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# A STUDY ON THE DESIGN OF MICRO-LATHE FOR EDUCATION AND APPLICATION

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## ABSTRACT

As the factory automation progresses, the number of specialized product is increasing rapidly. Previous years have been characterized by the growth of 3-D micro-components production. Now-a-days, machined parts are becoming progressively smaller. So, production of machinery which remains in a conventional size is often inappropriate for such products. The term "micro factory'' represents an entirely new approach to design and manufacture which minimizes production systems to match the size of the parts they produce. The micro-lathe was one of key components in "Micro-factories" claiming "small machine tools for small mechanical parts". There is an alternative to manufacture micro-components by micro-machine tools and micro-manipulators using conventional mechanical techniques.

In India, Robot, Micro-factory, several prototypes of micro-machine tools (MMTs) and micro-manipulators (MMs) have been developed. Furthermore, there is an increased need for engineers trained in micro-machine tool design and operation. This development necessitates thorough and systematic education in both industry and education institution. Inexpensive educational micro-machine tools will facilitate the required education in India. In this study we design and manufacture a prototype of an inexpensive LabVIEW controlled micro-lathe. This will facilitate the micro-machine tool education in India as these activities become active.

***Keywords:*** Micro-machine, micro-lathe, LabVIEW

## 1 INTRODUCTION

### 1.1. RATIONALE AND STIPULATION OF THE MICRO-MACHINE TOOL

There is a great effort towards the miniaturization in the last few decades. We can see the effects of that trend in every aspect of our lives. From the laptops to the cellular phones, we always prefer the smallest one since the idea of "the smaller the better" has penetrated into our minds and one can be equipped with more gadgets as miniaturization goes further. Miniaturization process of mechanical components started with micro fabricated sensors and was followed by micro fabricated parts and micro actuators. In recent years integration of micro components such as precision mechanisms, sensors, actuators and embedded electronic circuits into micro systems has become one of the most prominent research areas all over the world. When the micro components were first introduced, they were simple and could be naturally integrated directly into the product. However, developments in micro system technology resulted in a large variety of micro components made from dissimilar materials and technologies. These miniaturized products use even smaller components, and in more and more cases they are micro components with sizes of components less than one millimeter.

A new bid to manufacture pieces with overall sizes smaller than 1mm using conventional mechanical technology was made in[1]. This proposal was based on the development of micro-factories (composed of micro-machine tools, micro-manipulators (MMs), assembly devices, etc.) to manufacture and assemble 3-D micro-devices employing conventional mechanical techniques. The micro-factories can help to reduce the consumption of resources (energy, materials and space); and can help to increase the productivity[2]. The micro-machine tools (MMTs) in such micro-factories must be sufficiently precise to produce components according to industrial and research demands.

The conservation of energy has been the slogan for the past decade in order to reduce energy consumption. The conservation of energy by reducing the machine tool size for machining micro components is attaining popularity as micro-factory. Micro-factory can be said that it is a small manufacturing system for achieving higher throughput with less space and reduced consumption of both resource and energy via downsizing of production processes.

The energy-saving effect factoriesareminiaturizedto1/2size.Theenergy-saving effect is large when the size of the processing and assembly Equipment is extremely large compared to the dimensions of the products. As for watch manufacturing, the amount of Energy consumption may be reduced to approximately 30 Percent of the conventional factory by the half-miniaturization of the production systems [3].The term micro-factory represents an entirely new approach to design and manufacture that minimize production systems to match the size of the parts they produce. In the earliest attempt to turn the concept of micro-factory [4] in to a reality a micro-lathe smaller than a human palm was developed in 1996[5].

And it was the first big success for the further step into the concentration on process physics of micromachining including materials and micro structural effects, machine tools, tooling and sensing, workpiece and design issues, software and simulation tools, and other issues [6] micro factory. The first micro press was developed in the year 2000[7].

In the micro-world, the error sources of MMTs can be reduced by reducing their sizes [8],[9],[10] and [11]. Some prototypes were made in order to demonstrate the advantages of this proposal. Countries such as Japan, Ukraine and Mexico have developed micro-machines tools with overall sizes from 130 × 160 × 85 mm to 32 × 28 × 30 mm[12],[13], and [14]. In Mexico, the research in this area began in 1999 and the main goal was to develop micro-mechanical technology for automated production systems based on low-cost and high efficiency equipment and instrumentation [15].In the low-cost micro-equipment development, the principal challenge is to obtain high precision employing low-cost components. Advanced countries like Japan, Taiwan, Korea, Europe, Ukraine ,Mexico, Gemany and USA not only manufacture production micro-machine tool but also educational micro-machine tool in a balanced manner. As the economic development of India progresses toward becoming an advanced nation there is a need for an effective policy for science, engineering and technology and their education. Particularly, that for the machinery, automobile and electrical industries is more urgent. Because the resources, fund and technology for the domestic industry are not sufficient, and also technology protection policy in the level of advanced nation is nonexistent, there is a great deal of problems associated with the Indian Machine tool Industry.

In particular, Micro-machine tool systems which are based on an industry are less manufactured in India. Therefore, it is an urgent problem that the Indian industry develops capability to manufacture integrated special tool system, such as Micro-factory ,Micro-machine tool, micro-manipulators, Robots; Educational high level technicians for the special fields. Sufficient equipment and other necessary materials are needed for experiments essential for effective education. It is more suitable to use specially built micro machine tool for educational uses.

In our country, certain educational institutes recognize this problem and utilize educational micro-machine tool, but this machinery depend on total import. Therefore it is expected that this research contributes towards micro-equipment education by domestic production of educational MICRO LATHE so it can reduce the import and foreign exchange and eventually manufacture of Micro-lathe for production.

The necessity of educational Micro-machine tool is considered by this method: and an economical prototype micro-lathe is designed, manufactured and studied. In the low-cost micro-equipment development, the principal challenge is to obtain high precision employing low-cost components. For this reason, we have proposed to use the labVIEW control systems to increase the micro-machine tools accuracy without increasing significantly the total device cost.

### 1.2 DEVELOPMENT OF MICRO-LATHE

An interest to produce mechanical parts with sizes less than 1 mm arose worldwide in the 80's. Some methods based on micro-electronic technology were proposed; nowadays, these developments are called Micro Electro Mechanical Systems (MEMS) [8]. The micro-electronic technology allows developing micro-mechanical components with simple shapes (two and a half dimensions), and the materials employed in this technology are silicon, silicon oxide, metallic films (mainly aluminum), and piezoelectric materials like quartz. These micro-devices applications are encountered in many industries such as the automotive, the biomedical, electronics, computer, etc.

The manufacture of micro-components employing micro-mechanical systems (micro-factories) was proposed in the 90's as a new alternative to cover some of the micro-world applications where MEMS could not be applied. A research group from Japan proposed the development of tools that allow generating other kind of application which can be made from different materials and can have 3-D geometry shapes. The main goal was to create MMTs, micro-manipulators (MMs), etc. at a scale comparable with the size of the produced micro-components. Their proposal consisted of transferring the conventional mechanical methods to the micro-world and to develop micro-factories able to produce micro-devices. A micro-factory contains several systems: a manufacturing system, an assembly system, a quality control system, a transport system, a maintenance system, and others. The micro-factories allow a decrease in the consumption of energy, space, and resources[16]. The produced micro-components can be used in the watch industry, the automotive industry, medical facilities, biology investigations, etc. [16] and [17]. For example, in the medical field, the micro-equipment demands are: microscopy, diagnosis, non-invasive surgery, etc. in the industrial field for the development of micro-robots to inspect inaccessible or dangerous places, pipe inspection, transportation machinery, archeological research, etc. Another interesting application field is the development of micro-actuators, for example: micro-grippers for manipulation with living cells, micro-generators, micro-motors, etc.[13].

The first micro-machine tool was developed in the National Institute of Advance Industrial Science and Technology of Japan in 1996 [12]. Nowadays, there are many groups in different countries around the world such as Germany, Korea, Switzerland, Mexico, USA, etc. interested in this field [18], [19] and [20]. Researchers from the National Institute of Advance Industrial Science and Technology of Japan developed an automated micro-factory to produce components for micro-bearings in 2000 [21]. The assembly of micro-bearings was made in the same micro-factory with a semi automated process.

Particularly, in Mexico, investigation in micro-mechanics began in 1999. The main goal is to create technology for automated micro-mechanical devices for production based on low-cost and high efficiency equipment and instrumentation. To achieve this goal, it was proposed to work out the micro-equipment as sequence of generations where the first generation of micro-equipment is produced by conventional machine tools. The micro-equipment of this generation will be able to produce the second generation of micro-equipment having smaller overall sizes than the previous one. Employing the second generation, it would be possible to produce the third generation of micro-equipment, and so on. The sizes of each new generation devices are smaller than the sizes of the prec++edent ones. This process can be repeated until the micro-machines with overall sizes of some micrometers have been obtained [14]. Based on this study, the prototype of LabVIEW controlled Micro-lathe is developed for production maximized education efficiency, it can be learned easily and a disjointing and assembling are possible.

## 2 .0 DESIGN OF HEADSTOCK

Headstock is the heart of any machine tool. Design of head stock covers motor selection, estimation of cutting forces, spindle design, bearing selection, belt drive selection and headstock housing. It is necessary to justify developed cutting forces with available motor power. Headstock housing has to do properly to prevent transmission of vibration to other machine elements.

### 2.1 MOTOR SELECTION

DC motors are electric motors that use electricity and a magnetic field to produce torque, which turns the motor. To drive the spindle, Permanent Magnet DC motor (PMDC), rated power of 1.6 W is selected. Characteristic curve of the motor is shown in figure 1. Torque varies greatly with the speed ranging from a maximum (stall) torque at zero speed to Zero torque at maximum (no load) speed. This relationship comes from the fact that Power = torque X angular velocity. Since the power available from the motor is limited to some finite value, an increase in torque requires a decrease in angular velocity and vice versa. Its torque is maximum at stall which is typical of all electric motors. This is an advantage when starting heavy loads.

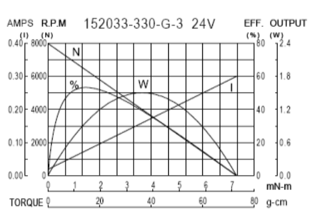


**Fig 1** Characteristic curve of PMDC (Source: Igarashi Motors Ltd, Chennai)

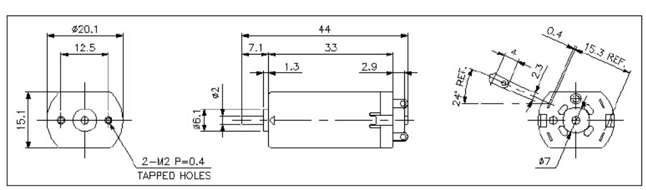


**Fig .2**. 2-D Diagram of motor

From figure 1 load lines represent a time varying load applied to the driven mechanism. The problem comes from the fact that as the required load torque increases the motor must reduce speed to supply it. Thus input speed will vary in response to load variations in most motors, regardless of their design.It is a PMDC Motor as shown in figure 2 which runs at 10,000 rpm (without load condition).

**2.2 ESTIMATION OF CUTTING FORCES**

The single point cutting tools being used for turning, shaping, planning, slotting, boring etc. are characterized by having only one cutting force during machining. But that force is resolved into two or three components for ease of analysis and exploitation. Figure 3 visualizes how the single cutting force in turning is resolved into three components along the three orthogonal directions X, Y and Z. The resolution of the force components in turning can be more conveniently understood from their display in 2-D as shown in Figure 4.

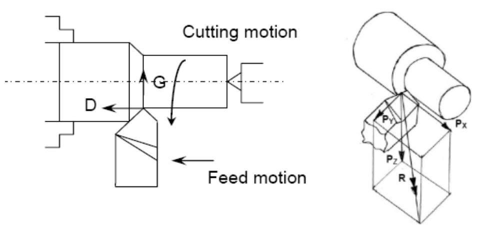


**Fig .3** Cutting forces in turning operation

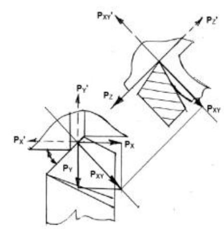

**Fig. 4** Turning force resolved into $P_Z$, $P_X$ and $P_Y$

Where, $P_Z$ = tangential component taken in the direction of Z axis
$P_X$ = axial component taken in the direction of longitudinal feed or X axis
$P_Y$ = radial or transverse component taken along Y axis.

In figure 3 and figure 4 the force components are shown to be acting on the tool. A similar set of forces also act on the job at the cutting point but in opposite directions as indicated by $P_Z'$, $P_{XY}'$, $P_X'$ and $P_Y'$ in figure 4.

**2.3 DESIGN OF SPINDLE**

Spindles are rotating drive shafts that serve as axes for cutting tools or hold cutting instruments in machine tools. Spindles are essential in machine tools and in manufacturing because they are used to make both parts and the tools that make parts, which in turn strongly influence production rates and parts quality. To obtain the desired result, a normal spindle design must take into consideration the required power, torque, tooling system used, Speed, Accuracy and life.

**2.3.1 SPINDLE STYLE -**To get a typical style of a spindle, the first thing to decide is whether a belt-driven spindle or integral motor-spindle design is required. This depends upon the requirements of the machine tool which also include the maximum speed, power and stiffness required and also cost. Based on these factors belt driven spindle is chosen. Reaction of cutting forces transferred to the spindle through Collet chuck. Based on the reaction forces, shear force and bending moment diagram has been drawn for different load condition. Optimum space between bearing supports is given by thumb rule

$$L \leq (Ds4/3 / k1/3) \qquad (1)$$

Where L = Optimum span between bearing supports. By logically assume L = 20 mm, reaction forces at supports are calculated.

DS = Average diameter of the supported length of the spindle, 5 mm

k = 0.1 for precision machine tools

Belt force at the pulley end is calculated by assuming pulley diameter is equal to 16 mm and the belt force = 0.4 N. Radial force acting at the centre of pulley is = 1.5 X 0.4 = 0.6 N.

### 2.3.2 MATERIAL SELECTION

Distortion is the function of Young's modulus of the material. Hence to satisfy first requirement the spindle material should have high Young's modulus. Costly high tensile steel doesn't have significant stiffness when compared to structural and alloy steel. In our precise machining application any alloy steel is suitable. For calculation purpose, AISI 1040 cold rolled carbon steel properties are taken as it is widely used as spindle material.

### 2.3.3 Spindle Design Calculations

Equivalent bending moment and twisting moment is already found by using equations 8 and 9. Now Spindle has to design to withstand these load conditions by applying factor of safety 3. Mechanical properties of spindle material are given below:

Yield strength = 490 MPa; Shear strength = 280 MPa;Young's Modulus = 210GPa

Brinell hardness no $H_B$= 192 ;$T_e = (\pi/16) X \zeta_s X D_s^3$

**Diameter of the spindle = 3mm**

However, to prevent angular deflection below $25^0$ the following equation is used:

$$D_s = 128\sqrt[4]{\frac{KW}{Rpm}} = 4mm \quad (2)$$

Power is in kW and operational speed is in rpm. Diameter of the spindle is varying from 3 to 5mm. For calculation purpose let us take Ds= 5mm. Deflection of the spindle can be calculated by using McCauley's method. After derivation the final equation of deflection of the spindle is given by

$$y = \frac{1}{EI}\left[0.05x^3 - 153.75x + 2137.5 + \left(0.1375(x-15)^3\right) + \left(0.485(x-35)^3\right)\right] \quad (3)$$

Maximum deflection of the spindle at the machining end $y_{max}$ = 2.12 microns

### 2.4 BEARING SELECTION

Deep groove, "Conrad", ball bearings are the most common form of ball bearings used for supporting radial load and bidirectional axial loads equal to the radial load because all balls share the load. Balls have to roll from one side of the contact groove to the other, so bidirectional stiffness is non-linear. Since in our application radial loads are major loads, deep groove miniature ball bearings are selected base on spindle diameter. After that bearing selection is justified with given load conditions. NSK miniature ball bearings specification is used for calculation purpose. Samples of bearings are got from KHF Components private limited, Bangalore. They are exporting bearings to NSK bearings. Table 1 gives specification of miniature ball bearings.

**Table 1 Specification of miniature ball bearing**

| MODEL NO. | OUTSIDE DIAMETER (mm) | INSIDE DIAMETER (mm) | THICKNESS (mm) | LIMITING SPEED (rpm) | BASIC DYNAMIC LOAD RATING (kgf) | BASIC STATIC LOAD RATING (kgf) |
|---|---|---|---|---|---|---|
| MR84 | 8 | 4 | 3 | 56000 | 40 | 14 |
| DDL1040 | 10 | 4 | 3 | 54000 | 73 | 40 |

**2.5 CIRCLIP SELECTION**

To prevent axial movement of bearings, Circlip or locknut can be used. Standard Circlip dimensions are shown in figure 5. to meet with spindle dimensions. Specification of Circlip is given below:

Thickness T = 0.4 mm; Clearance diameter C = 8.64 mm; Groove width W = 0.64 mm; Groove diameter G = 3.8 mm; Material = Stainless steel

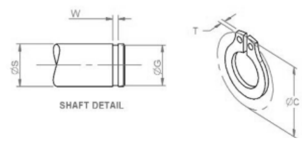


**Fig .5** Circlip (Source: Reliance Precision Mechatronics Pvt Ltd)

**2.6 MODEL OF SPINDLE**

3- D model of spindle is shown in figure 6. Grooves have given to accommodate Circlip in spindle. Step on spindle has given to prevent axial movement bearings.

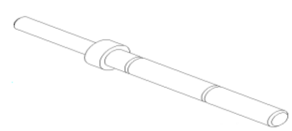

**Fig .6.** 3-D model of Spindle

**2.7 BELT AND PULLEY SELECTION**

Timing Belt is used to transmit the power from motor to spindle. Timing belt efficiency ranges from 95 -98% better than flat or vee belts which rely on friction to transmit power. Timing belt drives do not require as much tension as other belt drives which depend on friction to transmit the load. The belt should be installed with a snug fit, neither taut nor loose. As a general guide the correct level of tension can be determined by measuring the force necessary to deflect the belt an amount equal to 1/64th of the span centers "a".

The belt must be rigidly mounted. Variations in center distance can lead to premature wear. The belt and pulley system must be assembled loose to prevent over stretching. The belts are guided on the pulleys by flanges. To minimize belt fatigue pulleys of minimum 20 teeth are recommended. Knowing the centre distance the belt length can be calculated from the following:

For ratios = 1:1

$$L_B = (Z * t) + 2a$$

Where, $L_B$ = Length of belt, mm

Z = No. of teeth on pulley = 12 (from standards)

t = Belt Pitch = 2.5 mm (from standards)

a =Centre distance between spindle and motor shaft = 30 mm

Therefore, Length of belt = 90 mm. The standard 2.5 mm pitch timing belt is shown in figure 7

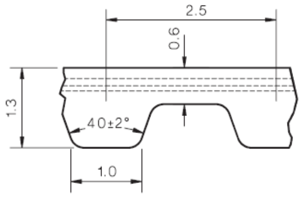


**Fig. 7** Timing belt (Source: Reliance Precision Mechatronics Pvt Ltd)

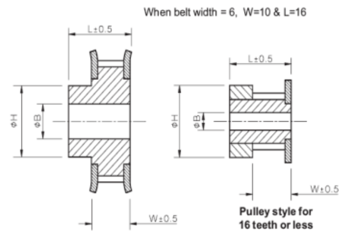


**Fig . 8** Pulley

Material: High Tensile steel reinforced Polyurethane;Width: 6 mm;Maximum Peripheral load: 65 N Maximum Peripheral speed: 80m/s;Temperature range: -$30^0$ to $80^0$

The pulley corresponding to timing belt is shown in figure 8. It is made of Aluminium pulley and flange is made of Zinc coated plates. Bore diameter = 3mm; Hub diameter = 12mm.

## 2.8 MATERIAL SELECTION OF HEADSTOCK HOUSING

The weight of the structure is inversely proportional to the quantity of unit stiffness. Unit stiffness is the ratio of young's modulus and specific weight. The larger the unit stiffness of the material the smaller is the weight of the structure required to ensure that the deflection of the structure due to a particular given load does not exceed a specified value. Mild steel has unit stiffness of 2.69 X108 and cast iron has a unit stiffness of 1.66 X108. Hence Mild steel is selected as material for headstock housing.

## 2.8.1 MODEL OF HEADSTOCK HOUSING

Typical 3-D model of headstock housing is shown in figure 9 and 10. It is split type housing and it has top and bottom casing. Since it is the first prototype development, there will be lot of inspection has to do inside the microlathe. There will not be much intention given to functionality. It is just claiming for operation. Hence split type housing is selected. Top casing will be assembled with lathe bed. The detailed 2-D diagram is available in appendix.

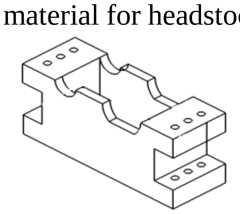

**Fig 9** Bottom casing

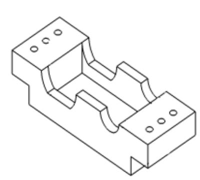

**Fig 10** Top casing

## 2.9. MATERIAL SELECTION OF SLIDEWAY DESIGN

The wear of slideways depends to considerable extent upon what materials are used to make the ways of the bed and of the travelling unit. An inexpedient selection of these materials may lead to premature wear which is not uniform along the length of the slide ways. This, in turn, results in an inevitable loss of accuracy of travel. The wear resistance of slideways is determined primarily by the physic-mechanical properties of their material. In most cases it is more expedient to use the harder material for the stationary slideways since their shape is copied in travel of the moving unit.

The most common slideway materials are cast-iron and low carbon or alloyed steel. If the slideway is integral with the bed, it is almost exclusively made from gray cast iron. This material is cheap but does not have good wear resistance when subjected heavy loading. The wear resistance can be improved through proper heat treatment. If both slideways are hardened the improvement may be up to four times. Therefore, gray cast-iron is chosen as slideway material for this application.

**2.9.1 SHAPE OF SLIDEWAYS**

The commonly used shapes of slideways used in machine tools are flat, V, dovetail, and cylindrical. They may be closed or open. Closed flat and closed V is employed for precision application. The included angle of V, both in closed and open version is generally 900. For proper functioning of slideways it is imperative that the friction be kept as low as possible by ensuring that a certain minimum amount of lubricant is always present between sliding surfaces.

**2.9.2 DESIGN CRITERIA AND CALCULATIONS**

Slideways are designed for the following two parameters:

- Wear resistance and Stiffness

The wear resistance of slideways depends upon various conditions, one of the most important being as uniform as possible distribution of the pressure over the way surfaces, the average specific pressure not exceeding a certain definite value established on the basis of experience in machine tool operation. The specific pressure is determined by checking calculations based on the assumption that the specific pressure is distributed according to linear function lengthwise along the slideway, across the width of each face of the slideway; the specific pressure is considered to be distributed uniformly.

The **wear resistance** of slideways is governed mainly by the maximum pressure acting on the mating surfaces. This condition may be written down as

$$p_{max} \leq [p_{max}] \quad (4)$$

Here, $P_{max}$ = Maximum pressure acting on the mating surfaces

$[P_{max}]$= Permissible value of the maximum pressure

It will be seen during the subsequent analysis that slideway design in terms of maximum pressure is quite complicated. Sometimes, this design is replaced by a simple procedure based upon the average pressure acting on the mating surfaces. The condition is that:

$$p_{av} \leq [p_{av}] \quad (5)$$

Here, $P_{av}$ = Average pressure acting on the mating surfaces

$[P_{av}]$= Permissible value of the average pressure

The design condition for **stiffness** stipulates that the deflections of the cutting edge in directions that significantly influences the machining accuracy should not exceed certain permissible values. The condition may be expressed as follows:

$$\delta_i \leq [\delta_i] \quad (6)$$

## 2.10 MODEL OF GUIDEWAYS

Typical 3-D model of lathe bed, tool post guideway and tool post is shown in figure 11,12 and 13 respectively.

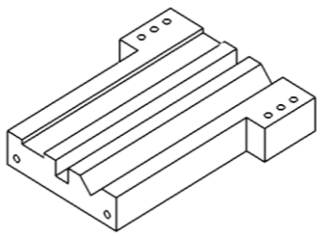

**Fig. 11** Lathe bed

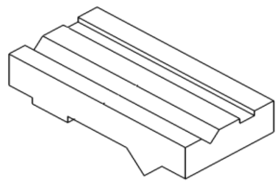

**Fig .12** Tool post guide way

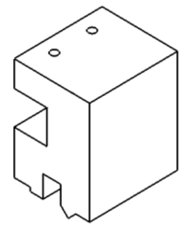

**Fig. 13** Tool post

## 2.11 DESIGN OF NUT

Nut is designed based on the lead screw profile. There is a relationship available to find out the length of nut. The relationship is given below:

$$\lambda' = L/d_p \qquad (7)$$

Where λ' – Constant, it varies between 3 and 5. Let us assume λ' = 3

$d_P$- Pitch diameter of thread = 4 mm

From the equation 7 length of nut can be found.

Length of nut (L) = 12 mm.

For support, miniature ball bearings are used with simply supported as shown in figure 14. Bearing inner bore diameter is 3mm.

**Fig 14** Bearing supports for lead screw

## 2.12MODEL OF LEAD SCREW AND NUT

Typical 3- D model of lead screw and nut is shown in figure 15 and 16. The lead screw is designed based on load conditions that act on the lathe bed. Hence the same lead screw profile is used for both lathe bed and tool post guideway.

**Fig 15** Lead screw

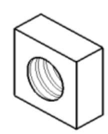

**Fig 16** Nut

Since run out leads to efficiency of the lead screw, it has to maintain with high accuracy. For precision applications, the value is 4 microns.

## 3. RESULTS AND DISCUSSIONS

The operating features of machine tool and, in particular, its production capacity, convenience and ease in servicing and its reliability in operation, depend to great extent upon how well its control system has been designed. The control system of a machine tool is often combination of mechanical, electrical and electronic devices. The two main functions of machine tool control system are changing speeds, feeds and providing the working and auxiliary motions in the desired sequence necessary for machining a particular part.In this microlathe, LabVIEW software is used to control the feed movement of lead screw coupled with stepper motor. Stepper motor is interfaced with LabVIEW software through Data Acquisition Card. The operative member of the machine tool is directed to move to a certain position. However, whether it precisely arrives at the desired position or not is not ascertained. For simplified design, in this application open loop control system is collected.

The spindle is driven by a PMDC motor. The linear axis is controlled by stepper motor is shown in figure 25.The experimental setup of micro lathe is shown in figure 17.

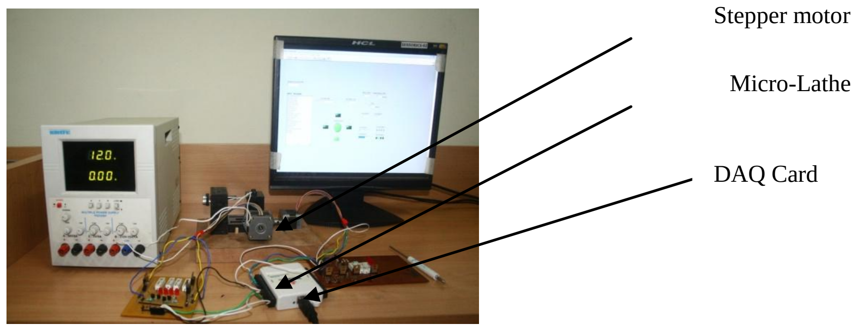


**Fig.17** Experimental setup of the microlathe with stepper motor

A stepper motor, as its name suggests, moves one step at a time, unlike those conventional motors, which spin continuously. If we command a stepper motor to move some specific number of steps, it rotates incrementally that many number of steps and stops.

figure 18 shows 2-D diagram of stepper motor.

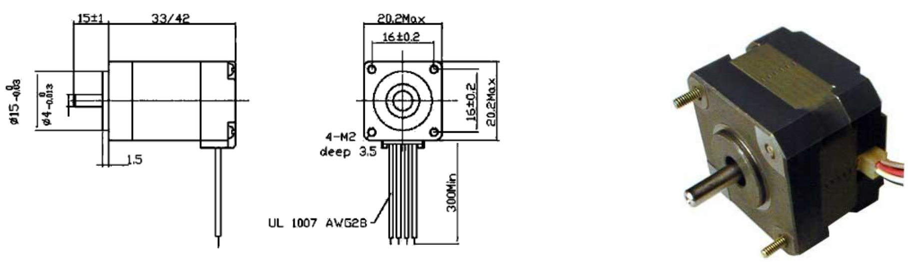


**Fig 18** Stepper motor (Source: ARK Motion Controls Pvt Ltd., Kochin)

Table 3 describes specifications of stepper motor. Maximum pulling force is only 5N. The feed movement also will be small. To suit this requirement, stepper motor is selected.

The linear axis drive is used for controlling the X and Z axis of the Micro lathe. The linear axis drive is a combination of two stepper motors with slides mounted on them. The tool post is mounted on the drive. By controlling the linear axis drive through LabVIEW software, the feed and depth of cut of the operations are controlled. Both the X and Z drives can be controlled at the time thus making operations taper turning possible. The linear axis drive contains two stepper motors. These two stepper motors are connected through LabVIEW, the linear axis drive can be controlled.

Virtual instruments get their name because of the reason they imitate physical instruments such as oscilloscopes and multimeters. The VI software used in the project is LabVIEW 8.5. LabVIEW stands for Laboratory Virtual Instrumentation Engineering Workbench.

The LabVIEW software is used to control the PMDC motor, and stepper motors that operate the spindle and lead screws respectively.

The program consists of two VIs, one for reading the CNC codes and another to control the stepper motors according to the codes.

The sequence of tasks done in the first decoder VI is explained below.

- The file containing the CNC codes is given as input to the VI [10] i.e. the operator has to specify the location of the file containing the required codes.
- The VI splits the program into individual lines using the " ; " as the separator
- The individual lines are then split into separate words using the blank space as the separator.
- The words are arranged into an string array.
- The Different parameters such as spindle speed, feed, X and Z axis coordinates and their direction are extracted from the words.
- The string array is read by a separate loop containing a case structure. Different parameters such as spindle speed, feed, X and Z axis coordinates and their direction already extracted are then passed on to the sub VI called stepper VI.
- The program terminates whenever it encounters the code M30.

The linear axis drive contains two stepper motors. By interfacing these stepper motors with virtual instruments, the linear axis can be controlled. The driver circuit for stepper motor consists of a adaptor (transformer) to convert 230V into 12V since the rating of the motor is 12 V. There are four MOSFETs, one for each coil. The LEDs indicate which coil is being energized at that particular time. The stepper motor can be controlled by energizing its four coils in a sequence.

The sequence in which the stepper motor must be energized can be entered into an array of LEDs (Boolean array). If the motor operates in full step mode, it has four energizing steps i.e. each of the four coils is executed one after the other.

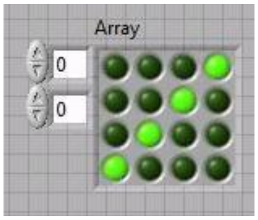


**Fig.19** Boolean array in full step mode

In the above figure 19 each column represents a coil of the stepper motor and each row denotes an energizing steps. The glowing LED denotes the excitation of that particular coil. Similarly in the half step mode there are eight energizing steps. In half step mode not only single coils are executed separately but also consecutive coils are executed simultaneously in the coil. The half step mode gives very precise movement compared to the full step mode. Hence full step mode of operation has been adopted for the purpose of controlling the linear tool movement.

- **Delay**

The delay is the amount of time (in milliseconds the computer waits between the subsequent executions of the energizing steps. Delay is used to control the speed of the motor. More the delay lower is the speed.

$$Delay \propto \frac{1}{speed}$$

- **No of Steps**

It is a factor that denotes the angle the motor must rotate. Motor in half step mode turns 0.9 rotations for every step.

- **Direction**

The motor can be made to rotate in both clockwise and anti clockwise directions. Anticlockwise direction is obtained by giving the above mentioned energizing sequence in reverse.

The stepper motor is controlled by generating a series of digital pulses in the sequence mentioned above. The DAQ is placed inside the for loop. The DAQ passes the signals from the computer to the motor through the driver circuit after amplification.

The stepper motor is driven with the help of the parameters obtained from the previous decoder VI.

- The X/Z coordinate is converted into no of steps, which the motor has to execute to move the tool to the desired location (coordinates). The conversion is obtained using the relation

  X/Z Coordinate × No. of steps required for moving the tool by 1 mm

$$No.of\ Steps\ required\ for\ moving\ the\ tool\ by\ 1\ mm = \frac{No.of\ rotations\ for\ 1\ full\ rotation}{Pitch\ of\ the\ screw}$$

Since pitch of the lead screw is the linear tool movement obtained for one full rotation of the lead screw and hence for one full rotation of the motor (the motor is coupled directly to the lead screw).

- The feed obtained from the decoder VI is converted to DELAY.

DELAY is the amount of time the computer must wait before giving the next pulse to the motor or in other words the time the computer waits after every execution of a step;.

Direction i.e. positive or negative X/Z coordinate is passed as a Boolean signal from the decoder VI.

If coordinates are positive then true signal is obtained and the motor rotates in clockwise direction, on the other hand false value is passed if the coordinates are negative and the motor rotates in anti clockwise direction.The final Exploded and assembly view of Micro-lathe is shown in fig 20 and 21

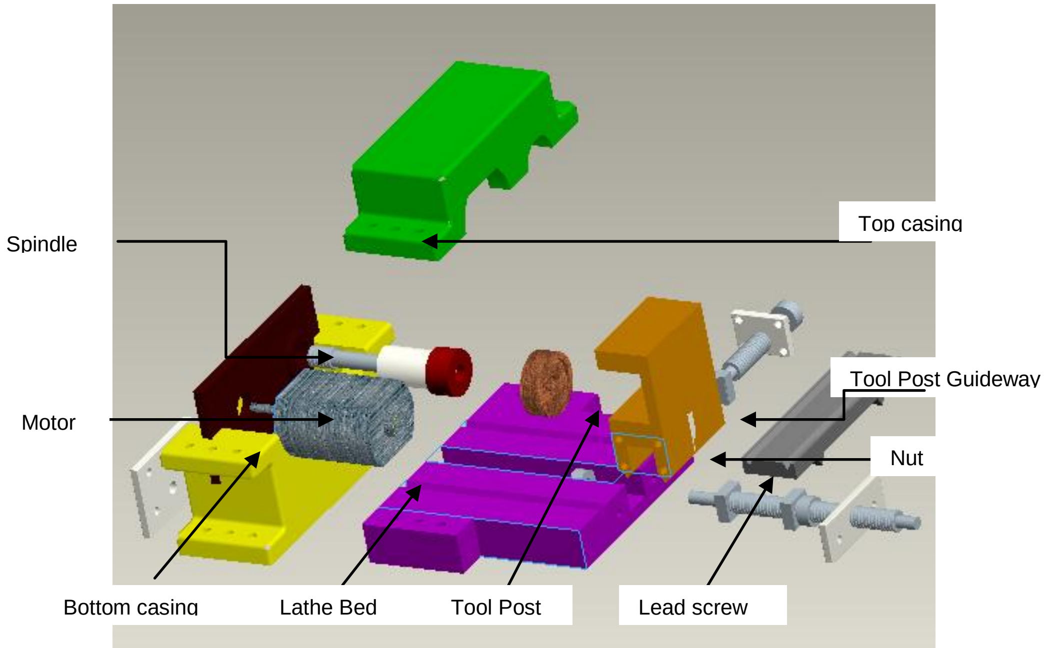


**Fig 20** Exploded view of microlathe

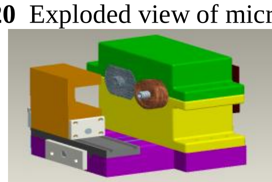

**Fig 21** Assembly view of Microlathe

## 4. CONCLUSION

In this research we developed Micro-lathe for education institute by using LabVIEW software .This developed Micro-Lathe will contribute to Micro-factory education and Micro-machine domestic production for education, and to prototype FMS for education by combining Micro-Lathe, Micro Milling, Micro grinding , Micro cutting, micro-manipulator, micro-machine tool and Micro-Factory system.

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