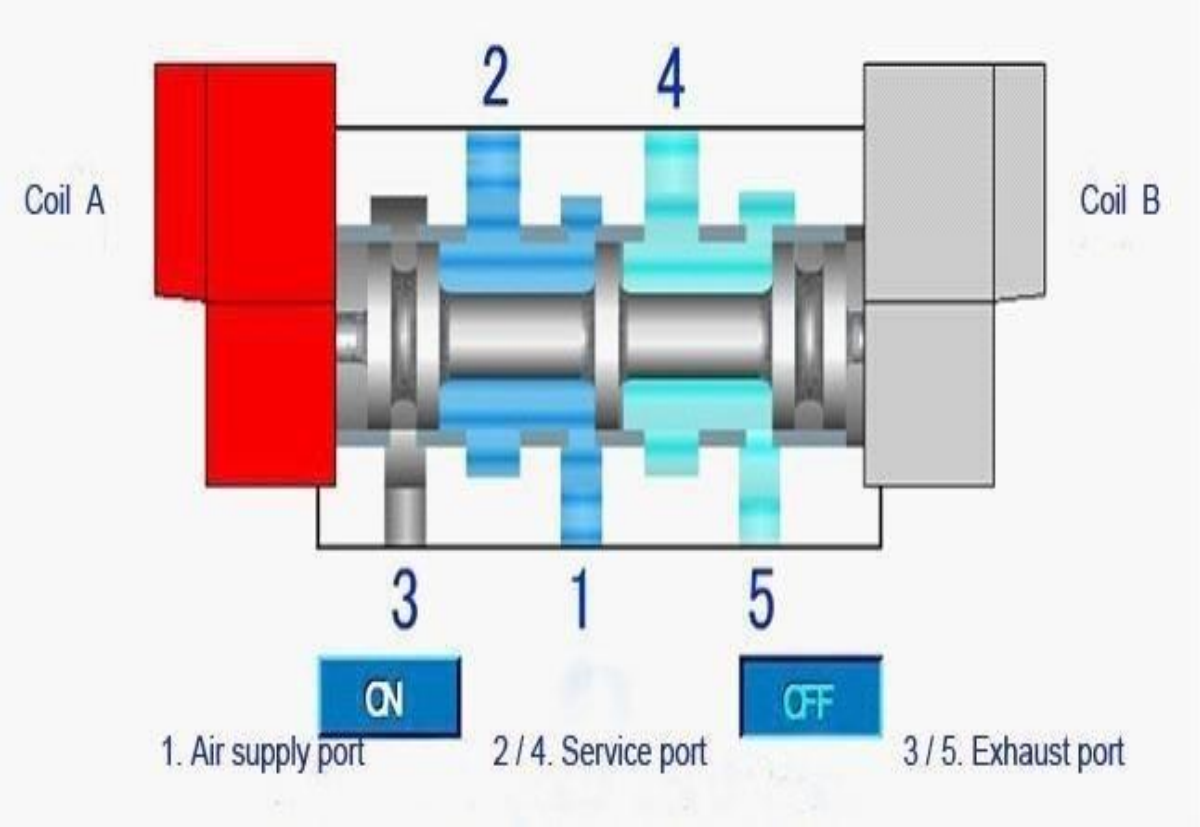


Figure: 3.8 Pneumatic valve

3.4.5 Directional Control Valve:

A 3/2 directional control valve can be used to control a single-acting cylinder (Fig. 5). The open valves in the middle will close until ‘P’ and ‘A’ are connected. Then another valve will open the sealed base between ‘A’ and ‘R’ (exhaust) as shown in Fig 5. The valves can be driven manually mechanically, electrically, or pneumatically. 3/2 directional control valves can further be divided into two classes: Normally open type (N.O.) and normally closed type (N.C.).

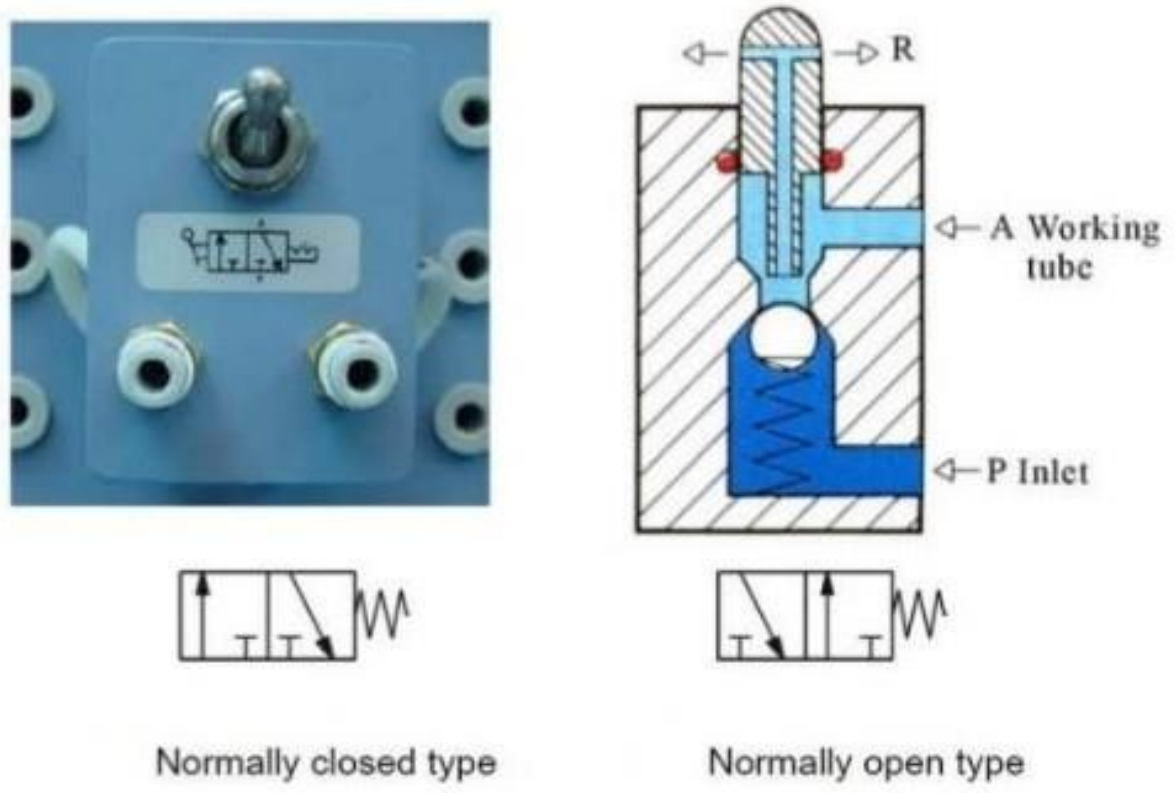


Figure: 3.9 Directional Control Valve

3.4.6 Two-way direction valve:

A two-way directional valve consists of two ports connected with passages, which are connected and disconnected. In one extreme spool position, port A is open to port B; the flow path through the valve is open. On the other extreme, the large diameter of the spool closes the path between A and B; the flow path is blocked. A two-way directional valve gives an on-off function. (Flow path open and Flow path closed).



Figure: 3.10 Two-way direction valve

3.4.7 High-speed Cutting Blade:

Sheet metal is metal formed by an industrial process into thin, flat pieces. It is one of the fundamental forms used in metalworking and it can be cut and bent into a variety of shapes. Countless everyday objects are fabricated from sheet metal. Thicknesses can vary significantly.



Figure: 3.11 High-speed Cutting Blade

3.4.8 Pneumatic Pipe:

The Pneumatic pipe connects the solenoid valve and the cylinder block. Pipes are made of layers of elastomer (or) synthetic rubber and braided fabric which takes up the higher pressure. If the pipe is subjected to rubbing, it should be enclosed in a protective sleeve.



Figure: 3.12 Pneumatic Pipe

3.4.9 Pneumatic Fitting:

Pneumatic fittings come in a variety of styles and materials with threaded ports or push-to-connect designs to attach pneumatic tubing to valves—all courtesy of Automation Direct.



Figure: 3.13 Pneumatic Fitting

3.5 Operation Flow chart:

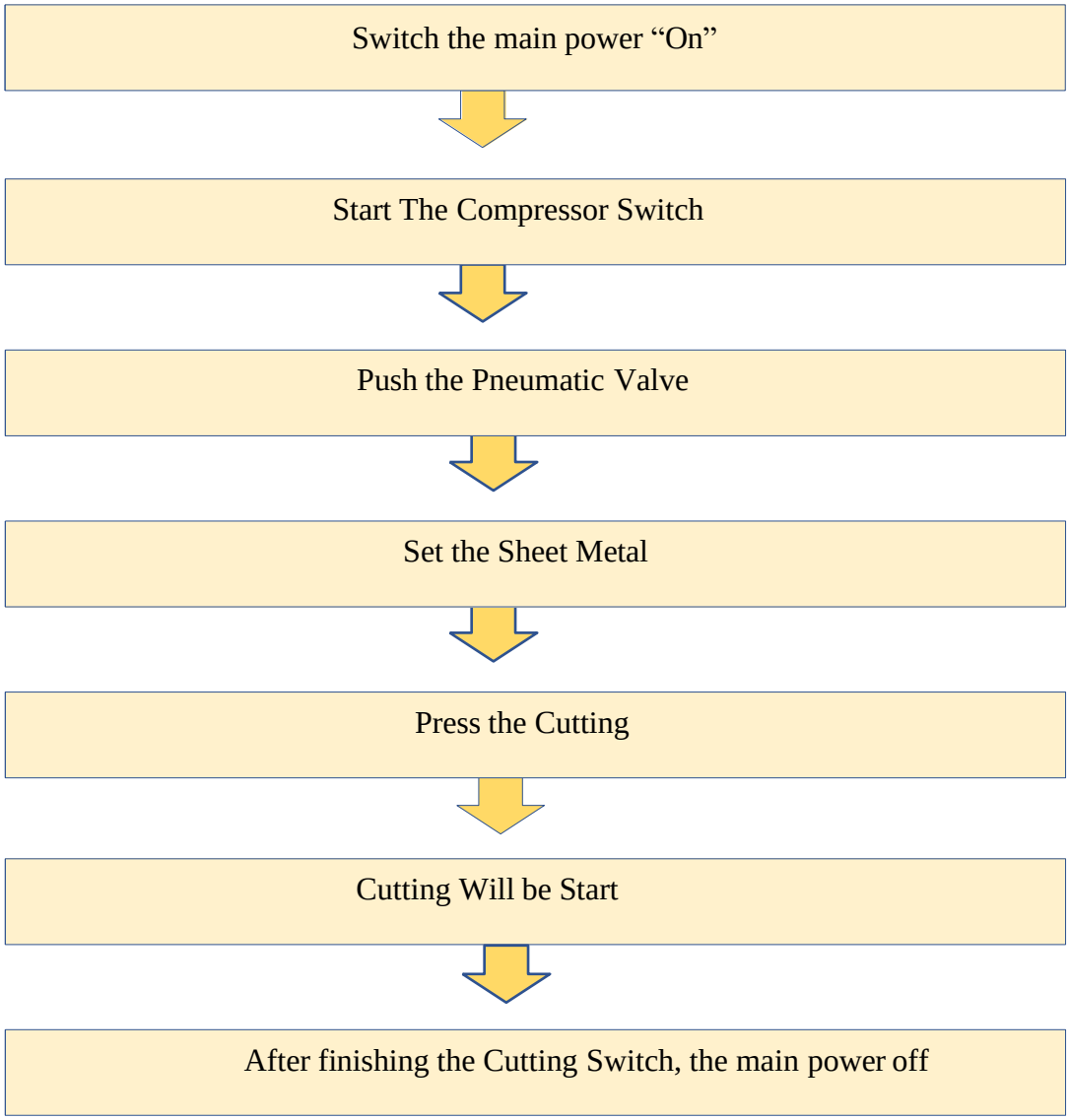


Figure: 3.14 Flow Chart Operating Process

3.6 Methodology of the study:

The pneumatic sheet metal cutting machine is a much-undeveloped system in our country's industry. Industries are used to cut sheets in manual sheet-cutting machines by humans. This is a risky process for workers. Please see the below picture

.



Figure: 3.15 Usual Risky Process for Workers

Chapter 4

Data Collection and Analysis

4.1 Introduction:

We develop this machine by using industrial scrap or waste of machine parts. Every industry can flow us because they can develop this machine without any countable cost.

4.2 New part price list:

If anyone thinks about this machine will be a new machine. They have to bear the following cost of parts.

Sl. No	parts name	Require Qty.	Specification	Price per unit (BDT)	Total price (BDT)
01	Sheet Cutter + Moving Cutter	1 Pcs	8 inches	3000	3000
02	Pneumatic Cylinder	1 Pcs	length 240 mm 50 mm dia. 07 bar	2500	2500
03	Air Compressor	1 Pcs	08 bar 24 Litre.	12000	12000
04	Pneumatic Valve	1 Pcs	Stock length 163 Diameter 35	1310	1310
05	Pneumatic Pipe	30 Fit	6 mm	12	360
06	Pneumatic Fitting	6 Pcs	Nipple	45	270
07	Table Sheet Metal	1 Pcs	370(L)x 200(W)x 200(H) mm	3200	3200
08	Filter Regulator & Lubricator	1 Pcs	0-6 bar	900	900
09	Paint	1 Pcs	Standard	150	150
Total Cost					**23690**

Table No: 4.1 New part price list

4.3 Analysis:

Every industry wants a better solution. This machine is more efficient in the running process. This machine's operation is very safe and needs less operation time. The maintenance cost of this machine is very low.

Chapter 5

Results and Discussions

By this topic ‘pneumatic sheet metal cutting machine’ we can say that this machine is a low-cost and efficient performer. It can serve continuous production.

5.1 Performance Test Table:

SL.	Pressure (Bar)	M.S. Sheet thickness (mm)	Cutting Status
01	2	0.5	Successful
02	2.5	1.0	Successful
03	3	1.5	Successful
04	3.5	2.0	Successful
05	4	2.5	Unsuccessful

Table No: 5.1 Performance Test Table

Explanation: At first, 2 bar pressure was applied to a 0.5 mm thick metal sheet and it was successfully cut. Similarly, 2.5 bar, 3 bar and 3.5 bar pressure were applied to 1 mm, 1.5 mm and 2 mm thick metal sheet respectively and all these 3 metal sheets were cut successfully. On the other hand, 4 bar pressure was applied to a 2.5 mm metal sheet and it was not cut successfully. Though the highest limit of compressor pressure is 8 bar the blade capacity is not beyond 4 bar and the blade performed with low hardness and sharpness beyond that pressure.

Graph:

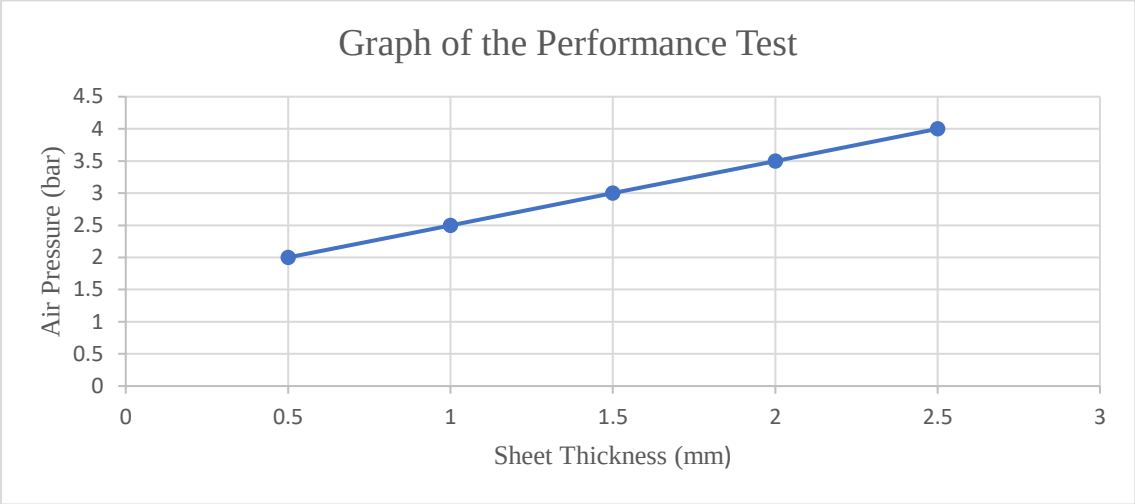


Figure: 5.1 Graph of Performance Test

Explanation: Here above the graph shows that Sheet Thickness (mm) in X-axis and Air Pressure (bar) in Y-axis. when started 0.5 mm metal cut at 2 bar pressure, then increased the pressure accordingly 2.5, 3 and 3.5 bar with 1 mm, 1.5 mm and 2 mm sheet metal could cut smoothly. But when we increased pressure at 4 bar with 2.5 mm metal sheet the operation was unsuccessful.

5.2 Summary Results:

After analysing the previous sheet-cutting system many limitations were found. Dangerous processes need an experienced and robust operation and need more time. If we avoid the running sheet-cutting machine and use a pneumatic sheet-cutting machine to cut the metal, we will finish the facilities of this machine with are easy operation system. No need to repeatedly set measurements and the maintainers cost is low for simple construction.

5.3 Discussion:

During this project completion we faced several challenges such as:

a) Material Selection: Finding materials strong enough to withstand the force of cutting 2.5 mm thick metal.

b) Force Calculation: Determining the amount of pneumatic pressure required to cleanly cut through metal of varying thicknesses.

c) Pneumatic System Design: Designing a pneumatic system that delivers consistent pressure and operates efficiently.

d) Safety Concerns: Ensuring the machine is safe to operate, considering the high pressure and sharp blades involved.

e) Cost Management: Keeping the cost of components and production within budget while maintaining functionality and durability.

Chapter: 6

Conclusion & Future Scope

6.1 Conclusion:

It will be improving industrial production by using pneumatic sheet cutting machine. During the completion of project, we find several optimize material usage by ensuring precise cuts, leading to minimum wastage of sheet material. We try to minimize cost and operation time but the initial cost was high and the operation time was as expected. Reduce the risk of occurrence of an accident compare to other typical sheet cutting machine. There is no need any operation skill to operate our machine as like we have no idea about this type of machine before but when finished the project, we can easily operate the machine and cutting smoothly.

There are several potential upgrades we could consider for pneumatic sheet metal cutting machine to improve its performance, usability, or versatility. Here are a few ideas:

a) Automated Control System: This would allow for more precise, repeatable cuts.

b) Improved Safety Features: Add safety sensors, safety guard for reducing the risk of accidents during machine operation.

c) User-Friendly Interface: Add a touchscreen or digital interface that allows users to control and monitor the machine more easily. this would make the machine more intuitive to use.

d) Noise Reduction: add soundproofing materials or quieter pneumatic components.

6.2 Scope and Limitation of the Study:

There is a lot of opportunity and demand in our country's industrial sector, this is a running problem of all industry in our country Most industry wants a Suitable solution for this Pneumatic sheet metal cutting system. The project is designed to benefit metalworking industries, small workshops, and educational institutions. The machine is applicable in environments where precision cutting of thin metal sheets is required. The owners of Industries also invest money to get an easy, suitable, highly efficient machine. The machine is specifically designed for sheet metal. Other materials like plastic, wood, or composites might not be effectively cut without significant modifications. Pneumatic systems can generate significant noise and vibration, which may affect operator comfort over long periods or in noise-sensitive environments. The limitation of this study is sheets more than 1.5 mm thick can't be cut easily.

References:

We made this project with our idea with the help of

[1] https://www.ijraset.com/fileserve.php?FID=13055
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