

Productivity Improvement on a CNC Lathe by Automatic Loading and Unloading of Throttle Valve Component

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Abstract— Industrial Automation is a broad field among other engineering disciplines. The major activities of Automation stem from manufacturing industries and include cycle time improvement, productivity improvement, cost reduction, efficiency improvement, materials handling, analyze and improve the work methods, to eliminate waste and proper allocation and utilization of resources. Automation in a manufacturing shop is one of the most challenging tasks, as it has an impact of many interrelated variables and parameters. A detailed study by large data acquisition and analysis is essential for understanding the trends in productivity improvement. Productivity improvement is achieved through analyzing the current method by eliminating unnecessary movements, reducing cycle time and providing appropriate solutions to various problems during the machining of components to improve productivity. The project titled “**Productivity Improvement on a CNC Lathe by Automatic Loading and Unloading of Throttle Valve Component**” includes analysis and detailed study of manufacturing process including loading and unloading methods of components on a machine. This project involves the use of automation techniques namely pneumatics automation to increase the productivity and efficiency. Present work aims at improving the productivity of throttle valve components on a CNC turning centre. Here emphasis is placed upon improving the existing time consuming methods. An effort is made to bring down the total cycle time.

Keywords: Industrial Automation, Cycle time, productivity, efficiency, cost reduction, pneumatics automation, loading and unloading methods.



1 INTRODUCTION

Present techno economic scenario is marked by increasing competition in almost every sector of economy. The expectations of the customers are on rise and the manufacturers have to design, and produce goods in as many varieties as possible to cater to demands of the customers. Thus there is a challenge before the industries to manufacture goods of right quality and quantity at right time and at minimum cost for their survival and growth. This demands the increase in productive efficiency of the organization. Automation techniques play a pivotal role in increasing the productivity. Various automation techniques are used to analyze and improve the work methods, to eliminate waste and proper allocation and utilization of resources. Automation is concerned with the development, improvement, implementation and evaluation of integrated systems of people, knowledge, equipment, energy, material and process. Automation draws upon the principles and methods of engineering analysis and synthesis, as well as mathematical, physical sciences together with the principles and methods of engineering analysis and design to specify, predict and evaluate the results to be obtained from such systems. Engineers work to eliminate wastes of time, money, material, energy and other resources. Automation is an engineering approach to the detailed analysis of the use and cost of the resources of an organization. The objective of increasing productivity, reducing time, reducing cost and improvement in efficiency can be achieved using Automation Techniques. The

philosophy and motivation of the Automation profession is to find the most efficient and effective methods, procedures, and processes for an operating system, and to seek continuous improvement. Thus, automation helps companies grow and expand

2 PROBLEM DEFINATION

SPM Tools, Ichalkaranji, has been serving a wide spectrum of Indian Industries for the past few decades. SPM Tools has developed wide range of CNC and Special purpose machines for different applications with a strong presence in the domestic market. SPM Tools has now moved on to compete in the market in line with its vision to move ahead with continual improvement in its product quality maintaining its highly competitive price.

A recent survey could reveal that there is a scope for productivity improvement by using these machines by using some automation techniques at much lower rates. The various operations, loading, and unloading methods were studied and the following problems were identified

- Sequence of performing the operations was not proper.
- Production rate was meeting by taking extra machines.
- Labor fatigue was more.

- Cycle time was higher because of manual loading and unloading of the components.
- Cutting time was higher because of turret indexing.

3 PROBLEM APPROACH

SPM Tools produce several assemblies of various machines which include CNC, VMC, and Broaching Machines etc. This paper concerns product KWAG throttle valve which is produced on Safal Turn 4 CNC machine. There are eight types of throttle valve components with different demand from the customer.

Throttle valve is the fast moving component in Climax Enterprises. Various sized throttle valves are routed through several machines. Throttle valve component has four operations on one side namely facing, chamfering, drilling, and grooving. These all operations are carried out on CNC Turning centre (Safal 4 make). The monthly requirement of this component is 3, 00,000 pieces.

The machine has an eight station turret on which three tools are posted. The various tools used are: Carbide form tool for grooving, Carbide form Tool of 6mm for facing and Combination drill of size 3.06mm/3.20mm.

The loading and unloading of these components is done manually.

3.1 Existing Scenario

To meet the required demand, company is using Safal 4 and Safal 5 CNC machines. These machines operate for two shifts per day of 8 hours each. Company operates 26 days per month.

3.2 Cycle Time for Each Component

Time required to complete one component on CNC machine is calculated and it is tabulated in table 3.1. Taking that as ideal cycle time, ideal production rates are calculated. By considering operators overall efficiency the actual production rate is also calculated

TABLE1
CYCLE TIME CALCULATION

Sr No	Operation Name	Time in Sec	RPM	Cutting Length mm	Feed mm/r ev
1	GROOVING		1900	5.3	0.06
	Loading	3			
	Spindle Start	1.4			
	Home to App	0.4			
	Cutting	2.7			
	Home	0.4			
	Spindle Increase	0.8			
2	FACING		3800	17.6	0.075
	Tool change	0.5			
	Approach	0.4			
	Cutting	3.6			
	Home	0.4			
	Spindle decrease	0.4			
3	DRILLING		3000	8.9	0.054
	Tool Change	0.5			
	Approach	0.4			
	Cutting	3.3			
	Home	0.4			
	Indexing	0.8			
	Spindle Stop	1.7			
	Unloading	3			
Total Cycle Time		24.1			

components/shift.

For two shifts, the production rate on each machine is $1280 \times 2 = 2400$ components/day.

Monthly production rate of each machine is $2400 \times 26 = 62,400$ components per month.

Required demand is 3, 00,000 components per month. Therefore total no. of machines required are $3, 00,000/62,400 = 4.8$ i.e. 5 machines.

Therefore 5 machines can produce $2400 \times 5 \times 26 = 3, 12,000$ components per month

Total no of operators required per day is 10 (for two shifts, on 5 machines)

3.4 Actual Production Rate

The production rate is highest during the early hours of each shift. This is because the operator is fresh and has highest efficiency.

Considering operator's overall efficiency to be 85%, the per hour actual production rate becomes

$150 \times 0.85 = 128$ components.

Per shift production rate is $128 \times 8 = 1024$ components

Per hour Production rate on each machine is $3600/24.1 = 150$ components/hour.

Per shift production rate on each machine is $150 \times 8 = 1200$

Per day production rate is $1024 \times 2 = 2048$ components.

On 5 machines, the production rate is $2048 \times 5 = 10,240$ components.

Monthly production rate is $10,240 \times 26 = 2,62,240$ components

The company is falling short by 33,760 components to meet the required demand.

To fulfill this demand company has installed sixth machine.

Because of which production rate achieved is 3,19,488 components per month. The installation of sixth machine has added two more operators. So the total no. of operators required is 12 to fulfill the demand.

3.2 Observations

The existing study shows the different operations that are to be carried out on throttle valve component and associated time calculations. It is observed that tool indexing time is bit high. It is analyzed as follows.

- i) Tool has to travel from its home position to cutting position
- ii) Tool has to approach the job
- iii) Tool has to perform the cutting
- iv) Tool has to retract
- v) Tool change for next operation
A significant amount of time is wasted in tool indexing.

Since loading and unloading operations are done manually on the machine the time required to perform those operations may also vary. This is because the operator cannot perform the task with same frequency all the time. So there is a scope for development of such a method which can reduce the efforts of operator by keeping the loading and unloading time constant all the time.

From the study of existing scenario it is seen that the company is not meeting its monthly demand. The company is making use of extra machines and operators. To fulfill the demand company is taking extra time which is not feasible. It is adding extra cost to the company. The detailed study of cycle time and loading and unloading methods it seen that there is a scope for improvement of productivity. The total cycle time can be brought down.

Table 1 shows total cycle time in detail. Based on this table current production rate is calculated and it is found that company is not meeting the required demand. Still there is a scope for bringing this cycle time down.

3.3 Development of Loading Unloading System

Pneumatic type of automation is selected for the development of automatic loading and unloading method. The main reason behind selecting pneumatic system over hydraulics is liquids exhibit greater inertia than do gases. Therefore, in hydraulic systems the weight of oil is a potential problem when accelerating and decelerating actuators and when sud-

denly opening and closing valves. Liquids also exhibit greater viscosity than do gases. This results in larger frictional pressure. Since the weight of the component is only 30 grams the pressure required to handle the component is less. For this application, pneumatics is much more suited since it is fast in actuating and deactivating and economical compared to hydraulic systems.

3.4 Selection of Important Pneumatic Components

a) Separator

From Festo Catalogue

- a) Conditions at conveyor usage
- b) Movement of Components : By Gravity
- c) No. of parts on the tray, n: 22
- d) Weight of each part, m : 30 grams
- e) Angle, a : 13
- f) Distance between the fingers, h : 18.24 mm (Diameter of the job)

The selection of angle is a critical parameter. The ideal condition would be zero degrees. With zero degree, some external force is required to push the components into the chute. Therefore the tray has to be inclined at some angle so that gravitational force should help in moving the jobs into the chute. If the inclination is more, load coming on the separator will also be more. On the other hand, if the inclination is too less then also parts cannot slide. This is because the job is having some burrs. Due to this parts cannot slide that easily. The inclination is obtained by trial and error method. At a certain angle these parts move very easily without any obstacles. The angle obtained by trial and error method is 13° .

- g) Geometry of the feed separator:
- h) Horizontal distance between part and reference line, L : 57.5 mm
- i) Vertical distance between part and reference line, R : 0 mm
- j) Pressure, p : 4 bars
Based on these inputs software provides us different type of separators available and which one is suitable for the mentioned working condition.

The Separator selected is **HPV-14-20-A**

b) Gripper

Selection of the gripper with respect to weight of the component:

Although conditions differ according to the work piece shape and the coefficient of friction between the attachments and the work piece, select a model that can provide a gripping force of 10 to 20 times the work piece weight, or more. If high acceleration, deceleration or impact forces are encountered during motion, a further margin of safety should be considered.

Now let us assume the gripping force to be at least 20 times the work piece weight.

The weight of the work piece is = 30gm = 0.030kg

Required gripping force,

$$F = 0.030 \text{ kg} \times 20 \times 9.8 \text{ m/s}^2 = 5.88 \text{ N}$$

Thus minimum gripping force on the work piece = 5.88 N

From FESTO Product Catalogue

- a) Information about object and gripper finger
 - b) Application : Gripping without eccentricity
 - c) Information about the object:
 - d) Distance 0-line -> centre of gravity: 47 mm
 - e) Weight of the object: 30 grams
 - f) Required stroke: 5 mm
 - g) Data for a single gripper finger:
 - h) Weight of one finger gripper: $\frac{2.5 \times 1.3 \times 1.3 \times 2.7}{1000} = 11$ grams
 - i) Distance 0-line -> centre of gravity: 13 mm
 - j) Distance 0-line -> gripping point: 47 mm
 - k) Acceleration in: Z direction
 - l) Maximum linear acceleration: 1 m/s²
 - m) Mounting position
 - n) Gripper position: Horizontal
 - o) Gripping direction: Closing
 - p) Gripping with: Positive engagement
 - q) Gripping inclination: 30°
 - r) Working pressure: 4 bars
 - s) Co efficient of friction: 0.25
 - t) Safety factor: 1.5
 - u) Device temperature: 30° C
- The Gripper selected is **HGR-1-A** radial gripper.

c) Cylinder

The selection of pneumatic cylinder is done based the following analysis.

We know that,

Force = Pressure x Area

Area = (Force/ Pressure) x Factor of safety

$$\left(\frac{\pi}{4}\right) \times d^2 = \frac{(0.030/4) \times 2}{1}$$

$$d^2 = \frac{(2 \times 4 \times 0.030)}{4 \times \pi}$$

$$d = 0.138 \text{ cm}$$

$$d = 1.38 \text{ mm}$$

Required Piston Rod Diameter = 1.38mm

Therefore, we have to select cylinder with minimum available diameter i.e 25 mm. The selected cylinder is **ADVUP-25-A-P-A85Z1-115Z2**.

3.5 Circuit Diagrams

a) For Cylinder

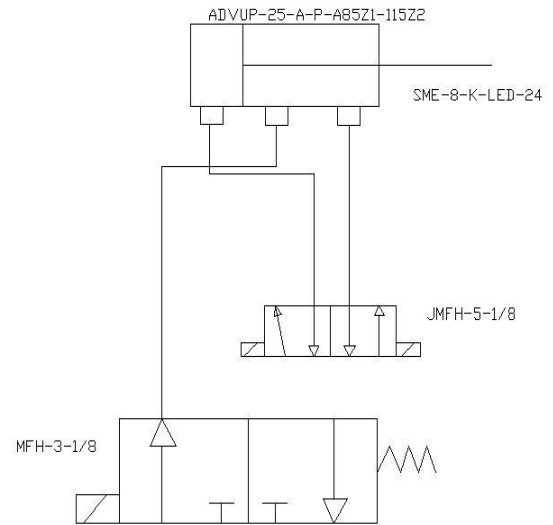


Fig 1 Cylinder Working

b) For Gripper

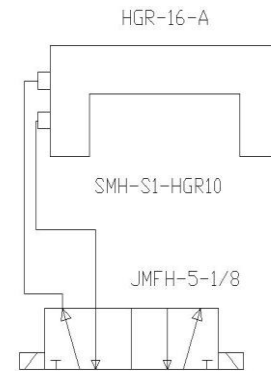


Fig 2 Gripper Working

c) For Separator

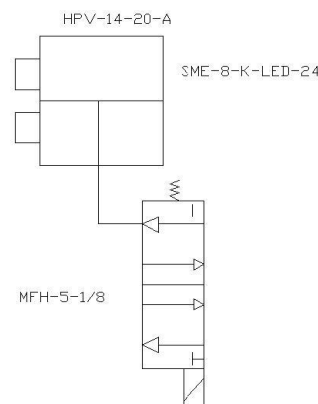


Fig 3 Separator Working

3.6 Linear Tooling Arrangement

It is seen from the table 4.5.1 a significant amount of time is consumed in tool indexing when a turret is used. The turret used in Safal 4 Turning centre can accommodate 8 tools. The process of metal cutting is as follows. Tool from its home position comes near the work piece i.e. tool index. Then the tool approaches the work piece. Then it performs the cutting

operation. Once cutting has been taken place the tool retracts back. Then spindle stops. The next tool for next operation is indexed. To perform operations there has to be three times indexing.

On throttle valve component the number of operations those have to be performed are fixed. Therefore the tool movement can be done linear instead of circular indexing type. In linear tooling arrangement tools are placed on a block in a straight line as shown in figure 4.9.1. This makes the tool advancement and retraction quick. A significant amount of time can be saved which is lost in tool indexing.

The advantages of linear tooling arrangement are as follows:

- i) Cycle time drastically comes down. Since the cycle time goes down, productivity obviously improves. From cycle time calculations it is seen that by using turret type of tool indexing total cutting time was 9.6 seconds (2.7 sec for grooving, 3.6 sec for facing, 3.3 sec for drilling). Total cycle time including tool change time, tool approach time, tool retract time was 24.1 seconds. By making use of the linear tooling arrangement the tool approach time, tool indexing time can be brought down.
- ii) Increased efficiency.
- iii) Weight on the machine reduced. The total weight of the turret used in Safal 4 turning centre was 40 kilo grams. This heavy weight leads to some inertia problems. The weight of linear tooling system along with the sleeves is only 4 kilo grams.
- iv) Improvement in the quality of the product.
- v) Easy maintenance. Turret type of tool indexing has its own maintenance problems. The turret used in Safal 4 was PRAGATI BTP-6. It has 18 oil seals which have to be replaced when they get damaged. Also turret oil has to be replaced after every six months. The turret torque motor has to be replaced after every three months. If any short circuit takes place it has to be rewind.
- vi) Skilled operator not required. If any breakdown takes place to identify that a skilled person is needed when turret is used. Unless and until the problem is attended machine is kept off. That is not a case with linear tooling arrangement.

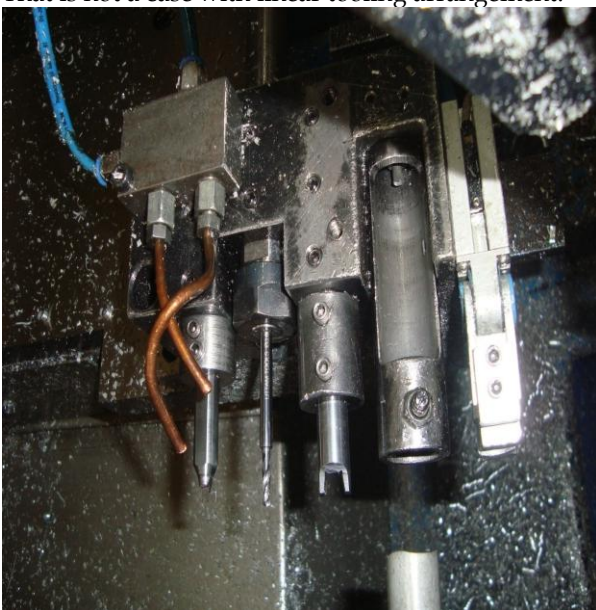


Fig 4 Linear Tooling Arrangements

3.7 Working

The complete assembly is as shown in the figure 4. The working of the system is as follows. The components are loaded in the chute. The chute is inclined at an angle. The parts move by gravity force. The chute guides the components into loading tube. The loading tube houses these components. One end of the cylinder is connected to the loading tube. The cylinder used here is multi-stroke cylinder. Total stroke length is 115mm. It is divided into two strokes. In the first stroke piston moves to 85 mm and in the second stroke it moves 30 mm. In first stroke it pushes the component to 85 mm. It means the component just comes out of the loading tube. In second stroke the component moves further 30mm. During this stroke the component is admitted into the chuck. Separator blades holds the components and discharges one by one into the loading tube. Once the part gets machined the pneumatic gripper holds the machined component and unloads it from chuck and finally drops it down.

A new program has been developed for linear tooling with little modifications to old program.



Fig 4 Automatic Loading and Unloading system

4 RESULTS

TABLE NEW CYCLE TIME

SR No	Operation Name	Time in Sec	RPM	Feed mm/r ev	Cutting Length
1	GROOVING		3500	0.084	5.3 mm
	Cutting Time	0.92			
	Spindle Start Approach	1.08			
	Approach	-			
	Retract	0.24			
	Spindle stop Indexing	-			
	Tool index	0.6			
Total Time		2.84			
2	FACING		4600	0.18	17.6 mm
	Cutting Time	1.28			
	Spindle Start Approach	-			
	Approach	0.4			
	Retract	0.2			
	Spindle stop Indexing	-			
	Tool index	0.64			
Total Time		2.52			
3	DRILLING		4200	0.08	8.9 mm
	Cutting Time	1.58			
	Spindle Start Approach	-			
	Approach	0.5			
	Retract	0.24			
	Spindle stop Indexing	2.03			
	Tool index	-			
Total Time		4.35			
4	Loading and Unloading	6			
Total Cycle Time		15.71			

From above table the ideal production rate is calculated as follows

Per hour Production rate on each machine is $3600/15.71 = 225$ components/hour.

Per shift production rate on each machine is $225 \times 8 = 1800$ components/shift.

For two shifts, the production rate on each machine is $1800 \times 2 = 3600$ components/day.

Monthly production rate of each machine is $3600 \times 26 = 93600$ components per month.

Required demand is 3, 00,000 components per month. Therefore total no. of machines required are $3, 00,000/93600 = 3.2$ i.e. 4 machines.

Therefore 4 machines can produce $3600 \times 4 \times 26 = 3, 74,400$ components per month

Total no of operators required per day is 8 (for two shifts, on 4 machines)

Since loading and unloading are done automatically, loading and unloading time remains constant. Also linear tooling arrangement drastically reduced the cutting time. Operator only has to load the parts into the chute. It hardly requires any effort. Considering operator's overall efficiency to be 95%, the per hour actual production rate becomes $225 \times 0.95 = 213$ components.

Per shift production rate is $213 \times 8 = 1704$ components

Per day production rate is $1704 \times 2 = 3408$ components.

On 5 machines, the production rate is $3408 \times 4 = 13,632$ components.

Monthly production rate is $13,632 \times 26 = 3, 54,432$ components.

PROFIT TO THE COMPANY

Earlier 12 operators were required to fulfill the demand.

Operator wages are as follows: Rupees 4500 per month per operator.

For 12 operators, $12 \times 4500 = 54,000$ Rupees per month

For one year, $12 \times 54,000 = 6, 48,000$ Rupees

Since loading and unloading is done automatically, operator only has to feed the parts on chute. Therefore two machines can be easily handled by one single operator. Hence total number of operators required is 4.

But now company requires only 4 operators to fulfill the demand. Therefore annual salary of 4 operators = $4500 \times 4 \times 12 = 2, 16,000$. Rupees

Net savings to the company $6, 48,000 - 2, 16,000 = 4, 32,000$ Rupees per year.

5 CONCLUSIONS

Development of automatic loading and unloading methods along with linear tooling arrangement in the manufacturing of throttle valve components resulted in streamlining of the activities by employing the appropriate sequence for the machining throttle valves. The total cycle time is minimized.

For KWAG type throttle valves, by using the proposed method, the total cycle time gets reduced to 15.71 seconds. Hence by using automatic loading and unloading methods along with linear tooling arrangements the unproductive elements can be eliminated. Also the use of additional labors can be minimized since a single operator can handle two machines.

For all kinds of throttle valves, by using the proposed method of automatic loading and unloading with linear tooling arrangement, the total cycle time can be reduced. Since the efficiency of all the operators will increase, it results into increased productivity. Operator fatigue is minimized. Annually Rs. 4, 32,000 of labor cost can be saved.

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