DESIGN OF MULTI SPINDLE CHAMFERING AND TAPPING ATTACHMENT FOR SPECIAL PURPOSE MACHINE OF HYDRAULIC LIFT COVER

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ABSTRACT

The main aim of mass production is to increase productivity with maximum accuracy. While manufacturing job in mass scale it is important to reduce set up cost and manual fatigue. Most of the manufacturing industries are going for automation to increase the productivity and to overcome shortage of skilled labor. The purpose of this project is to reduce the cycle time by replacing radial drilling machine and by attachment to special purpose machine(SPM) for chamfering and tapping operation. The concept is that the hydraulic lift cover has drilling, chamfering and tapping operations and is performed on two different machines. All the operation performs on same machine having two separate multi spindles. This paper gives the detail information of design and analysis of attachment for special purpose machine and compares the cycle time for conventional method. This machine is containing automation by using hydraulic system. Modeling is done using CATIA software.

Keywords: Tapping Attachment, Form tool, SPM, CATIA Software

I. INTRODUCTION

The present work relates to chamfering and tapping attachment and more particularly to a relatively compact type of device which operates automatically to milling, drilling plus chamfering and tapping operations and design which is very easy to handle and simple in operation by a single person. Special purpose machine is part of multi-tasking machine. This is new approach to increase the productivity of organization. If we compare between ordinary machine and special purpose machine in terms of time, costs, number of steps involved etc. The technology of SPM is decided upon the principles of minimization of cost, improved productivity and improved safety, which posses with high initial investment, higher maintenance cost. The following studies are carried out, time saved by component handling (loading and unloading), increase in productivity both qualitative and quantitative, less human intervention, indirectly reduction in operator fatigue, increase the profit of company. In this paper the SPM for milling, 3 multi drilling plus chamfering (Φ 9.3), tapping operation for these 3 drilled holes. Multiple-spindle machines are used for mass production, a great time saver where many pieces of jobs having many holes are to be drilled and tapped. Multi-spindle head machines are used in mechanical industry in order to increase the productivity of machining systems.

International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.01, March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

II. PROBLEM DEFINITION

This paper includes project on "DESIGN OF MULTI SPINDLE CHAMFERING AND TAPPING ATTACHMENT FOR SPECIAL PURPOSE MACHINE OF HYDRAULIC LIFT COVER**"** The part manufactured by the company is Hydraulic Lift Cover of Escort Tractors. The operations performed on H. L. cover part are Taper Milling, Drilling, Chamfering and Tapping. In order to perform these operations a horizontal SPM for Milling and Drilling and Radial Drilling Machine for Chamfering and Tapping are used. For this it is necessary to transfer job from one machine to another. This process takes more time, increase worker fatigue, consumes more space and also there is chance of occurring human error due to variation in feed during tapping.Company presently uses the conventional manufacturing process. Due to separate arrangements in machine the operation, there arises a question on safety issues of operator and there may be chance of accidents. Due to fatigue of operator, operators are trying to avoid this operation also it is difficult to new operator for working on these machines.

Fig: - Hydraulic Lift Cover (Job)

Fig: - Milling and Drilling Machine

Fig: - Radial DrillingMachine

ACTUAL PROBLEM

a) Desired production rate is not achieved.
b) Cycle time is more as tapping is done on single spindle
c) Operator Fatigue Issue.
d) Possibility of error while tapping operation as feed rate is given manually,hence accuracy depends on operator skills.
e) More space is required.

III. SOLUTION

The solution for this problem is providing another multispindle head besides the existing the drilling head. But before the tapping operation chamfer and countersink are additional features and necessary to be performed to guide the tap during tapping operation.But while providing the new tapping head it is necessary to adjust the chamfer operation i.e. is countersink operation somewhere. So, the chamfering operation can be combined with the drilling operation. For this the, the current tool of drilling in multi spindle drilling (i.e. drill bit) is to be replaced by the stepped or pilot drill. These types of stepped drills are available in market or it can be manufactured as per requirement. These drill bits are similar to the regular drill bit, but it has two diameter i.e. smaller diameter and larger diameter. The smaller diameter of this drill is equal to the diameter of previous i.e. regular drill but the larger diameter of this drill is equal to diameter of countersink. The figure below shows the stepped/Pilot drill.

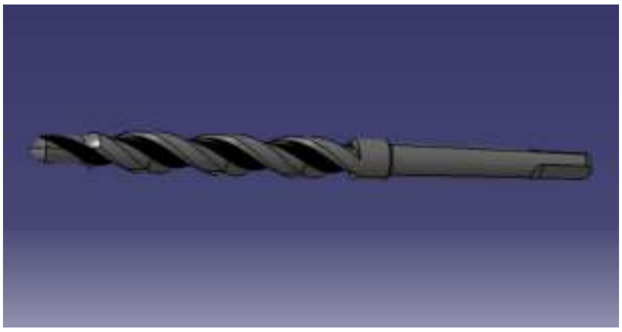

Fig: - Stepped Drill The table given below shows the dimension of the stepped drill bit.

Name of Component: - Step / Pilot Drill

Step Drill Specifications: -Ø9.4×FL 21.5 ×Ø14 ×OAL 200

Material	High Speed Steel (HSS)
Overall Length	200
Small Diameter Drill Length	21.5
Larger Diameter Drill Length	92
Small Diameter Of Drill	9.4
Larger Diameter Of Drill	14
Point/Starting Angle	118
Lip Relief Angle	12
Helix Angle	30
Body Length	115
Shank Length	66
Shank Designation	M.T.1 (Morse Tap, Grade-1)

The manufacturing for stepped drill is as follows:

- Initially a new drill of diameter equal to larger diameter of step drill is taken . The point angle of a new drill bit generally 118°
- Then this drill bit is machined to achieve point angle equal to 30° on a machine known as tool and cutter machine.

IJARSE
ISSN: 2319-8354

- This machine can be used for setting various angles on drill bit as well as reducing the diameter of drill bit.
- After achieving the 30° point angle, the diameter of drill bit is reduced from drilling side end upto the length of depth of small diameter hole. Also an additional tolerance of nearly 5mm is given in the length of small diameter drill to compensate error in length.
- This reduction of diameter of drill is done by a process called as grinding.
- Then again angle setting is done on larger diameter of drill of 90° in total.
- After this the by fixing the required length of small diameter of drill , again the angle setting is done . During this process the point angle in machined to 118° again.

Tapping attachment:-

Now, as the countersink operation is combined with the drilling operation, hence the new attachment will include only tapping operation.As the tapping operation was previously done on a single spindle the time required was more. Hence now the time required for tapping will be reduced as multi spindle head will be used for tapping operation.

TYPE OF MULTISPINDLE

Fixed Multispindle tapping head: - In this type we cannot separate the spindle according to requirement. Features of this type multispindlehead are:-

A. By using these multispindles tapping heads, increase in productivity is substantial.

B. Time for tapping one hole is the time for multiple number of tappings.

C. Multispindle tapping ensures the positional accuracy.

Multispindle heads can be of fixed centre construction for mass and large batch production and for batch production, adjustable centre type design is offered. Here planetary gear train type fixed multispindle drilling head is selected. It includes the three spindles which are arranged in circular shape as shown in above figure which are attached with each other with the help of planetary gear. The whole assembly is connected to main arbor shaft.

Multispindle tapping head includes various parts like spindle i.e. driving gear, driven gear, shaft on which these gears are mounted, bearings and finally the housing for spindle. The drive for this head is to be given be the means of hydraulically operated servo motor. The selection of motor is as follows:-

SELECTION OF MOTOR:-

From the guidelines and suggestions from the SPM manufacturers, the approximate requirement of the torque of the motor for tapping must be between 8-9 Nm

We selected net 8.7 Nm and speed requirement 342 rpm.

Power requirement,

$$P = \frac{2\pi NT}{60\times1000} = \frac{2\pi\times342\times8.7}{60\times1000} = 0.31 \text{ kW}$$

For 3 taps, power required = 3* 0.31* 1.25 = 1.1626 kW

i.e.1.5 H.P.

As losses in between pulley arrangement is considered, such that belt pulley power transmission efficiency is 85-95%.

SPECIFICATION OF MOTOR

1. Power - 1.5 H.P. Double speed
2. RPM- 750
3. Phase- 1
4. Voltage- 190/240 v AC
5. Current- 10A , 50 HZ

Further this drive is given to spindle through timing pulley and timing belt. Timing pulley and timing belt are directly selected. The selection of timing pulley and belt is as follows;-

Timing Belt and Timing Pulley

Timing belts are parts of synchronous drives which represent an important category of drives. Characteristically, these drives employ the positive engagement of two sets of meshing teeth. Hence, they do not slip and there is no relative motion between the two elements in mesh.Due to this feature, different parts of the drive will maintain a constant speed ratio or even a permanent relative position. This is extremely important in applications such as automatic machinery in which a definite motion sequence and/or indexing is involved.The positive nature of these drives makes them capable of transmitting large torques and withstanding large accelerations.

Gear Arrangement

The gear arrangement in the spindle is done as epicyclic gear train. In epicyclic gear train one gear(i.e. sun gear) is at the center and other gears(i.e. planetary gears) are rotating due to Sun gear around the Sun gear. Sun and planetary gear are mounted on different shafts. The drive from timing pulley is further given to the sun gear and sun gear transmits the drive further to all the planetary gears. Planetary gears provide this drive to the tap through the tap adjuster.For this the spindle is to be designed. Design of spindle includes the design of sun and planetary gears, design of shaft, design or selections of bearings. The design of spindle is as follows;-

IV.DESIGN OF GEAR

Material: - 40Ni2Cr1Mo28

Direct Hardened Steel

Ultimate Tensile Strength (UTS) = 1520.55 N/mm^2

Brinell hardness number = 615

Power = 1.1626 kW

N_p =342 rpm

Torque (M_t):-

$$M_t = \frac{60 \times 10^6 \times kW}{2\pi n_p} M_t = \frac{60 \times 10^6 \times 1.1626}{2\pi(342)}$$

$$Mt = 32459.23 \, Nmm$$

Lewis Form Factor (Y):-

Lewis Form Factor for 18 number of teeth is Y = 0.308 (From Table no. 17.3 Bhandari)

Service Factor (C_s):-

$$ServiceFactor C_s = \frac{StartingTorque}{RatedTorque}$$

$C_s = 1.5$

Velocity Factor (C_v):-

Velocity Factor C_v is selected, by assuming velocity,

$$V = 5\, m/s$$

$$C_v = \frac{3}{3+5} = \frac{3}{8}$$

Module (m):-

$$m = \left[\frac{60 \times 10^6}{\pi} \times \left\{\frac{(kW) \times (C_s) \times (F_s)}{(z_p) \times (n_p) \times (C_v) \times \left(b/m\right) \times (\frac{S_{ut}}{3}) \times Y}\right\}\right]^{\frac{1}{3}} m$$

$$= \left[\frac{60 \times 10^6}{\pi} \times \left\{\frac{(1.1626) \times (1.5) \times (1.5)}{(18) \times (342) \times \left(\frac{3}{8}\right) \times 10 \times (\frac{1520.55}{3}) \times 0.308}\right\}\right]^{\frac{1}{3}}$$

$$m = 2.4022 \approx 2mm$$

$$m = 2mm$$

Gear Dimensions:-

$$d_p = mz_p = 2(18) = 36mm$$

$$d_g = mz_g = 2(34) = 68mm$$

$$b = 10m = 10 \times 2 = 20mm$$

Dedendumh_p = 1.25 m = 1.25 × 2 =2.5 mm

Addendum h_a = m = 2 mm

Check for dimensions:-

$$P_t = \frac{2M_t}{d_p} = \frac{2 \times (32459.2316)}{36} = 1803.29$$

$$P_t = 1803.29\, N$$

Corrected Velocity:-

$$V = \frac{\pi d_p n_p}{60 \times 10^3} = \frac{\pi \times 36 \times 342}{60 \times 10^3} = 0.6446\, m/s$$

$$V = 0.6446\, m/s$$

Corrected Velocity Factor:-

$$C_v = \frac{3}{3+v} = \frac{3}{3+0.6446} = 0.8231$$

$$C_v = 0.8231$$

Effective Load (P_{eff}):-

$$P_{eff} = \frac{C_s}{C_v} P_t = \frac{1.5 \times (1803.29)}{0.8231} = 3286.27\, N$$

$$P_{eff} = 3286.27N$$

Beam Strength (S_b):-

$$S_b = m \cdot b \cdot Y \cdot \sigma_b = 2 \times 20 \times 0.308 \times (\frac{1520.55}{3})$$

$$S_b = 6244.39\ N$$

Factor of Safety (f_s):-

$$f_s = \frac{S_b}{P_{eff}} = \frac{6244.39}{3286.27}$$

$$f_s = 1.9$$

Design is safe.

Wear Strength (S_w):-

$$Q = \frac{2z_g}{z_{g+}z_p} = \frac{2 \times 34}{34 + 18} = 1.3076$$

$$K = 0.16 \times \left(\frac{BHN}{100}\right)^2 = 0.16 \times \left(\frac{615}{100}\right)^2 = 6.0516$$

$$S_w = b \cdot Q \cdot d_p \cdot K = 20 \times 1.3076 \times 36 \times 6.0516$$

$$S_w = 5697.41\ N$$

Factor of Safety (f_s):-

$$f_s = \frac{S_w}{P_{eff}} = \frac{5697.41}{3286.27} = 1.733$$

$$f_s = 1.733$$

Design is safe.

2. Design of Shaft:-

Power= 1.1626 kW

For material 8620 Case Hardened Steel

S_{yt}= 590 MPa

S_{ut}= 820 MPa

By ASME code for shaft design,

$K_b = K_t$ =1.5

We have Diameter of gear = 68mm

Diameter of pulley = 518mm

n = 181 rpm

Permissible shear stress:-

$0.3S_{yt}$ = 0.3 x 590 = 177 N/mm^2

$0.18S_{ut}$ =0.18 x 820 = 147.7 N/mm^2

For keyway,$\tau_{max} = 0.75 \times 147.7 = 110.77\ N/mm^2$

Torque transmitted/ Torsional Moment (M_t):-

$$M_t = \frac{60 \times 10^6 \times 1.1626}{2\pi \times 181}$$

$$M_t = 61337.08\ Nmm$$

For Bending Moment (M_b):-

Pulley have a relation ($P_1 = 3P_2$)

$$(P1 - P2) \text{ x } 259 = 61337.08$$

AsP1 = 3P2

$$2P2 = 236.355.23 \text{ N}$$

$$P_2 = 118.41\ N$$

$$P_1 = 3P_2 = 355.23N$$

For Gear,

$$\mathrm{P_t} = \frac{2\mathrm{M_t}}{\mathrm{d}} = \frac{2 \times 61337.08}{68}$$

$$P_t = 1804.03\ N$$

$$P_r = P_t \tan(\alpha) = 1804.03 \times \tan(20)$$

$$P_r = 656.61\ N$$

For finding moment (Vertical forces):-

Taking moment at A,

656.61 x 75 – F_cx 150 + 473.63 x 180 = 0

F_c = 896.66 N

ΣF_y =0

656.61 + 473.63 - 896.66 + F = 0

F = - 233.58 N

For Vertical

B.M. at B =-17518.35 N(Maximum)

For Horizontal,

Taking Moment at A,

1809.03 x 75 - F_c x 150 = 0

$F_A = F_C$ = 902.01N

Bending Moment diagram for Horizontal forces,

B.M. at B = -67650.75 (Maximum)

At point B,

$$(M_b)atB = \sqrt{(17518.35)^2 + (67650.75)^2} = 69882.16\ Nmm$$

M_b = 69882.16 Nmm

M_t = 61337.08 Nmm

Shaft diameter,

$$\tau_{max} = \frac{16}{\pi d^3}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

$$110.77 = \frac{16}{\pi d^3}\sqrt{(1.5 \times M_b)^2 + (1.5 \times M_t)^2}$$

$$D = 18.57 \approx 20\ mm$$

$$\boldsymbol{D = 20mm}$$

For 2nd shaft,

For 8620 Case Hardened steel,

$$\tau_{max} = 110.77\ Nmm$$

Torque transmitted,

$$M_t = \frac{60 \times 10^6 \times 1.1626}{2\pi \times 342} = 32459.23\ Nmm$$

$$P_t = \frac{2M_t}{d_p} = \frac{2 \times 32459.23}{36} = 1803.29\ N$$

$$P_r = P_t \tan(\alpha) = 656.34\ N$$

Finding moment vertical,

B.M. at B = 24612.75 Nmm (Maximum)

Finding Horizontal forces,

B.M. at B = 67623.375 Nmm (Maximum)

$$M_b atB = \sqrt{(67623.375)^2 + (24612.75)^2}$$

$$M_b = 71963.24\ Nmm$$

$$D = \frac{16}{\pi\tau_{max}}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

$$D = 17.59 \approx 20\ mm$$

$$\boldsymbol{D = 20mm}$$

3. Design of Key:-

Type of Key:-

Square Parallel (Sunk) key

Diameter of shaft: - 20mm

Power transmitted by shaft: - 1.1626 kW at 181 rpm

Key Material: - Steel 50C4

S_{yt}= 460N/mm^2

S_{yt}=S_{yc}= 460N/mm^2

Factor of Safety= 3

$$\sigma_c = \frac{460}{3} = 153.33\ N/mm^2$$

According to maximum Shear Stress Theory of Failure,

$$\text{Ssy} = 0.5\text{Syt} = 0.5 \text{ x } 460 = 230 \text{ N/mm2}$$

$$\tau = \frac{S_{sy}}{f_s} = \frac{230}{3} = 76.67\ \text{N/mm}^2$$

Torque transmitted by the shaft,

$$M_t = \frac{60 \times 10^6 \times (kW)}{2\pi N} = \frac{1.1625}{2\pi \times 1.81} M_t = 61337.08\ Nmm$$

Key Dimensions:-

$$b = h = \frac{d}{4} = \frac{20}{4} = 5mm$$

$$l = \frac{2M_t}{\tau db} = \frac{2 \times 61337.08}{76.67 \times 20 \times 5} = 16mm$$

Dimensions of key= 5x5x16 mm

Similarly for shaft with speed =342 rpm

Change$M_t = \frac{60\times10^6\times1.1626}{2\pi\times342} = 32459.23\ Nmm$

Diameter of shaft = d = 20mm

$$l = \frac{2M_t}{\tau bd} = 8.46 \approx 9mm$$

$$l = \frac{2M_t}{\sigma_c dh} = 9mm$$

Dimensions of key =5x5x9

For this tapping, the feed is given with the help of lead screw and nut arrangement. For this the selection of lead screw is to be done. While selecting the lead screw it is necessary that the pitch of tap and the lead screw must be same, otherwise the tap will break. The threads of the lead screw will be square. And if the rotates in clockwise direction the lead screw must also rotate in clockwise direction.

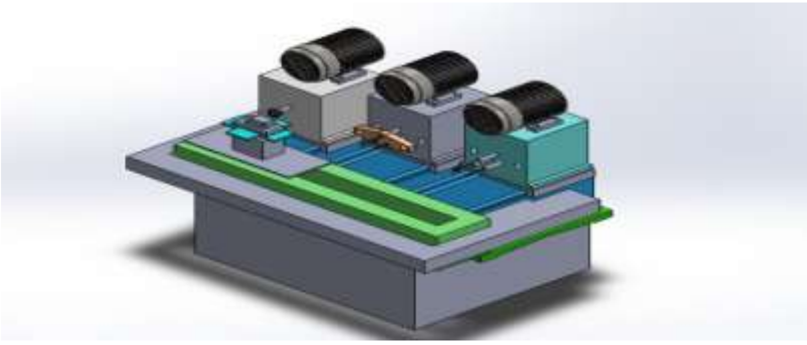

Fig: - Setup of Attachment

Parameters	Number of jobs		Target
	Before	After	4500 jobs per month
Per shift	35	51	Cannot be achieved
Per day	105	153	Can be achieved

V. CONCLUSION

By using multi spindle head productivity will increase, because with the present process chamfering and tapping are done for each hole separately and it needs changing of tool. Due to multispindle tapping, possibility of missing any hole is eliminated, as all holes are to be tapped at a time. Hence, the cycle time is reduced and cost per piece is reduced. By combining two machines, maximum utilization of space is possible and reduces the necessity of skilled worker. The fatigue of worker is also reduced.

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