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Design of Semi-Automated Robotic System For Rod Cutting

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Abstract- *The first fundamental activity in each manufacturing process is the cut-off operation; while it does not add value to the finished product, it is vitally necessary. Normally, cutting off is done on fully automatic equipment, however there is potential for low-cost automation to shorten cycle times, improve cut length accuracy, and lower cost per cut. The project explores a low-tech approach to the cutting-off process that makes use of an electro-pneumatic circuit and a proximity sensor. The goal is to use intelligent automation circuit control to shorten cycle time by at least 50%, improve cutting accuracy, and conserve power. Cutting speed of the cutter and air pressure, which determines cutter feed rate, are the two factors that will affect cutting.*

Keywords- Cut-off, Pneumatic, Feed, Clamping, Accuracy

I. INTRODUCTION

Cutting off steel bar stock to the proper length in accordance with the finished size requirements of the work piece is the first step in the fabrication of any component made from steel bar stock. Normally, a power hacksaw machine handles this task.

The following is the order of the operations:

1. Feed bar stock into the stopper, which is adjusted for the length of the workpiece to be cut.
2. Clamp the bar stock in place.
3. Feed the blade of the cutter to the desired length.
4. Pull the cutter back
5. Remove the workpiece's clamps.
6. Repeat the process.

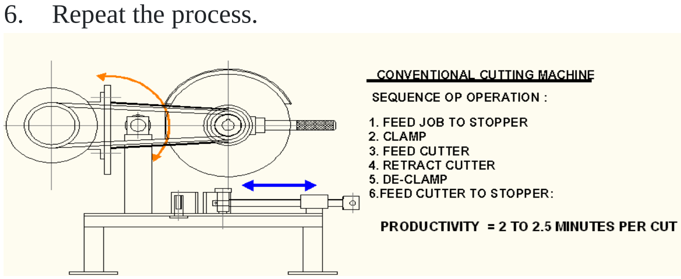

Figure 01: Conventional Cutting Machine

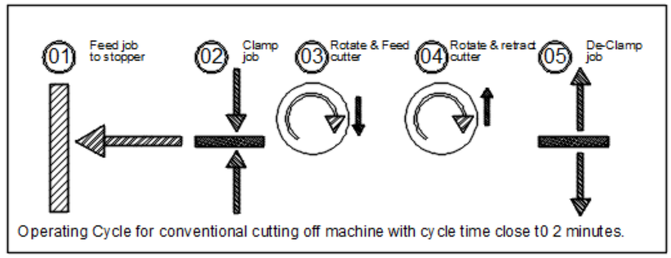

Figure 02: Operating Cycle

If the aforementioned sequence is followed, human interaction is required at every stage, and bar cutting does not increase the value of the final product, therefore it might be considered to be a waste of time. In order to cut down on idle time to the absolute minimum, continuous cutting off machines are used. Once the bar stock has been fed into the stopper of the machine, the machine automatically feeds the cutter to the work piece during the cutting stroke until it has been cut to the desired length. Likewise, during the return stroke, the bar will be automatically fed into the stopper by the machine itself, as will the clamping and unclamping of the bar stock during the cutting stroke.

II. REVIEW OF LITERATURE

Literature review: Study of various configuration of roll forming process by using handbooks, United State Patent documents, Technical papers, etc.

Design and Development:

- System design as to and theoretical derivation of dimensions of the cutter , motor power , gear box design , selection of pneumatic circuit components.
- System Design and theoretical derivations of critical components of the system as to shaft, bearings etc.

Facilities available:

The following facilities to carry out fabrication work are available at workshop:
(i) Centre lathe

(ii) Milling machine
(iii) DRO – Jig Boring machine
(iv) Electrical Arc Welding
(v) Digital Vernier

III. COMPONENTS USED AND METHODOLOGY

Cutter motor and cutter head:

The output speed of the cutter will be 2600 to 0 because it has a 100 watt motor with a standard 1:3 ratio gear head that has a variable speed range of 0 to 8000 rpm.

Linear slide and cutter feed arrangement:

Two linear motion bearings with guide bars and set-up helical compression springs are part of a linear slide on either side. A pneumatic cylinder with dual acting performs the feeding motion. While the flow control valve in the circuit controls the speed of the piston in the forward direction, or the cutter feed, the return stroke is standard (fast action). For a quick restoration of the cutter head to its original position, springs are available.

Job clamping and guide arrangement:

The job is guided by the task guide, and clamping is done with a set of clamps called the set-clamp (which may be adjusted to fit jobs of different sizes). The movable jaw of the set-clamp is attached to a different pneumatic cylinder that operates concurrently with the cutter feed cylinder.

Job Feeding and sensing arrangement:

The job is manually fed in the job guide up to the stopper for the semi-automatic version of the machine, which uses a proximity sensor to detect the job. The electrical circuit, which includes a push button system and an electronic 8-pin relay, is then activated by the sensor.

Proximity sensor and electrical circuit:

Proximity sensor and the electronic relay circuit is a simple electrical circuit used to sequence the operations in the circuit. The circuit decides the on/off of the 5/2 way direction control valve in the pneumatic circuit and thereby the clamping/cutting /return action.

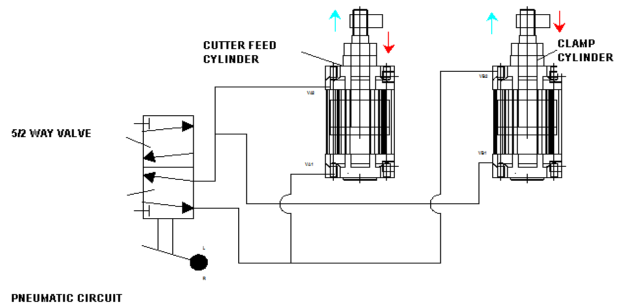

Figure 03: Components Used

IV. METHODOLOGY AND PROBLEM STATEMENT:

Problem Statement:

If the aforementioned sequence is followed, human interaction is required at every stage, and bar cutting does not increase the value of the final product, therefore it might be considered to be a waste of time. In order to cut down on idle time to the absolute minimum, continuous cutting off machines are used. Once the bar stock has been fed into the stopper of the machine, the machine automatically feeds the cutter to the work piece during the cutting stroke until it has been cut to the desired length. Likewise, during the return stroke, the bar will be automatically fed into the stopper by the machine itself, as will the clamping and unclamping of the bar stock during the cutting stroke.

Solution:

The invention of a low-cost automation-based machine utilising a proximity sensor to sense work feeding (for semi-auto model feeding, the job to length is manual) is the solution to the aforementioned issue. Operations such as additional clamping, cutter feed, cutter retraction, and de-clamping are automatic and quick.

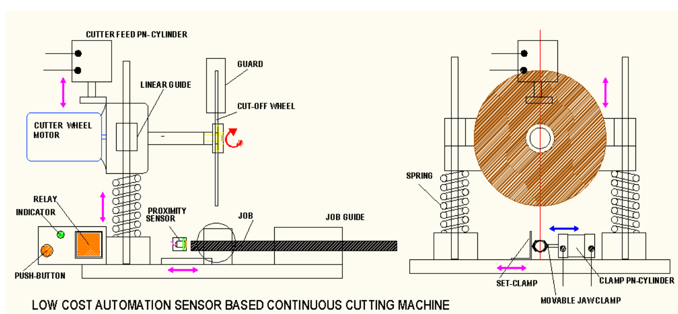

Figure 04: 2d Design of Semi-Automated Robotic System

Advantages:

- Task feeding up to the stopper is sensor-based, ensuring accuracy in job size.

- Automatic clamping of bar stock occurs during cutting strokes.
- Bar stock automatically unclamps following a cutting stroke.
- Job feeding occurs during the machine's return stroke, significantly minimising idle time.
- The machine only requires minor human involvement to replace the bar supply.

V. PROJECT DESIGN AND FINDINGS

Design is the process of using technical knowledge, scientific concepts, and creative thinking to create a new or improvised system or mechanism that will carry out a specified purpose as economically and efficiently as possible:

- System architecture.
- Mechanical Engineering.

System design is primarily concerned with various physical limitations and ergonomics, space requirements, the arrangement of various components on the system's main frame, interactions between humans and machines, the number and location of controls, the working environment of the machine, the likelihood of failure, the need for safety precautions, servicing aids, the ease of maintenance, the potential for improvement, the weight of the machine from the ground up, the overall weight of the machine, and many other factors.

In mechanical design, the parts are divided into two categories: 1. Designed Parts, based on their procurement and design.

2. To be purchased components.

Detachable designs are created for designed parts, and the distinctions that result are compared to the next highest dimensions that are easily accessible on the market. This intensifies the assembly and post-production maintenance tasks. On the works, numerous tolerances are established. After being created, the process flowcharts are given to the production stage.

System Design:

In system design we mainly concentrated on the following parameters: -

- System Selection Based on Physical Constraints:

While selecting any machine it must be checked whether it is going to be used in a large-scale industry or a small-scale industry. In our case it is to be used by a small-scale industry. So space is a major constrain. The system is to be very compact so that it can be adjusted to corner of a room.

- Arrangement of Various Components:

Keeping into view the space restrictions the components should be laid such that their easy removal or servicing is possible. More over every component should be easily seen none should be hidden.

- Components of System:

As already stated the system should be compact enough so that it can be accommodated at a corner of a room. All the moving parts should be well closed & compact. A compact system design gives a high weighted structure which is desired.

- Man Machine Interaction:

The friendliness of a machine with the operator that is operating is an important criteria of design. It is the application of anatomical & psychological principles to solve problems arising from Man – Machine relationship.

- Servicing Facility:

The layout of components should be such that easy servicing is possible. Especially those components which require frequents servicing can be easily disassembled.

- Scope of Future Improvement:

Arrangement should be provided to expand the scope of work in future. Such as to convert the machine motor operated; the system can be easily configured to required one. The die & punch can be changed if required for other shapes of notches etc.

STUDIES AND FINDINGS:

PART –A

ANALYSIS FOR POWER REQUIRMENT OF MACHINE.

1)Abrasive wheels used for bar cutting applications are;
B88 x –44 A24 T

These wheels have following performance characteristic

MATERIAL REMOVAL RATE (MRR) = 0.05 cm^2 / Sec.
MAX OPERATING SPEED = 6000 RPM.

TARGET
Application is pvc. conduit cutting
Maxm diameter = 20 mm
To CUT
Material = PVC
Power Requirement at m/c spindle = 0.8 x 0.06
= 0.048 Kw
= 0.064343 Hp
Let us round off the Input power to; 1/15HP

INPUT POWER= 1/15 HP

2)Ideal metal removal rate = 0.05 cm^2/Sec;
A30TBF
When B88 x Resinoid bonded abrasive wheels are used.
INPUT POWER = 1/15 Hp

- **MOTOR SELECTION**

1 PHASE AC/DC MOTOR
MAKE : ANY
230 VOLTS , 50 Hz,
POWER = 1/15 HP (50 WATT)
SPEED =0 TO 9000 RPM (VARIABLE)

Design of Main Spindle:
Tdesign = 0.2 N.m
= 0.2×10^3 N.mm
selection of main spindle material
Reff. :- PSG design data

Designation	Ultimate Tensile strength N/mm^2	Yield strength N/mm^2
EN24	800	680

Table 01

Using ASME code
To determine Allowable shear stress
fs_{all} =0.30 syt =204N/mm^2
fs_{all} = 0.18sult =144 N/mm^2
Considering the minimum of the values ;
fs_{all} = 144 = N/mm^2

A] Considering pure torsional failure ;

T design = fs_{act} d^3 16
The shaft is provided with threading M16 x 2 pitch for clamping the cutter wheel at the front end ;
Core diameter = 14 mm
fs_{act} = $16 \times 0.2 \times 10^3 \times 8.5^3$

fs_{act} = 1.65N/ mm^2

As; $fs_{act} < fs_{all}$

Spindle is safe under torsional load.

But ; shaft is also subjected to bending loads ; due to cutting force at new periphery of grinding /cutting off wheel .

Cutting force (ft) x r = Torque input
The mechanism for cutting is manually driven by means of crank and handle arrangement the length of crank is 100 mm and assuming an manual input equivalent to 50N,
Hence torque = 100 x 50= 5×10^3Nmm

Cutting off wheel is 6” in dia ; ie 150 mm
r = 75 mm
ft = 66.67

- **LOAD DIAGRAM**

Fy = 0

F T +R A+R B= 0

R A+R B = -66.6 N-----------------(A)

M B = 0

- R A x 80 = 66.6 x 140

- R A = -116.65 N

R B = 49.95N

Max BM = 9.332 x 103 N.mm

- Te = M2 + 72

= 9.335 x 103 N.mm

Me = Te + ½ M

= 13.98 x103

Me = 13.98 x103N.mm

Check for torsional shear failure of shaft

Te = fs d3 16
fs act =16 x 9.335 x 103 x 8.53

fb act = 116.7N/mm^2

As; fs act < fs all

Spindle is safe under torsional load.

Check for bending failure of shaft

Max bending moment occurs at point ‘A’ the section diameter of spindle at poin t’A’.
DA= 25 mm

No; Me = /32 fs act x d3

fs act = 32 x 13.98 x 103
x(17) 3

fs act = 28.98 N/mm^2
As fs act = fs all
(28.98 N/mm2) (200 N/mm2)

Spindle is safe under bending load.

5.3 DESIGN OF KEY:

Selection parallel key (5x5x15) IS 2048- 1962 both ends round .
Reff: PSG Design data;

Note : It is general practice to select similar material for key as that of shaft;

material of key = EN9 (C45)

Material selection:- Ref:- PSG(1.10&1.12)

Designation	Ultimate Tensile Strength(N/mm^2)	Yield Strength (N/mm^2)
C45	520	340

Table 02

- CHECK FO SHEAR FAILURE OF KEY

Te = lxbxd/2 x fs $_{act}$

fs $_{act}$ = 2 x Te
l x b x d
= 2x9.332x 10^3
15x5x2.5

fs $_{act}$ = 99.54 N/m^2

As fs $_{act}$ < fs $_{all}$

Key is safe in shear.

- CHECK FOR CRUSHING FAILURE OF KEY

Te = L X t x d x fs $_{act}$
2 2
fs $_{act}$ = 2x2x12.195 x 10^3
15x5x2.5
fs $_{act}$ =199.08N/mm^2

As fs $_{act}$ < fs $_{all}$

Key is safe in crushing.

DESIGN (SELECTION OF BALL BEARING) AT A:

In selection of ball bearing the main governing factor is the system design of the drive i.e.; the size of the ball bearing is of major importance; hence we shall first select an appropriate ball bearing first select an appropriate ball bearing first taking into consideration convenience of mounting the planetary pins and then we shall check for the actual life of ball bearing.

BALL BEARING SELECTION:
Series 62

BRG. NO.	D	D_O	B	C	C_O
6004	20	42	12	9560	4500

Table 03

P = X Fr + Yfa.
Where;
P=Equivalent dynamic load, (N)
X=Radial load constant
Fr= Radial load (H)
Y = Axial load contact
Fa = Axial load (N)
In our case;
Radial load FR = RA=116.65

Axial load (Fa)
Fa = 0
P=X x Fr

=116.65 N
No of revolutions of bearing = 60 x 4000 x 3000
106
L= 720mrev

L= (C/p) p

L = 60 n L h =720mrev
106
3

720 = C 116.65
C = 1045.5 N
AS; required dynamic of bearing is less than the rated dynamic capacity of bearing;

Bearing is safe.

DESIGN (SELECTION OF BALL BRG)AT B:

In selection of ball bearing the main governing factor is the system design of the drive i.e.; the size of the ball bearing is of major importance; hence we shall first select an appropriate ball bearing first select an appropriate ball bearing first taking into consideration convenience of mounting the planetary pins and then we shall check for the actual life of ball bearing.
BALL BEARING SELECTION.
Series 62

BRG. NO.	D	D_O	B	C	C_O
6003	17	35	10	9560	4500

Table 04

P = X Fr + Yfa.
Where;
P=Equivalent dynamic load, (N)
X=Radial load constant
Fr= Radial load (H)
Y = Axial load contact
Fa = Axial load (N)
In our case;
Radial load FR = RA=116.65

Axial load (Fa)
Fa = 0
P=X x Fr
=116.65 N
No of revolutions of bearing = 60 x 4000 x 3000
106
L= 720mrev

L= (C/p) p

L = 60 n L h =720mrev
106
3

720 = C
49.9
C = 447.24 N
AS; required dynamic of bearing is less than the rated dynamic capacity of bearing;

Bearing is safe

DESIGN OF THE DRIVER LINKAGE:

Ref :- PSG (1.10 & 1.12) + (1.17)

DESIGN ATION	ULTIMATE TENSILE STRENGTH N/mm^2	YEILD STRENGTH N/mm^2
EN 9	650	480

Table 05

Cross section of link may be determined by considering lever in bending ;
The linkage has an section of (32 x 10)mm
Let; t= thickness of link
B= width of link
Bending moment;
Section modules; Z= 1/6 t b2
Fb=m/z = PL
1/6 t B2
= 6PL
tB2
fb= 6 x 100 x 50
10 x 32 2

fb =2.92
As fbact< fball
Thus selecting an (32 x 21) cross-section for the link.

MOTOR SELECTION FOR AUTOMATIC DRIVE:

Thus selecting a motor of the following specifications
Single phase AC motor
Commutator motor

TEFC construction
Power = 1/6hp=120 watt
Speed= 0-6000 rpm (variable)
Motor is a Single phase AC motor, Power 120 watt, Speed is continuously variable from 0 to 6000 rpm. The speed of motor is variated by means of an electronic speed variator. Motor is a commutator motor i.e., the current to motor is supplied to motor by means of carbon brushes. The power input to motor is varied by changing the current supply to these brushes by the electronic speed variator, thereby the speed is also is changes. Motor is foot mounted and is bolted to the motor base plate welded to the base frame of the indexer table.

SELECTION OF PNEUMATIC CYLINDER:
Standard cylinder (14167)
DNU-20-15-PPV-A.

Figure 05: Standard Cylinder

Specifications of Standard cylinder (14167)
DNU-20-15-PPV-A.

Criterion	**Feature**
Stroke	15
Piston diameter	20
	Pneumatic cushioning, adjustable at both ends (PPV)
Assembly position	Any
Design structure	Piston Piston rod
Variants	Single-ended piston rod
Operating pressure	0.3 - 12 bar
Mode of operation	Double-acting
Operating medium	Dried compressed air, lubricated or un-lubricated
Materials information for cover	Aluminum
Materials information for seals	TPE-U(PU)
Materials information for piston rod	High alloy steel
Materials information for cylinder barrel	Materials information for cylinder barrel Anodized

Table 06

Theoretical force at 3 bar when advancing of piston = 50 N
Piston rod threading end = M4 x 0.8 pitch

DESIGN OF PISTON ROD:

Material selection:

Ref :- (PSG – 1.12)

Designation	Tensile Strength N/mm^2	Yield Strength N/mm^2
EN9	600	380

Table 07

Direct Tensile or Compressive stress due to an axial load:-
W

(/4) x dc2

Fc act = 50(/4) x 3.2 2
Fc act = 2.54 N/mm2
As fc act < fc all; Piston rod is safe in compression.

Shear stress in threaded end due to axial load:-

W N dc t
Fess act =

t = width thread at root = p/2
t= 0.5 mm
n = No of threads in contact = 12/1 =12

Fess act = 50X12x5 x 0.25

Fess act = 0.5305 N/mm2

As; fess act < fess all, the screw threads are safe in shear.

Stresses due to buckling of piston rod:-
According to Rankine formula,
Where
Fc A
Wcr = l + a (le/k) 2
Where; Wcr = Crippling load on screw (N)

A = Area of c/s at root (mm2)
A= constant
Le= Equivalent unsupported length of screw (mm)
Decided by end conditions.
K= Radius of gyration = dc/4 (mm)
Fc= Yield stress in compression (N/mm2)

Le = 0.707L; as one end of screw are considered to be fixed and other free (Ref. PSG Design Data Pg. No. 6.8)

Here transverse of the piston is 50 mm, total length of piston rod =172 mm

Le = 0.707 x 72 = 50.94 mm

300 x (/4 x 102)

Wcr =

1+ (1/7500) (50.94/ (10/4)) 2

Wcr =23.56x103 N

As, The critical load causing buckling is high as compared to actual compressive load of 0.240 kN the piston rod is safe in buckling .

DESIGN DIAGRAMS:

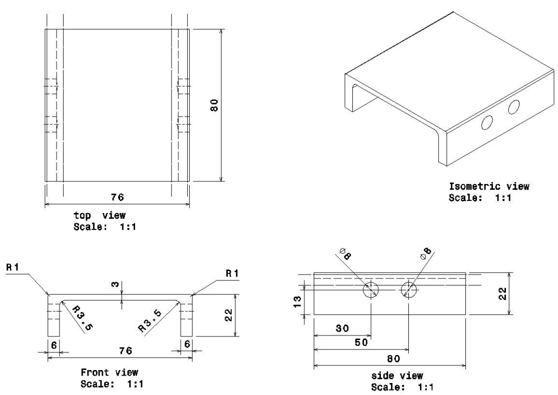

Figure 06: U-Channel

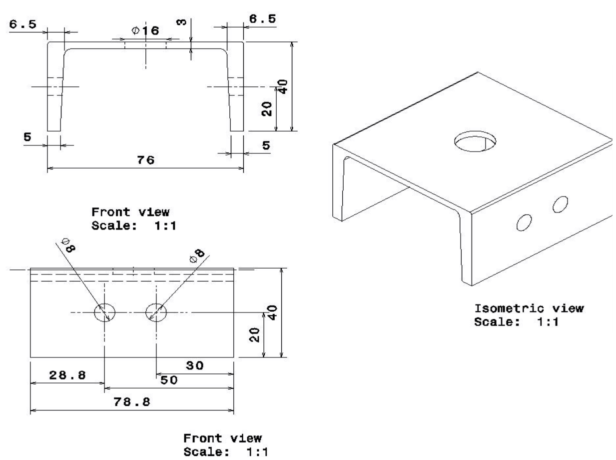

Figure 07: U-Channel

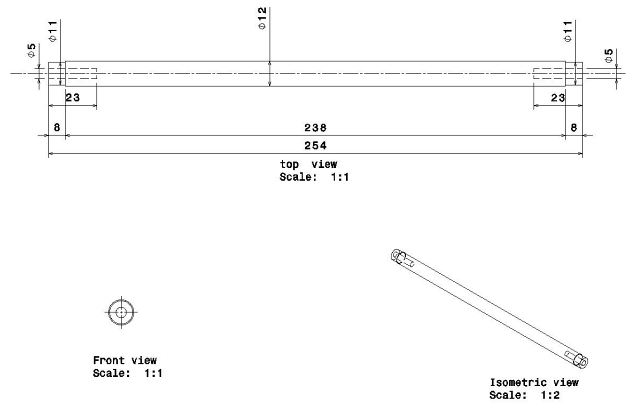

Figure 08: Pillar

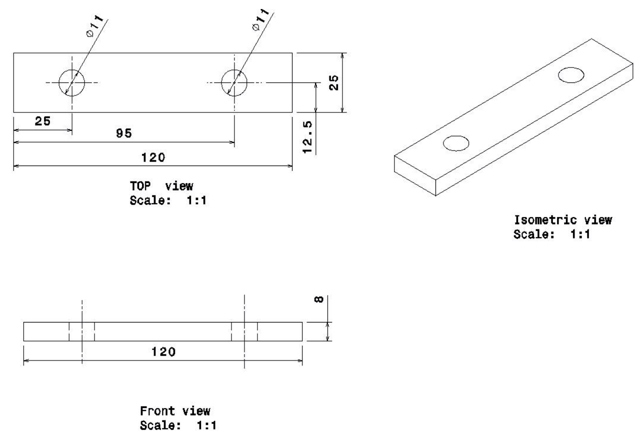

Figure 09: Top Plate

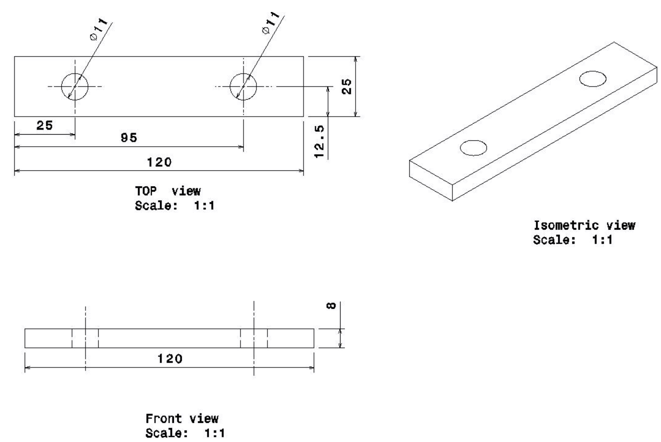

Figure 10: Bottom Plate

V. CONCLUSION

According to the statement made in the project's conclusion, the results from the model that cuts the pipe in a semi-automated manner were created in a way that the design could be satisfied in a sturdy specification and operate in a very effective approach. The task feeding up to the stopper is sensor-based, ensuring accuracy in job size, automatic clamping of bar stock occurs during cutting strokes, bar stock automatically unclamps following a cutting stroke, job feeding occurs during the machine's return stroke, significantly reducing idle time, and the machine only needs minimal human involvement to replace the bar supply. With the aid of our model, we were able to reduce the efforts of workers. Utilizing our prototype will enable producers and employees to operate more effectively, efficiently, and accurately when cutting the rod.

VI. FUTURE SCOPE

- Increased motor power is possible.
- The cutter's size can be increased.
- Capacity can be increased by adding larger cylinders.

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