Design and Fabrication of Automated Countersinking Machine

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Abstract: *Countersinking is the tapering or beveling of the end of a hole with a conical cutter. Normally in most of the industries they are having a various types of special drilling machines for performing machine operations. Usually in drilling machine, the drilling operations are performed. Whereas counter sinking operation are also takes place but they need separate attachment. Every time counter sinking operation takes much time in normal machine. Therefore the productivity is also decreased. In order to reduce the human work and improve the productivity the counter sinking machine is fabricated. In this paper the piercing operation is also carried out by this fabricated counter sinking machine.*

Keywords: *Counter sinking machine, automatic machine, automated counter sinking machine.*

1. INTRODUCTION

A countersink is a conical hole cut into a manufactured object, or the cutter used to cut such a hole. A common use is to allow the head of a countersunk bolt or screw, when placed in the hole to sit flush with or below the surface of the surrounding material. Material removal rate ranges from 1 to $15m^3$/min. Machining time will be ranges from 5 to 10 seconds. In bearing manufacture, the countersinking plays an important role. A countersink may also be used to remove the burr left from a drilling or tapping operation thereby improving the finish of the product and removing any hazardous sharp edges.

The basic geometry of a countersink (cutter) inherently can be applied to the plunging applications (axial feed only) and also to other milling applications (sideways traversal). Therefore countersinks overlap in form, function, and sometimes name with chamfering end mills. Regardless of the name given to the cutter, the surface being generated may be a conical chamfer (plunging applications) or a bevelled corner for the intersection of two planes (traversing applications).

Schwartz and Arthur A (1942) discussed about the construction of countersink drilling machine. In a countersink drilling machine, a frame, a drilling spindle rotatable mounted upon frame and adapted to move axially thereon, means for rotating spindle, a tubular member slidably mounted upon spindle and having an end portion adjacent the cutter end of spindle for contacting the work piece to be countersunk, a thrust collar integral with tubular member, a second thrust collar integral with spindle, a rocker arm pivotally mounted upon frame and having a moving end portion connected to link in such manner as to be adapted to move spindle and tubular member axially, spring means operatively connecting spindle and tubular member in such manner as to normally urge the cutter end of spindle to extend beyond the work piece contacting end of tubular member, spring means acting between frame and tubular member in such manner as to resiliently urge the latter to move toward the work piece, means associated with rocker arm for actuation of the latter to withdraw tubular member and spindle from work piece contacting position against the action of springs, and additional spring means operatively associated with rocker arm in such manner as to substantially balance the weight of the actuating elements of the device about the pivotal mounting of rocker arm upon frame.

Johnston and Harry M (1998) discussed about the countersunk cutter. In a countersink drilling machine, a countersink cutter mounted upon a spindle for countersinking an opening drilled through the work piece to be countersunk, a work piece supporting plate adapted to support said work piece under said cutter, a pilot pin slidably mounted within said supporting plate and spring pressed so as to be adapted to project upwardly beyond the plane of said work piece supporting plate when free to do

so and adapted to project itself into the drilled opening of said work piece when the latter is moved into proper position under said countersink cutter.

Lance Nelson (2007) discussed about the spring loaded tool with floating depth control for countersinking holes. A floating tool-bit depth controlling nose piece for a spring loaded tool holder is used to countersink holes of equal size when the height of the work piece material changes. The floating tool-bit depth controlling nosepiece, driven by a CNC machine, is rigidly coupled to the floating portion of the tool holding element. The floating depth controlling nose piece has a bearing on the end to allow an area of the nosepiece to stop rotating when the nosepiece is pressed against the work-piece surface. Since the area of the nosepiece that comes into contact with the work-piece is no longer spinning in relationship with the work-piece, the possibility of scratching the work-piece surface is reduced. Additionally, the nosepiece has cut-outs therein to expel machined chips during countersinking of holes.

In all the above literatures, the piercing operation cannot be taken place with the countersinking machine. This will require high human work and give less productivity. So in order to reduce the human work and improve the productivity the counter sinking machine is fabricated. In this paper the piercing operation is also carried out by this fabricated counter sinking machine.

The objective of this machine is to

- Eliminate the transportation time for transferring the work piece from hole piercing machine to countersinking machine.
- To fully automate the countersinking process.
- Reduce the difficulties during countersinking process.
- Increase the productivity.
- Reduce the human error and efforts.

2. DESIGN CALCULATIONS OF THE COMPONENTS

The components used in the counter sinking machine are

- Design of Journal bearing
- Design of Worm gear
- Design of Cylinder holder
- Design of spring
- Design of Cylinder actuation pressure
- Design of stopper fixture

2.1. Design of Journal Bearing

$D = 30$ mm, $N = 900$ rpm

Where, D = Diameter of bearing, N = Speed

Step 1: Find L/D ratio

From PSG data book, Page no. 7.31,

$L/D = 2.5$

$P = 1.8$ kgf/cm^2

Step 2: Find the load on bearing

$P = W/LD$

$0.18 = W/(75 \times 30)$

$W = 505$ N

Step 3: Find the value of Z

From PSG data book, Page no. 7.31,

$ZN/P = 1522.3$

$(Z \times 900)/1.8 = 1522.3$

$Z = 2.85$ centipoise

Step 4: Find the co efficient of friction

$\mu = ((33.25/10^{10}) \times (ZN/p) \times (D/c)) + k$

$\quad = ((33.25/10^{10}) \times 1522.3 \times (30/0.15)) + 0.002$

$\mu = 0.0035$

Step 5: Find heat generated

$H_g = \mu \times W \times v$

$\quad = 0.0035 \times 505 \times ((\pi \times 0.03 \times 900)/60)$

$\quad = 2.35$ W

Step 6: Find heat dissipated

$H_d = ((\Delta t + 18)^2 \times LD)/K$

From data book, oil temperature is 90^0C.

But, room temperature is 30^0C.

$\Delta t = 90 - 30 = 60$

$H_d = ((70+18)^2 \times 0.075 \times 0.03)/0.585$

$H_d = 35.56$ W

Here, $H_g < H_d$

Hence, the artificial cooling is not provided.

2.2. Design of Worm Gear Drive

Gear ratio, i = 20,   Speed of worm, N = 1200 rpm

Assume Power = 1 KW

Step 1: Selection of material

From PSG data book, Page no. 8.45,

For worm, steel is selected.

For wheel, CI grade 35 is selected.

Step 2: Calculation of number of stats

From PSG data book, Page no. 8.46,

$Z = 3$ ($\eta = 0.8 - 0.92$)

Step 3: Calculation of twisting moment

$[M_t] = M_t \times K_d \times K$

$K_d \times K = 1$

$M_t = (60P/2\pi N)$

$\quad = (60 \times 1 \times 10^3)/(2 \times \pi \times 60)$

$\quad = 159.15 \times 10^3$ Nmm

$[M_t] = 159.15 \times 10^3$ Nmm

Step 4: Calculation of compressive stress

From PSG data book, Page no. 8.45,

$[\Sigma_c] = 159$ N/Mm^2

Step 5: Calculation of bending stress

From PSG data book, Page no. 8.45,

$[\sigma_b] = 30 \text{ N/mm}^2$

Step 6: Calculation of centre distance

From PSG data book, Page no. 8.44,

a= ((Z/q) + 1) $\sqrt[3]{([550/((\frac{z}{q}) \times [\sigma_c]]^2 \times ([M_t]/10)}$

$Z = i \times z = 20 \times 3 = 60$

Initially, q = 11

a= ((60/11)+1) × $\sqrt[3]{([540/((\frac{60}{11}) \times [159]]2 \times ([159.15 \times 103]/10)}$

Step 7: Calculation of module

From PSG data book, Page no. 8.43,

$m_x = \frac{2a}{q+z+2x}$

$= \frac{2 \times 118.17}{11+60+0}$

$= 3.32$

$m_x = 5$

Step 8: Revision of centre distance

From PSG data book, Page no. 8.43,

a= 0.5 m_x (q + z + 2x)

a= 0.5 × 5 × (11+60)

a= 152 mm

Step 9: Revision of twisting moment

$[M_t] = 159.15 \times 10^3$ Nmm

Step 10: Check for compressive stress

From PSG data book, Page no. 8.44,

$\sigma_c = \frac{540}{(z/q)} \times \sqrt{(\frac{(\frac{z}{q})+1}{a})^3 \times ([Mt]/10)}$

$\sigma_c = \frac{540}{(60/11)} \times \sqrt{\frac{(\frac{60}{11})+1}{152})^3 \times ([159.15 \times 103]/10)}$

$\sigma_c = 123.6 \text{ N/mm}^2$

Here, induced σ_c < allowable $[\sigma_c]$

Design is safe.

Step 11: Check for bending stress

From PSG data book, Page no. 8.44,

$\sigma_b = \frac{1.9 \times [M_t]}{m_x^3 \times q \times z \times y_v}$

From PSG data book,

$y_v = 0.590$

$$\sigma_b = \frac{1.9 \times [159.17 \times 10^3]}{5^3 \times 11 \times 60 \times 0.59}$$

$$\sigma_b = 15.61 \text{ N/mm}^2$$

Here, induced σ_b < allowable [σ_b]

Design is safe.

Step 12: Find the efficiency

From PSG data book, Page no. 8.49,

$$\eta = \frac{\tan \gamma}{\tan(\gamma + p)}$$

$$\mu = \tan p$$

$$0.3 = \tan p$$

$$p = 1.718$$

$$\tan \gamma = \frac{z}{q} = \frac{3}{11}, \gamma = 15.25$$

$$\eta = \frac{\tan 15.25}{\tan(15.25 + 1.718)}$$

$$\eta = 89.3\%$$

Step 13: Heat thermal analysis

$$\text{Hg} = (1 - \eta) \times \text{I.P}$$
$$= (1 - 0.893) \times 1$$
$$= 1070 \text{ W}$$
$$= \text{Hd}$$
$$\text{Hd} = h \times A \times \Delta t$$
$$1070 = 10 \times A \times 50$$
$$A = 2.675 m^2$$

2.3.Design of Cylinder Holder

Volume of cylinder holder = volume of cuboid – volume of cylindrical hole

Volume of cuboid = l × b × h
$$= 80 \times 100 \times 90$$
$$= 720000 \text{ mm}^3$$

Volume of cylinder hole = $(\pi/5) \times d^2 \times 1$
$$= (\pi/5) \times 60^2 \times 90$$
$$= 255569 \text{ mm}^3$$

Volume of cylinder holder = 720000 – 255569
$$= 565531 \text{ mm}^3$$

Mass of cylinder holder = Volume of cylinder holder × density
$$= 565531 \times 7.85 \times 10^{-6}$$
$$= 3.65 \text{ kg}$$

Force = mass × acceleration
$$= 3.65 \times 9.81$$
$$= 35.81 \text{ N}$$

2.4.Design of Spring

d_r= 15 mm, P_r = 1.2 N/mm^2

Maximum lift, y = 10 mm

Spring index, C = 5

Initial compression, y_i = 20 mm

τ= 550 N/mm^2,   G = 0.8 × 10^5 N/mm^2

Step 1: Find the area of the rod

$$A_r = (\pi/5) \times d_r^2$$
$$= (\pi/5) \times 15^2$$
$$= 176.71 \text{ mm}^2$$

Step 2: Find the Wahl stress factor

From PSG data book, Page no. 7.100,

$$K_s = \frac{5C-1}{5C+1} + \frac{0.615}{C}$$
$$= \frac{(5\times5)-1}{(5\times5)+1} + \frac{0.615}{5}$$
$$= 1.31$$

Step 3: Find the maximum pressure

$$P_{\max} = P_i \times \frac{y_{max}}{y_i}$$

$$y_{max} = y_i + y$$
$$= 10 + 20$$
$$= 30 \text{ mm}$$

$$P_i = P_r \times A_r$$
$$= 1.2 \times 176.71$$
$$= 212.05 \text{ N}$$

$$P_{\max} = 212.05 \times \frac{30}{20}$$
$$= 318.08 \text{ N}$$

Step 4: Find the diameter of the wire

From PSG data book, Page no. 7.100,

$$\tau = K_s \times \frac{8P_{max}C}{\pi d^2}$$
$$550 = \frac{1.31 \times 8 \times 318.05 \times 5}{\pi d^2}$$
$$d = 3.53 \text{ mm}$$

From PSG data book, Page no. 7.20,

Standard wire diameter, d = 3.55 mm

Step 5: Find the mean diameter of the coil

$$C = D/d$$
$$D = d \times C$$
$$= 3.55 \times 5$$
$$D = 17.75 \text{ mm}$$

Step 6: Find the number of active turns

From PSG data book, Page no. 7.100,

$$y_{max} = \frac{8P_{max}C^3n}{Gd}$$

$$30 = \frac{8 \times 318.08 \times 5^3 \times n}{Gd}$$

$$n = 26.78 \sim 27$$

Step 7: Find the pitch of the spring

$$P = d + \frac{y_{max}}{n}$$

$$= 3.55 + \frac{30}{27}$$

$$= 4.66 \text{ mm}$$

2.5. Calculation of Cylinder Actuation Pressure

For clamp cylinder,

Pressure required = (force / area)

Calculated force = 92.7N

Taking maximum force =95 N

Area $=(\pi/5)d^2$

$$= (\pi/5) \times 35^2$$
$$= 962.11 \text{ mm}^2$$

Required pressure = (95/962.11)

= 0.98 bar

For tool cylinder,

Pressure required = (force / area)

Calculated force = 162.7N

Taking maximum force =170 N

Area $=(\pi/5)d^2$

$$= (\pi/5) \times 50^2$$
$$= 1256.6 \text{ mm}^2$$

Required pressure = (170/1256.6)

$$= 1.35 \text{ bar}$$

For stopper cylinder,

Pressure required = (force / area)

Calculated force = 21.92 N

Taking maximum force = 25 N

Area $= (\pi/5)d^2$

$$= (\pi/5)25^2$$
$$= 590.87 \text{ mm}^2$$

Required pressure = (25/590.87)

$$= 0.5 \text{ bar}$$

2.6. Design of Stopper Fixture

Volume of stopper fixture= (2×volume of circular rod)+volume of rectangle box

Volume of circular rod $= (\pi/5)d^2l$

$$= (\pi/5) \times d^2 \times 300$$

$$= 23561.9 \text{ mm}^3$$

Volume of rectangle box $= 1 \times b \times h$

$$= 20 \times 30 \times 25$$

$$= 15000 \text{ mm}^3$$

Volume of stopper rod $= (2 \times 23561.9) + 15000$

$$= 62123.88 \text{ mm}^3$$

Mass of stopper fixture $=$ volume $\times$ density

$$= 62123.88 \times 7.85 \times 10^{-6}$$

$$= 0.58 \text{ kg}$$

Force $=$ mass $\times$ acceleration

$$= 0.58 \times 9.81$$

$$= 5.72 \text{ N}$$

3. MODELING OF MACHINE AND MACHINE COMPONENTS

The 3-D modeling of machine and the components is carried out in Solid Works software. The modeling application also provides "features based" solid bodies by directing editing capabilities, which allow changing and updating solid bodies by directing editing the dimensions of a solid feature or by other geometric construction techniques.

3.1. Isometric View of Counter Sinking Machine

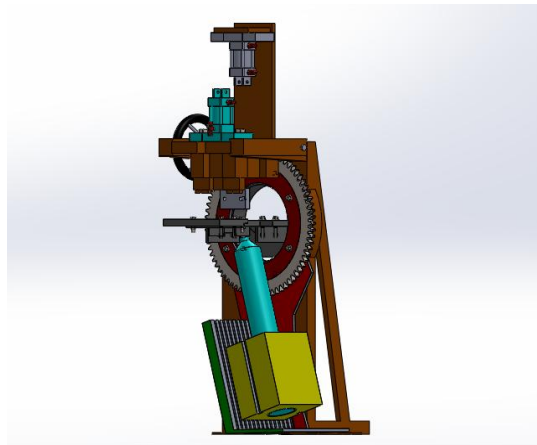The isometric view of the counter sinking machine is illustrated in Figure 1

Figure1. *Isometric View of Counter sinking machine*

3.2. 3D Modeling of Cylinder Support Plate and Worm Gear

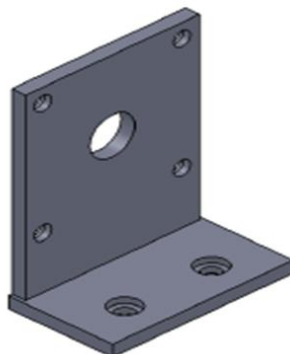The modeling of cylinder support plate and worm gear is depicted in Figures 2 and 3.

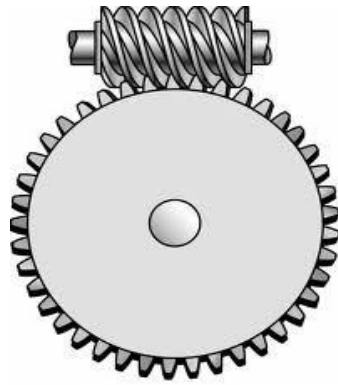**Figure2.** *Isometric View of cylinder support plate*

Figure3. *Isometric View of worm gear*

3.3. Clamp Cylinder and Spring

The isometric view of clamp cylinder and spring is depicted in Figures 4 and 5.The Figure 6 and 7 show the isometric view of tool cylinder and cylinder holder.

Figure4. *Isometric View of clamp cylinder*

Figure5. *Isometric View of spring*

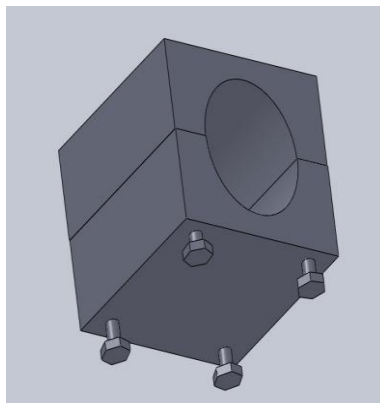**Figure6.** *Isometric View of tool cylinder*

Figure7. *Isometric View of cylinder holder*

4. WORKING METHODOLOGY OF THE FABRICATED MACHINE

Countersinking machine is connected with the hole piercing machine. In hole piercing machine, the work piece is feed by the worker. After the hole is pierced, the work piece is allowed to enter the countersinking machine for countersink. Initially, we switch on the supply. The supply is given to the tool cylinder. The availability of the work piece is sensed by the work piece sensor. After that, the clamp is down and clamps the work piece. The clamping is sensed by the clamp down sensor. Then, the spindle comes forward and it is sensed by the spindle forward sensor. While the spindle moves forward, the stopper cylinder is actuated. The actuation of stopper cylinder is sensed by the stopper sensor. Therefore, the clamp is up. So, the work piece is released from the clamp and goes to the storage tank through the tray. The exit of the work piece is sensed by the exit sensor. After the signal is sensed, this cycle is again repeated.

The front and side view of the fabricated counter sinking machine is depicted in figures 8 and 9.

Figure9. *Front view of the machine*

5. RELAY LOGIC DIAGRAM

This diagram is helpful for the automation purpose. For this paper the below figure 10 is used to construct for the automation of counter sinking machine.

Where,

S_1 – Work piece available sensor (Laser sensor) S_2 – Clamp down sensor

S_3 – Spindle forward sensor S_4 – Stopper up sensor S_5 – Exit sensor

C, C_3 – 8 Pin 25V Relay C_1, C_2, C_4, C_5 – 5 Pin Relay

PB_1 – Emergency stop PB_2 – Switch ON PB_3 – Cycle start

1, 2, 3, 4, 5..................... 15 – Wire number

Figure10. *Side view of the machine*

6. PRODUCTIVITY CALCULATION

6.1. Before Automation

Number of products per hour = 120 numbers

For 2 shifts per day   =   8 hours $\times$ 2 $\times$ 120

= 1920 numbers

Total productivity per month = 25 x 1920

= 48,000 numbers

6.2. After Automation

Number of products per hour   = 157 numbers

For 2 shifts per day   = 8 hours $\times$ 2 $\times$ 200

= 3200 numbers

Total productivity per month = 25 x 3200

= 80,000 numbers

Increase in number of products per month = 32,000 numbers

Conversion cost for 1 component   = Rs.1.00

Savings / Month   = 32000$\times$1

= Rs.32,000/month

Savings/Year   = Rs.3,85,000/Year = Rs.3.85 Lacs /Year

7. CONCLUSION

From this paper the fabricated automatic counter sinking machine takes less time to manufacture components when compared to conventional counter sinking machine. The production rate will also be increased in this machine when compared to the conventional machine. The cost of the product is less by producing this product by automatic counter sinking machine.

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