Design and Fabrication of Hydraulic Cutting Machine

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Abstract- **Hydraulic cutting machine is a machine tool for cutting flat sheet metal to create geometric features required as machine elements or to increase the static stability of sheet metal profiles. There are two types of cutters: mechanical cutters and hydraulic cutters. Mechanical cutters are highly productive, easy to set up and environmentally friendly. However, its lack of variable stroke length limits its application. Larger stroke length ranges and more flexible hydraulic cutting machines are used to solve this problem. Our project deals with the design and fabrication of a hydraulic cutting machine for cutting mild steel plate with a thickness of up to 6mm. The tool is attached to the piston of the cylinder. This cylinder has a stroke length of 100 mm and has a maximum working pressure of 210 bar for performing the cutting operations. It uses a 2.25KW motor and runs on hydraulic oil stored in a 40-litre oil tank. We have also integrated IOT into the project. A magnetic sensor is attached to the machine that counts the number of cuts, and this is connected to the counter board to digitally display the number of cuts. Based on the calculation of pump pressure, cutting force, output piston force and piston stroke length, the hydraulic cutting machine is manufactured.**

Key Words- Hydraulic, Metal Cutting, Product Design

I. INTRODUCTION

Hydraulics is the applied science of engineering, chemistry, and other sciences dealing with the mechanical properties and applications of liquids. Fluid mechanics provides a theoretical foundation for hydraulics with an emphasis on applied engineering that exploits the properties of fluids. Fluid power applications use hydraulics to generate, control, and transmit power using pressurized fluids.

The hydraulic machine uses the force of fluid flow to perform work. Heavy construction vehicles are a common example. In this type of machine, hydraulic fluid is pumped to various hydraulic motors and hydraulic cylinders throughout the machine and becomes pressurized according to the resistance encountered. Liquids are controlled directly or automatically via control valves and distributed via hoses, tubes, or pipes. Hydraulic systems are based on Pascal’s Law. Pascal’s law states that pressure applied anywhere within a confined incompressible fluid is transmitted equally through the fluid in all directions, so the pressure ratio (initial difference) remains the same. Hydraulic systems use incompressible liquids as fluids.

Cutting is the process of shearing sheet metal by applying mechanical force or pressure on it. Using the cutting tool and the application of appropriate load, the sheet metal is sheared. It has three basic stages:

1. Plastic deformation: Placing the metal between the top and bottom blades of a pair of scissors and applying pressure causes plastic deformation. It extends into the metal for approximately 5-40% of the metal thickness.
2. Fracture: Fracture occurs at the point of greatest stress concentration.
3. Shear: Small cracks are visible and the metal is sheared.

A hydraulic cutter is an industrial tool used for cutting metal bars and sheet metal. It is powered by a hydraulic system. The force of the hydraulic system presses the desired material against the steel plate. It also drives a cylinder to move the tool vertically. The force of the hydraulic system therefore actuates the cutting tool to push the material and cut it to the desired shape and size. A piece of metal with a thickness of about 0.2 mm to 6 mm is sheet metal. If it is less than 0.2 mm, it is called a metal foil, and if it is more than 6 mm, it is called metal plate.

In our hydraulic cutting machine, part of the system is a piston that acts as a pump, applying a small amount of mechanical force to a small cross-sectional area. The other part is a piston with a larger area producing a correspondingly larger mechanical force. If the pump is separate from the press cylinder, only small diameter hoses (more pressure resistant) are required. Mild steel was used for the frame of the hydraulic cutting machine and high-speed steel for the cutting tools.

Chapter 2 of this paper provides an overview of the relevant literature on punching machines, their design principles, and manufacturing. This also includes project goals.
Details of the project work, including methodology, material selection, design specifications, calculations, modelling, procured materials, and costs, are provided in Chapter 3.
Interpretation of the results is discussed in Chapter 4.
Chapter 5 consists of conclusions.

Finally, we see Chapter 6 for project references.

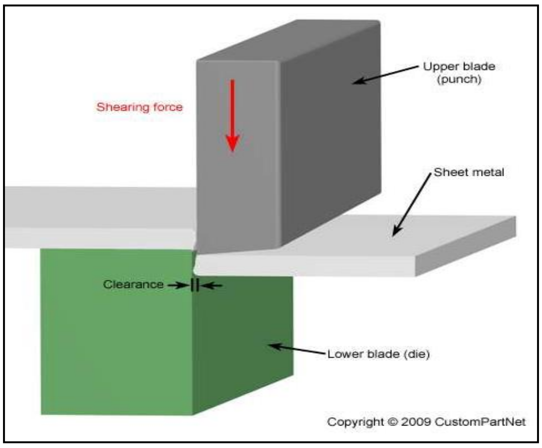

Figure 1. Shearing Process

II. LITERATURE REVIEW

1. Avinash Jathar, Avinash Kushwaha, Utkarsh Singh, Prof. Subhash Kumar, Sheet Metal Cutter, Volume 3, Issue 45162, Fabrication and Review of Hydraulic Heavy Sheet Metal Cutter

This paper is based on fabrication and review of hydraulic heavy sheet metal cutting machine. The authors have made a study on material selection, force calculation, designing of cylinder/solenoid valve and hydraulic oil/pump selection. Select appropriate materials, pumps and cylinder based on the above.

2. Khagendra Barman, Md. Nesar Ali, Md. Rayhan Hasnat, Dr. S. M. Humayun Kabir: Fabrication of Pneumatic Sheet Metal Cutting Machine

Study was conducted on various components of a pneumatic system including double- acting cylinder and 2/2-, 3/2- and 5/2-way valves. The machine is designed based on the calculation of cylinder thrust, theoretical air consumption and sheet metal cutting force. This article has discussed the benefits of pneumatic manual valves and high-speed blades.

3. F. Koenigsberger d.sc, m.i.mech.e., m.i.prod.e., mem.a.s.m.e, Professor of machine tool construction, metal cutting machine tool design principles which provides information on lubrication and cutting tools.

This work is based on Metal Cutting Machine Tool Design Principles which provides information on lubrication and cutting tools.

4. Manar Abd Elhakim Eltantawie. 2013. Design, build and simulation of a hydraulic bending press. International journal of mechanical engineering and robotics research. ISSN 2278- 0149 Volume 2, Number 1 (2013)

This document is based on the design, manufacture, and simulation a hydraulic bending press. Hydraulic bending press components, hydraulic circuit design calculations, and punch designs are presented, and a programmable logic controller (PLC) is employed for automation tasks. As a result, both the punch and die were designed to reduce spring back and spring forward springs.

5. Gebremichael Tasew, Ajay Jaswal.2018. Development of Sheet metal bending machine with hydraulic cylinder. International Research Journal of Engineering and Technology. IISN 2395-0056 Volume 5, Issue 1 (2018)

This document is based on the development of a plate bending machine with a single hydraulic cylinder. In order to manufacture a hydraulic cylinder-driven stainless steel plate bending machine with a thickness of 5 mm at low cost and light weight, we studied determination of force, selection of material, dimensional analysis, structural drawings of machine elements, drawing, specifications, etc.

III. METHODOLOGY

1. We start off by the material selection process that is, choosing the material we are going to be operating on. In our case, the material we have chosen to work with is mild steel.
2. For our design, we planned on optimizing the usage of the hydraulics, to ensure that we make best use of the pressure and force generating the hydraulic kit. To achieve the previously stated, we decided to use one cylinder placed vertically. The cylinder gets the oil supply and pressure input directly from the hydraulic powerpack. There is also a Solenoid Valve present to manage the flow of the hydraulic fluid.
3. After we defined the structure and model of our machine, we went ahead with the material selection, with which we plan on building the machine. And the material we are going to be using is mild steel.
4. For the raw material procurement, our component of high importance is the hydraulic kit itself. This includes the reservoir tank, pump, valves (pressure, relief), fluid tubes, accumulators, and the hydraulic fluid. Apart from these, we will need hydraulic cylinder, a cutting tool attachment, cutting tool die and steel for the whole structure of the machine.
5. We will then begin the fabrication process by putting together the main framework of the machine in order to first house the hydraulic system. Then we proceed with assembling the entire hydraulic system, keeping the circuit we prepared beforehand as reference. This system is then integrated into the main framework of the machine by attaching the cylinders to the top of the machine at their respective positions. We also need to ensure that the cylinders do not get mixed up in the process as each cylinder has an optimized value for stroke length, to carry out its operation effectively and precisely. After double checking to make sure everything is in the right place, we then need to proceed with the testing process.
6. In the testing process, we will first check if the hydraulic network-built works according to the required design. Individually check if each component (such as the pump, the DCVs, tubes etc.) is working and correct any errors made in the connections. Then we proceed to check if the cylinder- pistons are working properly. Followed by the testing of each

operation, till the theoretical maximum specifications of the metal plate being worked on.

7. For the cutting operation, the piston is attached with a HSS tool. The cutting operation is tested for a metal sheet of 6 mm thickness, and length of cut of 30mm.
8. For the IoT part of the project, these are the following features we plan on including in the machine. As the cutting process takes place, the magnetic sensor coupled with the counter board keeps track of the number of punches taking place and the number is constantly being displayed to the user. This data is also further stored on a cloud for further use, such as obtaining a datasheet at the end of the shift, to provide information about the stored operation details.

IV. DESIGN PARAMETER DETAILS

Motor: 3 Hp and 2.25 kW
Cylinder: 100 mm bore diameter, 100mm stroke length, 5lpm and max working pressure of 210 bar
Type of Pump: Gear pump Oil Tank Capacity: 40ltrs

V. SELECTION OF MATERIAL

Frame of the machine is made of mild steel. High speed steel is used for making punching and cutting tool. The following factors are considered while selecting material:

[1] Material availability
[2] Material compatibility with operation conditions
[3] Material cost

VI. SELECTION OF HYDRAULIC FLUID

High performance hydraulic fluid (AW Additive) with optimum anti- wear properties and high load capacity of lubricating film. Its excellent oxidation resistance enables good performance at high temperatures and extended service intervals. Antioxidant and corrosion inhibitor, high pressure absorption, excellent aging and heat resistance, no foam absorption, excellent demulsibility. Neutral to ferrous metals and almost all non-ferrous metals, straps, and sealants. Hydraulic systems with gears and bearings exposed to water, where high ambient temperatures require good wear resistance. Hydraulic oil HLP 68 is therefore suitable for the specified properties.

PROJECT WORK DETAILS

VII. CALCULATIONS

Diameter of punched hole = 10mm
Thickness of mild steel plate = 6mm
Shearing strength of mild steel = 35 / 2
Length of cut = 30
Cutting Force Required,

$$F_c = l \times t \times = 6300 \text{ kgf} = 61800 \text{ N}$$

Force produced by a cylinder of 100mm bore diameter(d), working at 100 bar pressure (p),

$$F = (3.14/4) \times d^2 \text{ x } p \text{ (d in cm, p in kg/cm2)}$$

= (3.14/4) × (10)^2 × 102
= 8007 kgf = 78550 N

VIII. IMPLEMENTATION OF INTERNET OF THINGS

In this project, we will use an IOT to count the number of cuts programmed on the Arduino and connect it to a counter board to display the count digitally. We are also using ESP32 module for storing the data in cloud. We are using Blynk IOT software, which will store the number of cuts/punches and the date of performing the operation in the form of google spreadsheet and can be downloaded onto your phone via the Blink IOT app.

Code:

```
#include <WiFi.h> #include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>

void setup()
{
// Template ID, Device Name and Auth Token are
provided by the Blynk.Cloud
// See the Device Info tab, or Template settings
#define BLYNK_TEMPLATE_ID "TMPLsas0JuwK"
#define BLYNK_DEVICE_NAME "LED on off"
#define BLYNK_AUTH_TOKEN
"qkVv5NNkcPExQq_2e6DZ-
8kCxQffqcQG"

int state=0, x=0;

// Comment this out to disable prints and save space
#define BLYNK_PRINT Serial

char auth[] = BLYNK_AUTH_TOKEN;

// Your WiFi credentials.
// Set password to "" for open networks.
char ssid[] = "Galaxy A31940B"; char pass[] =
"12345678"; BlynkTimer timer;

// This function sends Arduino's up time every second to
Virtual Pin (5).
// In the app, Widget's reading frequency should be set to
PUSH. This means
// that you define how often to send data to Blynk App.
void myTimerEvent()
{

{
// Debug console Serial.begin(115200); Serial.println
("Start: "); Blynk.begin(auth, ssid, pass);

timer.setInterval(1000L, myTimerEvent);
}
```

```
void loop()
{
int counter=digitalRead(2); if (state==0)
{
switch (counter){
case 1 : state=1; x=x+1; Serial.println (x);
Blynk.virtualWrite(V5, x); break;
case 0 : state=0; break;
}
}
if (counter==LOW){ state=0;
}
Blynk.run();
}

// You can send any value at any time.
// Please don't send more that 10 values per second.
Blynk.virtualWrite(V5, x);
}
```

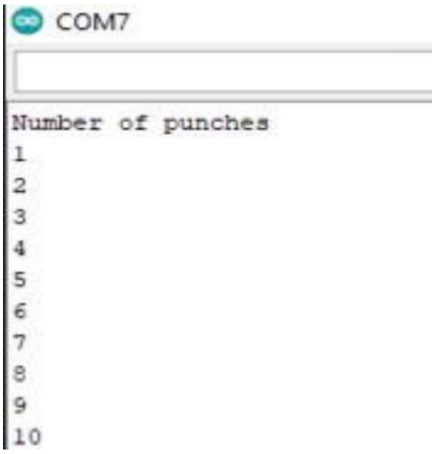

Figure 2. Output

IX. 3D MODELLING

The following designs are generated in Fusion 360 software. It is a powerful program used to create complex designs with great precision. This section representsthe 3D model made from thedimension mentioned in the design parameters.

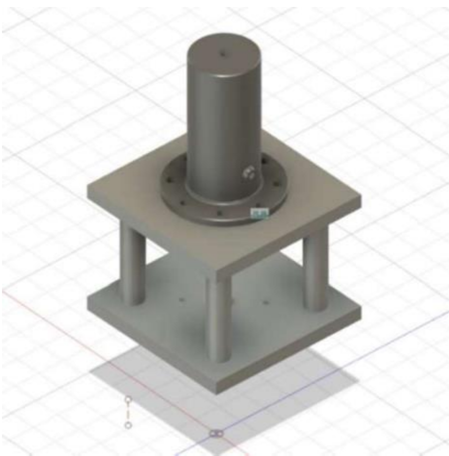

Figure 3. Orthogonal View of the Model

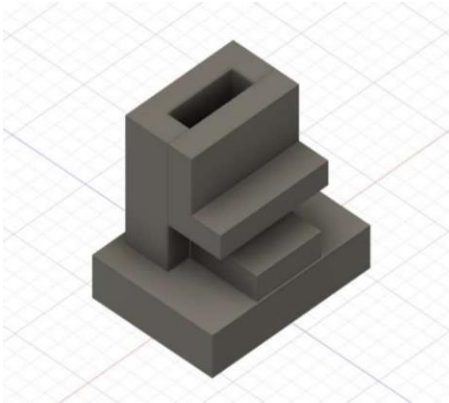

Figure 4. Cutting Die

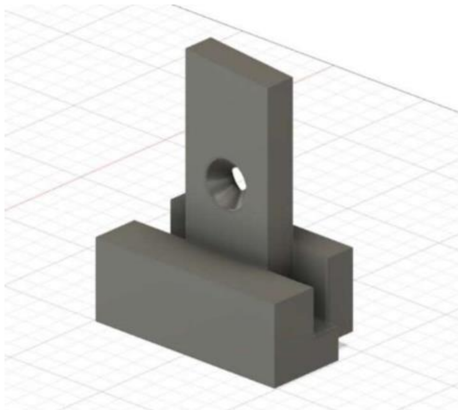

Figure 5. Cutting Tool

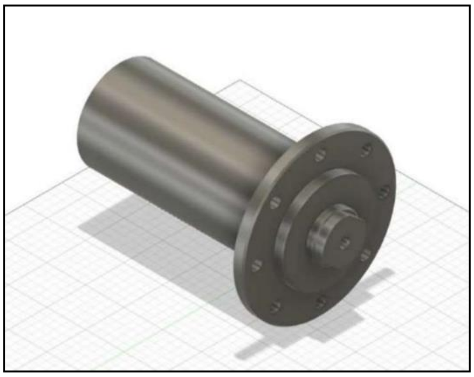

Figure 6. Hydraulic Cylinder Model

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Figure 7. Front View of the Model

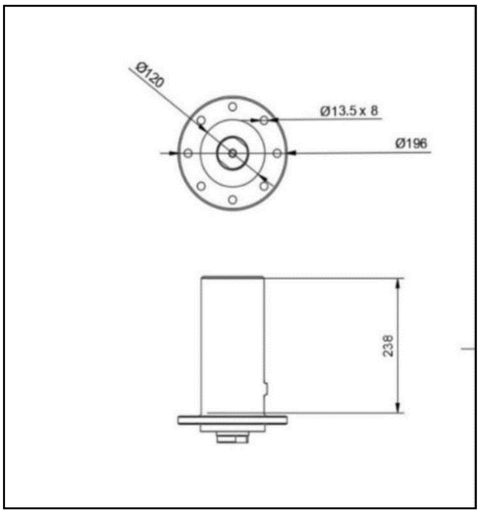

Figure 9. 2D Sketch of the Hydraulic Cylinder

X. FABRICATION PROCESS

The following materials were procured:

[1] Hydraulic Power Pack
[2] Hydraulic Cylinder
[3] High Speed Steel for Cutting Tool
[4] Mild steel to build frame of machine
[5] Arduino UNO
[6] Magnetic Sensor
[7] Counter Board
[8] Jumper Cables

Figure 10. Full Model

Figure 11. Hydraulic Powerpack

Figure 12. Hydraulic Cylinder

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Figure 13. Hydraulic Pump

Figure 14. Solenoid Valve

Figure 15. Hydraulic Oil Tank

XI. COST

MATERIALS	COST (In Rs)
Hydraulic Power Pack	70,000
Frame	18,000
Punching andCutting Tool	7,000
Electronics	5,500
HydraulicFluid	4,500
Miscellaneous	5,000
Total	**1,10,000**

XII. RESULTS

1. The production speedof hydraulic cutting machine is 1200 cuts/hour.
2. This machine can cut sheet metal with a maximum thickness of 6 mm and a minimum thickness of 1 mm.
3. Material stronger thanmild steel cannot be cut.

XIII. ACKNOWLEDGEMENT

We have taken a lot of effort into this project. However, completing this project would not have been possible without the support and
guidance of a lot of individuals. We would like to extend our sincere thanks to all of them.

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XIV. REFERENCES

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