Automated Pneumatic Sheet Metal Cutting Machine

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Abstract – Automated pneumatic sheet metal cutting has been used to shear the sheets made of galvanized iron and aluminium of various thicknesses. The pressure and force required for shearing these metal sheets have been listed accordingly. Automation in the process is incorporated by using microcontroller, inductive proximity sensor, electrically controlled solenoid valve and DC motor controlled roller feed system. The automation provides provision to enter the number of sheets to be cut and required length of the sheet.The system works by pneumatic means which consists of air compressor, pipe lines, control valves and pneumatic cylinder. The design is particularly suited for the applications where working space is contrained. Pneumatic systems are useful when sheet metals are need to be cut in hazardous areas such as oil and gas refineries and in chemical factories. Further it is observed that, the employment of automation system makes the cutting process accurate, time efficient and increases the productivity as compared to conventional non-automated cutting machine.

Keywords – Pneumatic, Automation, Ergonomics, Efficiency

1 INTRODUCTION

Sheet metal is a metal formed into thin and flat pieces. It is one of the fundamental forms used in metal working and can be cut and bent into variety of different shapes [1]. Sheet metals are available in flat pieces or as a coiled strip. The thickness of the sheet metal is measured in gauge. Commonly used steel sheet metal ranges from 30 guage to 8 gauge [2]. The larger the gauge number, the thinner the metal. Sheet metals has wide range of applications in car bodies, airplane wings, medical tables, roofs of buildings and many other things. Sheet metal of iron and other materials with high magnetic permeability are known as laminated steel cores [4].

The shearing machine is most important in sheet metal industry. In most of the small scale industries, hand sheet cutters are used, which requires human effort to cut down the sheets. It can be replaced by a pneumatic cutting machine which can cut the sheet metal at a faster rate and in a convenient way [5]. In shearing operation, the pressure exerted by the punch, causes the plastic deformation of the sheet metal. Since the clearance between the die and punch is very small, the plastic deformation takes place in the metal adjacent to the cutting edges. This causes the fracture to start on both sides of the sheet and the sheet is sheared [6].

A lot of researchers have worked on pneumatic systems as well as on sheet metal experiments. The work done by various authors are explained below.

- Pneumatics was first documented by Hero of Alexandria in 60 A.D., but the concept had existed before then [3].
- Vallance and Matlock (1992) studied the friction behavior of zinc-based coated sheet steels and laboratory scale friction analysis techniques that involve sheet sliding over cylindrical dies [3].
- Sanchez et al. (1999) has focused on systematic analysis of testing equipment as a measurement system of the friction phenomenon on sheet metal under plain strain. It has also provided experimental reference in order to optimize the usage of sheet metal and lubricants [3].
- Mutoh et al. proposed that the exhaust pressure of the cylinder hold middle level is 0.2-0.5 MPa. If the exhaust flow is used effectively, losses can be reduced in pneumatic systems. If the exhaust pressure is set near 0.2 MPa, it reduces the losses by 15% of total consumption [8].

The main objective of the present project is to automate the system so that the cutting operation can be

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done with high accuracy. To achieve this, microcontroller based system is incorporated in this project. This system controls the feed and performs the cutting action via pneumatic means.

2 METHODOLOGY

2.1 Material Selection

2.1.1 Frame:-

The frame is made up of mild steel material. Because, mild steel is readily available in market and is economical to use. It has good mechanical properties such as high ductility and high toughness. Mild steel has carbon content ranging from 0.15% to 0.25%. The ultimate strength and compressive of this steel increases with increase in the carbon content.

2.1.2 Shearing Blade:-

The shearing blade is made up of high speed steel material. The blade has to withstand the high cutting forces and this can be achieved by using high speed steel as a blade material. High speed steel offers reliable toughness and it retains good wear resistance. A typical composition is: 18% of tungsten, 4% of chromium, 1% of vanadium, 0.7% of carbon and the rest is iron.

2.2 Design

CATIA V5R20 software is used for designing and modelling. The blade design considerations are:

- Clearance is typically 2% to 10% of the material thickness.
- The upper blade is angled so that as the cutting progresses from one end to other end, thus reducing the required force (5^0 shear angle reduces force by 20%).
- Scissor type cutting blade is used.
- Square edged blade is preferred rather than knife edge.

The frame design considerations are:

- Based on the length of the cutting blade used, the width of the frame is selected.
- The length of the frame is designed to make the machine compact and also to accommodate the length of the sheet metal to be cut.

The figure 1 shows the dimensions and figure 2 shows the Isometric view of the model.

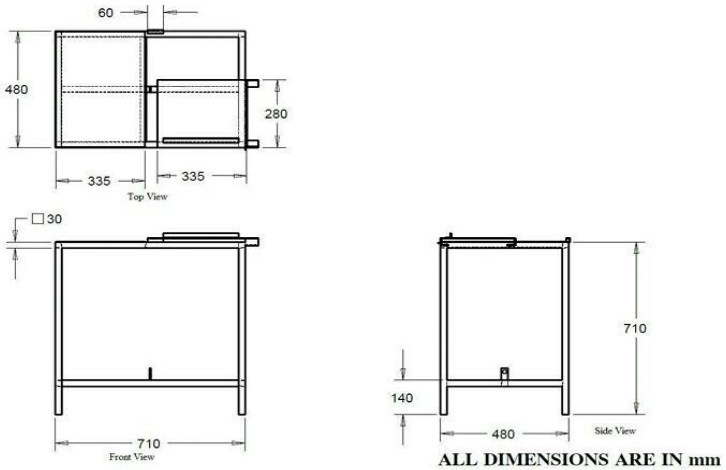

Fig. 1: Dimensions of the frame along with different views

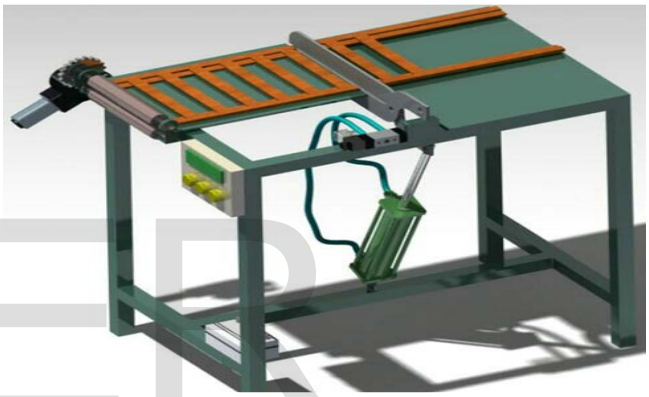

Fig. 2: Isometric view of CATIA V5R20 model

2.3 Force Calculation

The maximum pressure applied in the cylinder (P) = 10 bar

Daimeter of the cylinder bore (D) = 40 mm

Area of the cylinder (A) = $(\pi \times D^2)/4$

Area (A) = $(\pi \times 40^2)/4 = 0.0012564\ m^2$

Therefore, Force acting on the sheet (F) = P×A

Force (F) = $(10 \times 10^5) \times (0.001256) = 1256.4$ N

2.4 Components Used

2.4.1 Pneumatic Cylinder:-

The cylinders are the devices which use the power of compressed air to produce force in a reciprocating linear motion. In this project, double acting pneumatic cylinder in used as shown in figure 3. It develops pressure in both extend and retract strokes. The moving member inside the cylinder is piston which moves forward and backward due to the high pressure of air. The cylinder top and lower plate are flanged together by means of bolts and nuts. The bottom of the cylinder is also flanged with end covers for the movement of the piston in reciprocating manner [7].

Fig. 3: Double acting cylinder

2.4.2 Solenoid Valve:-

The direction control valve is used to control the direction of air flow in the pneumatic system. The figure 4 shows electrically controlled solenoid valve. A solenoid is a device that converts electrical energy into straight line motion and force [9]. Solenoid may be of push type or pull type. The push type solenoid is one in which the plunger is pushed when the solenoid is energized electrically. The pull type solenoid is one in which the plunger is energized [8].

Fig. 4 Solenoid valve

2.4.3 Air Compressor:-

An electric compressor is a device that converts power (using an electric motor, diesel or gasoline engine, etc) into potential energy stored in pressurized air. Figure 5 shows a air compressor of 12 bar pressure.By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When tank pressure reaches it'upper limit, the compressor shuts off. The energy contained in the compressed air can be used for a variety of applications. As the compressed air is released from the cylinder, the tanks depressurize. When tank pressure reaches it's lower limit, the air compressor turn on again and repressurizes the tank [10].

2.4.4 DC Motor

An electric motor is a machine which converts electrical energy to mechanical energy. It's action is based on the principle that when a current carrying conductor is placed in a magnetic field, it experiences a magnetic force whose direction is given by Fleming's left hand rule. When a motor is in operation, it develops torque. This torque can produce mechanical rotation. Figure 6 shows a DC motor.

Fig. 5: Air compressor

Fig. 6: DC motor

2.4.5 Microcontroller:-

A microcontroller as shown in figure 7 is a compact integrated circuit designed to govern a specific operation in an embedded system. It typically includes a processor, memory and input/output peripherals on a single chip.

Fig. 7: Microcontroller

2.4.6 Proximity Sensor:-

A sensor is an object whose purpose is to detect events or changes in its environment, and then provide a corresponding output. The sensor used in this project is inductive proximity sensor as shown in figure 8. Inductive proximity sensors enable the detection, without contact, of metal objects at distances of up to 60 mm. Their range of applications is very extensive and includes : the monitoring of machine parts (cams, mechanical stops, etc.), monitoring the flow of metal parts, counting, etc. They basically comprise an oscillator whose windings constitute the sensing face. An alternating magnetic field is generated in front of these windings. When a metal object is placed within the magnetic field generated by the sensor, the resulting currents induced form

an additional load and the oscillation ceases. This causes the output driver to operate and, depending on the sensor type, a NO, NC or NO + NC (complementary) output signal is produced.

Fig. 8: Inductive proximity sensor

2.4.7 Polyurethane Tubes:-

A pipe is a tubular section or hollow cylinder as shown in figure 9, usually of circular cross-section is used mainly to convey substances which can flow through it (liquids, gases, slurries, powders etc). It can also be used for structural applications.

2.4.8 Rollers:-

The electronic roll feeding is an integral part of almost every modern conveyor fed press and punch, and is frequently implemented as a stand-alone, electrically driven machine unit. Mechanical components of a complex construction in the roll feeding are replaced by intelligent units. The figure 10 shows the rubber rollers.

Fig. 10: Rubber rollers

3 WORKING PRINCIPLE

The sheet metal will be fed through feed rollers. The gear arrangement on the rollers is meshed with the DC motor, which feeds the sheet. The inductive proximity switch/sensor will be used, it detects the metal sheet and also records the sheet length as the sheet passes over it. After detection, these informations are sent as a input to the microcontroller circuit containing series of relays. The microcontroller carries out the computations according to the coding done on it. The output from the microcontroller will be sent to electrically controlled solenoid valve. The valve control the actuator to actuate according to the signal received.

DC motor meshed with the gear arrangement on the feed rollers receives input from the proximity switch, which will start/stop accordingly. This system provides provision to enter number of sheets along with the required length which is needs to be cut. The figure 11 shows the working model.

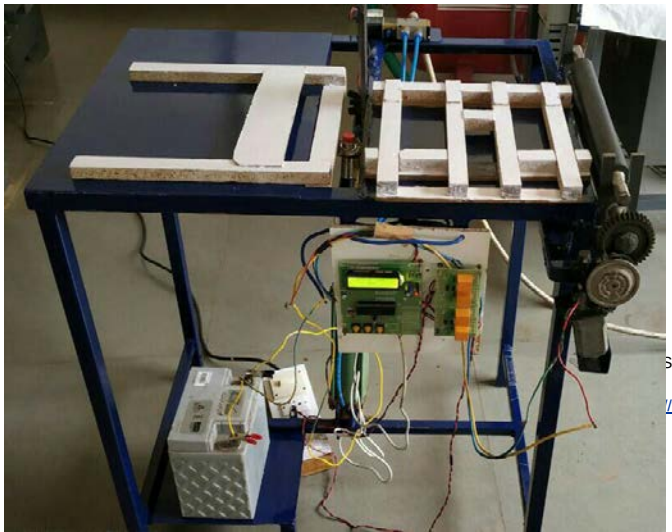

Fig. 11: Working model

4 RESULTS

The metal strips made of galvanized iron and aluminium with different thickness has been sheared by the pneumatic shearing machine at various pressures.

Table 1 shows the force and pressure required to cut the different sheets of various thickness.

Table 1: Force reading for different sheets

Material used	Thickness (cm)	Applied pressure (bar)	Force (N)
Galvanized iron sheet metal	0.1	3.5	431.24
	0.15	5	615.07
Aluminium	0.1	1	123
	0.2	3	370
	0.3	5	616.07

With the use of scissor type blades, it acts as a lever system. Less cylindrical force is used to generate the shearing force.

Automation has reduced the time taken in measuring and cutting the sheetmetal, with automation it takes 1-2 seconds per sheet.

The table 2 shows the comparison between hydraulic, pneumatic and mechanical system. An inference could be drawn that pneumatic system is less complex, cheap and efficient.

Table 2: Comparison between Hydraulic, Pneumatic and Mechanical System

Sr. No.	Point of comparison	Hydraulic	Pneumatic	Mechanical
1	Capital investment	Very high	Moderate	Low
2	Capacity	Very high	Moderate	Moderate / high
3	Running cost	Moderate	Moderate	High
4	Maintenance	Very high	Low	Moderate
5	Space requirement	High	Low	High
6	Speed of cutting	Low	High	Moderate
7	Requirement of skilled driver	Yes	Yes	No
8.	Requirement of foundation	Yes	Yes	Yes
9.	Rate of cutting	Low	High	Low
10.	Complexity	High	Low	High
11.	Power requirement	Moderate	Moderate	High

5 Conclusion

It is observed that the pneumatic cutting is very cheap as compared to hydraulic cutting machine. The range of the cutting thickness can be increased by using high pressure compressor and more hardedned blades. This machine is advantageneous to small sheet metal cutting industries as they cannot afford the expensive hydraulic cutting machine. Further with the employment of automation, it provides provision to enter the number of sheets to be cut and required length of the sheet. Hence human effort is reduced with increase in accuracy in operation.

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