

# Design and Implementation of Control System for Double End Tube Chamfering Machine

Salunke N. S<sup>#</sup>, Kulkarni S. A. <sup>#</sup> Rajankar S.O.\*

<sup>#</sup>Mechanical Engineering Department,

\*Electronics and Telecommunication Engineering Department, Sinhgad College of Engineering, Vadgaon, Pune

**Abstract:** *The design of control system for double end tube-chamfering machine based on programmable logic controller (PLC) is described in this paper. Chamfering operation is an important process after machining for almost all machined workpiece to control products appearance and function. The control system plays a key role in the development of special purpose machines. The work comprises design, assembly and testing of control system for double end tube chamfering operation. It consists of tool feeding, job loading and clamping mechanisms which are to be driven by PLC controlled actuators. From the tests on the machine it is found that there is considerable improvement in production efficiency as well the quality of product. Also, manual intervention for loading the job and feeding the tool is reduced to a great extent as compared to conventional machine and the machine can be used as production machine for mass production. The software used for MicroLogix 1000 PLC controller is RSLinx and RSLOGIX.*

## 1. INTRODUCTION

The finishing operation is a critical step in the manufacturing of parts manufactured from metals. After a part has been machined, a finishing operation is usually required to remove excess material or burrs to bring the part within tolerance of the specification. The primary finishing processes are deburring and chamfering. In the past and still presently the finishing operation has been performed manually at a burr bench with a hand held spindle grinder. This hand-crafting of parts tends to be expensive, inconsistent and inaccurate. Manual finishing can account for 10%–20% of the total labor cost and approximately 10%–30% of the manufactured parts need rework after the manual finishing process. Automation of the finishing process would prove to be very beneficial. By automating the finishing and chamfering processes, tolerances could be held to less than 0.08 mm (0.003 in), the finishing costs could be reduced as much as 50%, and the rework rates could be nearly eliminated. From metal working to wood working, various industries use a cut to

remove the 90 degree edge on material. These small cuts, typically 45 degrees, are called a chamfer. Another term often used is bevel. There are numerous uses for a chamfer as well as various methods for achieving it. Chamfer is a beveled edge connecting two surfaces. If the surfaces are at right angles, the chamfer will typically be symmetrical at 45 degrees.

## 2. MACHINE HARDWARE

The machine typically consists of four major hardware assemblies and controller for controlling these assemblies. Those are 1) Assembly for feeding the job 2) assembly for holding the job. 3) Assembly for holding and feeding the tool to produce relative movement between the tube and tool. Apart from this machine is having an element like a) structure which is formed by bed, column and frame. The strength and rigidity of the machine tool are provided of designing the structure suitably. b) Slides and guide ways to facilitate the various moments of machine during the process. 1500 X 400 X 400 mm base frame accommodates all these subassemblies. All these subassemblies are explained in detail in the following articles.

### 2.1 Mechanism for Tool Holding and Feeding

A tool mounted chuck is located in the front of the assembly which is driven by 2 HP 3 PH induction motor. Chuck is mounted on the center shaft. Power is given to tool holding chuck by motor which is connected to centre shaft by means of V belt pulley. Speed of the motor is 1440 rpm whereas the cutting speed is 95 m /min. speed reduction is 1.5:1 achieved by V-belt pulley. The chuck power assembly is mounted on the slides. These slides move longitudinally along the bed. This gives feed motion to the tool. This feed mechanism is driven by hydraulic cylinder 150 mm stroke length. Start and stop of the stroke can be adjusted by limit switch and stopper mounted at front and rear side of the assembly respectively. The same mechanism is mounted at other end of the machine. The mechanism is shown in fig 3.1

## 2.2 Tube Loading Mechanism

Gravity feed mechanism is used to feed the tube. A tray inclined at 10° angle used to load the tubes manually. Tray size is slightly more than tubes. Operator can load 15 to 20 tubes at a time. Loading capacity can be maximized by increasing the tray length. At the end of feeder, there is front plate and resting plates are fixed. These plates support the tubes and guide them to feed vertically downward to the clamps. Clamps are made up of two vices called die half 1 and die half 2. Jaws of the vices clamp and hold the tubes during the chamfering process. The specially made vice unload the tube automatically after completion of the operation at the bottom of the machine stored in the bin kept under the machine. The vice centre and machine centre are aligned together such that chamfering will start only after chuck centre and tube centre are in one line.

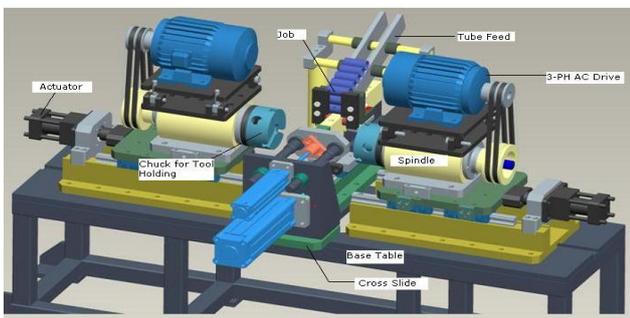


Fig1. Model of Tube chamfering machine



Fig2. Actual Machine set-up

## 3. CONTROL SYSTEM DESIGN

The concepts of controlling a control system are a very simple and easy task. It involves a systematic approach by following the operation procedure.

### 1. Determine the Machine Sequence of Operation

Firstly, you have to decide what equipment or system you want to control. The ultimate purpose of the

programmable controller is to control an external system. This system to be controlled can be machine equipment, or process and is often generically called the controlled system. The movement of the controlled system is constantly monitored by the input devices that give a specified condition and send a signal to the programmable controller. In response, the programmable controller outputs a signal to the external output devices which actually controls the movement of the controlled system as specified and thus achieves the extended control action. In simplicity, you need to determine the sequence of the operation by drawing out the flowchart.

### 2. Assignment of Inputs and Outputs Secondly,

All external input and output devices to be connected to the programmable controllers must be determined. The input devices are the various switches, senses, etc. The output devices are the solenoids, electromagnetic valves, motor, inductors etc. After identifying all the various INPUT and OUTPUT devices, assigned the numbers corresponding to the INPUT and OUTPUT number of the particular programmable controller you will be using. The actual wiring will follow the numbers of the programmable controller. The assignment of INPUT and OUTPUT numbers must be carried out before writing the ladder diagram because the number dictate what is the precise meaning of the contacts in the ladder diagram.

### 3. Writing of the Program

Next, write the ladder diagram program by following the control system sequence of operation as determined by step one. Programming into Memory Now, you can apply power to the programmable controller. Depending on the type of programmable controller, you may have to do a I/O generation to prepare the system configuration. After that, you can enter your program in the memory either by programming console or by computer aided ladder software tool. After completion of the programming, you should check for any coding errors by means of diagnostic function, and if possible simulate the whole operation to see that it is alright.

### 4. Running the System

Before the start push-button is pressed, thoroughly ensure that the input and Output wiring are correctly connected according to the I/O Assignment. Once confirmed, the actual operation of the PLC can now be started. You may need to debug along the way and fine

tune the control system if necessary. Test run thoroughly until it is safe to operate by anyone.

#### 4. CONTROL SYSTEM SETUP

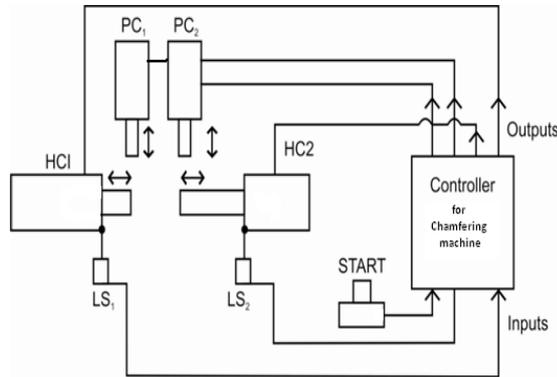


Fig3. Control system block diagram

Figure 5 shows simple process model of control system. Limit Switches LS1, LS2, push button for start etc are the inputs to the controller. The controller used is PLC controller. The controller processes the sequential logic in the program code and delivers the output. The outputs are two pneumatic cylinders PC1, PC2 and two hydraulic cylinders HC1, HC2. The system is designed for chamfering operations. HC1 and HC2 are used as slide drivers for spindle assembly. The slide motion is shown in figure with arrow. The slide moves linearly along the length of bed. Tube clamping assembly is driven by PC1 and PC2 mounted on cross slide. The cross slide brings the tube along the centre of the machine for chamfering operation. The motions of the hydraulic and pneumatic slides are perpendicular to each other. Controller processes the instructions in each rung and gives output.

#### 5. CONTROL CIRCUIT FOR PLC

The section focuses on power and control circuit for controller. It also include the input and output diagram for connections. Output Module shown in Figure 6. It shows PLC output module and its connections with hydraulic and pneumatic actuators and three phase induction motors. The PLC has 8 outputs from pin number 1 to 8. The PLC output voltage is 24 volt D.C. An eight channel relay card for isolation is used in the panel. This relay card works on 24 volt D.C. output pin number 1 is for auto mode. Pin number 2 and 3 is connected to limit switch LS1 and LS2. Pin 4 is for cycle start. Pin 5 and 6 are connected to solenoid valve PS<sub>1</sub> for double acting pneumatic cylinder 1. Pin number 7 and 8 are connected to solenoid valve PS<sub>2</sub> of double acting pneumatic cylinder 2. Output pin number 9 and 10 are

connected to solenoid valve HS<sub>1</sub> of hydraulic cylinder 1. Output pin number 11 and 12 are connected to solenoid valve HS<sub>2</sub> of double acting hydraulic cylinder 2. All these solenoid valves operate on single phase 230 volt, 50 HZ supply.

#### 6. PLC INPUT OUTPUT CONNECTION

Sinking -When active the output allows current to flow to a common ground. This is best selected when different voltages are supplied. Sourcing - When active, current flows from a supply, through the output device and to ground. This method is best used when all devices use a single supply voltage. This is also referred to as NPN (sinking) and PNP (sourcing). PNP is more popular. The PLC input, output connection diagram is shown in figure. A selector switch, connector, push button are the inputs for PLC. Whereas solenoid coils 1, 2, 3 are the output for PLC.

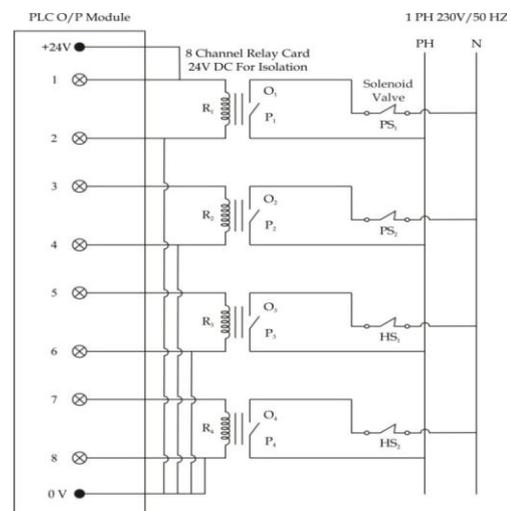


Fig4. PLC output module

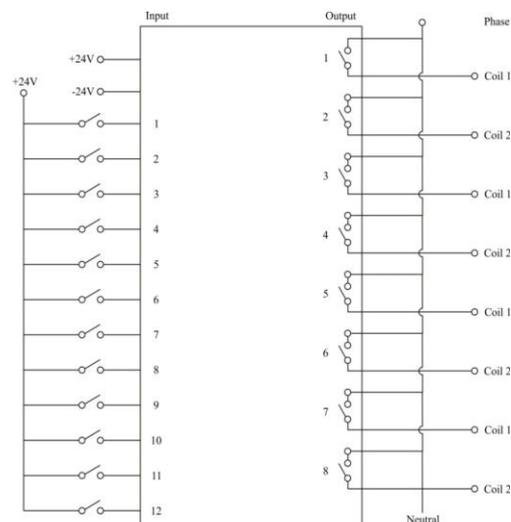


Fig5. PLC input output connection

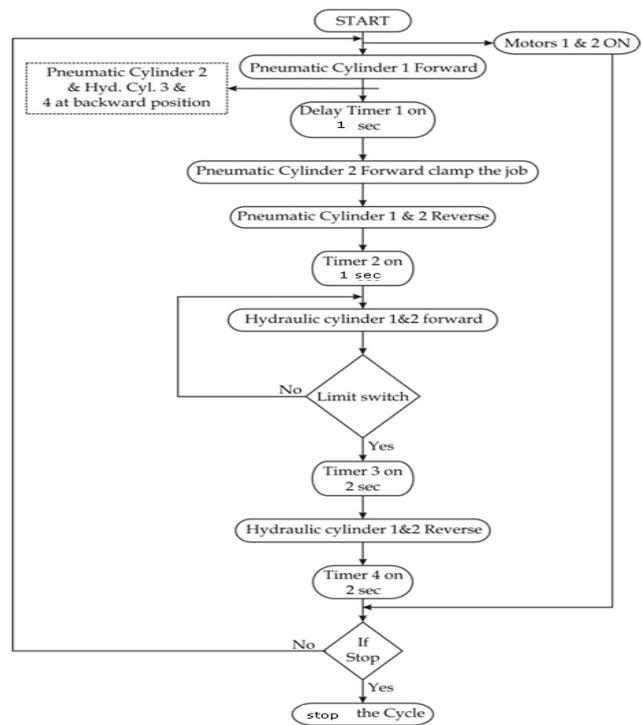
A PLC operator on +24 volt D.C. PLC input output connection diagram is shown in figure 4.3. A selector switch, connector, push buttons are the inputs for PLC. Also toggle type selector switch normally open type is given for manual control. Relay coils from 1 to 8 are the outputs from the PLC. In Input module pin number 1 is for power on, pin number 2 and 3 for limit switch 1 and 2. Pin number 4 is for cycle start. Pin number 5 is for selector switch for auto or manual cycle Pin 5 to 12 for cylinder 1, 2, 3, 4 respectively. Once the cycle is selected by Push button number 1 it shifts the cycle in auto mode. Limit switches LS<sub>1</sub> and LS<sub>2</sub> are connected pin number 2 and 3 and pin number 4 is cycle start button.

### 7. CONTROLLER SEQUENCE CYCLE AND FLOWCHART

Flow chart is shown in figure 8. In step 1 switch on the power for control panel for starting the machine and the various drives. Power circuit for controller will be on and at the same time two 3 phase induction motors used as a spindle drive will be on. In step 2, switch on the air pressure and oil pressure through FRL unit and set it to 5 bars for pneumatic drive and 0.6-0.8Mpa, 120ml/min for hydraulic drive.

In step 3, start the auto cycle, it will start the motor M<sub>1</sub> and M<sub>2</sub> on and pneumatic cylinder 1 forward stroke takes place. It will move the die half to clamp the job. In step 4 after delay of 1 second pneumatic cylinder 2 forward stroke takes place to move the other half of the die to clamp and hold the tube firmly for machining. In step 5, Pneumatic cylinder 1 and 2 reverse stroke takes place when hydraulic cylinder 3 and 4 are at backward position. This movement takes 200 mm stroke length. It will bring the job along the line of machining centre. In step 6, after 1 second hydraulic cylinder 1 and 2 forward stroke takes place. This will starts the motion of hydraulic slide operated by hydraulic power pack. The slide carries spindle drives and tool holding chuck. During the stroke tool is brought near to the workpiece and fed to it for chamfering.

In step 7 if the limit switch is on, the timer starts for 2 second. If not then cylinder stroke continue till the limit switch press on. Once the limit switch is pressed, timer starts and chamfering operation will be carried out. In step 8 after 2 second timer, hydraulic cylinder 1 to 2 reverse stroke takes place. This is the idle stroke where slide comes to its original position. Finally the job is unloaded into the tray kept under the machine. In step 9, cycles continues unless the stop button is pressed. This is the end of one cycle operation.



**Fig7. Flow Chart**

### PROGRAM CODE DESCRIPTION

In this section, ladder logic program for PLC Controller is developed. Each logical condition is explained with the help of individual rung. List of i/o used in the ladder diagram is given below.

#### 1) Inputs

- I : 0/0 – Cycle start
- I : 0/1 – Emergency start
- I : 0/2 – Auto mode

#### 2) Outputs

- O : 0/0 – Pnu. Cyl. 1 forward
- O : 0/1 – Pnu. Cyl. 2 forward
- O : 0/2 – Pnu. Cyl. 1 Reverse
- O : 0/3 – Pnu. Cyl. 2 Reverse
- O : 0/4 – Hyd.Cyl. 1 forward
- O : 0/5 – Hyd.Cyl. 2 forward
- O : 0/6 – Hyd.Cyl. 1 reverse
- O : 0/7 – Hyd.Cyl. 2 reverse

Complete program for double end tube chamfering machine is tested on and offline. In rung 00 when the cycle start button is pressed, and emergency button is off, the internal binary bit is on and it hold on.

In rung 01 if binary bit is on and auto button is on then pneumatic cylinder 1 forward stroke takes place. In rung 02 when binary bit is on, auto switch is on and third timer done bit is not available then timer 1 is start for 1 sec.. In rung 03 when timer 1 done bit is on and timer 2 done bit is not available pneumatic cylinder 2 forward stroke takes place.

In rung 04 when timer 1 done bit available and timer 4 done bit is not available then second timer is start for 1 sec.. In rung 05 when second timer done bit is on and third timer done bit is not off, then pneumatic cylinder 1 and 2 reverse stroke takes place. In rung 06 when timer 2 done bit is on and timer 4 done bit is off, third timer will be on. In rung 07 when third timer done bit is on and limit switch 1 is off, then hydraulic cylinder 1 forward stroke takes place and limit 2 is not on hydraulic cylinder 2 forward stroke takes place. In rung 08 when limit switch 1 and 2 are on then timer 4 is on for 2 sec. In rung 09 when timer 4 done bit is on hydraulic cylinder 1 and 2 reverse stroke takes place.

### 5.5 Controller Software

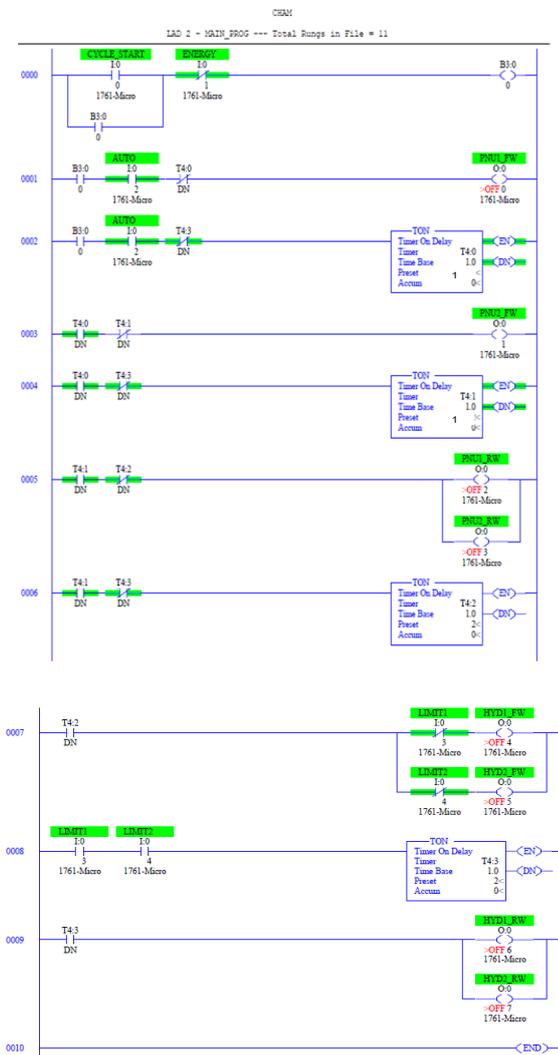
Differently from the way other computers run user-programs. A PLC operating system executes an initialization step once each time it is put into run mode, and then repeatedly makes the PLC executes a scan cycle .Operating System and Application Programs .The CPU module of a PLC comes with a very different system program than those used in most other computers, and comes complete with application programs programmed into the CPU's memory.

The operating system program causes the PLC to start when power is turned on, to run the user-program when the PLC is switched into run mode, and to respond to the user commands by running the appropriate application programs. The application programs allow the user to enter programs and data into the PLC's memory. Some Parts of the user accessible memory are retained even when the PLC's power is disconnected. A PLC retains its operating system, application programs, user programs, and some data in retentive memory (sometimes called nonvolatile memory) while the PLC is tuned off and even when disconnected from the power supply. A PLC can therefore resume running a user program as soon as power is restored, although PLCs are often programmed to require some operator action before restarting (for safety reasons).

The PLC operating system makes the PLC run user-programs very sequence as long as the PLC remains in run mode. Every time the PLC finishes one scan cycle and starts another, the operating system also restarts a watchdog timer. The watchdog timer runs while the scan cycle executes. If the watchdog timer reaches its pre-set value before being restarted (if a scan cycle takes unusually long to complete), the PLC will immediately fault, and stop running.

Setting up your MicroLogix:

- Go to the Comms -> Who Active Go Online dialog, and select the MicroLogix you wish to download to.
- Download your program and go online.
- Leaving the MicroLogix in remote run mode, close RSLogix 500.



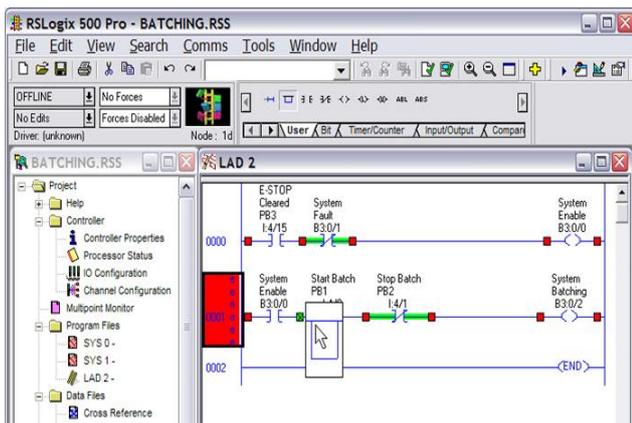


Fig8. Program window

### FEATURES OF PLC PROGRAMMING WITH RSLOGIX 500.

- One of the most popular SLCs in use today (including the SLC 5/01, SLC 5/02, SLC 5/03, SLC 5/04 and SLC 5/05) and a MicroLogix 1000 (which also uses RSLogix 500)
- shows you step by step how to make changes to the ladder logic online
- Save money and save time
- show you how to be comfortable programming a PLC with RSLogix
- teach you how Ladder Logic works in the Allen-Bradley SLC 500 series
- allow you to communicate intelligently with others regarding Allen-Bradley PLCs

### RESULTS

1. Test for chamfering accuracy is done on the machine for 100 jobs/tubes. Chamfering dimensions like length and angle are inspected by chamfering gauge. Theoretical values and actual values are compared.
2. Accuracy of SPM is within  $\pm 0.020$  which is marginally good one as compared to traditional lathe machine.
3. Tests are carried out for observation of production cycle time for randomly selected 10 jobs. The production cycle time calculated is then compared with manual method on lathe.
4. Tubes are inspected for chamfering angles. Designed angle tolerances are within  $\pm 5'$  of chamfered angle. Actual measurements for randomly selected 5 tubes are tabulated. The data

obtained shows that accuracy of chamfered angle are within the limits specified in the designed value.

5. The machine is tested for production cycle time. As per the order requirement is 5000 part per shift. Actual cycle time for five jobs are noted down and tabulated. The average actual cycle time is 6.2 sec. which can give production of 4750 parts per shift.
6. Also this rate of production is compared with the other similar processing machines like lathe and CNC operated lathe.
7. On conventional lathe machine the production average cycle time for one job is 4.33 min whereas CNC lathe gives average cycle time 20.4 sec. The SPM gives average cycle time 6.4 sec.

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