Design and Manufacturing of Special Purpose Subsystems for Drilling and Tapping Operations

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Abstract— The growth of mechanical industries depends on its productivity & quality. The decision making of company is largely based on the motives of improving traditional manufacturing practices to result in to major advantages like, reduced manufacturing lead times, fool-proofing of methods of processing & consistent results on a long run. In case of mass production where job variety is less and quantity produced is large, it is very important to produce faster job production. This paper includes case study and comparison of component using traditional radial drilling machine and SPM for drilling and tapping operations. The special purpose machine is used for drilling two holes of Ø5 and M6x1 tapping for those two holes. The following studies are carried out 1. Time saved by component loading and unloading on indexing unit, 2. Increase qualitative and quantitative productivity, 3. Minimum human intervention, 4. Minimum rejection due to automatic control, 5. Enhance the profit of organization.

Key words: Tapping Operations, Manufacturing of Special Purpose Subsystems

I. INTRODUCTION

Adapting to the new technologies in manufacturing is a fundamental function of a manager in a business organization. Special purpose machine are widely used for special kind of operations, which are not economical on conventional machines. It is design for getting higher accuracy at desired condition. The best way to improve the production rate along quality is by use of special purpose machine[2]. Productivity can be improved by reducing the total machining time, combining the various operations etc. Multi-spindle head machines are used in mechanical industry in order to increase the productivity of machining systems [3]. In any mass production organization, it is necessary to get maximum production within minimum time interval. To minimize the cycle time of new and existing product following practice are adopted:

- Process simplification
- Eliminate of delays
- Elimination of operational steps
- Combine and speed up operations [4]

Both spindle heads carry multiple tools for performing simultaneous machining operations. Rotary indexing table with servo motor is used for part transportation. In first operation that is drilling creates cylindrical hole in solid material. Next operation tapping creates internal threads in the hole, are useful for assembly purpose. Simply number of machining processes can done on this SPM which is made for only that component. The method of Taguchi for two factors at three levels can be used for the elaboration of the plan of experiments. The L9 array may be used, which has 9 rows corresponding to the number of tests with 2 columns at three levels. The factors and the interactions are assigned to the columns [5].

II. SETUP DETAILS

This SPM is designed for drilling and tapping operations of two wheeler cylinder block. The SPM includes UNIT A (Ø5 drilling for two holes) and UNIT B (M6x1 tapping for two holes). All these operations are performed simultaneously. These two units are very important therefore it is required design two units according to their specific operations. The units are as follows

A. Unit A-

Unit A used for the operation of 2 holes of Ø5. Unit A includes 2 drilling spindles, jig plate, motor, gear box, slide way, motor, belt with pulleys, hydraulic cylinder etc., The indexing unit is placed in between drilling and tapping heads. First the job is placed correctly from operator side on indexing table in between locators. Then the indexing table with component rotates till component comes at drilling station. The two hydraulic cylinders are used for clamping the job at drilling and tapping station. After clamping, drilling is done by feed forward motion of unit A. The hydraulic power is used for clamping and forward motion of drilling head. For gear box the 3 phase squirrel cage induction motor of 1.5 hp with speed of 930 r.p.m is selected. The design of hydraulic power pack, gear box, and selection of motor is done according to specific requirement. The multi drilling operation is completed in 34.14 seconds.

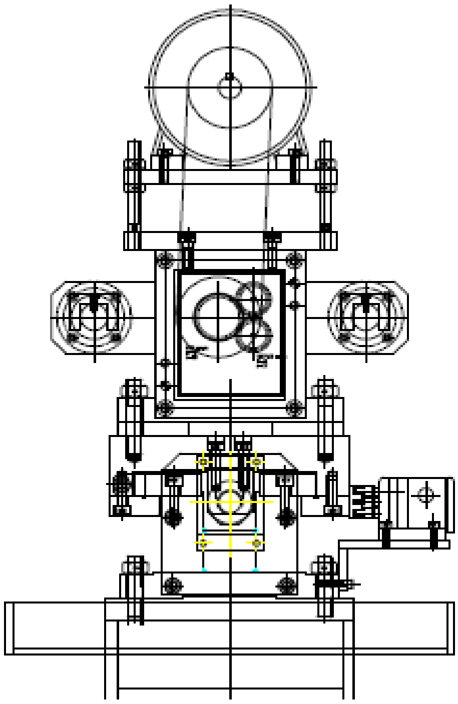

Fig. 1: Unit A

B. Unit B

Internal thread tapping is important and one of the most demanding machining operations. The major problems in process is tap breakage, resulting from excessive torque. In tapping operation, tap breakage is extremely costly [6]. In unit B the tapping operation of M6x1 is performed. The tapping operation is linear. The unit B contains pitch feed unit with lead screw, gear train and motor. The last gear of gear train is mounted on lead screw and motion is transmitted from motor to lead screw gear.

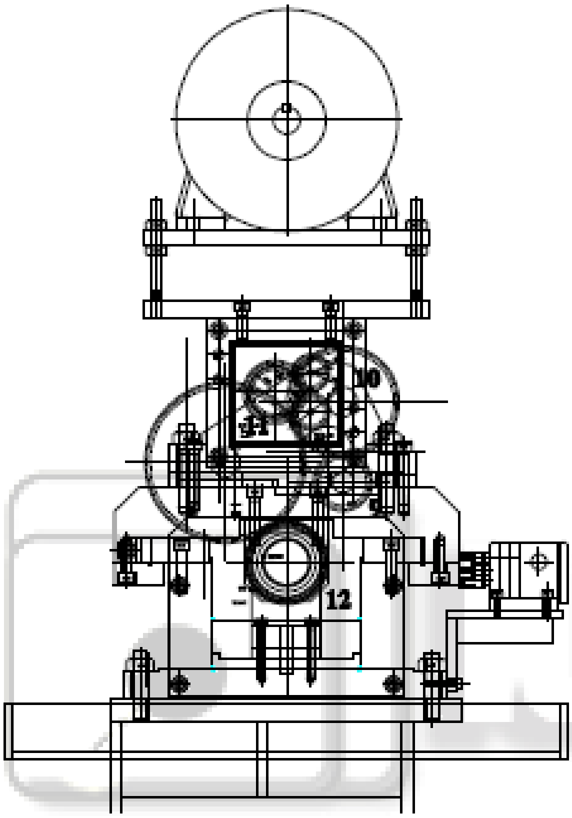

Fig. 2: Unit B

The rotation of lead screw gear results into tapping unit travel along required path. For this operation the motor of 2 hp of 705 r.p.m. is selected. The front view of SPM is as shown in fig.3.

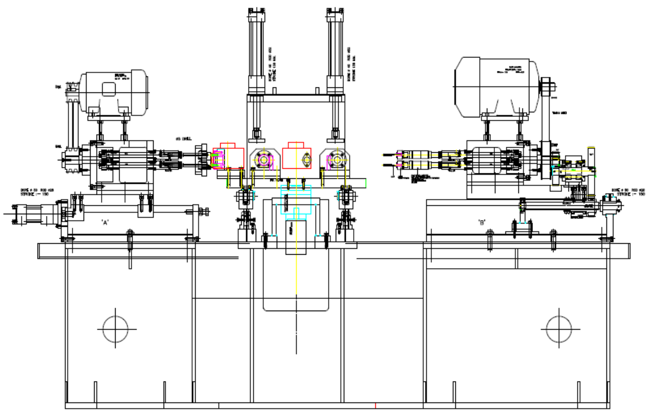

Fig. 3: Front view of SPM

The component is two wheeler cylinder block which has two holes with internal tapping. Conventional drilling and tapping machine requires more cycle time for completing these operation. The cylinder block component is shown in fig.4.

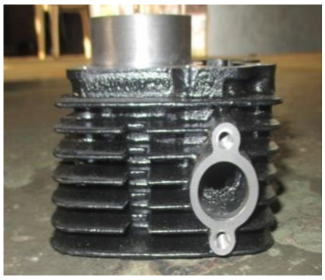

Fig. 4: Photograph of cylinder block

The newly developed SPM is shown in fig.4. below

Fig. 5: Photograph of SPM

III. ESTIMATION OF POWER AND FORCE REQUIREMENT FOR MACHINE [8]

A. For Drill Spindle 1 and 2 (Ø5)

Work material= Grey Cast Iron

1) Selection of speed of spindles (N) in R.P.M.

The recommended cutting speed is between 20m/min to 23m/min. Taking mean cutting speed Vmean=21 m/min.

$$V = \frac{\pi \times D \times N}{1000}$$

Where, N = revolution / min

D= diameter of drill

$$21 = \frac{\pi \times 5 \times N}{1000}$$

Spindle speed= N = 1336.9 r.p.m.

2) The next part is to select the suitable feed (S).

For the Grey Cast Iron range of feed,

S = 0.05-0.13 mm/rev

Mean feed (S) = 0.09mm/rev.

Approximately, 0.1 mm/rev.

3) Material factor (k) for Grey Cast Iron is 1.5-2.03.

Taking the material factor as k = 2.03

4) Calculation the power and force on the machine spindle.

Power at spindle P (kW)

$$P = \frac{1.25 \times D^2 \times k \times N\,(0.056 + 1.5\,S)}{10^5}$$

Where, k = material factor

s = feed

$$P = \frac{1.25 \times 5^2 \times 2.03 \times 1336.9 \times (0.056 + 1.5 \text{ x } 0.1)}{10^5}$$

$$= 0.1747\ kW = 0.234 \text{ hp}$$

For total 2 holes, $P = 2 \times .1747 = 0.3494\ kW$

$$= 0.468\ hp$$

5) Calculation of torque (Ts) on the spindle

$$\text{Ts} = \frac{975 \times \text{P1}}{\text{N}}$$

Where, N = revolution/min

$$Ts = \frac{975 \times 0.1747 \times 9.81}{1336.9}$$

Ts = 1.2499 N-m = 1249.9 N-mm.

6) *Calculation of the thrust force on the spindle*

Axial thrust on single drill spindle,

$$Th = 1.16 \times k \times D \times (100 \times S)^{0.85}$$

$$Th = 1.16 \times 2.03 \times 5 \times (100x0.1)^{0.85} \times 9.81\ N$$

$$Th = 817.698\ \text{N}$$

B. *For tapping spindle 1 and 2 (M6x1)*

Work material= Grey Cast Iron

1) *Selection of speed of spindles (N) in r.p.m*

The recommended cutting speed is between 12 m/min to 9 m/min. Taking mean cutting speed Vmean =10.5 m/min

$$Vmean = \frac{\pi \times D \times N}{1000}$$

Where, N = revolution / min

D= diameter of drill

$$12 = \frac{\pi \times 6 \times N}{1000}$$

Spindle speed= $Nmean$ = 557 r.p.m

2) *Thread pitch = 1mm*

3) *Material factor (k) for Grey Cast Iron is 1.5-2.03.*

Taking the material factor as k = 1.77

4) *Calculate the power and force on the machine spindle*

Power at spindle P (kW),

90% thread engagement,

$$P = \frac{0.433 \times D \times p\hat{}2 \times N \times K}{10^4} = \frac{0.433 \times 6 \times 1\hat{}2 \times 557 \times 2.03}{10^4}$$

$$= \frac{0.433 \times 6 \times 1\hat{}2 \times 557 \times 2.03}{10^4}$$

$$P = 0.294\ kW = 0.394\ hp$$

For total 2 taps, $P = 2 \times 0.294 = 0.588\ kW$=0.788 hp

5) *Calculation of torque (Ts) on the spindle,*

$$Ts = \frac{975 \times P}{N}$$

$$Ts = \frac{975 \times 0.294 \times 9.81}{557}$$

Ts = 5.049 N-m = 5049 N-mm

IV. Manufacturing

Both the drilling and tapping heads require various components, like gear box, main spindle gear, drive gears, idler gears, drilling and tapping spindles etc. Different types of machines are used to manufacture these components.

A. *Case Study*

Consider drilling drive gear of material EN24. The size of raw material is Ø56x24 mm.

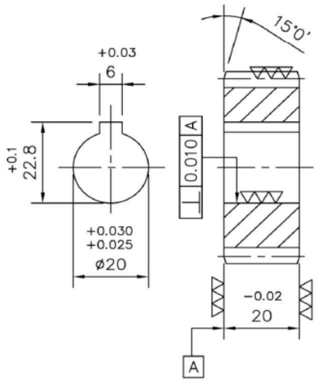

Fig. 6: Drawing of drive gear (drilling)

The process sheet for drilling drive gear is given in table 1.

Process No.	Operation Details	Machine Used
1	Cut the bar to the raw material size	Power hacksaw machine
2	Hold in the chuck, facing to remove 2mm material	Lathe machine
3	Turning Ø52x12mm length	Lathe machine
4	Boring Ø19.8 through	Lathe machine
5	Chamfering	Lathe machine
6	Reverse the component, hold in chuck to control length 20mm	Lathe machine
7	Turning Ø52 to remaining length	Lathe machine
8	Chamfering	Lathe machine
9	Internal key way 6x2.8 through	Slotting machine
10	Teeth cutting	Gear hobbing machine
11	Hardening hardness 45-50 HRC	-
12	Internal grinding Ø20	Internal grinding m/c
13	Teeth grinding	Gear grinding m/c
14	Remove burr & sharp corners	-

Table 1: Process sheet for drilling drive gear

V. Working of SPM

The technical and economic justification of utilization of these SPM should be made before any attempt to design and manufacture them. Proper determination of sequence of operation is very important in successful utilization SPM. It is possible to overlap and perform a number of operations in a single setup by minimizing machining times and costs with improving quality production[7]. The cycle time study for conventional radial drilling and tapping machine is as given in table I.

Process No.	Process	Observed time (seconds)
1	Loading & clamping of component	10
2	Drilling operation for one hole	36
3	Unloading of component	5
4	Idle time for transferring job to another drilling machine	3
5	Time required to perform process 1 to 3 on second drilling machine	51
6	Idle time for transferring job to tapping machine	3
7	Loading & clamping of component	10
8	Tapping operation for one hole	24
9	Unloading of component	5
10	Idle time for transferring job to another tapping machine	3
11	Time to perform process 7 to 9 on second drilling machine	39
Total cycle time		189

Table 2: Time study for component as per old process

The unit A (Ø5 drilling for two holes) and UNIT B (M6x1 tapping for two holes) are used to perform drilling and tapping operations simultaneously. In actual running condition of SPM, drilling and tapping operations are performed simultaneously. The loading and unloading of component is done during machining operations. Therefore time required for loading and unloading are not considered in total cycle time. The job indexing time is 4 seconds. The job clamping time is 3 seconds. The time required for all operations is 34.14 seconds. The job unclamping time is 3 seconds. Then the total cycle time is 44.14 seconds. The cycle time study for newly developed SPM is as given table II.

Process No.	Process	Observed time (seconds)
1	Indexing of component	4
2	Clamping of component	3
3	Drilling and tapping operations for two holes	34.14
4	De-clamping of component	3
Total cycle time		44.14

Table 3: Time study for component as per new process

The cycle time and productivity comparison between old process and new process is as given in tables below.

Standard time per component as per old process	Standard time per component as per new process	% time saved
189 seconds	44.14 seconds	76.65

Table 4: Cycle time comparison

Number of components per shift as per older machining process	Number of components per shift by using newly developed SPM	% Time saved
152	652	428.95

Table 5: Productivity comparison

The benefits of SPM are as given below.

1) The time required for component loading and unloading is saved.
2) Due to optimization of cycle time productivity improvement is done.
3) Because of less human interaction during process results into less operator fatigue
4) The processes are fully automated therefore rejection of component is reduced.

VI. Conclusion

The few conclusions are based performance of newly developed SPM are as follows:

1) Due to reduced cycle time, rate production increased with improved quality. In new improved machining method time saved is almost 76.65 %.
2) The cost per component is reduced.
3) The rejection level in older method was higher than new method therefore cost of rejection was reduced.

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