Design and Construction of Robotic Drilling Machine for Softer Materials- An Overview

Er. Ashis Saxena
Department of Mechanical Engineering, Amrapali Institute of Technology and Sciences, Haldwani, India.
E-mail: erashis@gmail.com

Er. Sumit Prasad
Department of Management Studies, Kumaun University, Nainital, India.
E-mail: tndsumit@gmail.com

Abstract**—Need for this paper arises to minimize the efforts in drilling process in industries, so that outputs can be optimized at reduced cost. This will also help in increasing the accuracy and efficiency of working, which will minimize the rejection loss of the end product. In the following paper we will propose a efficient robotic drilling process, which will serve the desirable.**

Keywords- robot; drilling machine; robotic drill; motor.

INTRODUCTION

Robotics, computer-controlled machine that is programmed to move, manipulates objects, and accomplishes work while interacting with its environment. Robots are able to perform repetitive tasks more quickly, cheaply, and accurately than humans. The term robot originates from the Czech word robota, meaning "compulsory labor." It was first used in the 1921 play R.U.R. (Rossum's Universal Robots) by the Czech novelist and playwright Karel Capek. The word robot has been used since to refer to a machine that performs work to assist people or work that humans find difficult or undesirable.

The project is mainly used for drilling of softer material. In this project there are three links, which are driven by three motors and six gears are used. Power is generated by motor and is transmitted through gear. The interfacing of the drilling machine is done through parallel port of the computer with the help of Male D-25 connector. If we talk about its prototype on a large scale than it will find many applications such as welding drilling etc. with some modifications.

WHAT IS ROBOT?

What is Robot?

Human shape dolls have been found in classical clock in Europe and Karakuri in Japan. We found such dolls in the story of Pinocchio. The word ``Robot" came from Czech ' 1920 Play ``Rossum' s Universal Robot" by Karl Capeck, where robotas, robot in Czech, meaning mechanical slaves developed by Rossum revolved against humans.

The stories about robots are found in Issac Asimov science fiction to Osamu Tezuka' s long story manga ``Astro-Boy" . They are mechanical men look like and work for humans. Especially in the science fiction of Issac Asimov(1920-92) ``I, Robot" three Laws of Robotics impressed the audience.

In spite the fact that the science fictions and animated comics have given vivid image of the robots and cyborgs, the robots found in the real life are placed in the factories and they are just arms with end effecter doing repeated simple tasks of moving, assembling, palletizing, painting, cutting and welding. Such robots are said industrial robots. In 1996, Honda Motor Co. announced the first humanoid robot P2 which could autonomously walk with biped, which bought the shock to scientists and engineers who had done researches on walking robot, since Honda had kept the project secret since 1986 from its start. In 1997 the more advanced P3 appeared and in November 2000, the popular Asimo appeared and humanoid researches have been progressed in Japan. Nearly the same time, Sony Co. announced its small autonomous biped robot SDR-3X which uses the similar software architecture with entertaining robot dog AIBO, which is a new robot product to entertain human. When AIBO was sold firstly through the network, it was said that 3,000 units were sold in twenty minutes.

The three laws of Robotics

- A robot may not injure a human being, or through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

SRUCTURE AND DESIGNING OF ROBOTIC DRILL

Description

In this project there are three links which is are driven by motors with the help of gears. One arm which is vertical can also rotate about its axis. Second arm has the motion in horizontal direction which can slide on the vertical arm. Third arm has the motion in vertical direction which slide on the horizontal axis. A drill chuck is fitted on the third vertical arm which is driven by DC motor. Other than this motors are stepper motors which are three in no.s. These motors are controlled by the computer with the help of a program. In our machine we use lead screw method to give sliding motion to arms. Arms are made of mild steel screw and rods which are covered by aluminum sheets.

Working

Power is given by the motor which is transmitted by the use of gear. Drill chuck is rotated by D.C. motor by 6v supply. We can rotate the stepper motor according to our need. A 25 pin D connecter is used to connect the circuit to computer through parallel port. We give 5v supply to activate stepper motors. These motors start rotating gear and then lead screw. Thus we can move the desired arm with the help of these motors. With the help of computer program we can rotate the motor in either direction. We can increase or decrease the speed of motor according to our will. After selecting the position on which drilling have to done, we set our machine links and then drilling is done on object on desired position.

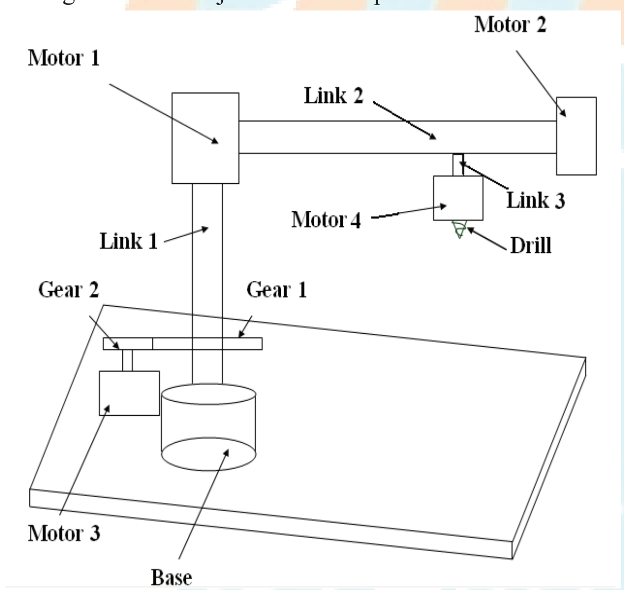


Figure 1: Robotic Drilling Machine

List of Components

Following is the list of Components required:

Components		Units Required
25 pin parallel port connector		1
Stepper Motor (5 V)		3
D.C. Motor (12 V)		1
Screw 7”		2
Transistor BD139		8
IC 7805		1
Diode (IN 4007)		4
Capacitor	1000 µF	1
	.1 µF	1
Transformer (0-9 V)		1
LED		1
Resistance	1KΩ	8
	680Ω	1
Main Lead		1
Wire		As per requirement
Rod 8”		4
Wood		As per requirement
P.C.B.		1
Drill Chuck		1
Drill Bit		1
Aluminium Sheet		As per requirement
Spur Gears		6
Bearings	608z (small)	3
	6201z	1

Table 1: List of Components

Circuit Used for Stepper motor interfacing

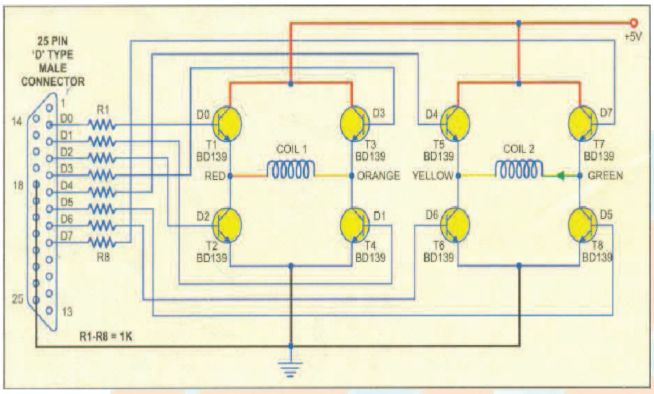


Figure 2: Circuit for Stepper Motor Interfacing

Pulse Sequence

TABLE I
Pulse Sequence to Rotate the Motor Clockwise

Data bit / Port pin	D7 9	D6 8	D5 7	D4 6	D3 5	D2 4	D1 3	D0 2
Phase 1	1	1	0	0	1	1	0	0
Phase 2	0	0	1	1	1	1	0	0
Phase 3	0	0	1	1	0	0	1	1
Phase 4	1	1	0	0	0	0	1	1

1= High, 0 = low

Table 2 (i): Pulse Sequence to Rotate the Motor Clockwise

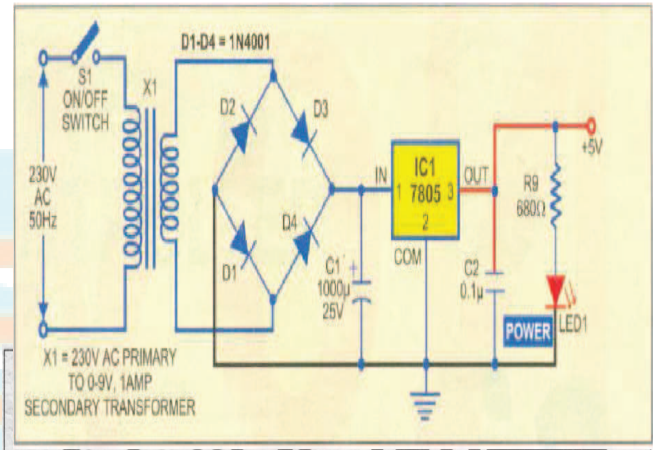
TABLE II
Pulse Sequence to Rotate the Motor Anti-clockwise

Data bit / Port pin	D7 9	D6 8	D5 7	D4 6	D3 5	D2 4	D1 3	D0 2
Phase 1	1	1	0	0	1	1	0	0
Phase 2	1	1	0	0	0	0	1	1
Phase 3	0	0	1	1	0	0	1	1
Phase 4	0	0	1	1	1	1	0	0

1= High, 0 = low

Table 2 (ii): Pulse Sequence to Rotate the Motor Anti-Clockwise

Circuit Used for Stepper motor power generation



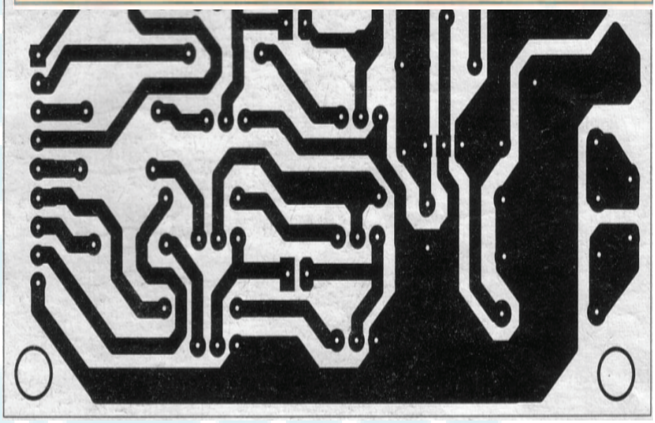


Figure 4: PCB For Stepper Motor Circuit

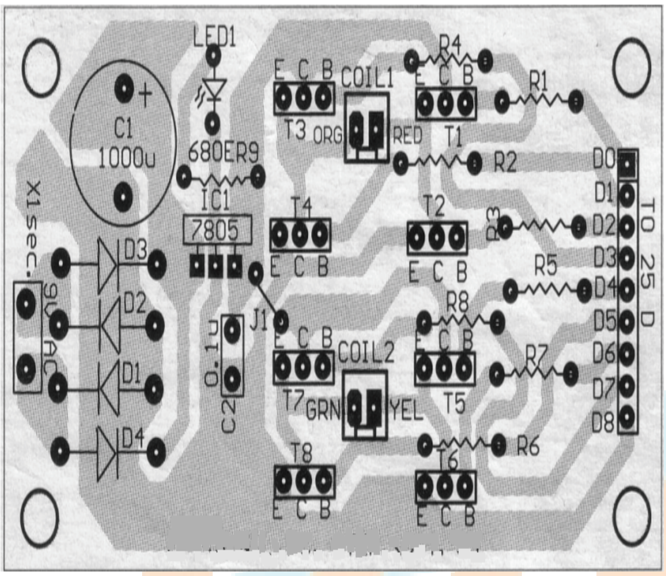


Figure 5: Components Mounted on PCB

Figure 6: PCB for the Project

Parameter of Robotic Drilling Machine

The Length:

L1=Link 1

L2= Link2

L3= Link3

Distance from axis of link 1:

D1=motor 1

D2=motor 2

D3=motor 3

Dg2=Gear 2

Dg3=Gear 3

Da=Auxiliary

Weight or Mass:

W1=Link 1

W2=Link 2

W3=Link 3

Wg2=Gear Box 2

Wg3= Gear Box 3

Wm=motor 2

Wm=Motor 3

Wa= plate +clips +auxiliary

W=Maximum load carrying capacity

Wt= total wt. of all above elements words.

Design of Links

For link 1:

Since link 2 is attached to link 1by hinged joint , so only compressive stress will be on link 1.

The total load acting on link 1 is weight of elements attached to it, if W be the total load and D1,D2 be the internal and external radius of link 1.

Let Fyp be the yield stress of material of link 1. Then

Area of cross section of link 1={Π*D22}/4

Let Ft be the compressive stress due to load

Ft=W/A

Let I be the moment of inertia of link 1 so,

The energy of rotating assembly=(1/2*I*w2)

=M*w

Thus M can be calculated,

Now torsion stress can be generated due to this M

Fs=(16*D2*M)/{pi*(D2*^4-D1^4)}

Maximum shear stress,

τ=1/2(Ft2+4 Fs2)1/2

if either of D1 or D2 is fixed or restricted then the other parameter can be find out by above equation by comparing maximum shear stress with shear strength.

For link 2 and 3:

Bending stress will occur in link 2and link 3,so the governing equation will be

$$\sigma/y = M/I$$

Where

σ=tensile or compressive stress due to bending or bending stress.

Y=distance from natural axis

M=bending moment

I=moment of inertia or second moment of area

The bending moment in the link will be maximum at joint.

Bending moment in link 2

M2=(W3 +Wg +W)*L2+ρ*A*(L22)/2

Where,
A=area of cross section of link 3
ρ=density of material of link 3
by the help of governing equation the maximum bending stress in the link can be calculated and the parameter of the cross section can be determined by comparing it with the safe bending stress.

Design of fixed link:

Load on the link=weight of whole assembly=W
Let inner and outer dia of link be D1 and D2, then
Area of cross section = (Π/4)*(D12/D22)
Compressive stress in link=W/A
The parameter of link can be calculated by comparing stress with yield point stress of the link.

Robot Motion Analysis

In robot motion analysis we study the geometry of the robot arm with respect to a reference coordinate system, while the end-effector moves along the prescribed path.

The kinematic analysis involves two different kinds of problems:

1. Determining the coordinates of the end-effector or end of arm for a given set of joints coordinates.
2. Determining the joints coordinates for a given location of the end-effector or end of arm.

The position, V, of the end-effector can be defined in the Cartesian coordinate system, as:

$$V = (x, y)$$

Generally, for robots the location of the end-effector can be defined in two systems:

a. joint space and
b. world space (also known as global space)

In joint space, the joint parameters such as rotating or twisting joint angles and variable link lengths are used to represent the position of the end-effector.

– $V_j = (q, a)$ for RR robot
– $V_j = (L1, , L2)$ for LL robot
– $V_j = (a, L2)$ for TL robot

where V_j refers to the position of the end-effector in joint space.

In world space, rectilinear coordinates with reference to the basic Cartesian system are used to define the position of the end-effector.

Usually the origin of the Cartesian axes is located in the robot's base.

– $V_W = (x, y)$

where V_W refers to the position of the end-effector in world space.

• The transformation of coordinates of the end-effector point from the joint space to the world space is known as forward kinematic transformation.

• Similarly, the transformation of coordinates from world space to joint space is known as backward or reverse kinematic transformation.

Description of Components

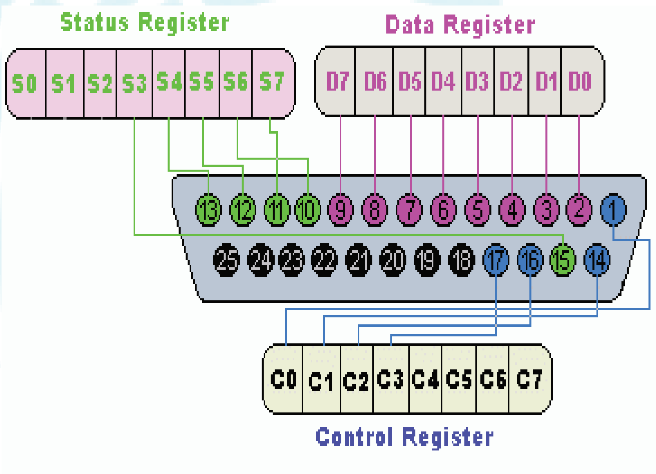
Parallel Port

The Parallel Port is the most commonly used port for interfacing homemade 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's found commonly on the back of your 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 primary use of parallel port is to connect printers to computer and is specifically designed for this purpose. Thus it is often called as printer Port or Centronics port (this name came from a popular printer manufacturing company 'Centronics' who devised some standards for parallel port).

Figure 7: 25-way Female D-Type Connector

Port Addresses

The Parallel Port has three commonly used base addresses. These are listed in table below. The 3BCh base address was originally introduced used for Parallel Ports on early Video Cards. This address then disappeared for a while, when Parallel Ports were later removed from Video Cards. They has now



reappeared as an option for Parallel Ports integrated onto motherboards, upon which their configuration can be changed using BIOS.

LPT1 is normally assigned base address 378h, while LPT2 is assigned 278h. However this may not always be the case as explained later. 378h & 278h have always been commonly used for Parallel Ports. The lower case h denotes that it is in hexadecimal. These addresses may change from machine to machine.

Address	Notes:
3BCh - 3BFh	Used for Parallel Ports which were incorporated on to Video Cards - Doesn't support ECP addresses
378h - 37Fh	Usual Address For LPT 1
278h - 27Fh	Usual Address For LPT 2

Table 3: Port Addresses

Hardware Properties

Below is a table of the "Pin Outs" of the D-Type 25 Pin connector and the Centronics 34 Pin connector. The D-Type 25 pin connector is the most common connector found on the Parallel Port of the computer, while the Centronics Connector is commonly found on printers. The IEEE 1284 standard however specifies 3 different connectors for use with the Parallel Port. The first one, 1284 Type A is the D-Type 25 connector found on the back of most computers. The 2nd is the 1284 Type B which is the 36 pin Centronics Connector found on most printers.

Pin No (D-Type 25)	Pin No (Centronics)	SPP Signal	Direction In/out	Register	Hardware Inverted
1	1	nStrobe	In/Out	Control	Yes
2	2	Data 0	Out	Data	
3	3	Data 1	Out	Data	
4	4	Data 2	Out	Data	
5	5	Data 3	Out	Data	
6	6	Data 4	Out	Data	
7	7	Data 5	Out	Data	
8	8	Data 6	Out	Data	
9	9	Data 7	Out	Data	
10	10	nAck	In	Status	
11	11	Busy	In	Status	Yes
12	12	Paper-Out / Paper-End	In	Status	
13	13	Select	In	Status	
14	14	nAuto-Linefeed	In/Out	Control	Yes
15	32	nError / nFault	In	Status	
16	31	nInitialize	In/Out	Control	
17	36	nSelect-Printer / nSelect-In	In/Out	Control	Yes
18 – 25	19-30	Ground	Gnd		

Table 4: Pin Assignments of the D-Type 25 pin Parallel Port Connector

Stepper Motor

Motion Control, in electronic terms, means to accurately control the movement of an object based on either speed, distance, load, inertia or a combination of all these factors. There are numerous types of motion control systems, including; Stepper Motor, Linear Step Motor, DC Brush, Brushless, Servo, Brushless Servo and more. This document will concentrate on Step Motor technology.

In Theory, a Stepper motor is a marvel in simplicity. It has no brushes, or contacts. Basically it's a synchronous motor with the magnetic field electronically switched to rotate the armature magnet around.

A Stepping Motor System consists of three basic elements, often combined with some type of user interface (Host Computer, PLC or Dumb Terminal):

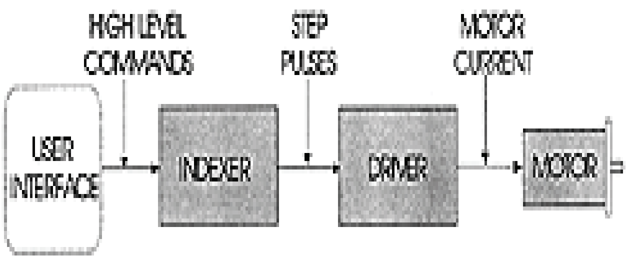


Figure 8: Stepper Motor System

The Indexer (or Controller) is a microprocessor capable of generating step pulses and direction signals for the driver. In addition, the indexer is typically required to perform many other sophisticated command functions.

The Driver (or Amplifier) converts the indexer command signals into the power necessary to energize the motor windings. There are numerous types of drivers, with different current/amperage ratings and construction technology. Not all drivers are suitable to run all motors, so when designing a Motion Control System the driver selection process is critical.

The Step Motor is an electromagnetic device that converts digital pulses into mechanical shaft rotation. Advantages of step motors are low cost, high reliability, high torque at low speeds and a simple, rugged construction that operates in almost any environment. The main disadvantages in using a step motor is the resonance effect often exhibited at low speeds and decreasing torque with increasing speed.

Transistor (BD 139)

BD139 is silicon Epitaxial Planar NPN transistors mounted in Jedec SOT-32 plastic package, designed for audio amplifiers and drivers utilizing complementary or quasi-complementary circuits. The complementary PNP type is BD140.

Robot Programming & Software

Robots perform tasks for a given application by following a programmed sequence of directions from the control system. The robot's program establishes a physical relationship between the robot and other equipment. The program consists of a sequence of positions for the axes of movement and any end-effector operation, path information, timing, velocities, sensor data reading, external data-source reading, and commands or output to externally connected systems. The program may be taught by manually commanding the robot to learn a series of positions and operations (such as gripper closing) that collectively compose the work cycle. The robot converts these positions and operations into its programming language. Alternatively, the robot programming can be input directly in its programming language at a terminal, which may be the robot's controller or a separate computer. Robot programming generally needs verification and some modifications. This procedure is called program touchup. It is normally done in the teach mode of operation with the teacher manually leading the robot through the preprogrammed steps.

Three different teaching or programming techniques are lead-through, walk-through, and off-line programming. A description of each is provided below.

Lead-Through Programming/Teaching

Lead-through programming usually uses a teach pendant. This allows the teacher to direct the robot through a series of positions and to enter associate commands and other information, such as velocities. The human teaches the positions. The robot's controller generates the programming commands to move between positions when the program is played. When using this programming technique, the teacher may need to enter the robot's working envelope. This introduces a high potential for accidents because safeguarding devices may have to be deactivated to permit such entry. Only the teach pendant may be used to program a robot, or it may be used with an additional programming console and/or the robot's controller.

Walk-Through Programming/Teaching

The teacher physically moves ("walks") the robot through the desired positions within the robot's working envelope. During this time, the robot's controller may scan and store coordinate values on a fixed-time interval basis. These values and other functional information are replayed in the automatic mode. This may be at a different speed than that used in the walk-through.

This type of walk-through programming uses triggers on manual handles that move the robot. When the trigger is depressed the controller remembers the position. The movement between these points when the program is played would then be generated by the controller. The walk-through methods of programming require the teacher to be within the robot's working envelope with the robot's controller energized at least in the position sensors. This may also require that safeguarding devices be deactivated.

Off-line Programming

Off-line programming uses a remote programming computer. The programmer establishes the required sequence of functional and positional steps. The program is transferred to the robot's controller by disk, cassette, or network link. Typically, positional references are established on the robot to calibrate or transform the coordinates used in the remote programming for the actual setup.

Conclusion

This project is used for drilling of softer material. Finishing and accuracy is obtained up to optimum level. By use of this machine, drilling is fast and accurate.

It is fully automatic. It is also used in industry as a drilling machine for softer material. By doing some modification in the project, it can be widely used in industry for softer and harder material also.

Further improvement is needed for this project. By doing some improvement, it will be very useful for industry. It can be manufactured on large scale and after some improvements and modifications we can achieve welding and other manufacturing processes based on same "ROBOTIC" principle- Robot Motion Analysis.

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