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Development and Analysis of Special Purpose Machine (Peck drilling machine)

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Abstract - *Peck Drilling is a concept which deals with the problems arising with the conventional methods for deep hole drilling in industries. Tool wear is a major concern in the industries. Difficulties like surface roughness, discontinuity in chip flowing, tool wearing , excessive temperature rise during operations and tool failure can be seen with the conventional machines during a deep hole drilling operation. The method of peck drilling nearly overcomes all the limitations listed above with some additional qualities like reducing the cost of hole drilling, smoother operations, less coolant wastage etc. Deep hole drilling is relatively a challenging task. As the aspect ratio of the hole increases it gives rise to problems like shifting of tool from axis, vibration of tool, cost of tool increase with length of drill bits, unwanted bending stresses which finally results in failure of the drill bit. To avoid that scenario, special purpose peck drilling machines are used. The machine which is used is auto-feed peck drill machine for experiment and the analysis and comparison of the results are done against the conventional drill machine.*

Key Words: **Peck drilling operation , Tool Wear, Hydraulic Power Pack , Surface Roughness, Drilling cycle, Tool life**

1. INTRODUCTION

Drilling is a cutting process for making holes of circular cross section in a solid surface or material. Drill bit is a tool which is used for making holes. These tools are often multi-point cutting. The process of drilling takes place when the drill bit fixed into a chuck is rotated at high speed which is pressed against the material for material removal process. Drilling can be done on any surface provided a suitable tool is used. The tool bits which are used for machining the metals are selected based on many factors like ultimate and yield strength of the tool and the material, the hardness or toughness of the tool which determines the penetration rate of the tool as well as wear factor of tool. The pecking operation which is to be used in this experiment is similar to a bird impart forces on the wooden log by repeated impact movements just the difference is here it is a high speed rotating tool rather than stationary impacting tool.

1.1 Types of Drilling

Classification of different drilling processes:

- Deep hole drilling- High depth to diameter ratio(aspect ratio)
- Spot Drilling- Acts as a guide for final hole drilling
- Center Drilling- Two fluted tool is used for drilling materials later mounted between center
- Trepanning- Used to create holes with larger diameters where standard drill bits are not used
- Micro drilling- Hole diameters are less than 0.5mm.
- Vibration Drilling- Uses vibrations as means for material removal process

1.2 Deep Hole Drilling

Deep holes are classified as high aspect ratio drilling. As the length of the tool shaft increases, after a certain point it become more prone to vibrations. The vibrations developed affect the quality of the drilled hole. The operator has to pause the operation several times to adjust the conditions of drilling which increases the cycle time period. The coolant supply is also challenging for conventional method as the coolant cannot reach to depths of hole due to several obstructions on the way. The chip removal system is also not efficient and the tool has to be pulled out at regular intervals for cleaning the chips. The chip formation also results in tool wear and blockage of the hole which decreases the penetration rate for the tool bit. The heat generation is also very high due to insufficient coolant which creates heat affected zones (HAZ) and compromises the hole quality and material strength of parent metal.

2. Proposed System

The system which is followed in this experiment is the development of a hand feed pillar type drilling machine into auto-feed peck drilling machine by replacing the feeding mechanism into pecking mechanism. Certain assembles are installed like hydraulic power pack, Programmable logic controller (PLC), Double acting cylinders, rack and pinion along with linear motion guide, limit switches on the head of the machine through welding and L-Brackets.

The pillar type drilling machine is used as it provides constant speed rate during the operation. The need to develop this special purpose machine is to decrease surface roughness and to optimize the cycle time to obtain increase in tool life and decrease the cost of production.

Although the initial investment is high on this machine but it reduces the operating cost due to lower maintenance.

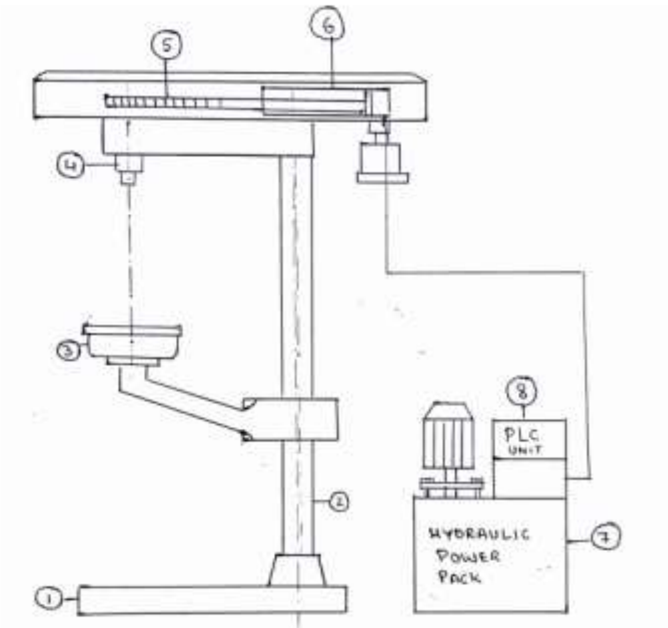

Figure 1: Block Diagram Of Auto-feed Peck Drilling Machine

2.1 Components of machine

1. Machine bed : Made of cast iron to support the system and to transfer the vibrations to ground
2. Column: Made of high carbon steel to uplift the machine and to withstand various stresses
3. Worktable: To clamp and fix the position of the work piece
4. Spindle head: Rotational feed from the motor is transferred to the drill bit
5. Rack and Pinion: Acts as translational feeding mechanism for auto-feed machines. These are mounted on LMR which guides the motion in one axis only.
6. Hydraulic Cylinder: Gives translational feeds by converting the hydraulic force to mechanical force. The cylinder used is double acting for controlled feeding and retracting motion
7. Power pack: It is the entire assembly for hydraulic circuit used for feed. It consist of the fluid reservoir, direction and flow control valves, inlet and exhaust lines , nozzles, pump and motor. The pump used is radial pump.
8. PLC control unit: It controls the rate of feed through constraints like time or displacement. The movement of tool is predefined in PLC by a program which eliminates the need of operator for constant feed rate.

Components not shown in block diagram :

9. L-Brackets: These are used for mounting the parts like hydraulic cylinder, rack and pinion etc. to the head of the machine. These are fixed onto head by bolts
10. Linear motion guide: The LMR guide is an assembly of rail and block which is used for the guided movement of machine elements restricted to one dimensional axis. Rack and pinion is mounted on rail for to and fro motion.
11. Drill bits: Many types of drill bits can be used in the peck drilling operation depending upon the properties of material. The material of the bit is high speed steel (HSS) for high speed and clear finish operations.

3. Calculations

1. Hydraulic cylinder

Let us consider A4 model of cylinder for reliable safety.

$$D_P = 75\text{mm} \qquad D_r = 45\text{mm}$$

For drilling only two forces are experienced. Torque and Thrust vary with drill diameter and feed rate .Taking references as 10mm drill with feed rate 0.3mm/rev will experience a torque of 15 Nm and thrust of 2500 N (250 kg). Force = 2500N

$$A_P = \frac{\pi}{4}(D_P)^2 = \frac{\pi}{4}\left(\frac{75}{1000}\right)^2$$

$$= 4.41 \times 10^{-3} m^2$$

$$\text{Pressure} = \frac{F}{A} = \frac{2500}{4.41 \times 10^{-3}} = 5.65 \text{ bar}$$

$$X = 5\text{mm}$$

$$t = 1\text{sec}$$

$$\text{Velocity} = \frac{5 \times 10^{-3}}{1} = 5 \times 10^{-3} \text{ m/s}$$

$$Q = A \times V = 4.41 \times 10^{-3} \times 5 \times 10^{-3}$$

$$= 2.205 \times 10^{-5} m^3/s$$

$= 2.205 \times 10^{-5} \times 60 \times 10^3 \; Lpm$

Q= 1.323 lpm

2. LMR guide:

The linear motion rails have holes on it with the standard bolt size which is for the mounting purpose. In order to install a linear motion guide one must know the pitch of the rail. So that equally spaced drilled holes are to be made on mounting surface too .For this purpose, we have to calculate the number of holes to be drilled and its formula is given by –No. of Holes= (L/f)

Where L = Required length of rail in mm

f = Pitch of LM rail in mm

From Manufacturer's Catalogue (THK)-

F for SR25 is 60mm.

No. of Holes = 400/60= 6.6

Neglecting decimal value,

So we get no. of holes = 6

Here G denotes the distance between the end of LM rail to the center of the adjacent hole .Now, Calculating G distance,

Formula is given by-

G= (Total Length -pitch of rail*no. of holes)/2

G= (400-60*6)/2=20mm

Therefore G for each side is 20-20mm.

3. Selection of spur pinion:

From the manufacturer's catalogue (KHK), model selected is-SS2.5-15

Where 1st Letter S denotes Type of Material (Here, Steel is used)

2ND Letter S Denotes for the Type of Gear (Here, Spur Gear)

Module of gear = 2.5

4. Selection of rack:

From the manufacturer's Catalogue (KHK) , model selected is-SR2.5-300

Where S is the Type of gear material (Here, Steel)

R is the type of gear (Here, Rack)

Module is 2.5

Standard Length of Rack is 300mm.

Effective No. of teeth = 37

4. Result and analysis

The analysis is done on various aspects and different results are obtained from those results:

1. Surface finish: The study of surface finish of hole is done through visual inspection and 10x micrograph observations. Both the specimen taken was of low carbon steel. The samples of 10mm*10mm are taken and the surfaces were smoothened by SiC abrasive papers. Then the etchant used was nital which is 90-95% ethanol and 3-10% nitric acid. Work piece was exposed to the medium for 30 seconds and observations were done.

   The surface finish obtained was of good quality in the peck drilled hole rather than conventionally drilled hole. The material removal process is constant in peck drilling rather than the latter because of the clogging of the metal chips due to inefficient evacuation of them.

2. Cycle time:

Table 1: Time taken per cycle

Cycle	Conventional machine (seconds)	Peck drill machine (seconds)
1	115	28
2	104	26
3	107	25

The result data clearly shows that the cycle time per operation of conventional machine is more than the peck drilling machine. Also the tool wear in case of conventional machine is higher that is because the clogging of chip results in more tool wear. Another problem with conventional method is that mostly the machines are hand feed, therefore it compromises the accuracy of dimensions and constant feed rate due to human input.

3. Heat affected zone(HAZ):

The constant running of the drill machine causes heat affected zones around the holes where the surface properties get altered of parent material due to heat. The drilling operations are most of the time done in steps rather than doing it in one stroke to avoid overheating. The conventional drill machine has to be stopped and start again which increases cycle time whereas in peck drilling the feed and retraction time and distance are preprogrammed hence the constant starting and stopping can be completely rejected.

4. Tool geometry:

   The tool used in this process is HSS twist drill. When deep holes are made then in conventional machine a long tool is required with longer shaft length which increases the cost. Other than that when a deep hole is drilled then the tool is designed such as the shank should be broader to sustain the radial and shear stresses as well. But in case of peck drilling the need for large tool is completely neglected.

5. Power usage:

   Both the machines were operated on the constant power input of 440V AC 10A 3phase. The power usage in the peck drilling machine is very high compared to the conventional machine where the electric power input is only utilized to run the rotational feed motor. In peck drilling the power input goes to the rotational motor and the hydraulic power pack. The hydraulic system consumes more electricity than any of the motors.

5. Conclusion

In the present work the performance of conventional and peck drilling machines were studied and compared with each other. Process of peck drilling machine is proven to be a good alternative than latter as it presents more efficient on the parameters on which this test is performed. Peck drilling provides better surface finish of the holes, better cycle time efficiency, better chip evacuation, better coolant supply to depth and less damage to the hole surface due to overheating.it reduces the cost of tool as well as the maintenance cost is reduced too. The limitations so far found in this test are the initial investment of this machine is approximately twice the regular machine. Also the power used by this machine is very large hence increase in the operating cost of the machine which increases the cost of product. It is also quite complicated to assemble and operate for the operator.

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