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DEVELOPMENT OF A LOW COST PC CONTROLLED LATHE AND IT'S OPERATION BY A CNC PROGRAMME

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ABSTRACT

With the entrance in new millennium, e-manufacturing has become one of the modern way of improving the quality and productivity in manufacturing industries. But now a days e-manufacturing hardwares like CNC milling, drilling are costly to be used in small workshops. This era needs more flexibility in product design. For that purpose industry needs low cost PC controlled based machinery. Objective of this work is to convert an existing manual low cost lathe for operating it with the help of PC. The designed machine has an open loop servo drive control system as there is no change in load conditions.The motor control circuit for the machine is designed on the principle that as the pulse rate increases, the speed of the motor increases and vice versa. Some of the Machine formats and programming formats are as follows: full floating zero, fixed block format, continuous path control system, incremental mode of listing the coordinate positions, and no restriction of giving dimensions (up to three decimal places). Programming format also contains absolute dimensioning mode, dimensions in millimeters, feed rate in mm/min.

INTRODUCTION

A machine tool is said to be numerically controlled if it operates in a semiautomatic or automatic cycle as per instructions transmitted to it in a coded form. The term "numerical control" is a misnomer, because the coded instructions are expressed not only through numerals, but also through letters, punctuation marks and other symbols. A comprehensive electrical, electronic and mechanical processing and transmission system is required to effect the movement of a slide or cutting tool from information coded on a program medium. Converted CNC lathe has an axis control in two directions, in cross and horizontal direction, controlled by servomotors by controlling the movements of saddle and cross slide while the spindle rotation isn't considered. In this lathe, the complete machining cycle involves the following motions:

1. Travel of the tool post in - X direction
2. Travel of the tool post in - Z direction
3. Travel of the tool post in + X direction
4. Travel of the tool post in + Z direction

BASIC PRINCIPLE OF CONVERSION

Power for driving a manual lathe comes from a single motor. On some machines, the motor is direct mounted, while on others, it is connected by means of a short belt, usually of the V-type. In the manual lathe that has to be converted, the motor is mounted under the head in the hollow machine base. For transformation of CNC lathe saddle and cross slide are detached from the drive motor and connected with two separate servomotors. Each motor will drive the saddle and motor independently.

When the program is run, it sends pulses to the printer port (Parallel port). An interface for each motor is connected to the port. Depending upon the number of pulses per second transmitted to the interface circuit, the interface controls the feed of the motors. These

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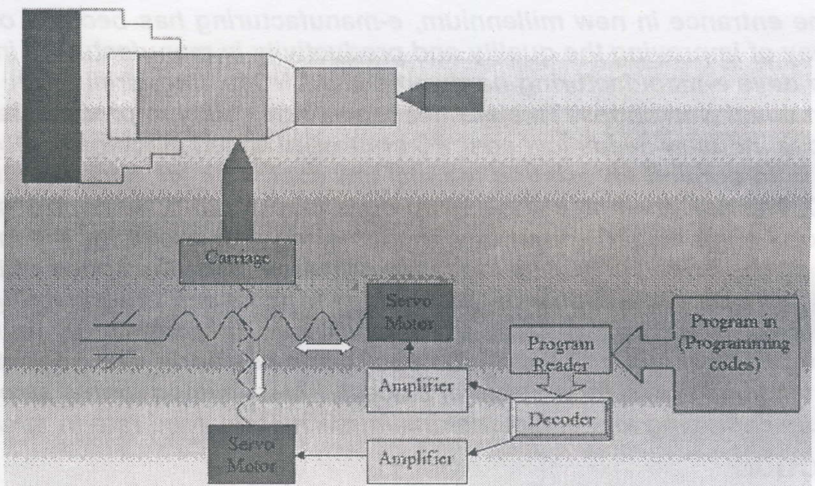
motors then control the cross slide and carriage to get the required movement. Since few codes were used in the software, the programming is rather simple and easy. If by mistake, any wrong code is given to the machine, it will not be considered for processing and will be ignored by the program. A simple line diagram of the process is shown in Figure 1.

Figure 1: Schematic representation of a open loop system in CNC lathe



CNC accepts information in the form of electronic signals passed to it through a program in coded form. This input data must be transformed by the CNC into specific output ports in terms of voltages, or pulses per second (PPS). The transformed data output is used to drive the motors to position the machine slides to the programmed positions. These slides or table drives are commonly known as servo drives. The principle function of CNC is the positioning of the tool or machine table in accordance with programmed data.

This designed machine has an open loop control system. Here, in this open loop servo drive control system the power supply level is set to a position for which the desired speed is indicated by the input. As the load on the machine slide varies, the servomotor speed would also be affected. However, the speed variance could not be sensed automatically because the system lacks feedback. For this reason, open loop control system can best be used in such a condition where there is no change in the load conditions. In this open loop servo system, the motor continues to run until the absence of power indicates that the programmed location has been attained and the driving mechanism is disengaged. Nevertheless, open loop control systems have been refined to 0.0025 mm resolution. The systems are reliable, considerably less expensive than closed loop systems, and their maintenance is far less complicated.

DESIGN OF RADIAL FEED MOTOR

Let for maximum cutting condition

Required power, W = 307 N, V = 60 mm/min, Pitch, p= 2.5 mm,

Lead screw diameter, d_o= 30 mm, Coefficient of friction, μ= 0.5

Then Mean diameter of lead screw, $d = d_o - (p/2)$

$= 30 - (2.5/2)$

$= 28.75$ mm $= 0.02875$m

$\tan \alpha = p/(\pi d) = 2.5/(\pi * 28.75) = 0.0277$

Where α =effective rake angle of tool as measured in a plane perpendicular to its cutting edge, deg.

Force required at the circumference of the screw,

$F = W [(\tan\alpha + \tan\Phi)/\{1 - (\tan\alpha.\tan\Phi)\}]$

$= 307*[(0.0277+0.5)/\{1-(0.0277*0.5)\}]$

$= 164.3$ N

Where Φ =shear angle; angle between shear plane and surface being generated, deg.

Torque required for the given feed, $T = F \times (d / 2)$

$= 164.3 \times (0.02875/2)$

$= 2.36$ N-m

Speed of the screw, N = (Speed of the nut/ Pitch of the screw)

$= 60/2.5 = 24$rpm

Angular speed, $w = (2\pi\ 24)/60 = 2.513$ radian / second

Power of the motor, $P = 2.36 \times 2.513 = 6$ W

This is the theoretical power required. The actual power required would be more because of the weight of the cross slide, efficiency of the gears and the safety factor. Hence the actual power required is

$P_{act} = P \times$ weight factor $\times$ (safety factor / efficiency)

$= 6 \times 1.5 \times (1.5/0.6) = 23$ W

DESIGN OF AXIAL FEED MOTOR

The axial feed is given through the saddle. The saddle has a gearbox with complex gear arrangement. It was difficult to calculate the power required using this arrangement. Hence, the same method as that of radial feed was used to calculate the power of motor for axial feed.

Let, for maximum cutting condition required

Power, W = 307 N, V = 60 mm/min, Pitch, p = 2.5 mm,

Lead screw diameter, d_o= 30 mm, Coefficient of friction, μ= 0.5

Then Mean diameter of lead screw, $d = d_o - (p/2)$

$= 30 - (2.5/2)$

$= 28.75$ mm $= 0.02875$m

$\tan \alpha = p/(\pi d) = 2.5/(\pi * 28.75) = 0.0277$

Where α = effective rake angle of tool measured in a plane per pendicular to its cutting edge, deg.

Force required at the circumference of the screw,

$F = W [(\tan\alpha + \tan\Phi)/\{1 - (\tan\alpha.\tan\Phi)\}]$

= 532*[(0.0277+0.5)/{1-(0.0277*0.5)}] = 285N

Where F = shear angle; angle between shear plane and surface being generated, deg

Torque required for the given feed, T = F x (d / 2)

= 285 x (0.02875/2)

= 4.1 N-m

Speed of the screw, N = (Speed of the nut/ Pitch of the screw)

= 60/2.5 = 24rpm

Angular speed, w = (2 π 24)/60 = 2.513 radian / second

Power of the motor, P = 4.1 x 2.513 = 11W

This is the theoretical power required. The actual power required is more because of the weight of the cross slide, efficiency of the gears and the safety factor. Hence the actual power required is

Pact = P x weight factor x (safety factor / efficiency)

= 11 x 2.5x (1.5/0.6) = 68 W

MOTOR SPECIFICATIONS

Due to uniformity of the designed motors in the market, the motors with following specifications were used. Both of these motors had speed reduction gearbox with them. Therefore, the gearbox was not required to design.

Specifications	Radial Feed Motor	Axial Feed Motor
Type	AC Servomotor	AC Servomotor
Power	70 Watt	70 Watt
Voltage	220 AC	220 AC
Current	0.9 A	0.9 A
Speed	1450 rpm	1450 rpm

DESIGN OF ADAPTER PLATE

In order to fix the motors with the saddle of the lathe, an adapter plate was required. This plate was designed in such a way that it can be disengaged easily for abling to use the lathe again for manual use. A schematic diagram of the plate is shown in Figure 2.

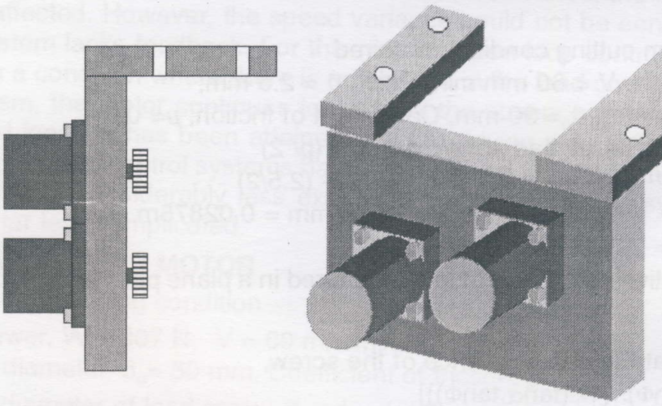


Figure 2: Adapter Plate with arrangement of servomotors.

DESIGN OF INTERFACE

The Parallel Port is the most commonly used port for interfacing projects. This port will allow the input of up to 9 bits or the output of 12 bits at any one given time, thus requiring minimal external circuitry to implement many simpler tasks. The port is composed of 4 control lines, 5 status lines and 8 data lines. it is found commonly on the back of PC as a D-Type 25 Pin female connector. There may also be a D-Type 25 pin male connector. This will be a serial RS-232 port and thus, is a totally incompatible port.

The motor control circuit for the machine is designed on the principle that as the pulse rate increases, the speed of the motor increases and vice versa. Output of microprocessor drives LED of Optocoupler. Output of phototransistor of Optocoupler turns on the TRIAC, which allows alternating, current to flow through the motor. It drives the saddle and cross slide individually. The Optocoupler is used for safety reasons to protect and isolate the computer from the circuit, to avoid the flow of any back current to the port. The following figure shows the connections for motor. The I/0 pulse selects the motor to be controlled and the feed goes to the motor according to the Figure 3.

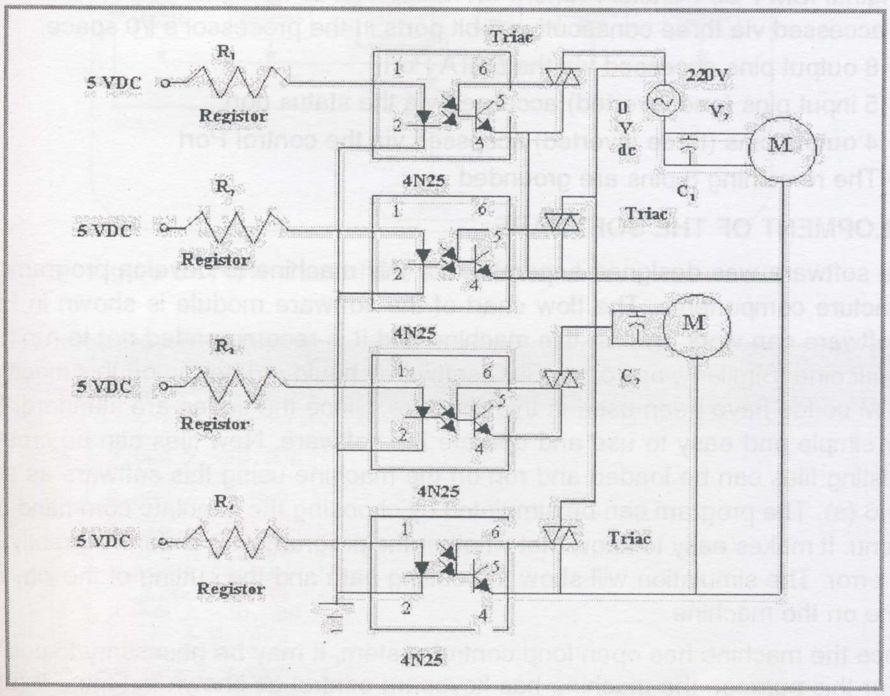


Figure 3: Motor control circuit

INPUT-OUTPUT INTERFACE

The printer port of the computer was used to transmit the data from the computer to the machine through the interface circuit. The pin configuration of the printer port is shown in Figure 4. For this purpose, pin no. 2, 3, 4 & 5 of the port were used. These pins are called data pins and are used to send data from the computer. Pins 2 & 4 have been used to select and control the motor speed (i.e. feed), while the pins 3 & 5 have been used to change the direction of the motors, either in positive or negative axis.

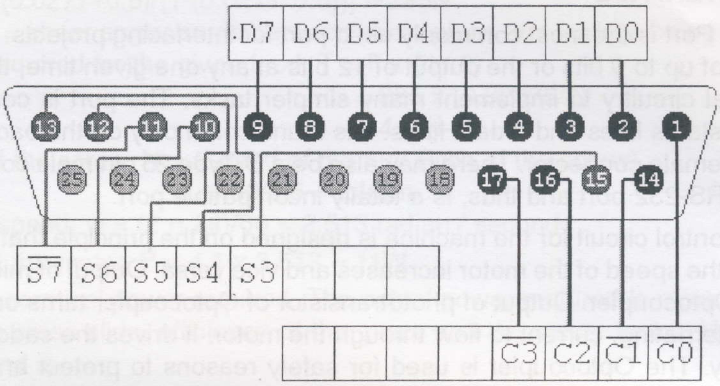


Figure 4: LPT port (Male)

The original IBM-PCs Parallel Printer Port had a total of 12 digital outputs and five digital inputs accessed via three consecutive 8-bit ports in the processor's I/0 space.

- 8 output pins accessed via the DATA Port
- 5 input pins (one inverted) accessed via the status port
- 4 output pins (three inverted) accessed via the control Port
- The remaining 8 pins are grounded

DEVELOPMENT OF THE SOFTWARE

The software was designed separately for this machine to develop programs and to manufacture components. The flow chart of the software module is shown in Figure 5. This software can work only on this machine and it is recommended not to run it on any other machine. Similarly, any other CNC software should not be run on this machine. The G and M codes have been used in this software. Since the codes are standard, hence it is very simple and easy to use and operate the software. New files can be created and the existing files can be loaded and run on the machine using this software as shown in Figure 6 (a). The program can be simulated by choosing the simulate command from the run menu. It makes easy to know that whether the programming is done correctly or there is any error. The simulation will show the cutting path and the cutting of the job, as it will be done on the machine.

Since the machine has open loop control system, it may be necessary to position the tool. For this purpose the machine has keyboard control as shown in Figure 6 (b). It can be controlled using keyboard while selecting the keyboard control option from the control menu. The software is dialogue guided. That is, if any G or M code will be given the other necessary parameters required with that code will be asked by the program one by one. The user does not need to remember and enter those parameters. When the program is being written, there could be any error of input codes. The program will check each code at the time of writing the program and any unknown code will be neglected. Some examples have been given in the help menu and can be consulted for the purpose o understanding.

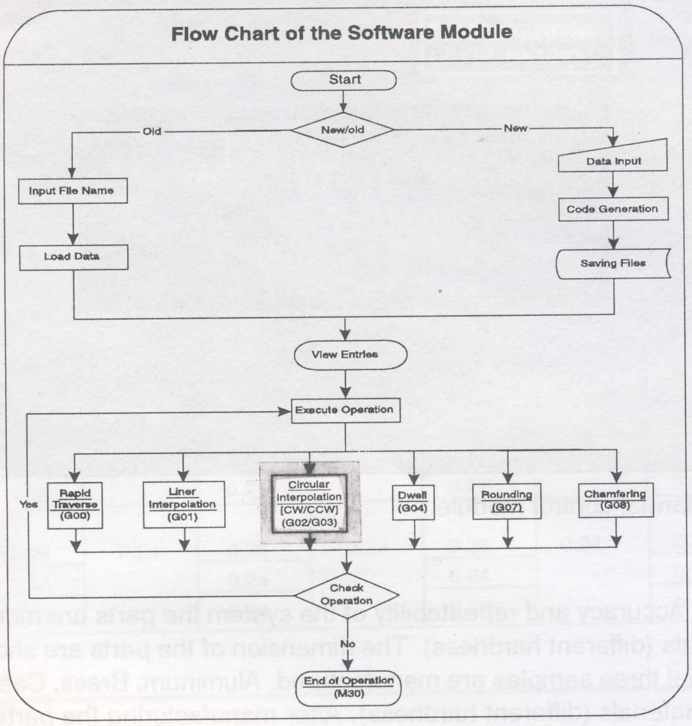


Figure 5 : Flow chart of the software module.

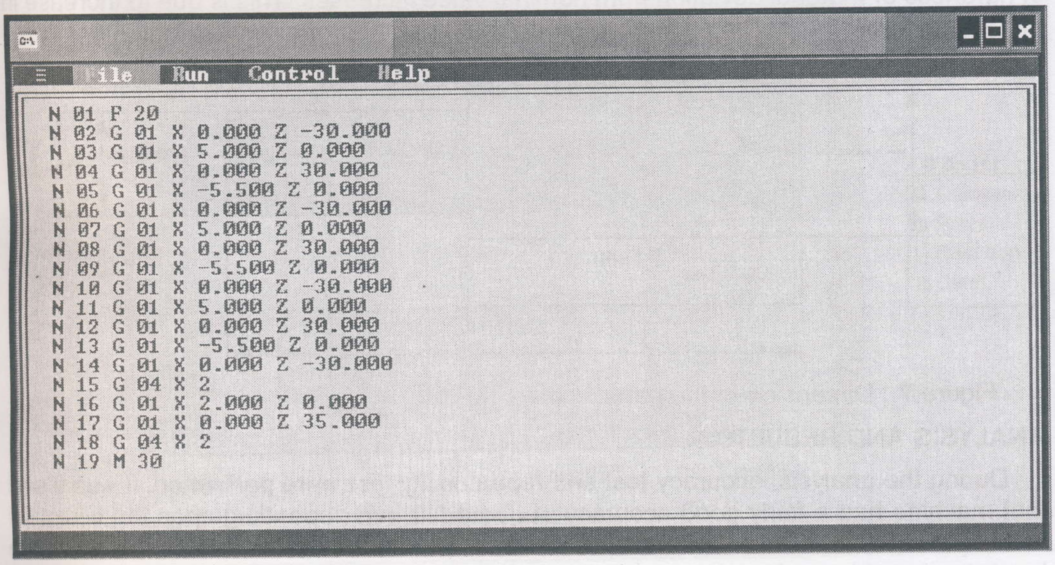


Figure 6 (a) : Output module

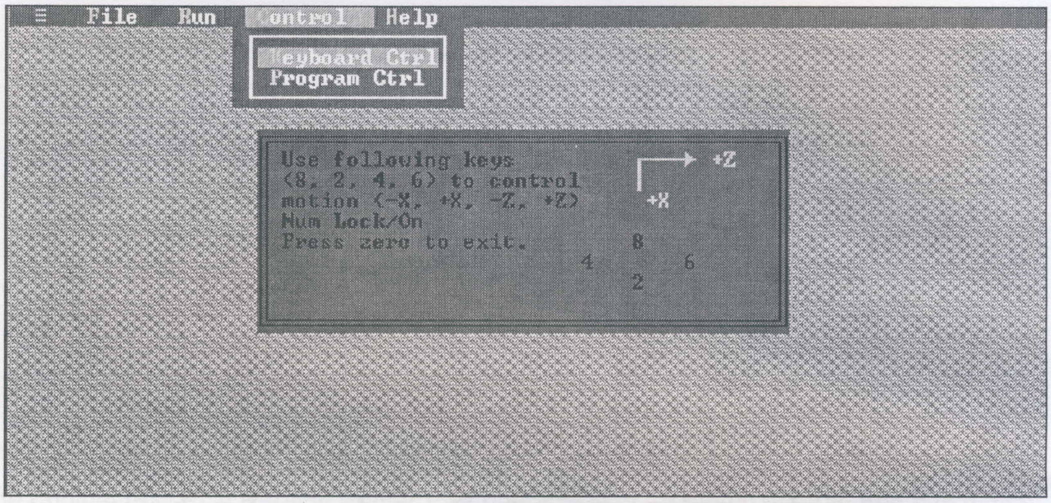


Figure 6 (b) : Manual control module

CASE STUDY:

To study the accuracy and repeatability of the system the parts are manufactured from different materials (different hardness). The dimension of the parts are shown in Figure 7. For each material three samples are manufactured. Aluminum, Brass, Cast Iron and Steel was taken as materials (different hardness). After manufacturing the parts are measured and compared with the nominal dimensions. Results are shown in Table no. 1; graphs plotted from this Table are shown in Figure 8-10. The study shows that with the increase of hardness of material deviation from nominal value increases. This is due to increase in the cutting force.

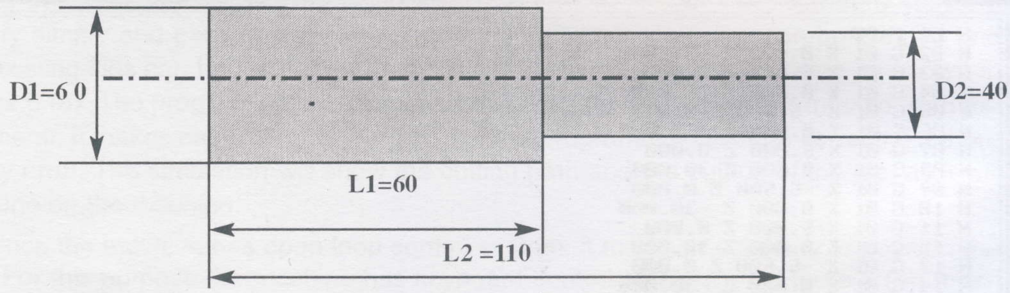


Figure 7 : Dimension of the parts.

ANALYSIS AND RESULTS

During the analysis, accuracy test and repeatability test were performed. It was found that machine had a fairly good accuracy of about 0.2 mm depending upon the designed value [D1=60,D2=40,L1=60,L2=110]. This is a reasonable value for an old machine because an old machine was converted to a CNC machine, which had a sizeable backlash error.

Table 1: Deviation in diameter and length for different materials

Sample (Vicker's Hardness number)		Variation found on different measurement							
		Diameter1 (Design value 60mm)		Diameter2 (Design value 40mm)		Length (Design value 60mm)		Length2 (Design value 110mm)	
Aluminum (44~189)	1	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.16
	2	0.17		0.16		0.15		0.16	
	3	0.16		0.16		0.15		0.16	
Brass (118~196)	1	0.19	0.18	0.18	0.18	0.17	0.16	0.17	0.16
	2	0.18		0.18		0.15		0.17	
	3	0.18		0.19		0.16		0.15	
Cast Iron (125~211)	1	0.21	0.21	0.22	0.22	0.20	0.20	0.21	0.22
	2	0.20		0.22		0.20		0.22	
	3	0.22		0.21		0.21		0.22	
Steel (107~240)	1	0.24	0.24	0.23	0.24	0.23	0.24	0.24	0.23
	2	0.24		0.24		0.24		0.24	
	3	0.24		0.24		0.23		0.20	

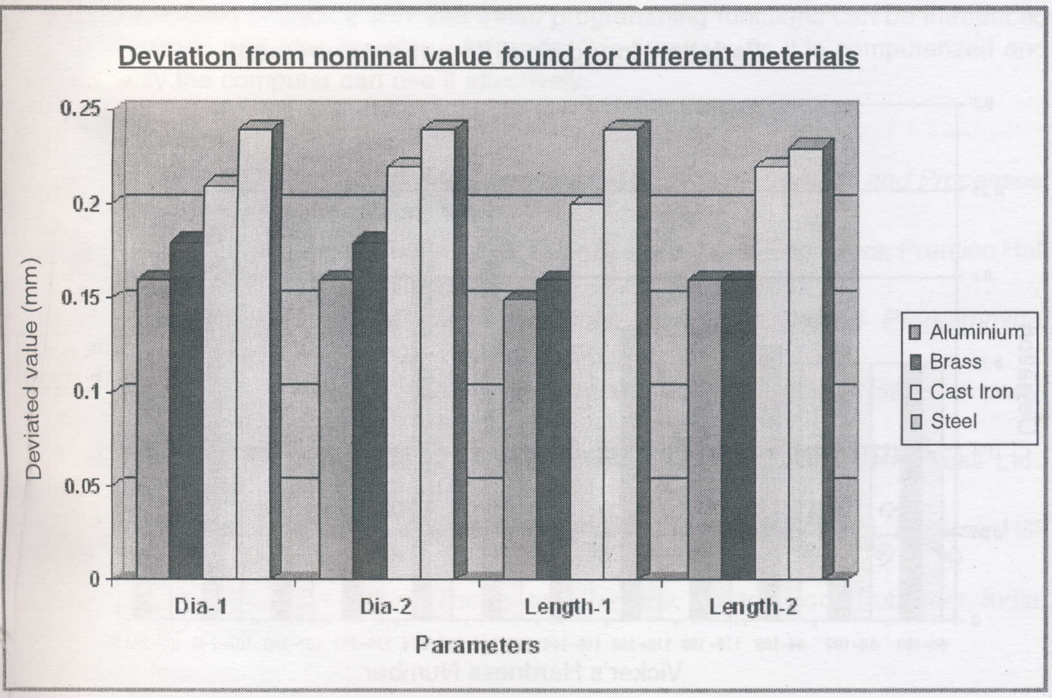


Figure 8: Accuracy found from different sample

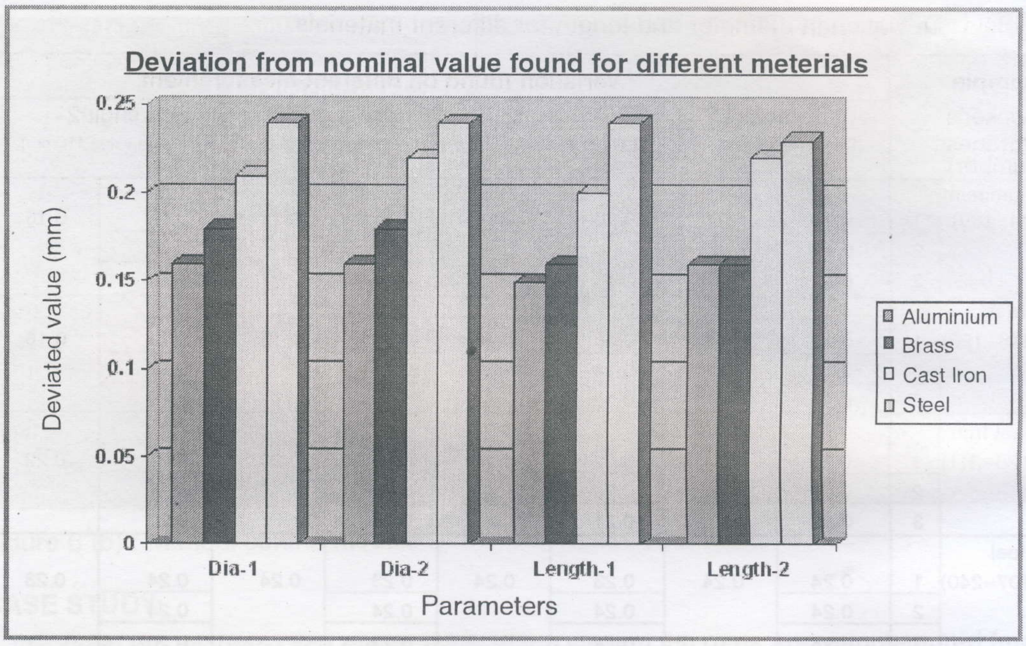


Figure 9: Deviation from nominal value on diameter for different material

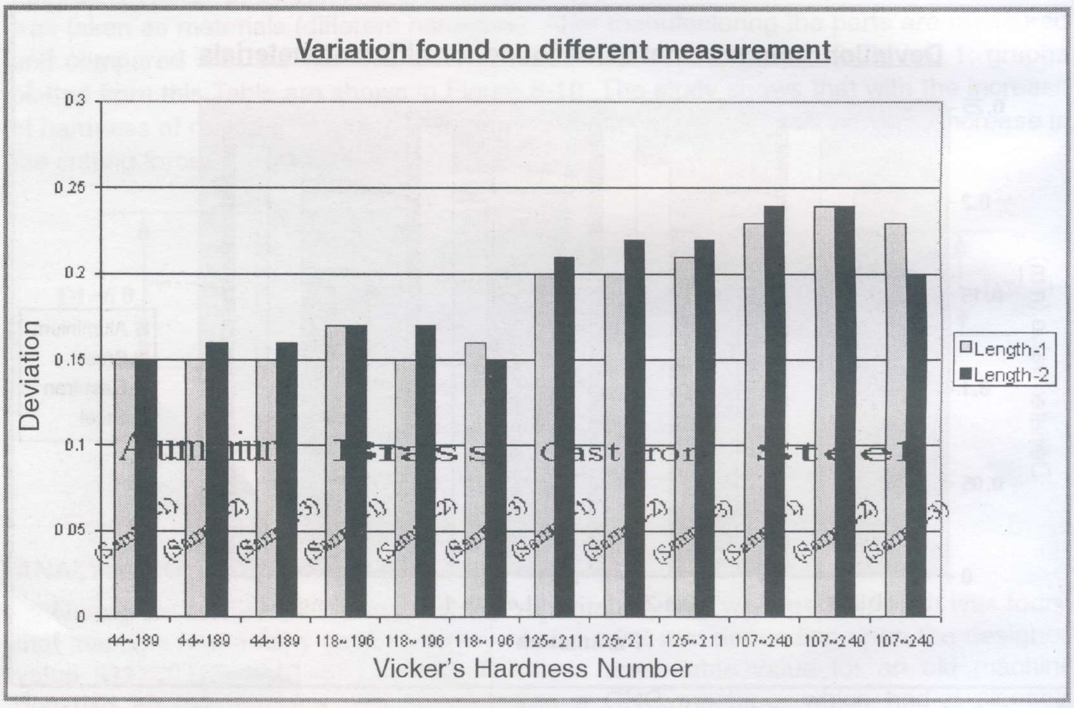


Figure 10: Deviation on length for different material

The curves show that as hardness of the material increases corresponding error in both diameter and length increases. Twelve jobs of same dimensions were manufactured on CNC lathe and manual lathe for the purpose of comparison. The time take by the CNC machine was much less than the manual machine. Manually it has taken about 11 min. while on the CNC lathe it was manufactured in 5 min. This shows the quick production feature of the machine.

CONCLUSION

The benefit offered by all forms of CNC lathe is improved automation. The operator intervention related to producing workpiece can be reduced or eliminated. The user's benefits include reduced operator fatigue, fewer mistakes caused by human error, and consistent and predictable machining time for each workpiece. Since the machine runs under program control, the skill level required of the operator (related to basic machining practice) is also reduced as compared to a machinist producing workpiece with conventional machine tools. The other benefit is consistent and accurate workpieces. It boasts almost unbelievable accuracy and repeatability specifications (though it is less in open loop system). This means that once a program is verified, two, ten, or one thousand identical work pieces can be easily produced with precision and consistency.

It is not possible to convert it totally into a CNC Lathe because of cost involved. However, certain options are left intentionally in the system for future feasibility study. It can be extended further for other machining operations. The on-off control of coolant and the control of spindle speed can be introduced into the stem. For this purpose, the software is designed in such a way that these programming functions can be introduced in it. Some printer, port pins are also left free for this purpose. As it is computerized and enclosed, only the computer can use it effectively.

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