Design and Manufacture of Low Cost Multi Operation (Cutting and Drilling) machine

PPC Prasad¹, Chundru Ranga Rao², P Parvathi Srutha Keerthi³, Ch. Sai Krupa⁴
Professor, Department of mechanical Engineering, St.Martin’s Engineering College, Secunderabad-14, Telangana, India
Associate Professor, Department of Mechanical Engineering St.Martin’s Engineering College, Secunderabad-14, Telangana, India
Assistant Professor, Department of Mechanical Engineering St.Martin’s Engineering College, Secunderabad-14, Telangana, India

E mail: ppcpsmec@gmail.com

Abstract. In any Engineering workshop Cutting and Drilling operations are common phenomenon. For this purpose a dedicated Hack saw can be used for cutting operation and a Drilling machine can be used for making a hole. In this paper we are highlighting a low cost special purpose machine for combining these two operations with a Single Motor. In this machine we are used Scotch Yoke mechanism which converts linear motion of a slider in to rotational motion and vice versa with bevel gear power transmission. This machine is designed, fabricated in our work shop, tested and has given satisfactory results.

Keywords - Special Purpose Machine, Low Cost Automation, Scotch Yoke mechanism

1. Introduction
Machining is a removal of excess material from the work piece. Manufacturing is done by using Conventional machines such as Lathe, Shaper, Planner and Shaping machines in a small engineering work shop to CNC machines for a modern machine shop which are cater the needs of the various customers as per their functional requirement. Traditionally Hack machine can be used for cutting materials and for making holes drilling machine can be used. In our Present case a low cost Multipurpose machine is designed to keep in mind MSME sector which are not in a position to spend more capital investment in their business process. The basic model is explained in Fig1 which consists of a bevel gear arrangement, a Vice and Driving motor and a mechanism.
2. Literature Review
For Medium and Small industries, every rupee saving is important than investment of new machines. Even though several dedicated machines are available in the market and these are used for specific purpose only. Power bill is one of the important factor. Several special purpose machines which are also available in the market but their costs are prohibitively high. Due to the above reasons, we have created a interest on the development of this machine which combine both cutting and drilling operations simultaneously.

Dr Toshimichi MORIWAKI in his paper(2006) has explained the importance of multipurpose machine in his article “Trends in Recent in recent machine tool technologies”. Sharad Sreevatsava et el(2014)A Conceptual model is developed and explained in his paper(2)The first paragraph after a heading is not indented (Bodytext style).

3. Design Philosophy
The design calculations involved for the drilling and hacksaw power cutting. The forces are calculated dia 3 to 8 mm HSS Twist drilling operations. Accordingly the cutting speeds, and feed rates are assumed and calculated power requirements and selected the Drive Motor.

3.1. Power available at motor
The power supplied from the motor is 0.25 HP. The motor is rotating at 1440 rpm. The motor is connected to a bevel gear with 30 teeth rotating at 1500 rpm. Assuming 70% efficiency, the power available for the operations is 0.1875hp

The power available at driver gear:

\[ P = \frac{2 \pi N T}{4500} \]

Here \( P = 0.25 \) HP
So, \( T = \frac{(0.25\times4500)}{(2\times\pi\times1500)} = 0.119 \) Kgf-m

This is supplied to 4 bevel gears.
The reduction ratio is 3. Which implies that each bevel gear is running at 500rpm Effective torque at each bevel gear is 0.119/4=0.0298kgf-m.
This can be taken as approximately 0.1kgf-m.

The drilling force that can be achieved is \( F = \frac{T}{d} \)

d- Drill bit radius=3mm.

The force is 326.96N

Power requirement for drilling operation

Let feed be \( f = 0.5 \text{mm/rev} \)

Thrust force for drilling is given by:

\[
F_d = k \cdot d \cdot f^{0.7}
\]

Where \( k \) is a constant

For steel \( k = 84.7 \)

For cast iron \( k = 64.5 \)

\( d \) is the diameter of the twist drill (mm)

Therefore for a 3mm drill dia, the force required is

\[
F_d = 31.2N
\]

Torque required is given by:

\[
T = C \cdot d^{1.9} \cdot f^{0.8} \text{ N-mm}
\]

\( C = 616-872 \) for steels

So, the required torque is 452.2N-mm=.452N-m

Power required is given by:

\[
P = \frac{2 \pi N \cdot T}{4500} \text{ HP}
\]

Where \( N \) is the speed of drilling, \( N = 500 \text{rpm} \)

So

\[
P = \frac{2 \pi \cdot 500 \cdot 452}{4500} = .032 \text{ Hp}
\]

This is the power required for one drilling operation.

For a 3mm drill bit, the power required for two simultaneous drilling operations is 0.064hp.

3.2. Power requirement for CUTTING operation

The cutting operation is achieved by the power saw which uses the scotch yoke mechanism. For this mechanism, the stroke length is \( R = 14.5 \text{mm} \).

The speed of the crank in the scotch yoke mechanism is 500 rpm.

Therefore the linear cutting speed is given by

\[
V = \frac{2\pi N \cdot R}{60}
\]

\[
V = .75 \text{m/s}
\]

Assume:

Orthogonal cutting

depth of cut \( t = 0.1 \text{mm} \)

feed \( f = 0.1 \text{mm/rev} \)

rake angle \( \alpha = 10^0 \)

width of cut \( b = 3 \text{mm} \)

coefficient of friction \( \mu = 0.5 \), therefore friction angle \( \beta = \tan^{-1} \mu = 29.5^0 \)

shear strength of the material (for mild steel) = \( \tau_s = 200 \text{MPa} \)

From Lee Shaffer theory of metal cutting,

\[
\text{Shear angle} = \phi = \frac{\pi}{4} + \frac{\alpha}{2} - \frac{\beta}{2} = 35.25^0
\]

\[
\text{Shear force} = \tau_s \cdot b \cdot s = 200 \cdot 3 \cdot 0.1 \text{ in 35.25} = 103.95 \text{N}
\]

\[
F_r = F_t / \cos(\phi + \beta - \alpha) = 104 / \cos(35.25 + 29.5) = 180 \text{N}
\]
\[ F_c = F_r \cos(\beta - \alpha) \]

\[ = 180 \times \cos(19.5) \]

=169.6 N

Power required \[ = \frac{F_c \times V}{4500} \text{ Hp} \]

\[ = 170 \times 0.75 \times 4500 \]

=0.028hp

Power requirement for two simultaneous cutting operations is =0.056hp

The total power requirement for 4 operations taking place simultaneously (2 drilling and 2 hacksaw cutting) = 2(0.032) + 2(0.028) = 0.064+0.056 = 0.12 HP. Therefore 0.25HP Motor is selected.

4. Multipurpose Machine
The developed machine consist of the following main elements

1. Driver Bevel Gear  1 No
2. Driven Bevel Gear  4 Nos
3. Main Spindle  1 No
4. Sub Spindles  4 Nos
5. Motor 0.25 HP  1 No
6. Yoke  2 Nos
7. Spur Gears  2 Nos
8. Bearings

Fig 2.: and 3 Shows the actual model of the machine.

Figure 2: Model of Machine
The following components are designed and manufactured in our workshop.

1. **Main Spindle**: It connects the motor with bevel gears. We have selected EN8 material for this component. Fig 4 shows the manufactured component.

![Fig 4. Main Spindle Component](image)

2. **Sub Spindle**: This spindle is used to transmit power from driver bevel gear drill chucks and scotch yoke components. Fig 5 shows the manufactured component of Sub spindle.

![Fig 5. Sub Spindle](image)

3. **Vice**: It is used for holding of the jobs while drilling operation. Fig 6 shows the manufactured component of Vice.

![Fig 6. Vice](image)
4. Yoke Assembly parts: This is used to convert the rotary motion of the gears in to reciprocating motion and vice versa. Fig.7 shows the final assembly of the scotch yoke mechanism.

5. Final Gear Assembly Four bevel gears are to the four spindle shafts. Fig 8 and 9 shows the gear box arrangement and mounting of the motor and spur gear arrangement.

References
[1] A reference
This reference has two entries but the second one is not numbered (it uses the ‘Reference (no number)’ style.
[2] Another reference
[3] More references