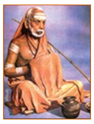
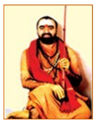
With the blessings of Their Holinesses

Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya

Enathur, Kanchipuram

Accredited with Grade 'A' by NAAC

ROBOTICS AUTOMATION AND PROCESS CONTROL

LABORATORY MANUAL

(SEVENTH SEMESTER - MECHATRONICS)

Subject Code: BMTF187P60

(For the Academic year - 2021-2022)

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SCSVMV

SYLLABUS

(For Students admitted from 2018 onwards)

COURSE OBJECTIVES

1. To impart basic knowledge on robotics and process control.
2. To impart basic knowledge on Programming in robotics software.
3. To introduce students how to interface with real time robotics and process control.
4. To make the students to understand the programming for Industrial application based onrobotics and process control.

ROBOTICS

1. Study components of a real robot and its DH parameters.
2. Forward kinematics and validate using a software (Robo Analyser or any other freesoftware tool).
3. Inverse kinematics of the real robot and validation using any software.
4. Positioning and orientation of robot arm.
5. Control experiment using available hardware or software.
6. Integration of assorted sensor (IR , Potentiometer, Stain gages etc..), micro controllersand ROS (Robot Operating System) in a robotic system.

PROCESS CONTROL

1. Characteristics of LVDT/LDR / Thermocouple /RTD / Thermistor
2. Characteristics of Strain Gauge, Torque Sensor.
3. Measurement of flow using Venturi Meter/ orifice Meter
4. Characteristics of control valve with and without positioner
5. Closed loop response of flow / level / temperature / pressure control loop
6. Operation of interacting and non-interacting systems
7. Tuning of controllers

COURSE OUTCOME

1. Able to understand the importance of robotics and process control.
2. Able to program robotics and process control for different Industrial Applications.
3. Able to interface different real time robotics program.
4. Able to interface different real time process control program.
5. Gains hands on knowledge on interfacing robotics and process control.
6. Able to build a suitable robotics automation technology for the given application.

INDEX

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ROBOTICS AUTOMATION

Forward Kinematics of Movemaster RM-501

EXP NO :

DATE :

AIM

To study the Characteristics of forward Kinematics of Movemaster RM – 201.

Introduction

Mitsubishi Movemaster RM-501 is a entry level industrial robot with five rotational joints having five degree of freedoms. Forward kinematics refers to the use of the kinematic equations of a robot to compute the position of the end-effector from specified values for the joint parameters. The kinematics equations of the robot are used in robotics, computer games, and animation. The reverse process that computes the joint parameters that achieve a specified position of the end-effector is known as inverse kinematics.

The essential concept of forward kinematic animation is that the positions of particular parts of the model at a specified time are calculated from the position and orientation of the object, together with any information on the joints of an articulated model. So for example if the object to be animated is an arm with the shoulder remaining at a fixed location, the location of the tip of the thumb would be calculated from the angles of the shoulder, elbow, wrist, thumb and knuckle joints. Three of these joints (the shoulder, wrist and the base of the thumb) have more than one degree of freedom, all of which must be taken into account. If the model were an entire human figure, then the location of the shoulder would also have to be calculated from other properties of the model.

Figure 1: MOVEMASTER RM-501

THEORY

MOVEMASTER RM-501

The Mitsubishi Movemaster RM-501 robot is a robotic arm having five degrees of freedom with five rotational joints. The robot unit consists of the waist, shoulder, elbow, wrist pitch, and wrist roll. These are actuated with DC motors to each of which two encoders are associated which allow differential directional information to be read for each joint.

Overall size:

The Robot Unit, including the base, weighs approximately 27 kg. The overall size of the robot is comparably small with a circular work envelope of 445mm maximum horizontal reach and a maximum payload of 1.2kg.

Components:

In addition to the robot itself, the complete robotic system for the Mitsubishi Movemaster consists of several components, which are shown in the following Figure 2:

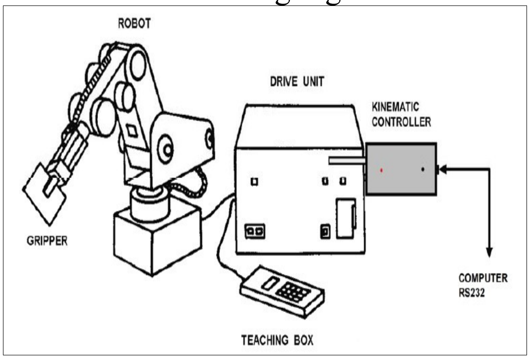


Figure 2: Movemaster RM501 components

The main components of the RM-501 include the Robot and the Drive Units. Options include the Teaching Box and the standard hand. The RM-501 drive unit provides the intelligence and control for the robot unit. The Drive Unit computes all arm control information for each instruction. It handles arm velocity, acceleration, deceleration and movement trajectories for the user. The Teaching Box allows a user to manually move all joints of the Robot Unit and store positions as desired. The Drive Unit is interfaced to the Computer host processor via a controller interface.

Range of movement of each joint:

Waist Joint	300
Shoulder Joint	130
Elbow Joint	90
Wrist Bend	±90
Wrist Roll	±180

Robot Kinematics:

Robot kinematics involves computing the end effector's position from the joint angles and vice versa for controlling the position of robot. The Mitsubishi RM-501 robot has 5 degrees of freedom (Figure 2) and the ability to grip with its two fingers. Its position can be described by the vector of joint coordinates **q** = $[q_1\ q_2\ q_3\ q_4\ q_5]^T$ and the vector of external coordinates **r** = $[\ x\ y\ z\ \varphi\ \Psi]^T$. Figure 3 shows the robots arm with its basic dimensions, from which the kinematics can be derived, i.e. the link between the **q** and **r** vectors.

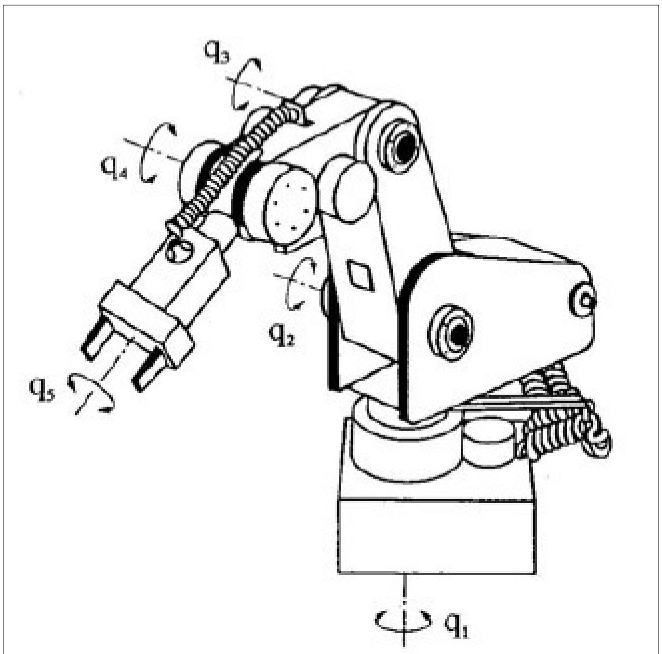


Figure 3: Degrees of freedom of the RM-501 robot

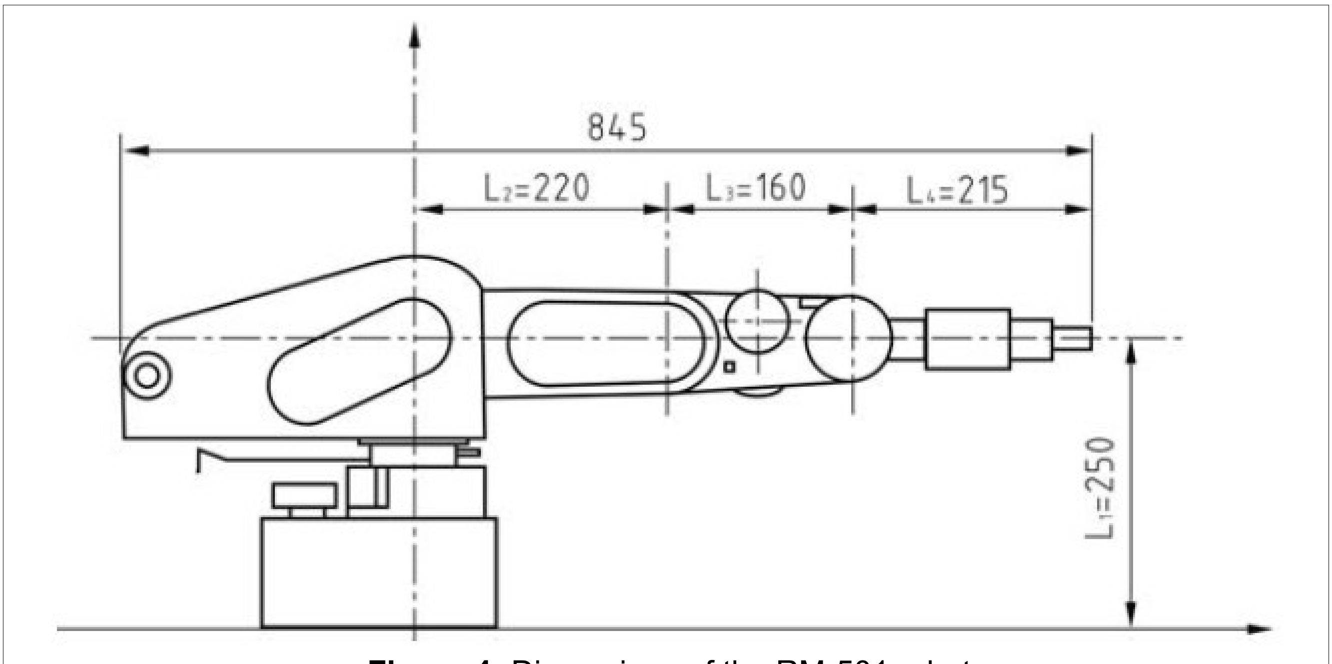


Figure 4: Dimensions of the RM-501 robot

Forward Kinematics

Forward kinematics involves computing the position and orientation of the end effector when the relative movements at various connections and other relevant geometrical parameters are prescribed. The forward kinematics of a kinematic chain can be established by defining a coordinate system at the root of each link and then defining transformation matrices between subsequent coordinate systems as:

A10A01, A20A02, A30A03, ... Ann−1An-1n

For rotational joints, each matrix will then contain the joint angle Î¸n as a variable. The overall transformation from the earth fixed reference frame to the end effector fixed reference frame is then given by

An0A0n=A10A01 A20A02 A30A03 Ann−1An-1n

For each joint of the robot :Aii−1Ai-1i the Denavit-Hartenberg matrix contains four parameters that fully define coordinate transformation from the coordinate system attached to the previous link to the coordinate system attached to the next link. The four parameters and a description of their meaning is given in Table

Parameter	Description
a_i	The distance between Z_{i-1} and Z_i measured along X_i
α_i	The angle between Z_{i-1} and Z_i measured along X_i
d_i	The distance from X_{i-1} to X_i along Z_i
θ_i	The angle between X_{i-1} and X_i measured along Z_i

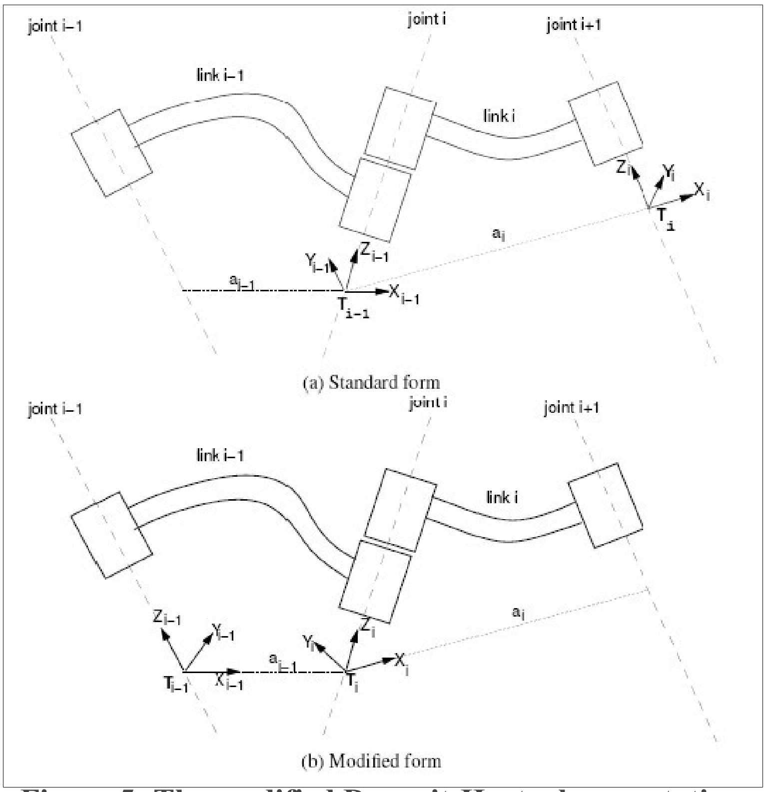
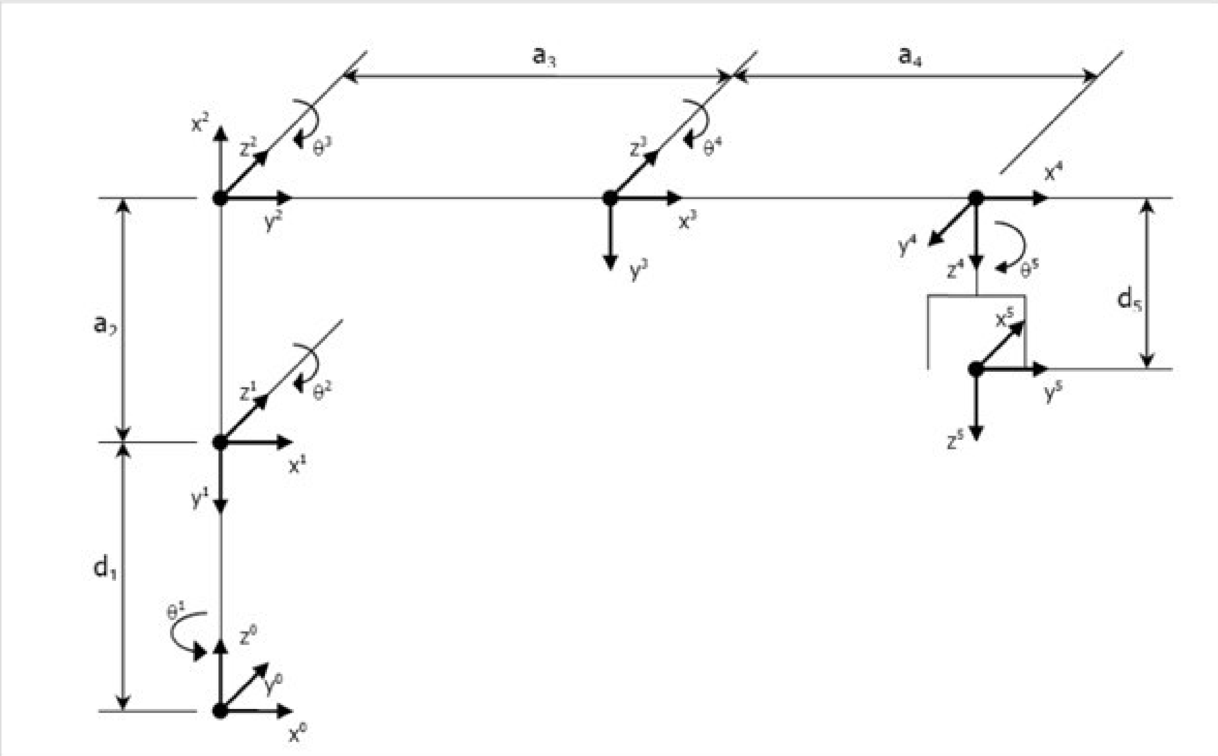


Figure 5: The modified Denavit-Hartenberg notation.

The Denavit-Hartenberg parameters derived for the Mitsubishi Movemaster RM-501 is given in table below. The schematic of the robot with the intermediate coordinate systems used to derive the matrix is given in Figure.

i	a_i	α_i	d_i	θ_i	Home
1	0	-90 °	250	Θwaist	0 °
2	220	0 °	0	Θshoulder	-90 °
3	160	0 °	0	Θelbow	90 °
4	0	-90 °	0	Θwristpitch	0 °
5	0	0 °	215	Θwristroll	-90 °



Robot schematic showing link coordinate systems used for deriving Denavit-Hartenberg matrix. Showing "soft" home position. Modified from: Schilling (1990).

From Schilling (1990) the arm matrix can be derived by analogy to the general arm matrix for five axes articulated robots[19]:

$$T_{base}^{tool} = \begin{bmatrix} C_1C_{234}C_5 + S_1S_5 & -C_1C_{234}S_5 + S_1C_5 & -C_1S_{234} & C_1(a_2C_2 + a_3C_{23} - d_5S_{234}) \\ S_1C_{234}C_5 - C_1S_5 & -S_1C_{234}S_5 - C_1C_5 & -S_1S_{234} & S_1(a_2C_2 + a_3C_{23} - d_5S_{234}) \\ -S_{234}C_5 & S_{234}S_5 & -C_{234} & d_1 - a_2S_2 - a_3S_{23} - d_5C_{234} \\ 0 & 0 & 0 & 1 \end{bmatrix}. \quad (4.)$$

This matrix can be understood as being composed of a vector p defining the position the end effector in space, and a 3 by 3 matrix R defining the orientation of the end effector:

$$T_{base}^{tool} = \begin{bmatrix} R_{11} & R_{12} & R_{13} & p_1 \\ R_{21} & R_{22} & R_{23} & p_2 \\ R_{31} & R_{32} & R_{33} & p_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Objective

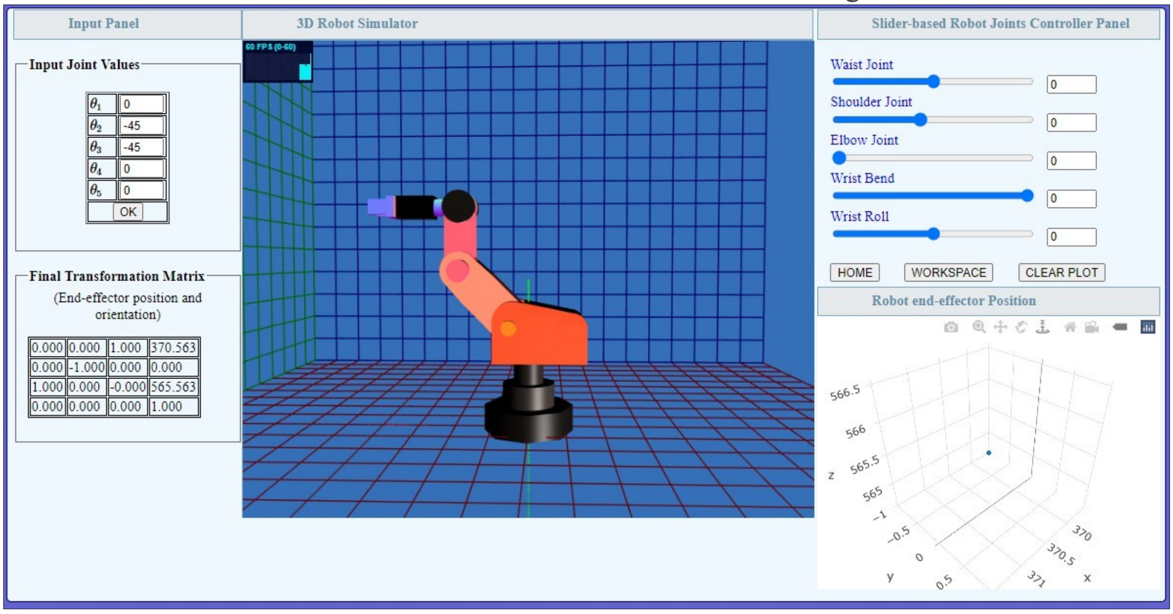
- To identify the geometric relationship between input and output motion parameters of Movemaster RM-501 robotic arm.
- Formation of the transformation matrix though which a relationship is established between different links of the manipulator.
- To have a brief idea about the workspace through a 3D graph plot of manipulator position for various inputs.
- Simulate the robot motion for various inputs of the joint angular value.
- Robot Trajectory Visualization while moving from one position to another

Procedure

- Insert different values of θθ within the joint range as prescribed in theory part and then click ok to get the output orientation and position of the end effector.
- To see the individual movements of the robot links drag the sliders on the controller panel.
- Manipulator position is shown in a 3D graph for every submission of joint values.
- The view can be rotated about a point by keeping the ***left mouse button*** pressed and rotating the mouse.
- The view can be translated by keeping the ***right mouse button pressed*** and translating the mouse in the desired direction.

SIMULATOR

- The ***scroll button*** or ***middle mouse button*** can be used for zooming.



Simulator Screen shot

http://vlabs.iitkgp.ac.in/mr/exp2/Forward_kinematics_RM501.html

RESULT

Thus, the Characteristics of forward Kinematics of Movemaster RM – 201 was studied.

FORWARD KINEMATICS OF PUMA 560

EXP NO :

DATE :

AIM

To study the characteristics of Forward Kinematics of Puma 560.

INTRODUCTION

The PUMA 560 is a industrial robot arm with six degrees of freedom and all rotational joints. In this experiment at first a brief theory about PUMA 560 robot is presented in the theory section. The theory for mathematical computations was obtained from a wide variety of sources encompassing books, papers and internet. In simulation section a virtual model is developed in javascript program which is used to investigate the forward kinematics problem. For more information on other aspects of PUMA 560 and robotics visitors are advised to follow the references.

Figure 1: PUMA 560

THEORY

- Programmable Universal Machine for Assembly, more popularly known as PUMA is an industrial robot arm developed by Victor Scheinman at Unimation, in the year 1978. PUMA comes in various makes viz. PUMA 260, PUMA 560, PUMA 761 etc. Figure 2 shows link-frame assignments in the position corresponding to all joint angles equal to zero. Here the frame {0} (not shown) is coincident with frame [1} when is zero. Note also that, for this robot, as for many industrial robots, the joint axes of joints 4, 5, and 6 all intersect at a common point, and this point of intersection coincides with the origin of frames {4}, {5}, and {6}. Furthermore, the joint axes
  4, 5, and 6 are mutually orthogonal. This wrist mechanism is illustrated schematically in Fig.4. In this experiment forward kinematics of PUMA 560 is described through a virtual model. The forward kinematics problem is concerned with the relationship between the individual joints of the robot manipulator and the position and orientation of the tool or end effector.

General Terminology in Robotics:

Workspace:

The reachable workspace of a robot's end-effector is the manifold of reachable frames.

Accuracy:

Accuracy refers to a robot's ability to position its wrist end at a desired target point within the work volume, and it is defined in terms of spatial resolution. It depends on the technology and the control increments.

Repeatability:

Repeatability is a statistical term associated with accuracy. If a robot joint moves by the same angle from a certain point a number of times, all with equal environmental conditions, the target is always missed by a large margin. If the same error is repeated, then we say that the repeatability is high and the accuracy is poor.

Safety:

The ability to reduce the human-robot impact force and ensure human safety is a fundamental requirement for human-friendly robots.

Forward Kinematics :

Forward kinematics (FK) mainly deals with constructing a Denavit-Hartenberg (D-H) transformation matrix with Puma's parameters obtained from a D-H parameter table shown below:

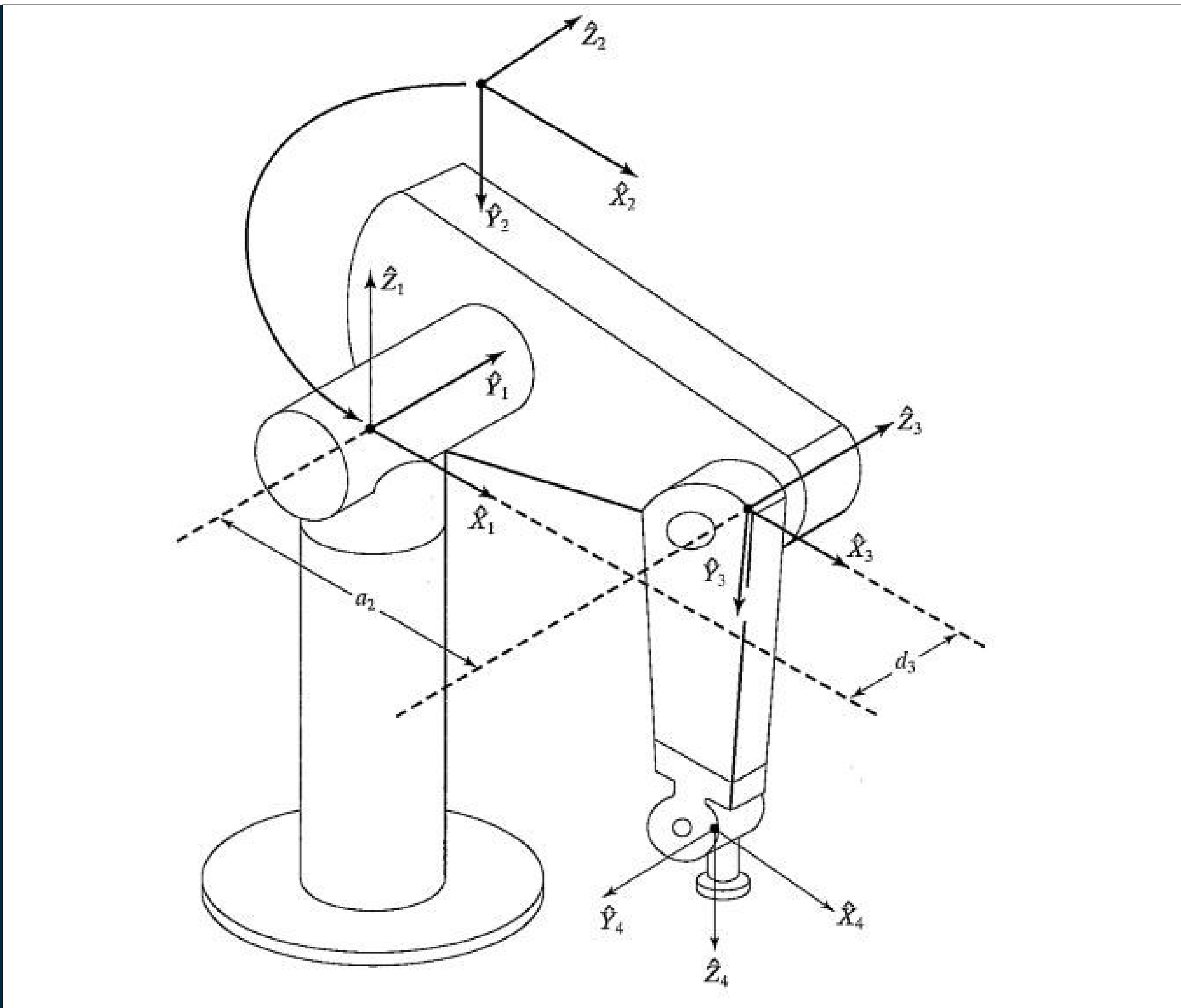


Figure 2: Kinematic parameters and frame assignments for the PUMA 560 manipulator

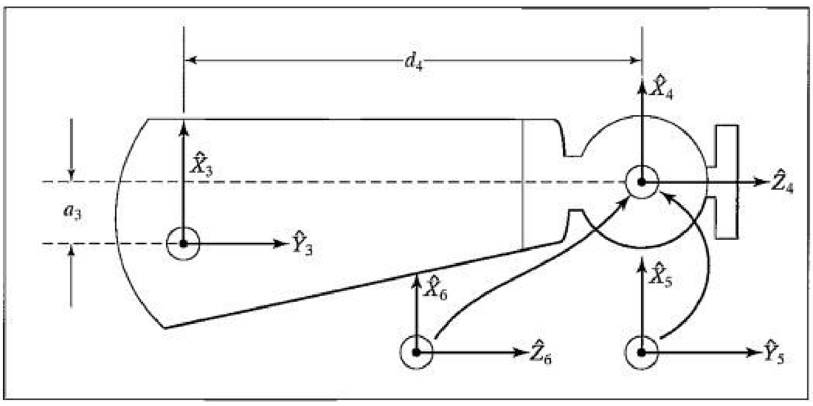


Figure 3: Kinematic parameters and frame assignments for the forearm of the PUMA 560 manipulator

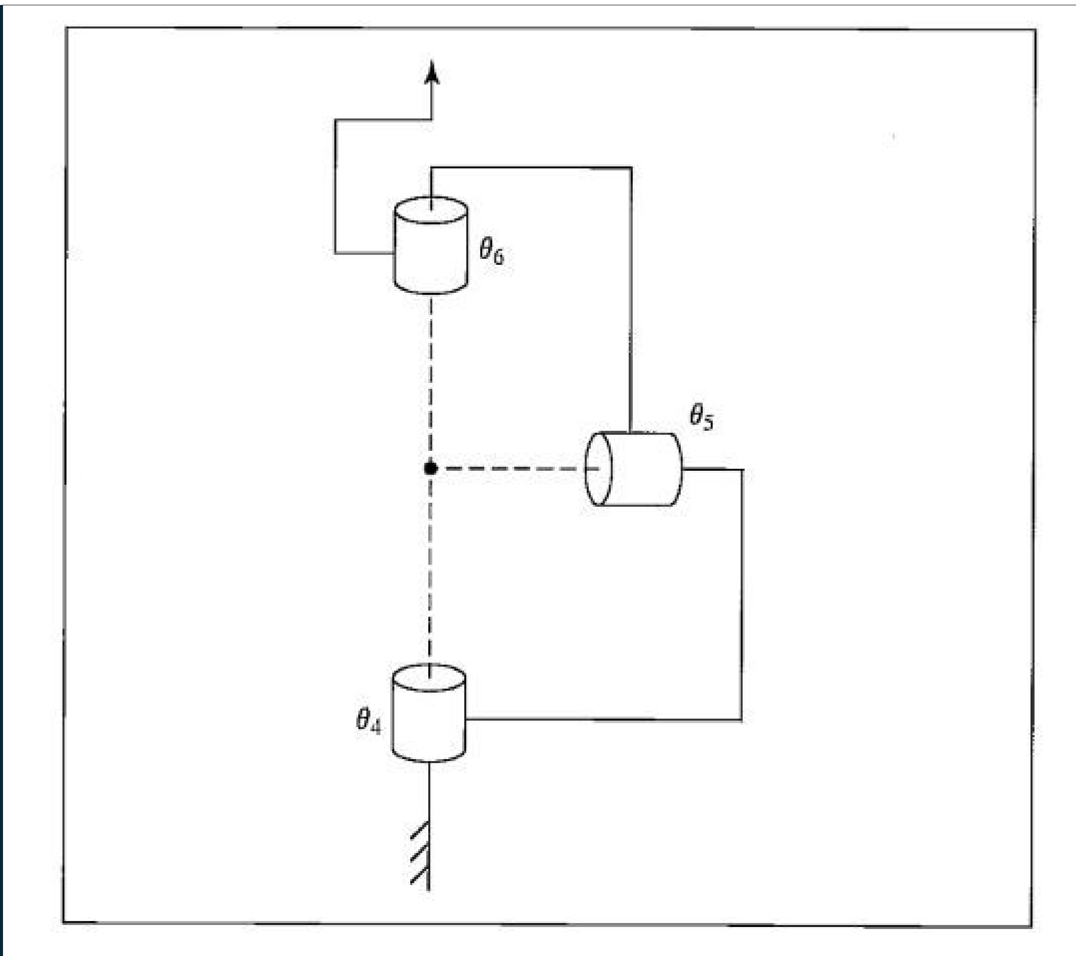


Figure 4: Schematic of a 3R wrist in which all three axes intersect at a point and are mutually orthogonal.

Table 1. Puma 560 D-H parameter table

`LINK_I`	`ALPHA_(I-1)`	`A_I-1`(M)	`D_I`(M)	`THETA_I`
1	0	0	0	`theta_1`

2	-90	0	0	`theta_2`
3	0	`a_2`	`d_3`	`theta_3`
4	-90	`a_3`	`d_4`	`theta_4`
5	90	0	0	`theta_5`
6	-90	0	0	`theta_6`

Transformation matrices of six joints for Puma 560 robot

`T_1 = [[cos \(theta_1\),-sin \(theta_1\),0,0], [sin \(theta_1\), cos \(theta_1\),0,0], [0,0,0,1], [0,0,0,1]]` `T_2 = [[cos \(theta_2\), -sin \(theta_2\),0,0], [0,0,1,0], [-sin \(theta_2\),-cos \(theta_2\),0,0], [0,0,0,1]]`

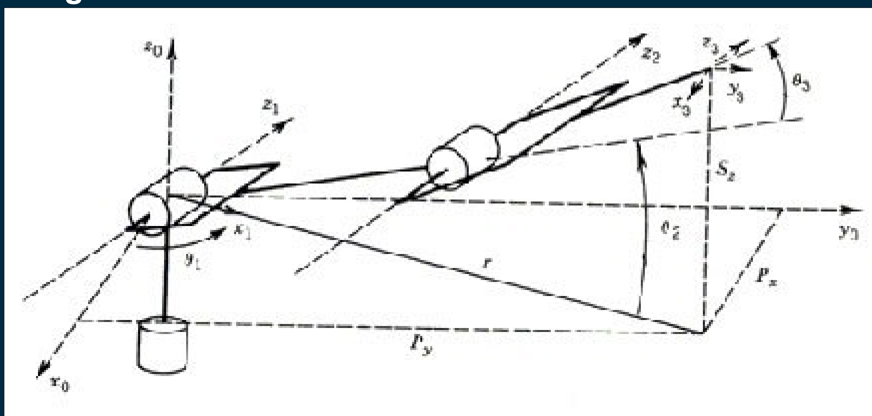
`T_3 = [[cos \(theta_3\),-sin \(theta_3\),0,a_2], [sin \(theta_3\),cos \(theta_3\),0,0], [0,0,1,d_3], [0,0,0,1]]` `T_4 = [[cos \(theta_4\),-sin \(theta_4\),0,a_3], [0,0,1,d_4], [-sin \(theta_4\), -cos \(theta_4\),0,0], [0,0,0,1]]`

`T_5 = [[cos \(theta_5\), -sin \(theta_5\),0,0], [0,0,-1,0], [sin \(theta_5\),cos \(theta_5\),0,0], [0,0,0,1]]` `T_6 = [[cos \(theta_6\),-sin \(theta_6\),0,0], [0,0,1,0], [-sin \(theta_6\),-cos \(theta_6\),0,0], [0,0,0,1]]`

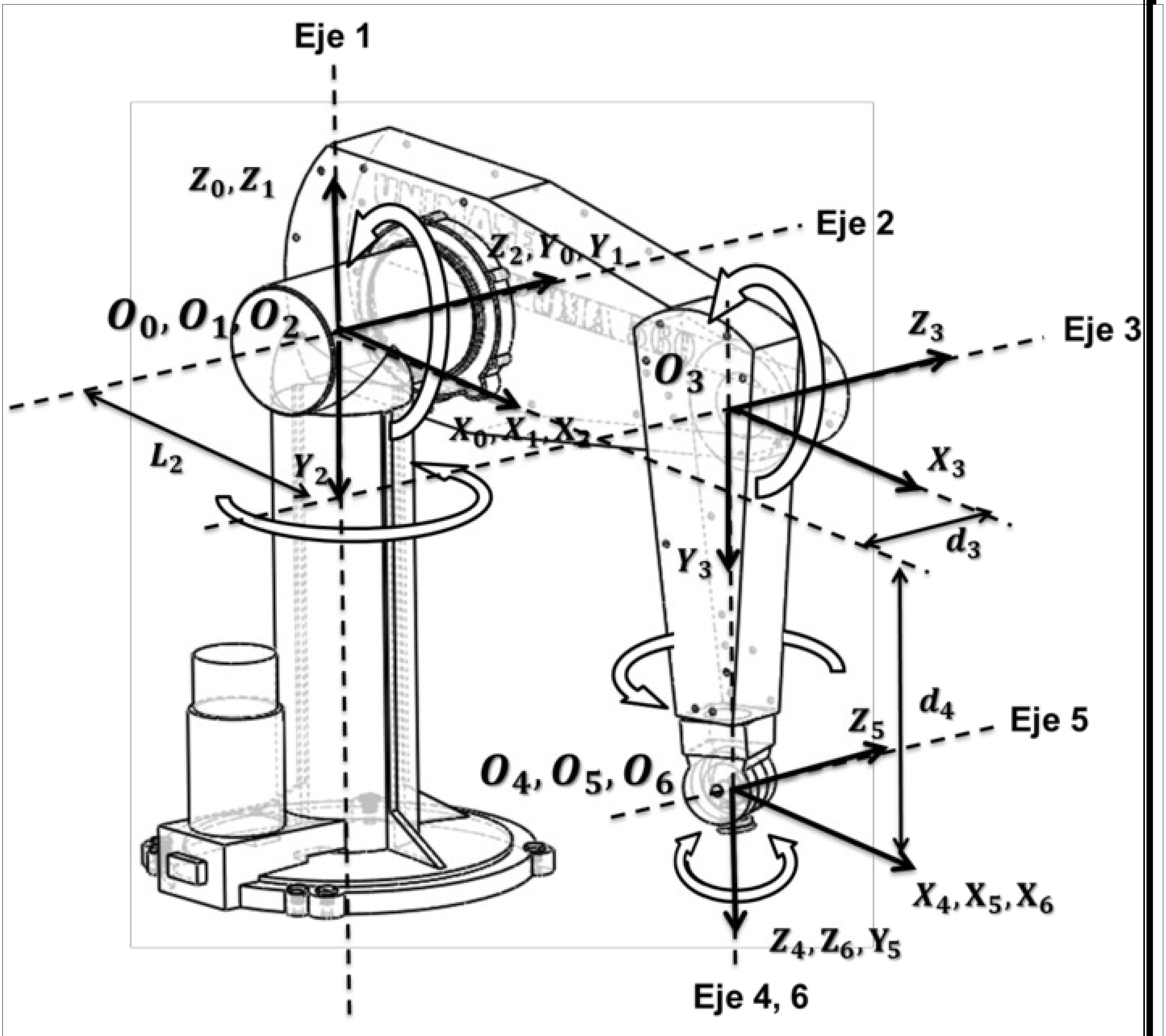
Final Transformation Matrix `T = T_1*T_2*T_3*T_4*T_5*T_6`

The orientation and position of the end effector with reference to the base coordinate is obtain from the final matrix `T = [[n,s, a,p], [0,0,0,0]]=[[n_x, s_x, a_x, p_x], [n_y, s_y, a_y, p_y], [n_z, s_z, a_z, p_z], [0,0,0,1]]`

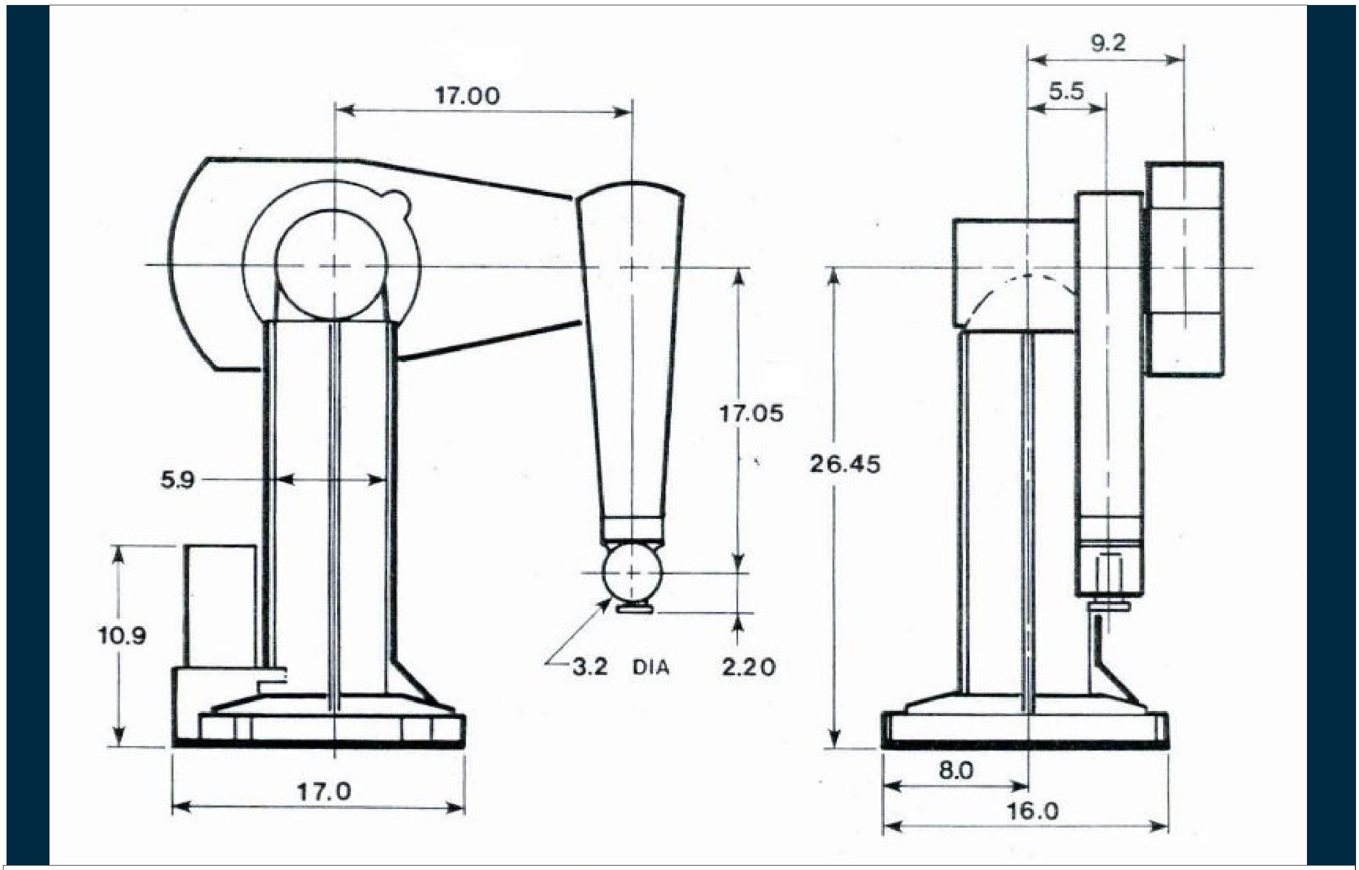
Puma kinematic diagrams



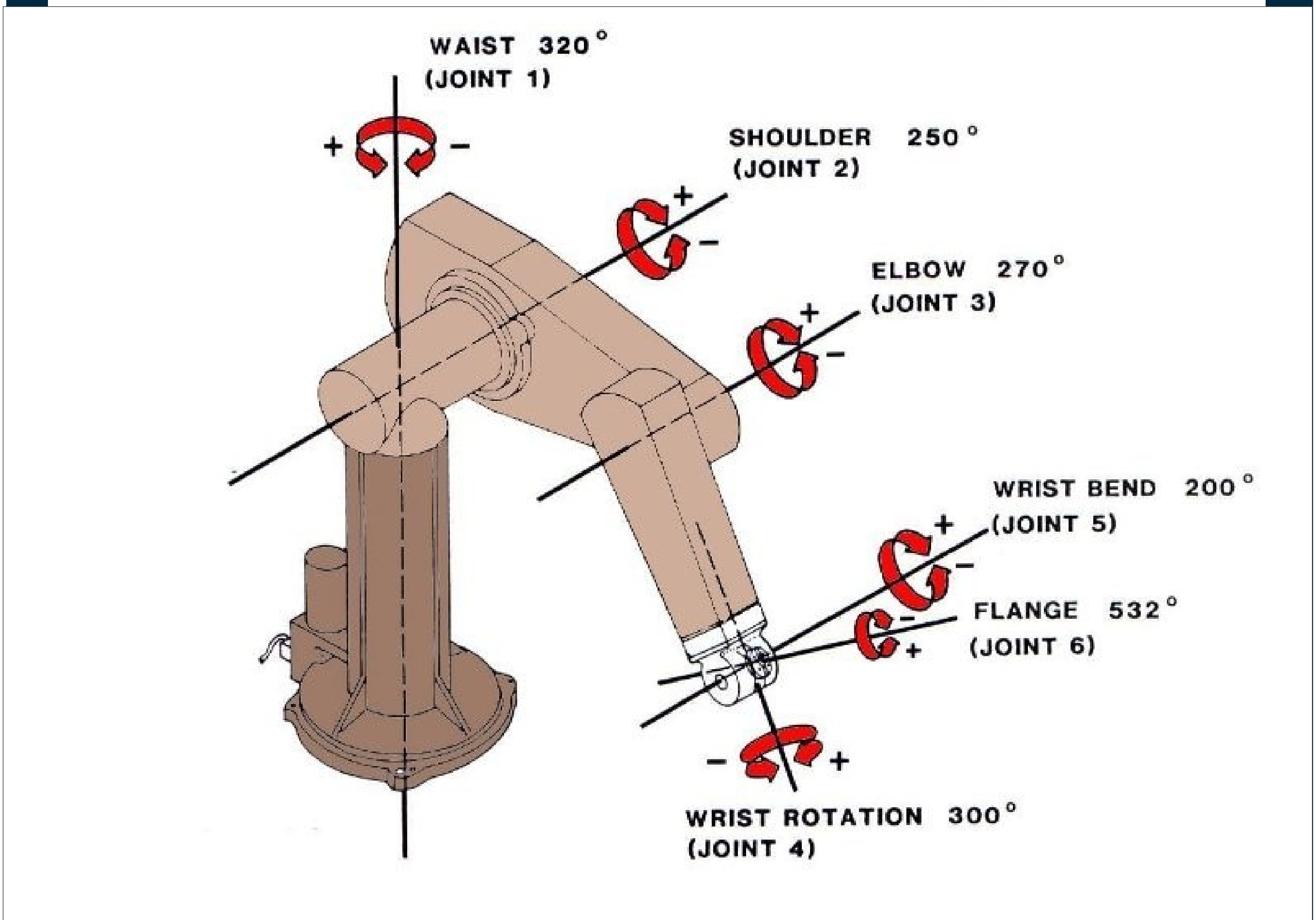
Simplified drawing of first three links of Puma 560 with transformation frames appropriately



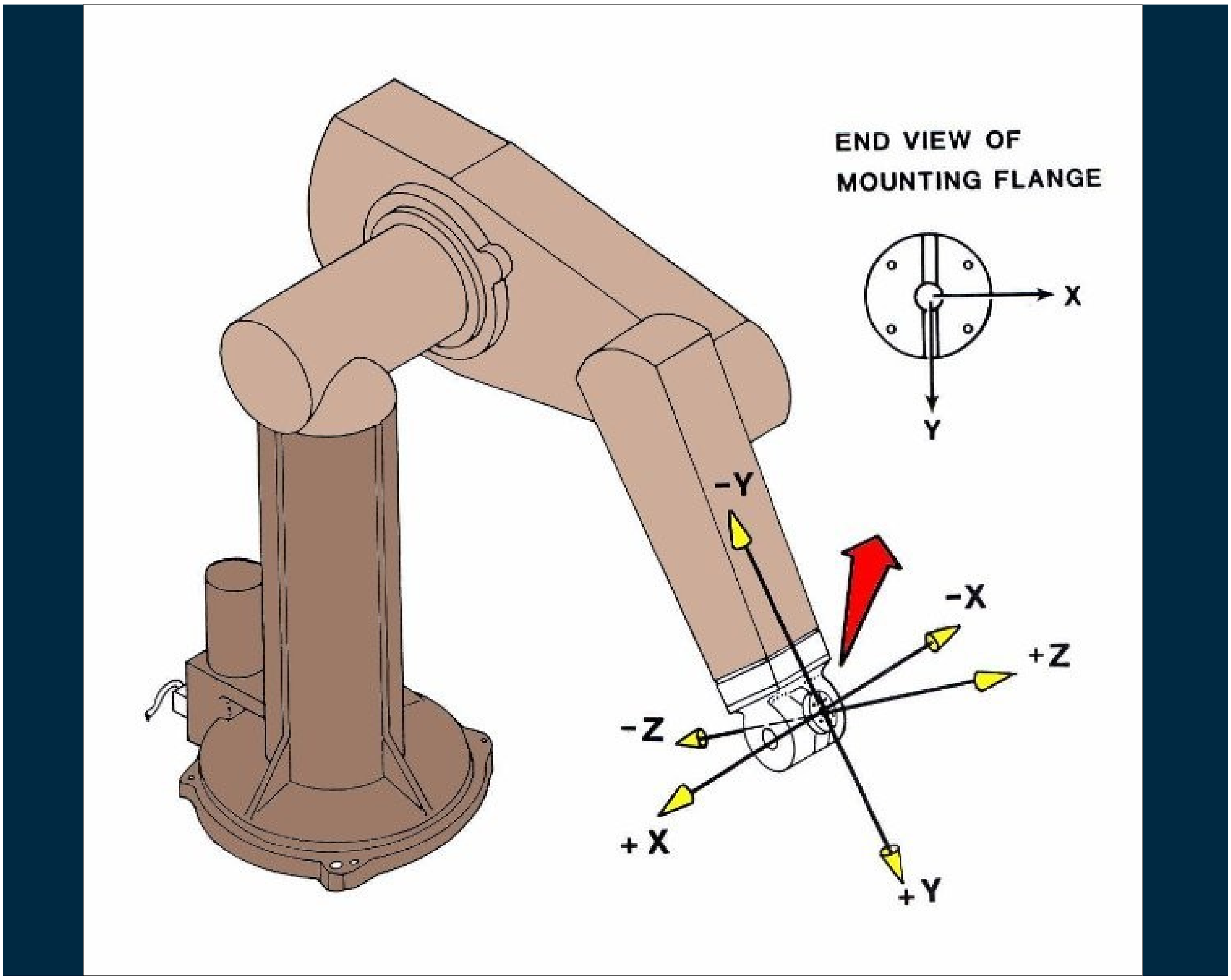
Eje 1
Z_0, Z_1
Eje 2
Z_2, Y_0, Y_1
O_0, O_1, O_2
O_3
Z_3
Eje 3
X_0, X_1, X_2
L_2
Y_2
X_3
d_3
Y_3
d_4
Z_5
Eje 5
O_4, O_5, O_6
X_4, X_5, X_6
Z_4, Z_6, Y_5
Eje 4, 6

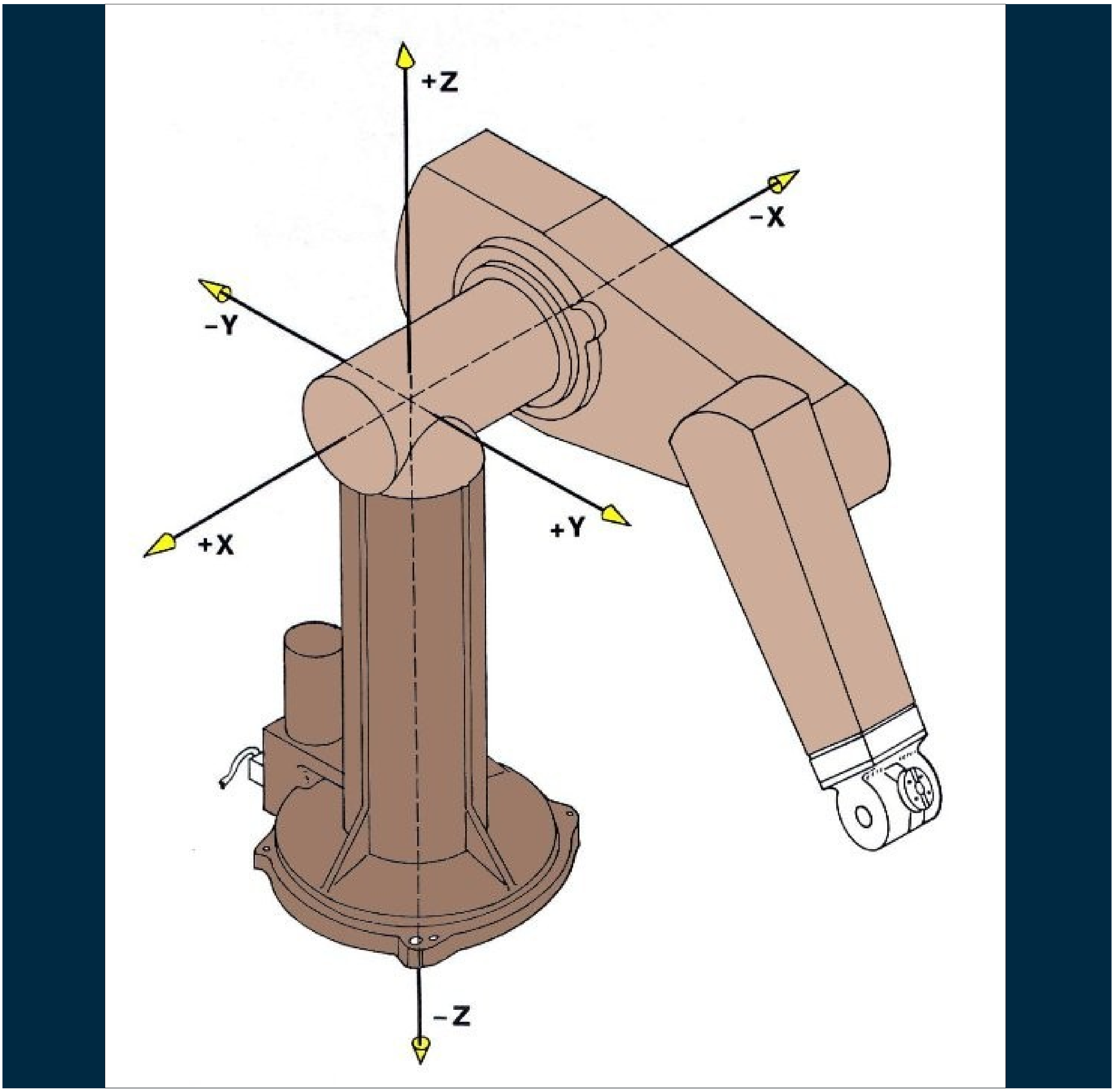


17.00
9.2
5.5
17.05
26.45
5.9
10.9
3.2 DIA
2.20
17.0
8.0
16.0



WAIST 320°
(JOINT 1)
SHOULDER 250°
(JOINT 2)
ELBOW 270°
(JOINT 3)
WRIST BEND 200°
(JOINT 5)
FLANGE 532°
(JOINT 6)
WRIST ROTATION 300°
(JOINT 4)


END VIEW OF
MOUNTING FLANGE
X
Y
-Y
-X
+Z
-Z
+X
+Y



OBJECTIVE

- To identify the geometric relationship between input and output motion parameters of PUMA 560 robot manipulator.
- Formation of the transformation matrix though which a relationship is established between different links of the manipulator.
- Simulate the robot motion for various inputs of the joint angular value.
- To have a brief idea about the workspace through a 3D graph plot of manipulator position for various inputs.

PROCEDURE

- Insert different values of `theta` within the joint range as prescribed in theory part and then click ok to get the output orientation and position of the end effector.
- To see the individual movements of the links drag the sliders on the controller panel.
- The Transformation matrix for a particular position and orientation can be obtained either through input panel or via the controller.
- Manipulator position is shown in a 3D graph for every submission of joint values.
- The view can be rotated about a point by keeping the ***left mouse button*** pressed and rotating the mouse.
- The view can be translated by keeping the ***right mouse button pressed*** and translating the mouse in the desired direction.
- The ***scroll button*** or ***middle mouse button*** can be used for zooming.

http://vlabs.iitkgp.ac.in/mr/exp1/index.html#

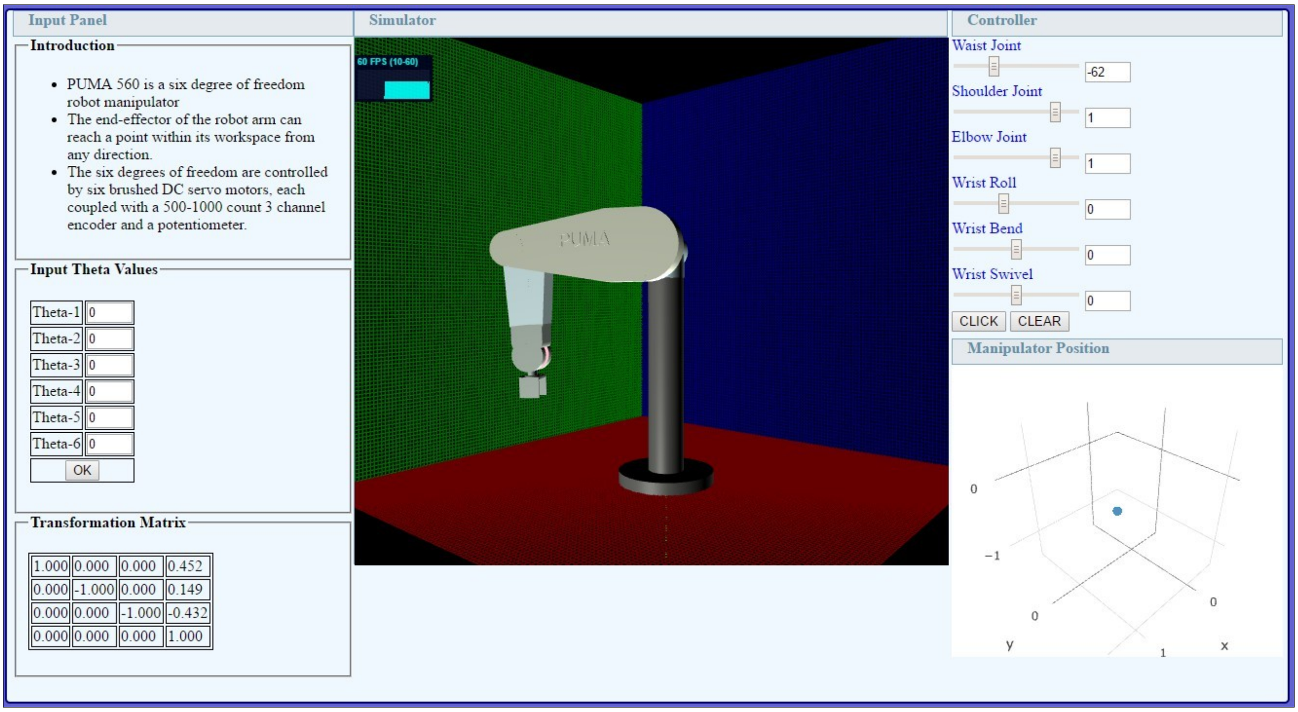
SIMULATOR

This program simulates a 6 link 3D Puma Robot using the javascript program. The model and its movement of different links are encoded in javascript language. Model With this program the forward kinematics of PUMA 560 is explained, and simultaneously movements of different joints at a time can be seen. Axis coordinates and orientation are setup according to the theory explained earlier. This program does not allow for the specification of angular speed or acceleration of the arms. Click on the screenshot given below to start the simulation.

Kinematics Panel consists of:

ANGLE	RANGE	DOF
`theta_1`: 320	-160 to +160	Waist Joint
`theta_2`: 270	-225 to +45	Shoulder Joint
`theta_3`: 270	-225 to +45	Elbow Joint
`theta_4`: 280	-110 to +170	Wrist Roll
`theta_5`: 200	-100 to +100	Wrist Bend
`theta_6`: 532	-266 to +266	Wrist Swivel

Click on the screenshot to start the simulation



Simulator Screen shot

http://vlabs.iitkgp.ac.in/mr/exp1/forward-kinematics-of-puma-560.html

RESULT

Thus, the characteristic of Forward Kinematics of Puma 560 was studied.

INVERSE KINEMATICS OF PUMA 560

EXP NO :

DATE :

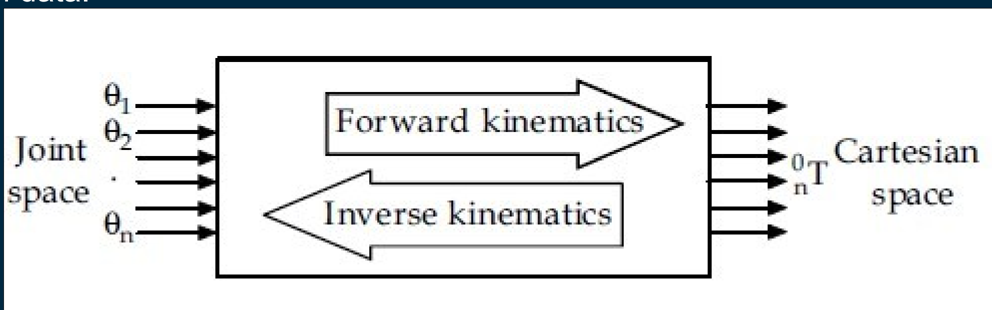
AIM

To study the characteristics of Inverse Kinematics of Puma 560

INTRODUCTION

Inverse kinematics problem deals with the determination of joint variables given a desired position and orientation for the tool. The inverse kinematics problem is significant because manipulation tasks are usually formulated in terms of the desired tool position and orientation. Analysis of Inverse Kinematics is in general more difficult and not straightforward like Forward Kinematics problem. Exact solution of Inverse Kinematics problem for complex configure manipulator is very difficult. The solution of Inverse Kinematics problem for control of a robot manipulator is attempted using various methods such as algebraic methods, geometric methods, and numerical methods. Algebraic methods are used to obtain closed-form solutions, but these methods, do not guarantee closed form solutions.

Given the end-effector position and orientation from Forward kinematics problem, the inverse kinematics approach is used to obtain the joint angles. But as stated in the introduction inverse kinematics is more difficult problem than forward kinematics as its include much complexity. The relationship between forward and inverse kinematics is shown in Figure 1. In general there are two main solution techniques for inverse kinematics problem one is analytic approach and other is numerical method. Analytic approach comprises of geometric and algebraic solutions in which joint variables are solved analytically according to given configuration data.



The schematic representation of forward and inverse kinematics.

Solving the problem of finding the required joint angles to place the tool frame, {T}, relative to the station frame, {S}, is split into two parts. First, frame transformations are performed to find the wrist frame, {W}, relative to the base frame, {B}, and then the inverse kinematics are used to solve for the joint angles.
Which corresponds to T_0^4 position
$p = p_6 - d_6a = (p_x, p_y, p_z)^T$

$$\begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix} = \begin{bmatrix} C_1(a_2C_2 + a_3C_{23} + d_4S_{23}) - d_2S_1 \\ S_1(a_2C_2 + a_3C_{23} + d_4S_{23}) + d_2C_1 \\ d_4C_{23} - a_3S_{23} - a_2S_2 \end{bmatrix}$$

Solution for Joint1

$\theta_1^L = \phi - \alpha; \quad \theta_1^R = \pi + \phi + \alpha$

$r = \sqrt{p_x^2 + p_y^2 - d_2^2}; \quad R = \sqrt{p_x^2 + p_y^2}$

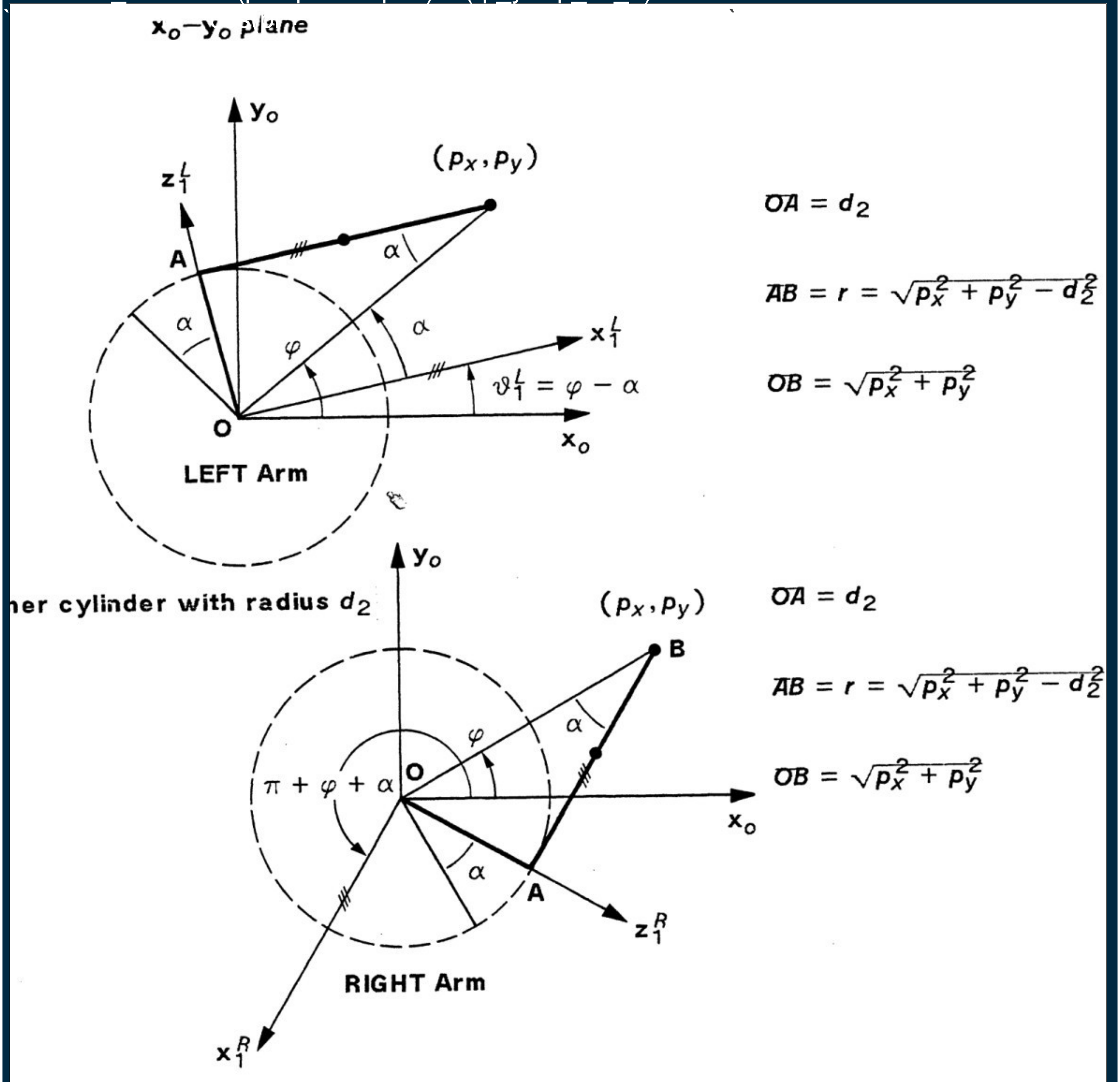
$\sin\phi = p_y/R; \quad \cos\phi = p_x/R$

$\sin\alpha = d_2/R; \quad \cos\alpha = r/R$

$\sin\theta_1^L = \sin(\phi - \alpha) = \sin\phi\cos\alpha - \cos\phi\sin\alpha = (p_y r - p_x d_2)/R^2$

$\cos\theta_1^L = \cos(\phi - \alpha) = \cos\phi\cos\alpha + \sin\phi\sin\alpha = (p_x r + p_y d_2)/R^2$

$\sin\theta_1^R = \sin(\pi + \phi + \alpha) = (-p_y r - p_x d_2)/R^2$

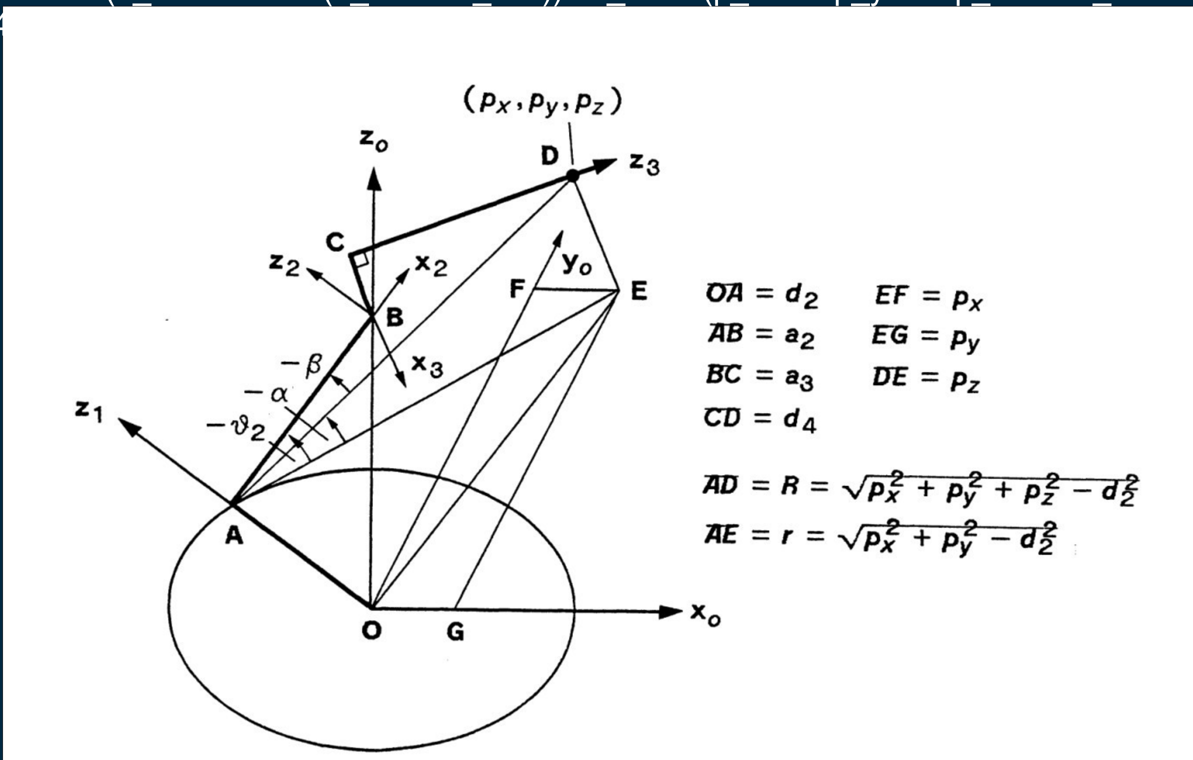


$\sin\theta_1 = \dfrac{-ARM \cdot p_y\sqrt{p_x^2 + p_y^2 - d_2^2} - p_x d_2}{p_x^2 + p_y^2}$

`theta = atan2[y/x] = {((0^{\circ} <= theta <= 90^{\circ}; +x and +y), (90^{\circ}<= theta <=
180^{\circ}; -x and +y), (-180^{\circ}<= theta <= -90^{\circ}; -x and -y), (-90^{\circ}<= theta <= 0^{\circ}; +x and -y))`
`theta_1 = atan2[sin theta_1/cos theta_1] = atan2[(- ARM * p_ysqrt(p_x^2 + p_y^2 -d_2^2) - p_xd2)/(- ARM * p_xsqrt(p_x^2 + p_y^2 -d_2^2) + p_yd2)]; -pi<=theta1<=pi`

Solution for Joint 2

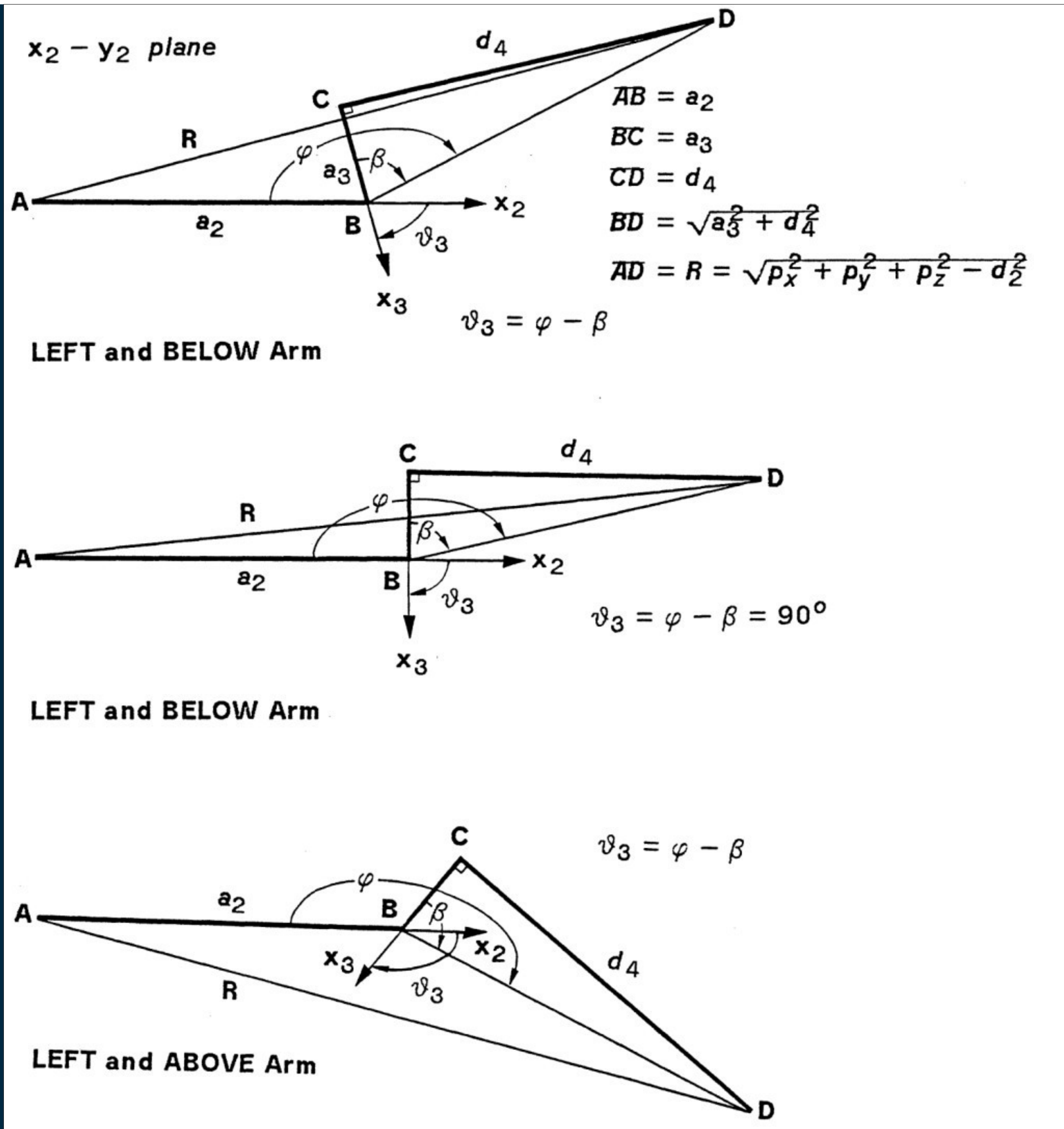
`R = sqrt(p_x^2 + p_y^2 + p_z^2 -d_2^2) ; r = sqrt(p_x^2 + p_y^2 -d_2^2)`
`sin alpha = -p_z/R = -p/sqrt(p_x^2 + p_y^2 + p_z^2 -d_2^2)`
`cos alpha = -(ARM * r)/R = -(ARM * sqrt(p_x^2 + p_y^2 -d_2^2))/sqrt(p_x^2 + p_y^2 + p_z^2 -d_2^2)`
`cos beta = -(a_2^2 + R^2 - (d_4^2 + a_3^2))/2a_2R = (p_x^2 + p_y^2 + p_z^2 + a_2^2 -d_2^2 - (d_4



`sin beta = sqrt(1-cos^2 beta)`
`sin theta_2 = sin(alpha + K*beta) = sin alphacos beta + (ARM * ELBOW)cos alphasin beta`
`cos theta_2 = cos(alpha + K*beta) = cos alphacos beta - (ARM * ELBOW)sin alphasin beta`
`theta_2 = atan2[sin theta_2/cos theta_2] ; -pi <= theta_2 <= pi`

Solution for Joint 3

`R = sqrt(p_x^2 + p_y^2 + p_z^2 -d_2^2)`
`cos phi = (a_2^2 + (d_4^2 + a_3^2) - R^2)/(2a_2sqrt(d_4^2 + a_3^2)) ; sin phi = ARM * ELBOWsqrt(1-cos^2 phi)`

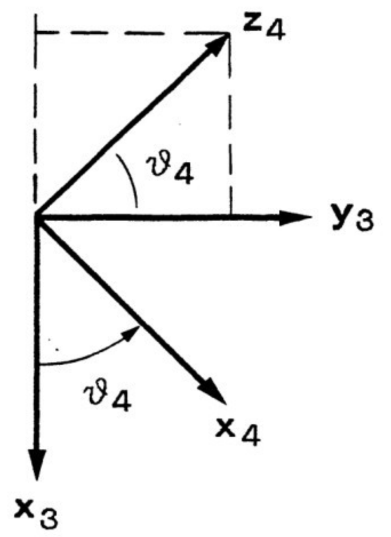


`theta_3 = phi - beta`
`theta_3 = atan2[sin theta_3/cos theta_3] ; -pi <= theta_3 <= pi`

Solution for Joint 4

$$\sin \vartheta_4 = -(z_4 \cdot x_3)$$

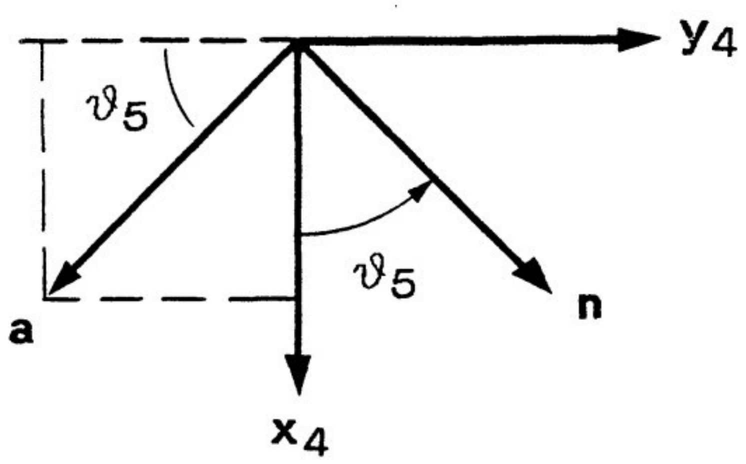
$$\cos \vartheta_4 = (z_4 \cdot y_3)$$



Solution for Joint 5

$$\sin \vartheta_5 = a \cdot x_4$$

$$\cos \vartheta_5 = -(a \cdot y_4)$$



$\sin \theta_6 = n * y_5$; $\cos \theta_6 = s * y_5$

$\theta_6 = \text{atan2}[\sin \theta_6 / \cos \theta_6]$; $-\pi \le \theta_6 \le \pi$

$= \text{atan2}[((-S_1C_4-C_1C_{23}S_4)n_x + (C_1C_4-S_1C_{23}S_4)n_y + (S_4S_{23})n_z)/((-S_1C_4-C_1C_{23}S_4)s_x + (C_1C_4-S_1C_{23}S_4)s_y + (S_4S_{23})s_z)]$

OBJECTIVE

- To identify the geometric relationship between input and output motion parameters of PUMA 560 robot manipulator.
- To verify the robot configuration for a particular set of joint solution.
- Simulate the robot motion for various inputs of the manipulator position.

PROCEDURE

- Insert three position of the end-effector and click OK button to see the joint values.
- Orientation of the manipulator can also be specified.
- The view can be rotated about a point by keeping the ***left mouse button*** pressed and rotating the mouse.
- The view can be translated by keeping the ***right mouse button pressed*** and translating the mouse in the desired direction.
- The ***scroll button*** or ***middle mouse button*** can be used for zooming.

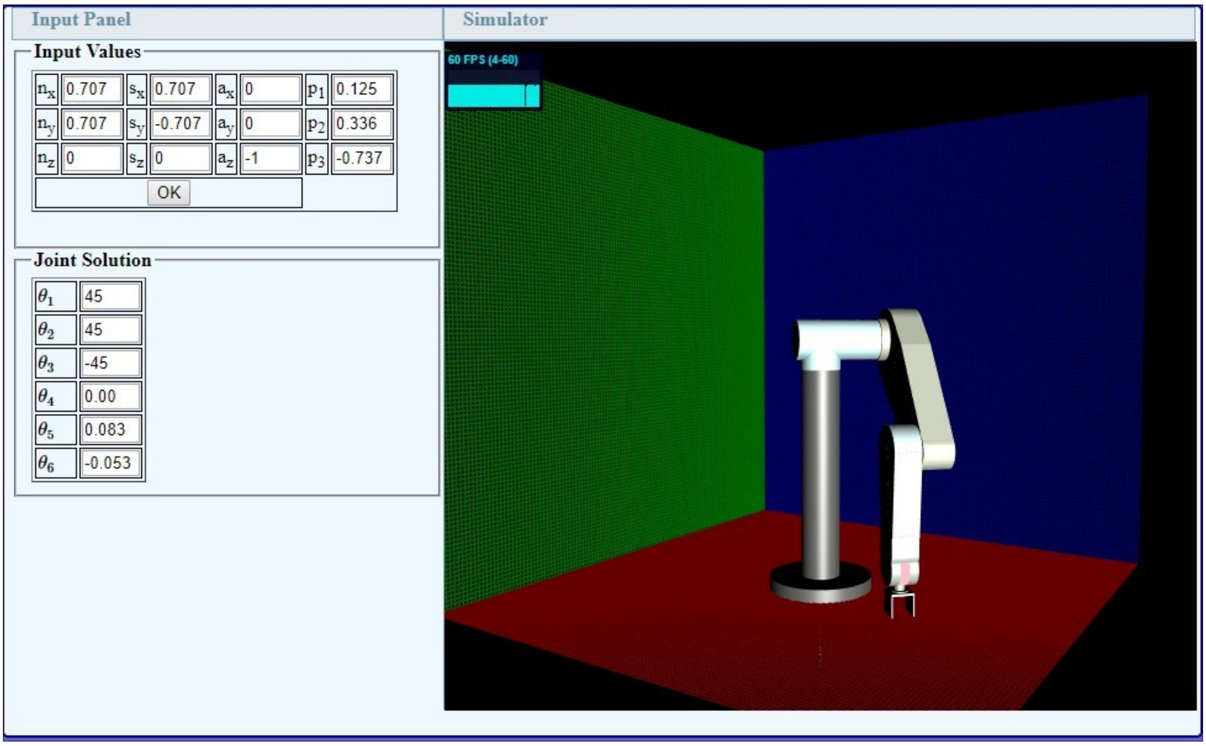
SIMULATOR

This program shows inverse kinematics part of PUMA560. The model and its movement of different links are encoded in javascript language. A default initial position and orientation is given in the input panel and the corresponding output results are shown in the output table. A user can change the position by specifing new values. This program does not allow for the specification of angular speed or acceleration of the arms. Click on the screenshot given below to start the simulation.

Default Ranges of Movements:

ANGLE	RANGE	DOF
`theta_1`: 320	**-160 to 160**	**Waist Joint**
`theta_2`: 270	**-225 to 45**	**Shoulder Joint**
`theta_3`: 270	**-45 to 225**	**Elbow Joint**
`theta_4`: 280	**-110 to 170**	**Wrist Roll**
`theta_5`: 200	**-100 to 100**	**Wrist Bend**
`theta_6`: 532	**-266 to 266**	**Wrist Swivel**

Click on the screenshot to start the simulation



Simulator Screen shot

http://vlabs.iitkgp.ac.in/mr/exp3/inverse-kinematics-of-puma-560.html

RESULT

Thus, the Characteristics of Inverse Kinematics of Puma 560 was studied.

KGP 50

EXP NO :

DATE :

AIM

To study the characteristics of KGP 50.

INTRODUCTION

The "KGP 50" is a state-of-the-art industrial prototype robot,positioned in the latest generation of industrial robot category. The product and technology, in its open architecture format, and the knowledge base from the IIT Kharagpur system, are strategic tools for any industries, educational institutions willing to promote or use them.

This robot can be made available for technology transfer and educational purposes. Currently, it is being used as a test bed for cutting edge technologies of human computer interaction and intelligent systems. Robotic technology, harnessed in the laboratory, has spawned and supported many growing areas of intelligent systems research. Prominent among these were the development of an intelligent driver vehicle interaction simulator. The system is a vehicle-driving simulator for a passenger car, where the driver's responses and automated vehicle control strategies under different driving conditions are generated and designs tested. A novel techniques of using fast learning neural networks for crisis management and control is being evolved on this test bed. It is expected to evolve a man machine collaborative learning system for intelligent systems in the new generation auto-mated vehicular systems.

Intelligent systems requiring complex human computer interaction, both in man machine systems and in complex knowledge based Internet environments, are being researched in this laboratory too. The future looks exciting, heading towards a new era of highly interconnected systems, devices and human life. The new prospects of research and development in this laboratory involve embedded systems, autonomous vehicles, etc.

Figure 1: KGP 50

SPECIFICATION

Industrial Robot KGP 50 Specifications and Characteristics

The following critical features have been incorporated in the design of the prototype. This is not a means of creating a one-off prototype, but more of a technology base for the entire commercial exploitation of a strategically important and state-of-the-art technology-intensive product.

Specifications:

- 6-Axis, Continuous path control
- 50kg Payload
- 1.5m reach
- 1.5m/s maximum speed
- 1mm repeatability

Characteristics:

- **Full 6-Axis, Continuous servo implementation :**
  This robot is designed for industrial specification of all 6 axis motion specification with a considerable workspace for manipulation and dexterity. The axis are in continuous servo mode and fine positioning and velocity control for continuous paths can thus be easily achieved in industrial applications with this model. This feature is comparable to top of the line models in all international robot models.

- **3-Phase AC digital servo technology implemented and tested:**
  The robot is powered by the state-of-the art digital servo control of AC motors. The drive technology is the muscle of the robot, which drivers high torque even at a low speed maneuver operations, as well as rapid acceleration and decelerations required in high production rate manufacturing operations. The choice of technology has also been influenced by the international trend by which servo drive technology is moving towards model-based control and direct torque control. This technology is comparable and equals that of the top of the line industrial robot models used for a variety of high production rate processes and heavy-duty assembly line operations. The robot has its six degrees of freedom and motors synchronized and precision- controlled for coordinated motions using a real-time digital control station working on a Digital Signal Processing-based motion controller. The real-time operating system in the robot enables it to interact well with its environment

- **DSP-based motion control implemented:**
  The skills of the robot are derived from the state-of-the-art motion control technology implemented in each of drivers and co-ordinate systems of the robot. A highly complex computational scheme in providing spline and continuous motion and trajectory interpolation in industry-desired co-ordinate frames has been adopted in the core design of the robot controller. This provides the computational capacity to operate the robot in the continuous path mode with extremely high repeatability and low error in all the six joint axis as well as cartesian or factory co-ordinate systems. It also provides the core for the extremely fast response of the robot to its own sensor systems as well as to interlock with other systems in any real application.

- **Model for online and offline programming based on industry standard robotics software developed:**
  Robot of such complex order (six axis in continuous path mode) are extremely difficult to program by operators on the shop floor without a considerable technological training. In order to reduce the complexity of the training and operation phase in use, as well as make the system more usable by intuitive operators, the design incorporates a novel 3-D geometrical programming environment. This is based on industry standard CAD systems that provide an interface for easy operability and verification of the robot program. this unique feature can help in drastically reducing the operational costs related to operate training, downtime due to programming errors, rapid reprogramming of robot and testing of synchronization with any other robots or devices in real shop floor.

- **Capability to fine-tune and implement motion control strategies incorporated in the design:**
  The robot has an open architecture heart built-in into the system, that enables robot developers to diagnose and improvise the design and/or performance of the robot, even after deployment. This is an important feature for technology developers that is not available to consumers of robot technology as technology adopters. The robot system has been specifically designed with this features, which is no available from any competitors (as it's the core technology of the system) and is very much required for a development industry as well as systems which can be adapted to any high-end applications

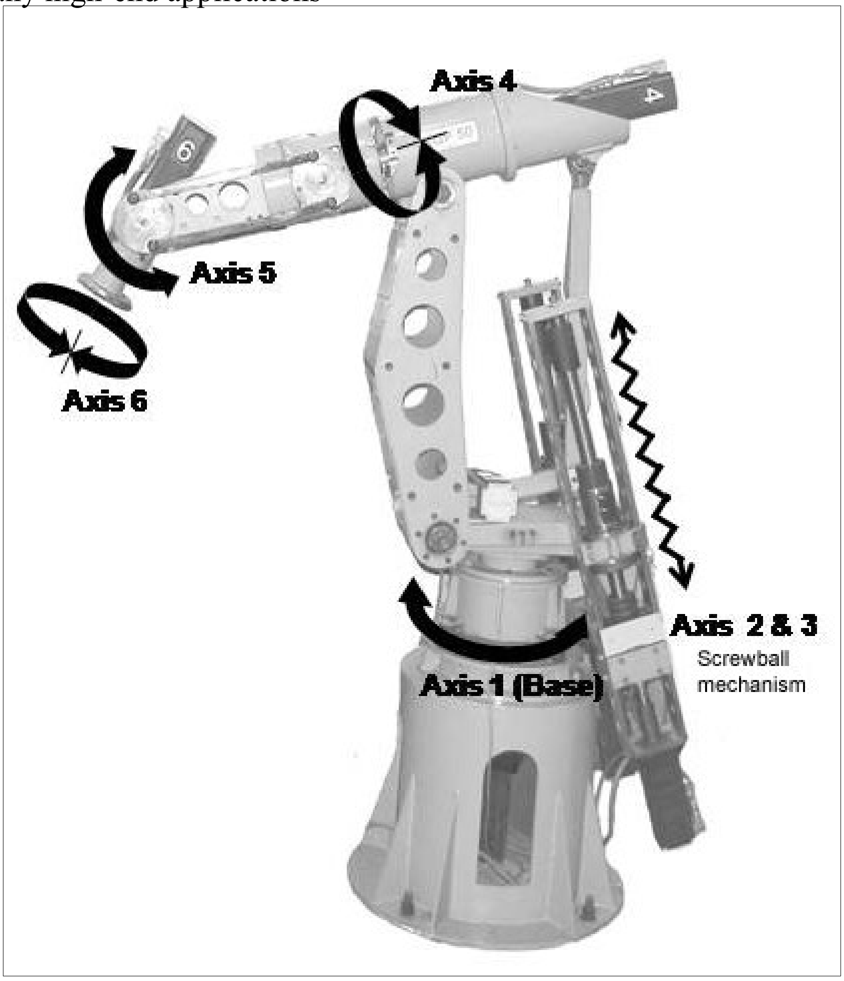
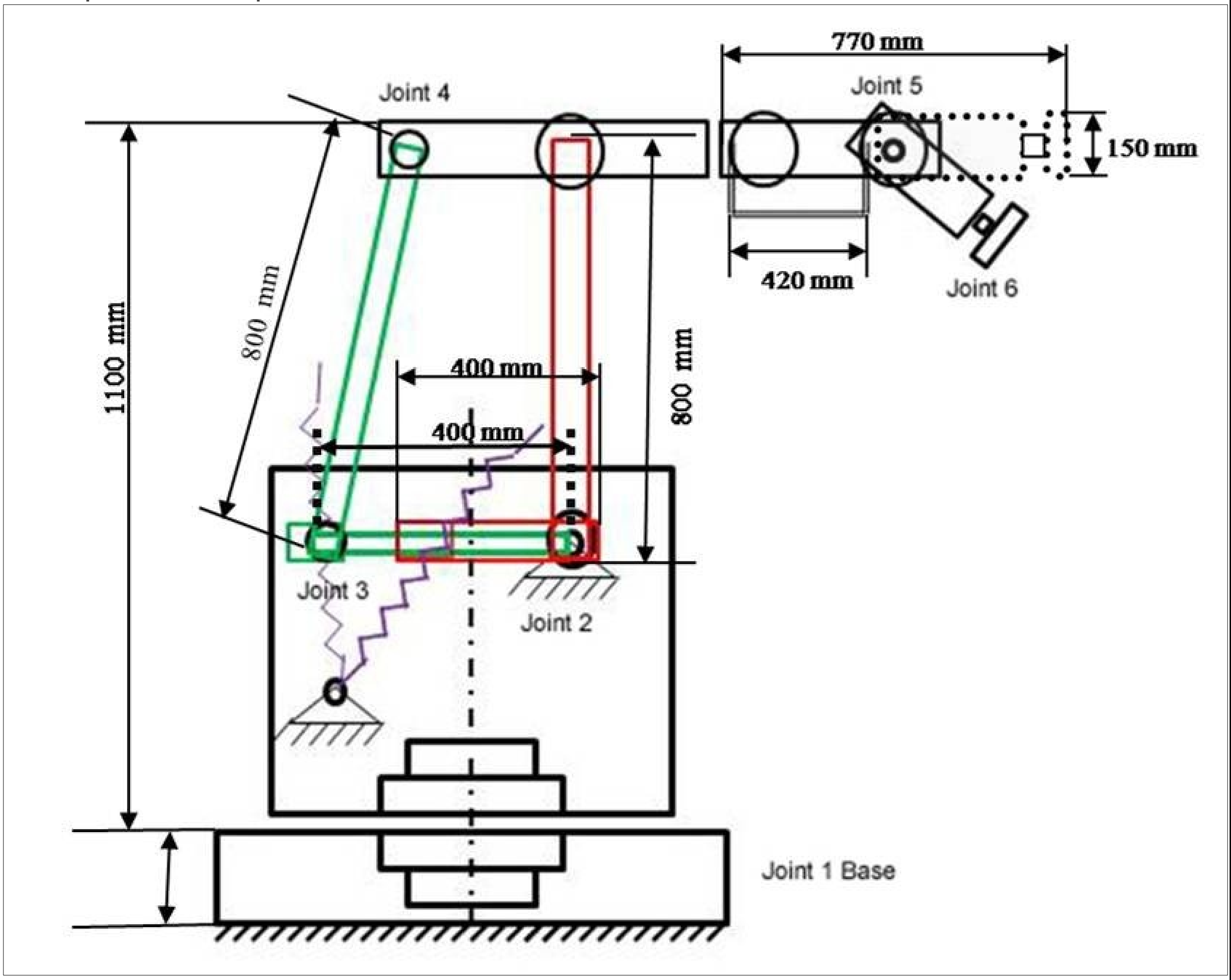


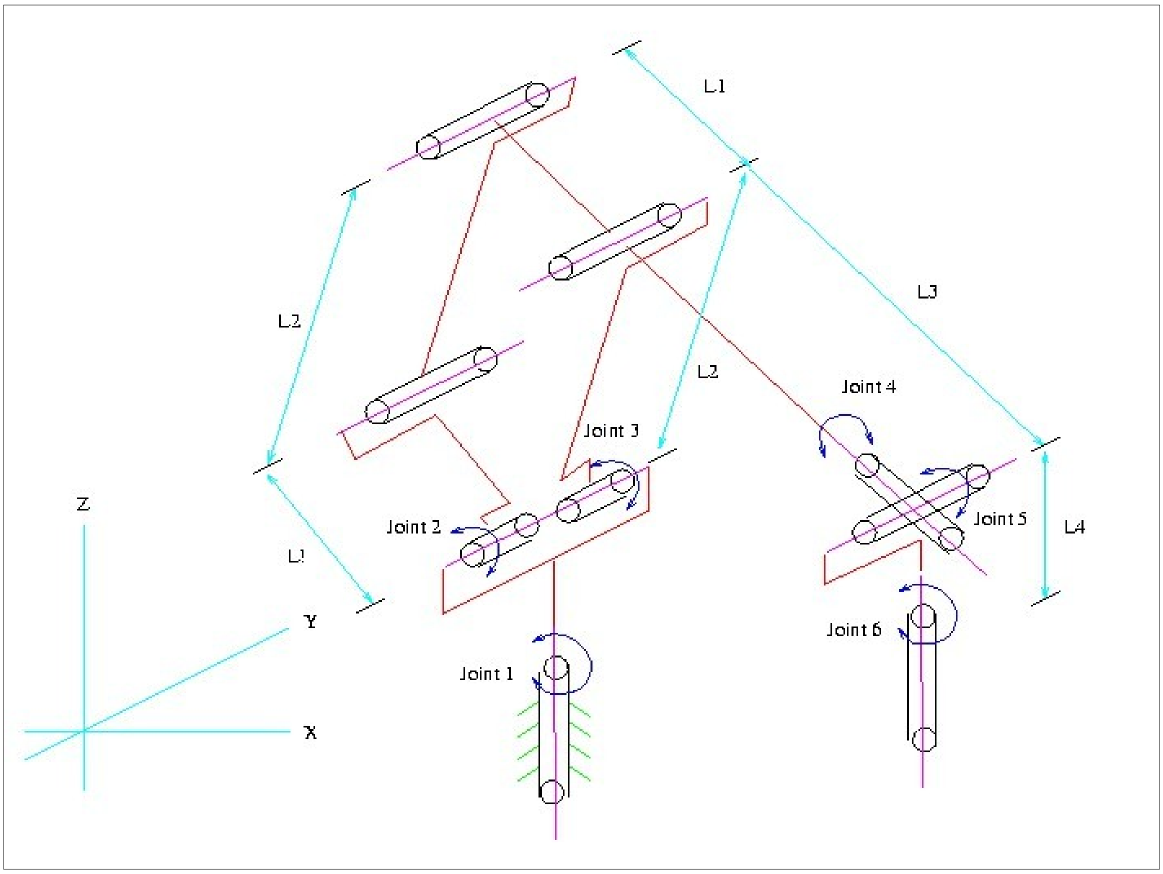
Figure 2: KGP 50 rotation diagram

TUTORIAL

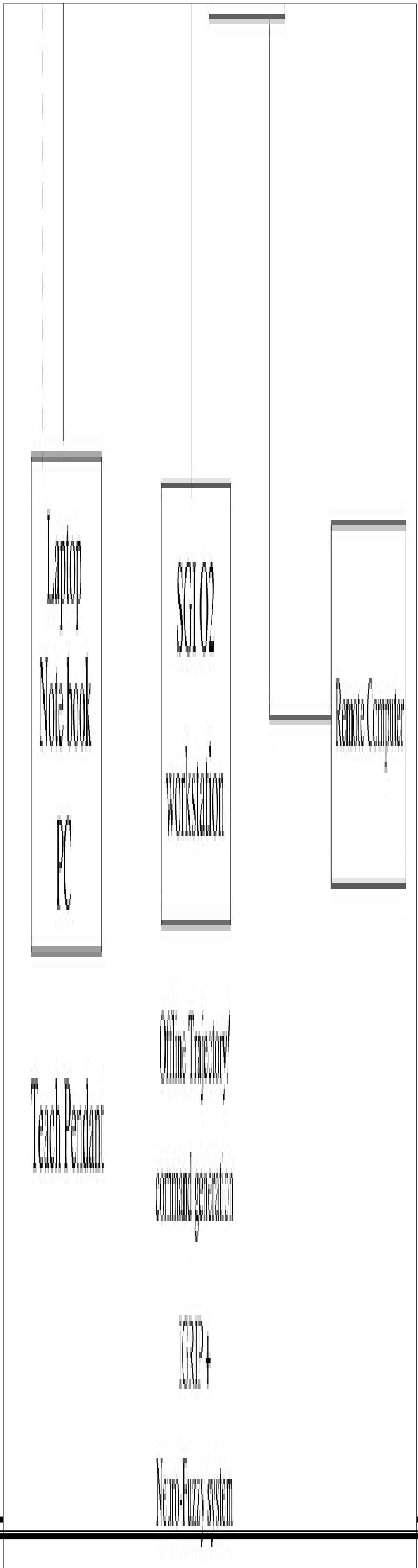
- Workspace Envelope



- Math model


L1
L2
L3
L2
Joint 4
Joint 3
Z
Joint 2
Joint 5
L4
L1
Y
Joint 6
Joint 1
X

- Controller

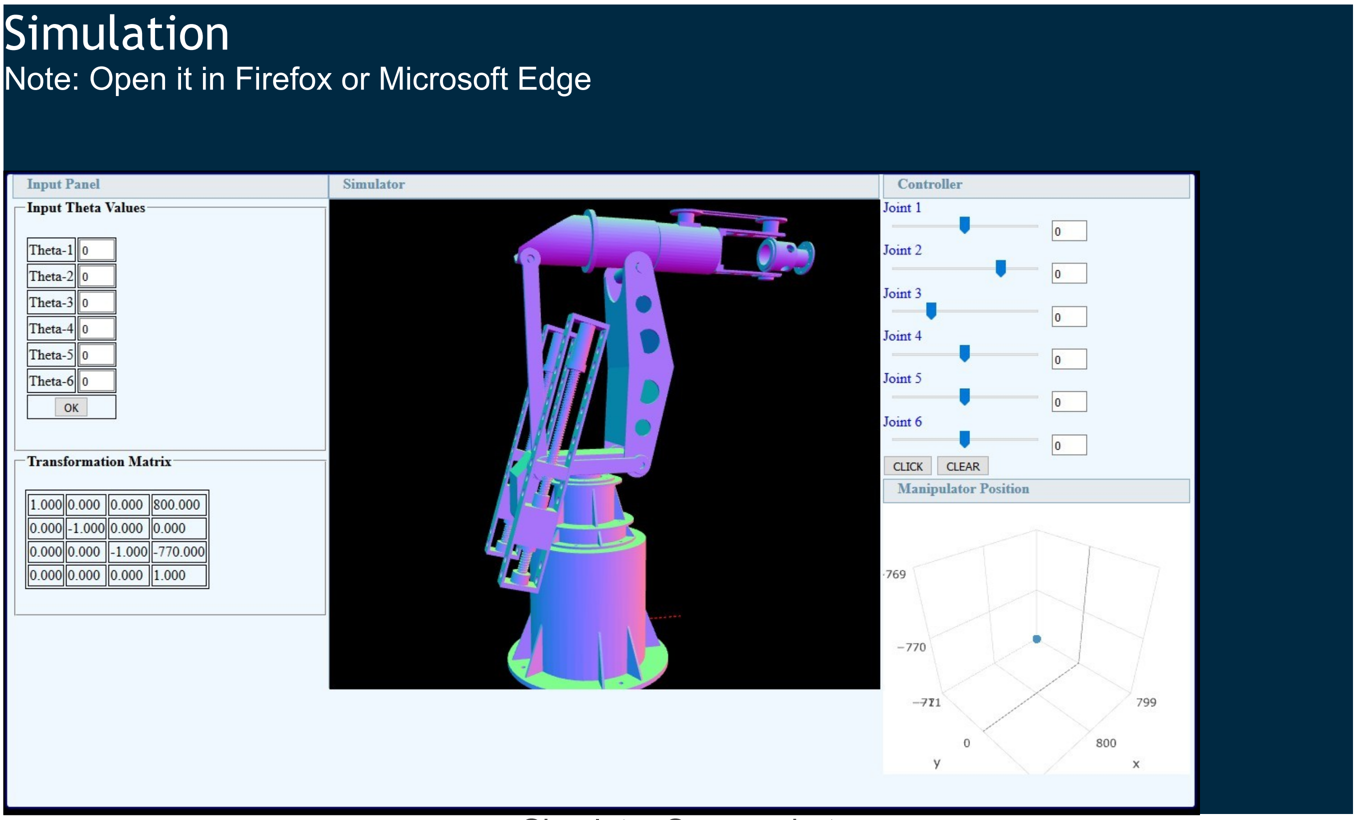

Laptop
Note book
PC
SGI O2
workstation
Remote Computer
Teach Pendant
Offline Trajectory/
command generation
IGRIP +
Neuro-Fuzzy system

- **Forward Kinematics**
  The Forward kinematics equation can be computed as:
  `T_1^0 = [[cos \(theta_1\),-sin \(theta_1\),0,0], [sin \(theta_1\),cos \(theta_1\),0,0], [0,0,1,0], [0,0,0,1]]` `T_2^1 = [[cos \(theta_2\),-sin \(theta_2\),0,0], [0,0,1,0], [-sin \(theta_2\),-cos \(theta_2\),0,0], [0,0,0,1]]`
  `T_3^2 = [[cos \(theta_3\),-sin \(theta_3\),0,l_1], [sin \(theta_3\),cos \(theta_3\),0,0], [0,0,1,0], [0,0,0,1]]` `T_4^3 = [[cos \(theta_4\),-sin \(theta_4\),0,l_2], [sin \(theta_4\),cos \(theta_4\),0,0], [0,0,1,0], [0,0,0,1]]`
  `T_5^4 = [[cos \(theta_5\),-sin \(theta_5\),0,l_3], [sin \(theta_5\),cos \(theta_5\),0,0], [0,0,1,0], [0,0,0,1]]` `T_6^5 = [[cos \(theta_6\),-sin \(theta_6\),0,0], [0,0,-1,0], [sin \(theta_6\),cos \(theta_6\),1,0], [0,0,0,1]]`
  `T_0^6 = [[R,P], [0,1]]` `T_6^0 = T_1^0 * T_2^1 * T_3^2 * T_4^3 * T_5^4 * T_6^5`
  `p_x = cos theta_1(l_2cos theta_2 + l_3cos(theta_2 + theta_3))`
  `p_y = sin theta_1(l_2cos theta_2 + l_3cos(theta_2 + theta_3))`
  `p_z = -l_2sin theta_2 - l_3sin(theta_2 + theta_3)`

PROCEDURE

- Insert different values of `theta` within the joint range as prescribed in theory part and then click ok to get the output orientation and position of the end effector.
- To see the individual movements of the links drag the sliders on the controller panel.
- The view can be rotated about a point by keeping the ***left mouse button*** pressed and rotating the mouse.
- The view can be translated by keeping the ***right mouse button pressed*** and translating the mouse in the desired direction.
- The ***scroll button*** or ***middle mouse button*** can be used for zooming.

http://vlabs.iitkgp.ac.in/mr/exp4/index.html#



Simulator Screen shot

http://vlabs.iitkgp.ac.in/mr/exp4/forward-kinematics-of-kgp50.html

RESULT

Thus, the characteristic of KGP 50 was studied.

Oldham Coupling Mechanism

EXP NO :

DATE :

AIM

To study the characteristics of oldham coupling mechanism.

INTRODUCTION

A mechanism is a combination of rigid or restraining bodies so shaped and connected that they move upon each other with a definite relative motion. A machine is a mechanism or a collection of mechanisms which transmits force from the source of power to the resistance to be overcome,and thus perform a mechanical work. Mechanisms generally consist of moving components such as gears and gear trains, belt and chain drives, cam and follower mechanisms, and linkages as well as friction devices such as brakes and clutches, and structural components such as the frame, fasteners, bearings, springs, lubricants and seals, as well as a variety of specialized machine elements such as splines, pins and keys.

A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. Couplings do not normally allow disconnection of shafts during operation, however there are torque limiting couplings which can slip or disconnect when some torque limit is exceeded.

An Oldham′s coupling is a third inversion of double slider crank chain and which is obtain by fixing the connecting link.It is used to join two shafts which have lateral mis-alignment. It consists of two flanges A and B with slots and a central floating part E with two tongues T1 and T2 at right angles as shown in Fig. 1. The central floating part is held by means of a pin passing through the flanges and the floating part. The tongue T1 fits into the slot of flange A and allows for to and from relative motion of the shafts, while the tongue T2 fits into the slot of the flange B and allows for vertical relative motion of the parts. The resultant of these two components of motion will accommodate lateral misalignment of the shaft as they rotate.

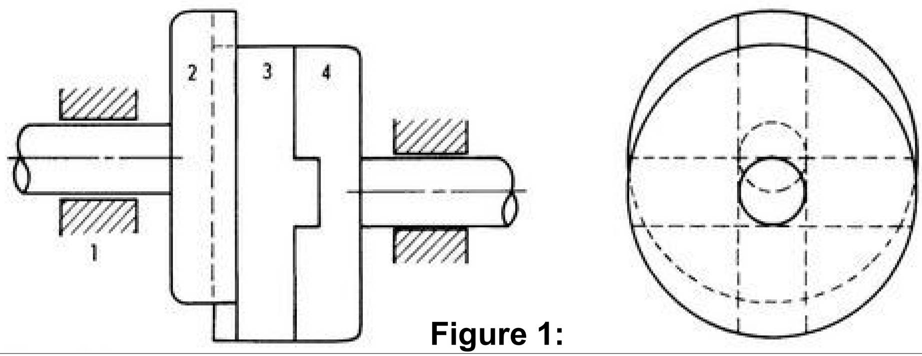


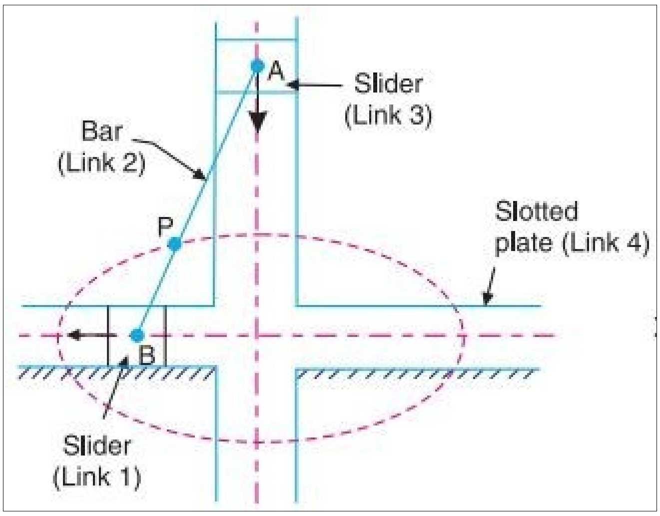
Figure 1:

THEORY

From the definition of mechanisms it can be realize that by fixing the links of a closed chain one at a time, we can get as many different mechanisms as the numbers of link in the chain. This process of fixing different links of a same kinematic chain to produce distinct mechanisms is called kinematic inversion. By distinct, it is meant that the input-output relation as given by the absolute motions of the links connected to the frame is different for these mechanisms. An Oldham′s coupling is a third inversion of double slider crank chain.

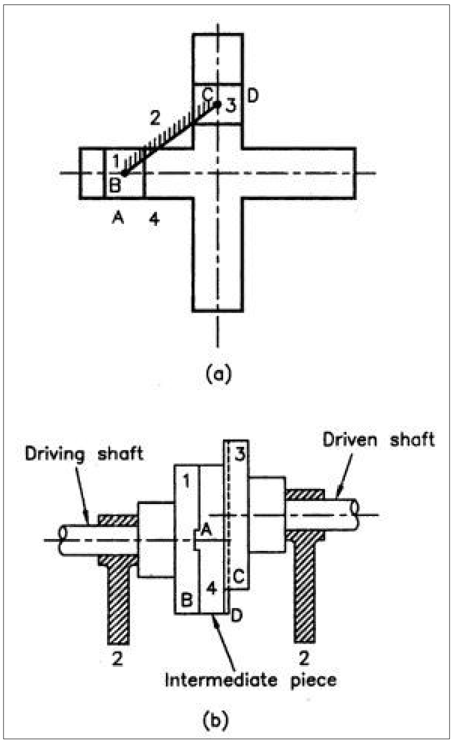
Inversions of Double Slider Crank Chain

A double slider crank chain consists of four links forming two sliding pairs and two turning pairs. Hence, the two pairs of the same kind are adjacent. They are three important inversions of double slider crank chain. 1) Elliptical trammel. 2) Scotch yoke mechanism. 3) Oldham′s Coupling. The line diagram of the double slider crank chain is shown in Fig.



Oldham′s coupling:

An Oldham's coupling is a third inversion of double slider crank chain and which is obtain by fixing the connecting link (link 2). Each of the two die-blocks may then turn bout the pins B and C. If one block is turned through a definite angle, the frame and the other block must turn through the same angle and as rotation takes place , the frame will slide relative to each of the two blocks. This coupling is used for connecting two parallel shafts when the distance between the shafts is small. The two shafts to be connected have flanges at their ends, secured by forging. Slots are cut in the flanges.

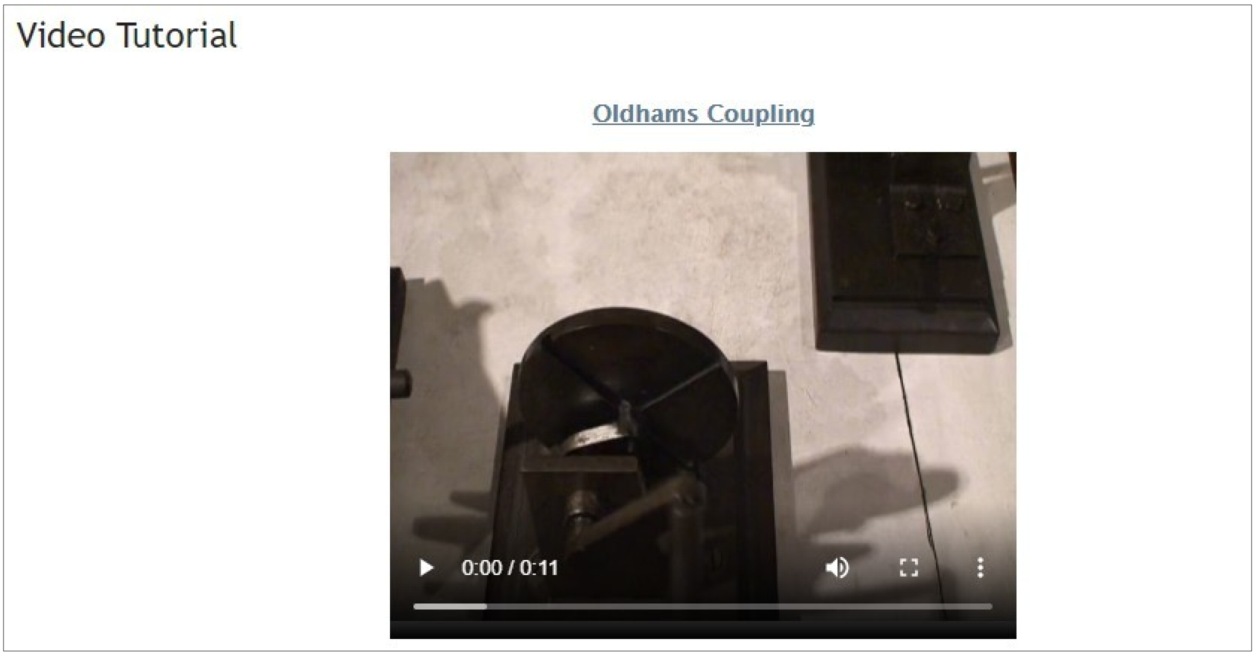


In Oldham's coupling, each half-coupling is identical in the form and hasa single groove cut diametrically across the face. A circular disc with a tongue passing diametrically across each face and the two tongues set at right angles to each other is placed between the two half couplings, so that each tongue fits into its corresponding groove in one of the half couplings. When the driving shaft 1 is rotated, the flange B (link 1) causes the intermediate piece (link 4) to rotate at the same angle through which flange B has rotated and it further rotates the flange C (link 3) at the same angle and thus the shaft 3 rotates. Hence, links 1,3 and 4 have the same angular velocity at every instant. A little consideration will show, that there is a sliding motion between the link 4 and each of the other links 1 and 3.

As stated earlier an Oldham's coupling is used for connecting two parallel shafts whose axes are at a small distance span. If the distance between the axes of the shafts is constant, the centre of intermediate piece will describe a circle of radius equal to the distance between the axes of the two shafts. Therefore, the maximum sliding speed of each tongue along its slot is equal to the peripheral velocity of the centre of the disc along its circular path.

- Link 1: Slider
- Link 2: Connecting Link, Fixed Link
- Link 3: Slider
- Link 4: Slotted Frame

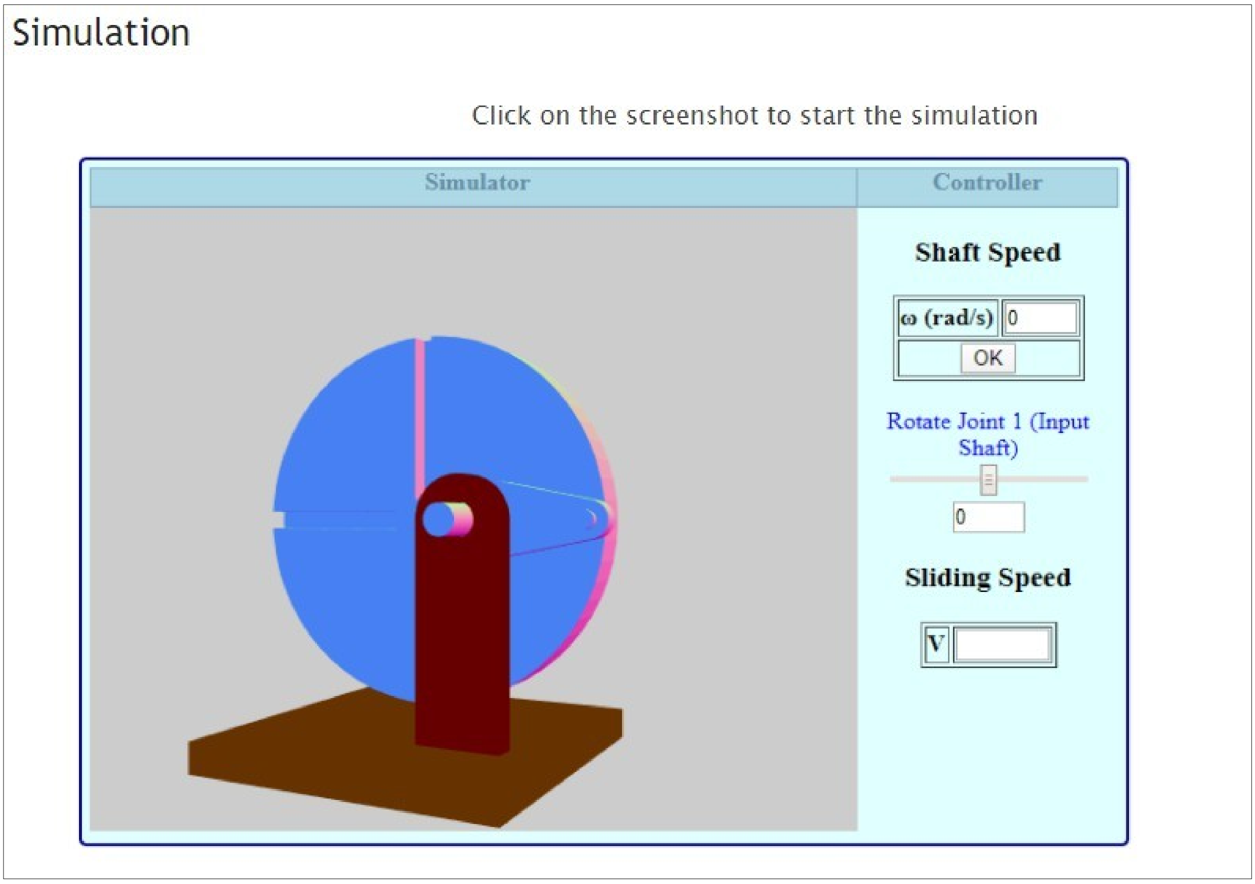
Let, w= Angular velocity of each shaft in rad/s and r=Distance between the axes of the shafts in meters. Therefore, maximum sliding speed of each tongue in m/s is given by; v=r.w



http://vlabs.iitkgp.ac.in/mr/exp6/index.html#

PROCEDURE

- Insert a value of shaft driving speed 'ω' within the suitable range and then click ok to get the output sliding velocity of the slider.
- Drag the slider to see the motion of the mechanism at that particular speed.
- The view can be rotated about a point by keeping the ***left mouse button*** pressed and rotating the mouse.
- The view can be translated by keeping the ***right mouse button pressed*** and translating the mouse in the desired direction.
- The ***scroll button*** or ***middle mouse button*** can be used for zooming.



http://vlabs.iitkgp.ac.in/mr/exp6/oldhams_coupling.html

RESULT

Thus, the characteristics of oldham coupling mechanism was studied.

Quick Return Mechanism

EXP NO :

DATE :

AIM

To study the characteristics of Quick Return Mechanism.

INTRODUCTION

A quick return mechanism is an apparatus that converts circular motion into reciprocating motion in presses and shaping machines, which are utilized to shape stocks of metal into flat surfaces. This mechanism is mostly used in shaping machines, slotting machines and in rotary internal combustion engines. The word quick return indicates that the returning stoke is faster than the forward stroke which help the tool to retrieve back faster after doing a particular job. Quick-return mechanisms feature different input durations for their working and return strokes. The time ratio of a Quick Return mechanism is the ratio of the change in input displacement during the working stroke to its change during the return stroke.

THEORY

From the definition of mechanisms it can be realize that by fixing the links of a closed chain one at a time, we can get as many different mechanisms as the numbers of link in the chain. This process of fixing different links of a same kinematic chain to produce distinct mechanisms is called kinematic inversion. By distinct, it is meant that the input-output relation as given by the absolute motions of the links connected to the frame is different for these mechanisms. An Oldham′s coupling is a third inversion of double slider crank chain.

Inversions of Single Slider Crank Chain

A single slider crank chain is a four-link mechanism. We know that by fixing, in turn, different links in a kinematic chain, an inversion is obtained and we can obtain as many mechanisms as the links in a kinematic chain. It is thus obvious, that four inversions of a single slider crank chain are possible. These inversions are found in the following mechanisms. 1) Pendulum pump or Bull engine. 2) Oscillating cylinder engine. mechanism. 3) Rotary internal combustion engine or Gnome engine. 4)Crank and slotted lever quick return motion mechanism. 5) Whitworth quick return motion mechanism.

Crank and slotted lever quick return motion mechanism

This mechanism is mostly used in shaping machines, slotting machines and in rotary internal combustion engines. In this mechanism, the link AC (i.e. link 3) forming the turning pair is fixed, as shown in Fig.1. The link 3 corresponds to the connecting rod of a reciprocating steam engine. The driving crank CB revolves with uniform angular speed about the fixed centre C. A sliding block attached to the crank pin at B slides along the slotted bar AP and thus causes AP to oscillate about the pivoted point A. A short link PR transmits the motion from AP to the ram which carries the tool and reciprocates along the line of stroke R1R2. The line of stroke of the ram (i.e. R1R2) is perpendicular to AC produced.

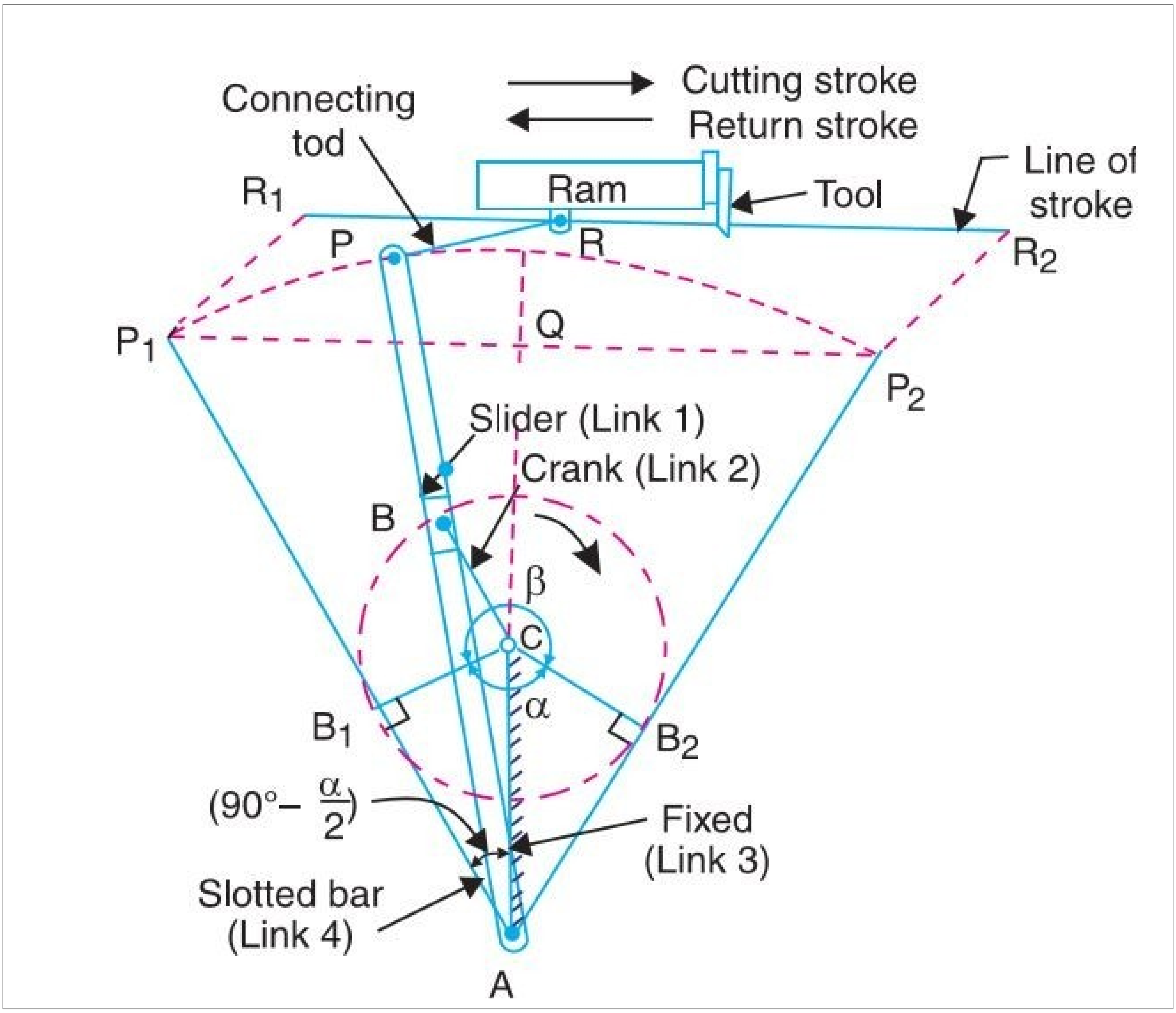


Fig1: Crank and slotted lever quick return motion mechanism.

In the extreme positions, AP1 and AP2 are tangential to the circle and the cutting tool is at the end of the stroke. The forward or cutting stroke occurs when the crank rotates from the position CB1 to CB2 (or through an angle β) in the clockwise direction. The return stroke occurs when the crank rotates from the position CB2 to CB1 (or through angle α) in the clockwise direction. Since the crank has uniform angular speed, therefore,

`(Time of cutting stroke)/(Time of return stroke)= β/ α`

Whitworth quick return motion mechanism

This mechanism is mostly used in shaping and slotting machines. In this mechanism, the link CD (link 2) forming the turning pair is fixed, as shown in Fig. 2. The link 2 corresponds to a crank in a reciprocating steam engine. The driving crank CA (link 3) rotates at a uniform angular speed. The slider (link 4) attached to the crank pin at A slides along the slotted bar PA (link 1) which oscillates at a pivoted point D. The connecting rod PR carries the ram at R to which a cutting tool is fixed. The motion of the tool is constrained along the line RD produced, i.e. along a line passing through D and perpendicular to CD.

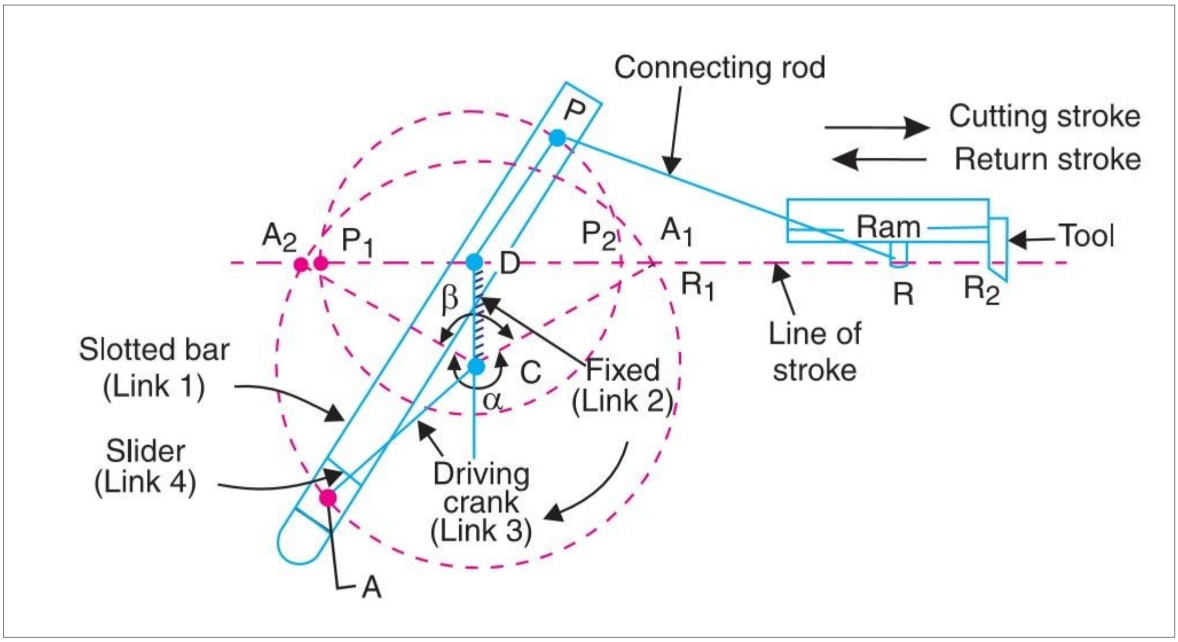


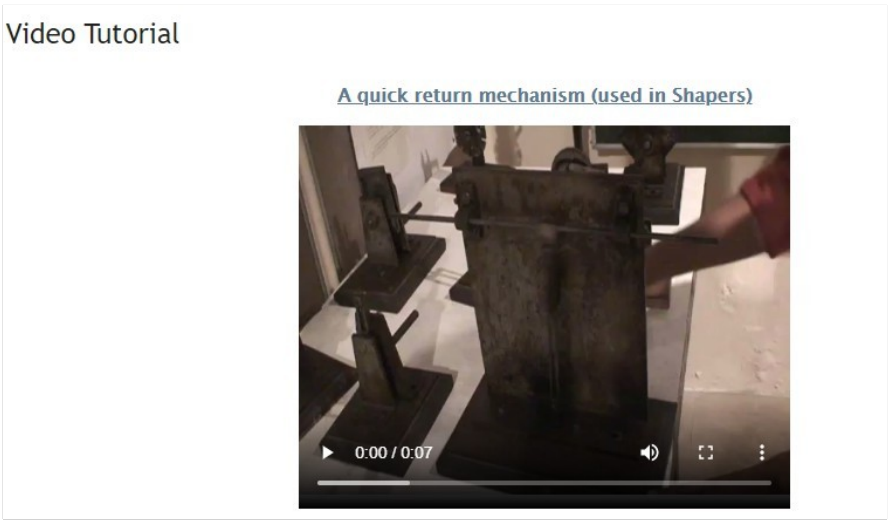
Fig2: Whitworth quick return motion mechanism.

When the driving crank CA moves from the position CA1 to CA2 (or the link DP from the position DP1 to DP2) through an angle α in the clockwise direction, the tool moves from the left hand end of its stroke to the right hand end through a distance 2 PD. Now when the driving crank moves from the position CA2 to CA1 (or the link DP from DP2 to DP 1) through an angle β in the clockwise direction, the tool moves back from right hand end of its stroke to the left hand end

A little consideration will show that the time taken during the left to right movement of the ram (i.e. during forward or cutting stroke) will be equal to the time taken by the driving crank to move from CA1 to CA2. Similarly, the time taken during the right to left movement of the ram (or during the idle or return stroke) will be equal to the time taken by the driving crank to move from CA2 to CA1.

Since the crank link CA rotates at uniform angular velocity therefore time taken during the cutting stroke (or forward stroke) is more than the time taken during the return stroke. In other words, the mean speed of the ram during cutting stroke is less than the mean speed during the return stroke. The ratio between the time taken during the cutting and return strokes is given by

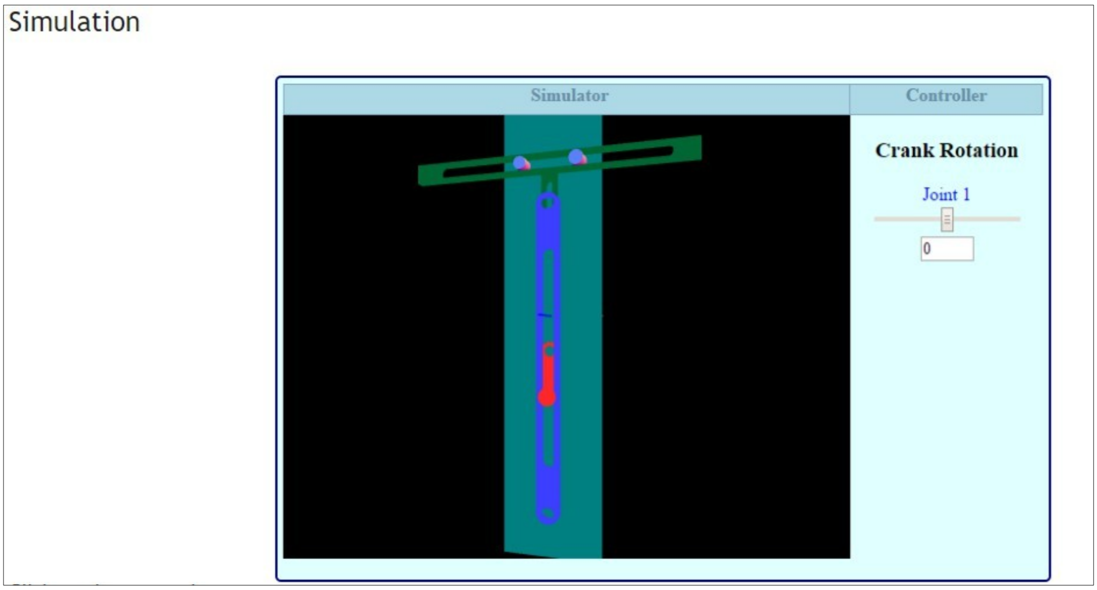
`(Time of cutting stroke)/(Time of return stroke)= α/β`



http://vlabs.iitkgp.ac.in/mr/exp7/index.html#

PROCEDURE

- Insert a value of shaft driving speed 'ω' within the suitable range and then click ok to get the output sliding velocity of the slider.
- Drag the slider to see the motion of the mechanism at that particular speed.
- The view can be rotated about a point by keeping the ***left mouse button*** pressed and rotating the mouse.
- The view can be translated by keeping the ***right mouse button pressed*** and translating the mouse in the desired direction.
- The ***scroll button*** or ***middle mouse button*** can be used for zooming.



http://vlabs.iitkgp.ac.in/mr/exp7/Quick_return.html

RESULT

Thus, the characteristics of oldham coupling mechanism was studied.

CAM FOLLOWER MECHANISM

EXP NO :

DATE :

AIM

To study the characteristics of CAM Follower Mecahnism.

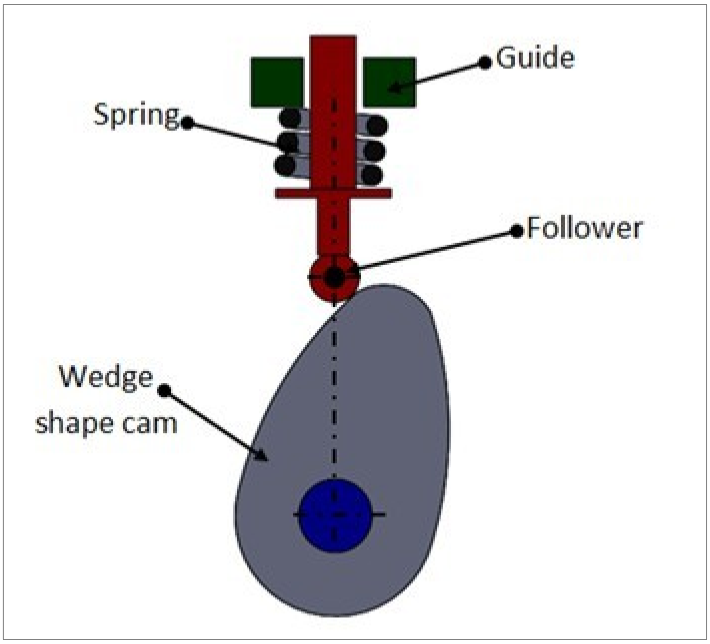
INTRODUCTION

A cam is a rotating machine element which gives reciprocating or oscillating motion to another element known as follower. The cam and the follower have a line contact and constitute a higher pair. The cams are usually rotated at uniform speed by a shaft, but the follower motion is predetermined and will be according to the shape of the cam. The cam and follower is one of the simplest as well as one of the most important mechanisms found in modern machinery today. The cams are widely used for operating the inlet and exhaust valves of internal combustion engines, automatic attachment of machineries, paper cutting machines, spinning and weaving textile machineries, feed mechanism of automatic lathes etc.

THEORY

Cams are mechanical devices which are used to generate curvilinear or irregular motion of mechanical elements. They are used to convert rotary motion into oscillatory motion or oscillatory motion into rotary motion.Necessary elements of a cam mechanism are:

- A driver member known as the cam
- A driven member called the follower
- A frame which supports the cam and guides the follower



Classification of Followers

1. According to the surface in contact:

The followers, according to the surface in contact, are as follows :

(a) Knife edge follower:

When the contacting end of the follower has a sharp knife edge, it is called a knife edge follower, as shown in Fig. 2(a). The sliding motion takes place between the contacting surfaces (i.e. the knife edge and the cam surface). It is seldom used in practice because the small area of contacting surface results in excessive wear. In knife edge followers, a considerable side thrust exists between the follower and the guide.

(b) Roller follower:

When the contacting end of the follower is a roller, it is called a roller follower, as shown in Fig. 2 (b). Since the rolling motion takes place between the contacting surfaces (i.e. the roller and the cam), therefore the rate of wear is greatly reduced. In roller followers also the side thrust exists between the follower and the guide. The roller followers are extensively used where more space is available such as in stationary gas and oil engines and aircraft engines.

(c) Flat faced or mushroom follower:

When the contacting end of the follower is a perfectly flat face, it is called a flat-faced follower, as shown in Fig. 2 (c). It may be noted that the side thrust between the follower and the guide is much reduced in case of flat faced followers. The only side thrust is due to friction between the contact surfaces of the follower and the cam. The relative motion between these surfaces is largely of sliding nature but wear may be reduced by off-setting the axis of the follower, as shown in Fig. 2 (f) so that when the cam rotates, the follower also rotates about its own axis. The flat faced followers are generally used where space is limited such as in cams which operate the valves of automobile engines.

(d) Spherical faced follower:

When the contacting end of the follower is of spherical shape, it is called a spherical faced follower, as shown in Fig. 2 (d). It may be noted that when a flat-faced follower is used in automobile engines, high surface stresses are produced. In order to minimise these stresses, the flat end of the follower is machined to a spherical shape.

2. According to the path of motion of the follower

The followers, according to its path of motion, are of the following two types:

(a) Radial follower

When the motion of the follower is along an axis passing through the centre of the cam, it is known as radial follower. The followers, as shown in Fig. 2 (a) to (e), are all radial followers

(b) Off-set follower

When the motion of the follower is along an axis away from the axis of the cam centre, it is called off-set follower. The follower, as shown in Fig. 2 (f), is an off-set follower.

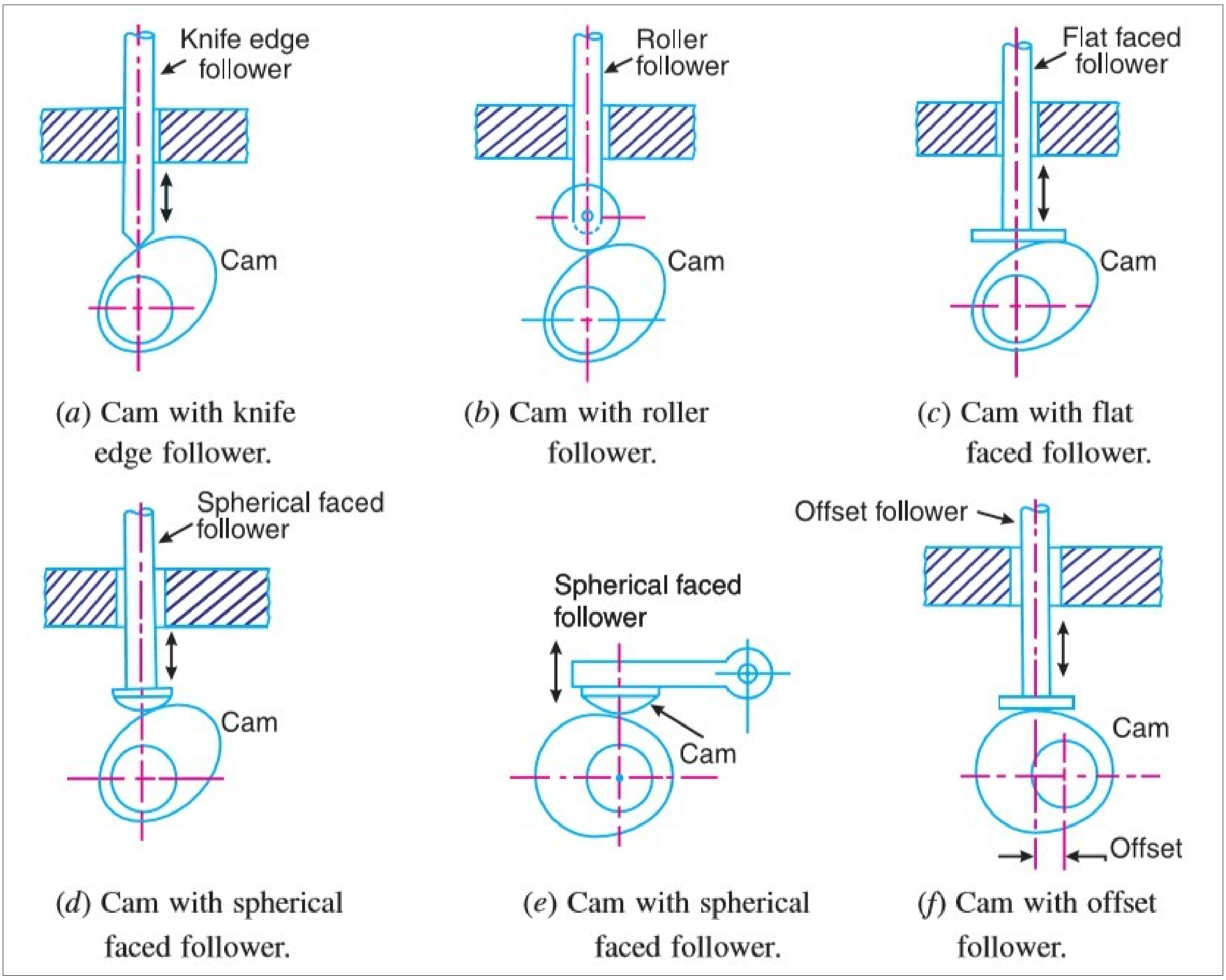


Fig. 2. Classification of followers.

Terms Used in Radial Cams:

Fig. 3 shows a radial cam with reciprocating roller follower. The following terms are important in order to draw the cam profile

1. Base circle.

It is the smallest circle that can be drawn to the cam profile.

2. Trace point.

It is a reference point on the follower and is used to generate the pitch curve. In case of knife edge follower, the knife edge represents the trace point and the pitch curve corresponds to the cam profile. In a roller follower, the centre of the roller represents the trace point.

3. Pressure angle.

It is the angle between the direction of the follower motion and a normal to the pitch curve. This angle is very important in designing a cam profile. If the pressure angle is too large, a reciprocating follower will jam in its bearings.

4. Pitch point.

It is a point on the pitch curve having the maximum pressure angle.

5. Pitch circle.

It is a circle drawn from the centre of the cam through the pitch points.

6. Pitch curve.

It is the curve generated by the trace point as the follower moves relative to the cam. For a knife edge follower, the pitch curve and the cam profile are same whereas for a roller follower, they are separated by the radius of the roller.

7. Prime circle.

It is the smallest circle that can be drawn from the centre of the cam and tangent to the pitch curve. For a knife edge and a flat face follower, the prime circle and the base circle are identical. For a roller follower, the prime circle is larger than the base circle by the radius of the roller.

8. Lift or stroke.

It is the maximum travel of the follower from its lowest position to the topmost position.

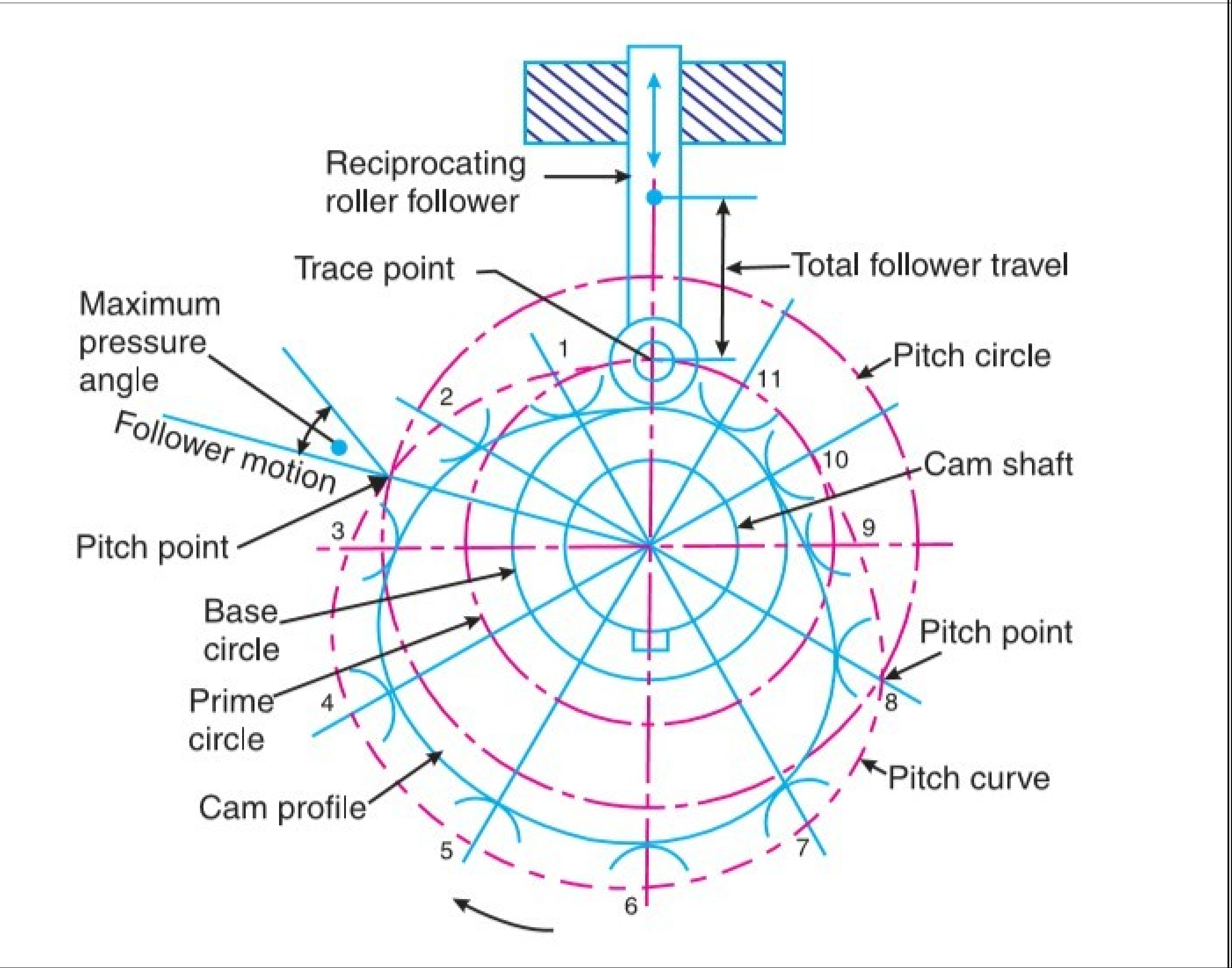
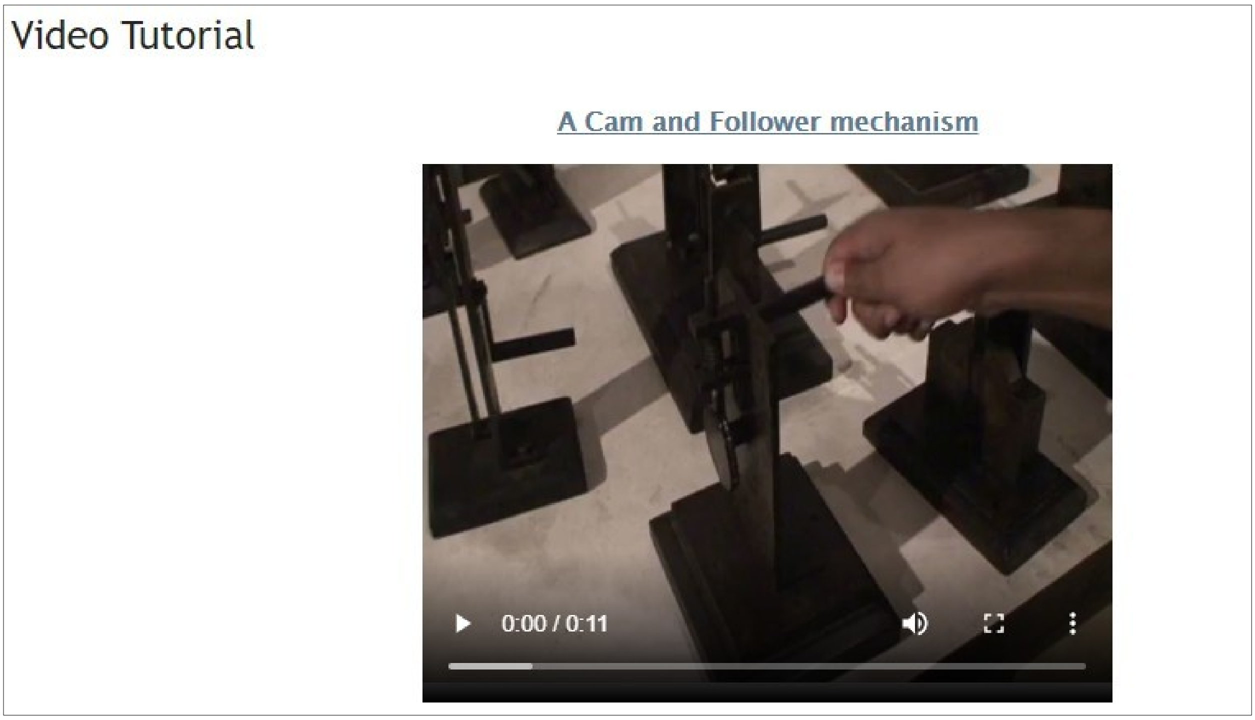


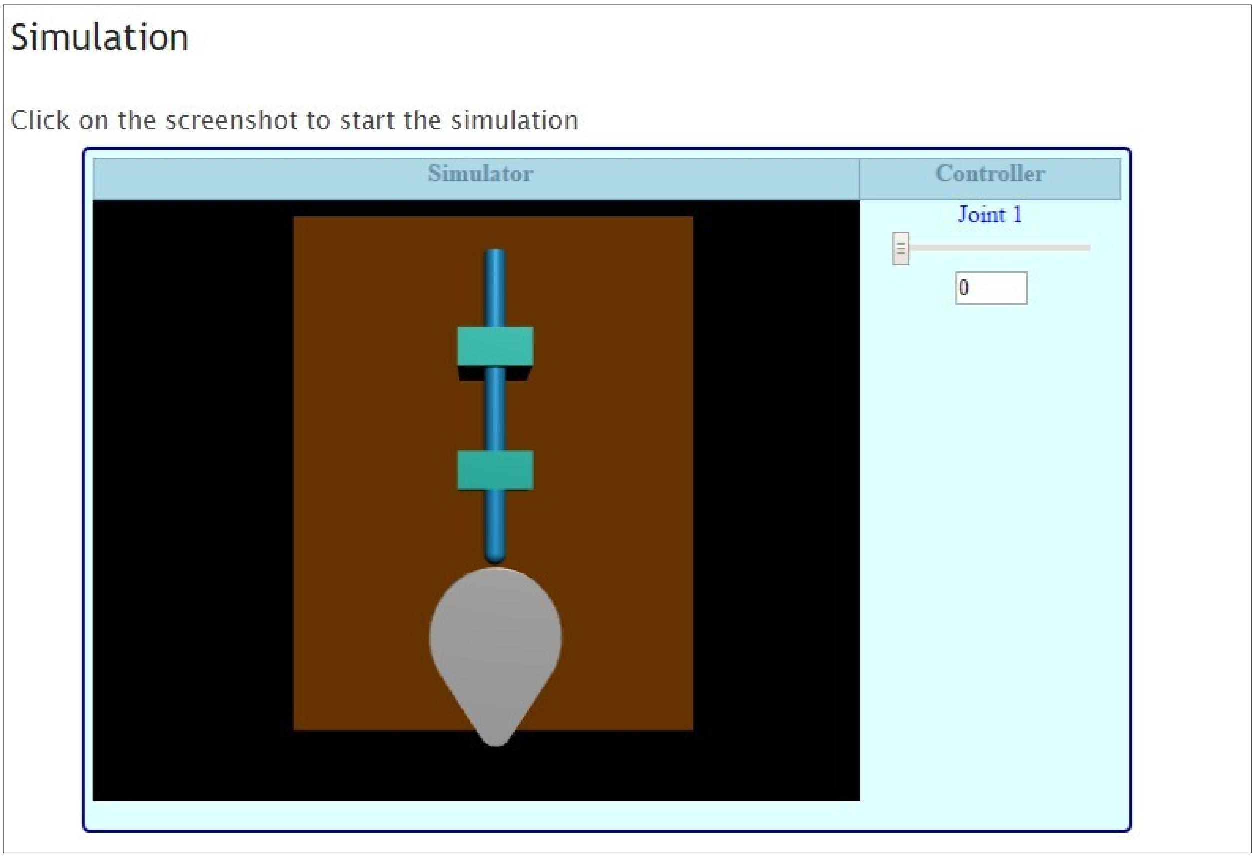
Fig. 3. Terms used in radial cams.



http://vlabs.iitkgp.ac.in/mr/exp8/index.html#

PROCEDURE

- Insert a value of shaft driving speed 'ω' within the suitable range and then click ok to get the output sliding velocity of the slider.
- Drag the slider to see the motion of the mechanism at that particular speed.
- The view can be rotated about a point by keeping the ***left mouse button*** pressed and rotating the mouse.
- The view can be translated by keeping the ***right mouse button pressed*** and translating the mouse in the desired direction.
- The ***scroll button*** or ***middle mouse button*** can be used for zooming.



http://vlabs.iitkgp.ac.in/mr/exp8/Quick_return.html

RESULT

Thus, the characteristic of CAM Follower Mecahnism was studied.

ROBOT TEACHING USING VAL (VERSATILE ASSEMBLY LANGUAGE) PROGRAMMING

EXP NO :

DATE :

AIM

To study the characteristics of Robot Teaching Using Val (Versatile Assembly Language) Programming.

INTRODUCTION

The PUMA 560 is an industrial robot arm with six degrees of freedom and all rotational joints. This experiment introduces the main features of VAL programming language for the PUMA-560 robotic manipulator. The VAL commands are used for offline programming based teaching of the robot. The theory section explains the teaching methods and VAL commands of the robot. In the simulation section, a virtual model is developed in the javascript program which is used to perform the programming experiment. For more information on other aspects of PUMA 560 and robotics, visitors are advised to follow the references.

Figure 1: PUMA 560

THEORY

- Programmable Universal Machine for Assembly, more popularly known as PUMA is an industrial robot arm developed by Victor Scheinman at Unimation, in the year 1978. PUMA comes in various makes viz. PUMA 260, PUMA 560, PUMA 761 etc. The PUMA robot is connected to a 1980 series controller that has a programming language called VAL II which translates simple commands into the electrical signals needed to drive the robot. The commands are send to the controller using a serial port from a PC/Computer.

General Steps to start a PUMA560 Robotic System:

Laptop/PC Setup Procedure:
To operate the PUMA we must first be sure that the PC or laptop/PC is running and that a serial connection is established so that we can enter commands directly. When the power for the PUMA controller is first turned on, it will ask specific questions that need to be answered before power will be applied to the arm. Without the computer connection, the robot arm will not function.

Follow these steps to bring the laptop/PC online before the PUMA is switched on.
1) Press the POWER switch on the laptop/PC.
2) When prompted, enter the password and press Enter.
3) Once the laptop/PC is completely powered up locate the icon for HYPERTERMINAL which is a simple terminal program. This is what we will use to communicate with the PUMA.
4) Double click on the HYPERTERMINAL icon to start the program.
5) The terminal program should start up and already be configured for the proper settings.
6) Power the PUMA Robot Controller on.

Note: If you are unable to communicate in the following steps, you may need to manually set the software to the following values.
a. Select the Communication Port (This depends on the laptop/PC you use. Example: COM1/COM2)
b. Set 9600 Baud, no parity, 1 stop bit.
c. 250 ms delay after a line feed. (This is important when sending files.)
d. 0 ms delay after a character.

Robot Power ON Procedure:

Once the laptop/PC is running follow these procedures.

1) Locate the switch marked RESTART/HALT/RUN and make sure it is in the RUN position.

2) Turn the POWER ON switch to the UP position.

3) On the laptop/PC you should get the first response from the puma INITILIZE (Y/N) ?

You need to answer Y or N to continue, the default answer is N press Enter. If you answer Y to this question, all programs will be erased, the speed will be set to 100%, and all location names will be erased. If you need to clear out all memory to start over, then you would answer Y press Enter.

4) After the question is answered, press the ARM POWER button.

5) You will hear a click and all joints of the robot will now freeze, you will no longer be able to freely move the gripper by pressing on it.

6) Do the PUMA CALIBRATION PROCEDURE using VAL command "CALI"

Robot Power OFF Procedure:

1) Press the red ARM POWER OFF switch.

2) Turn the POWER ON switch to the DOWN position.

3) Power off the laptop/PC if not being used.

WARNING: Turning the controller OFF before pressing the RED ARM POWER OFF switch may damage the driver boards of the robot controller. Always press the RED ARM POWER OFF switch first!

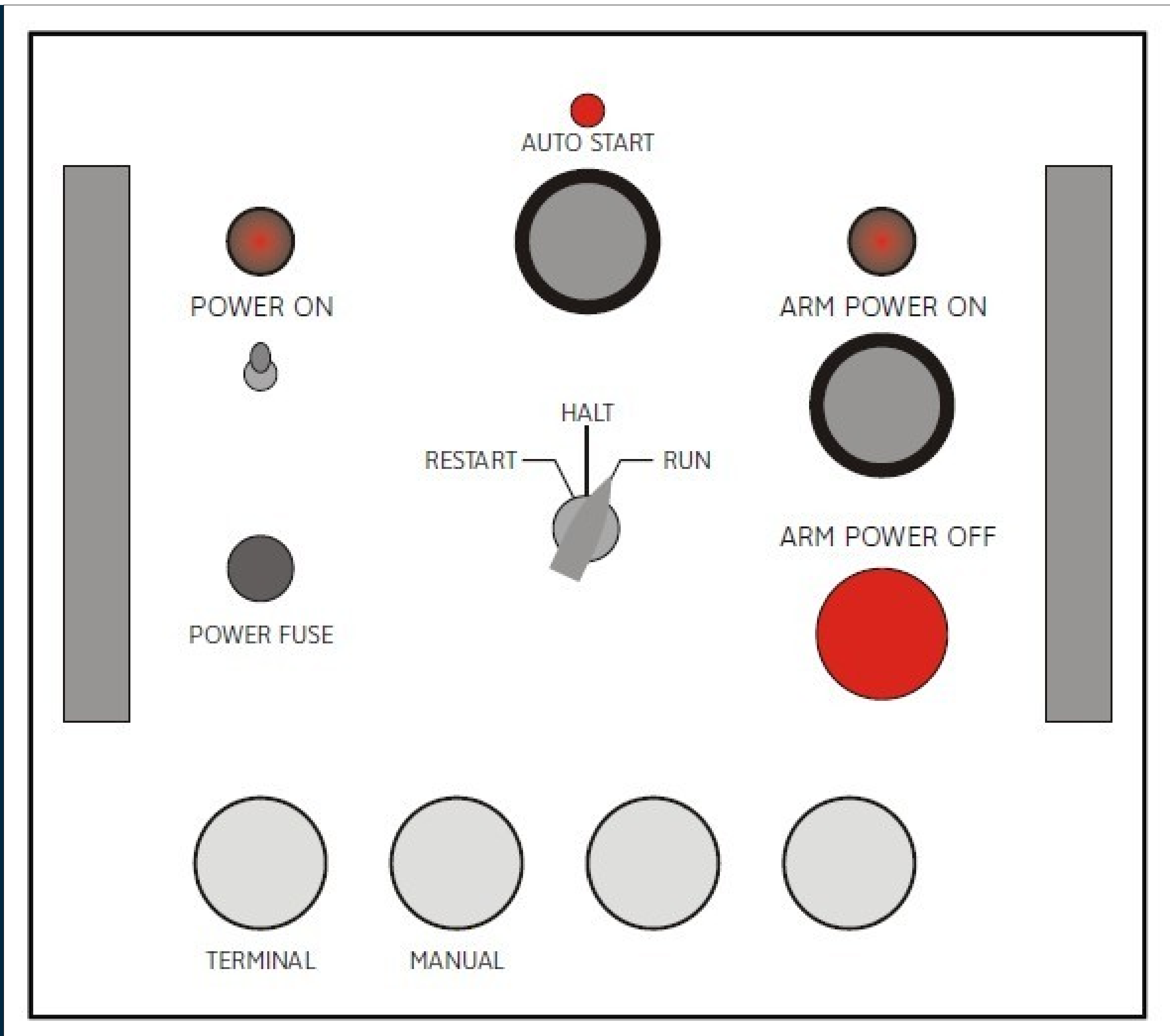
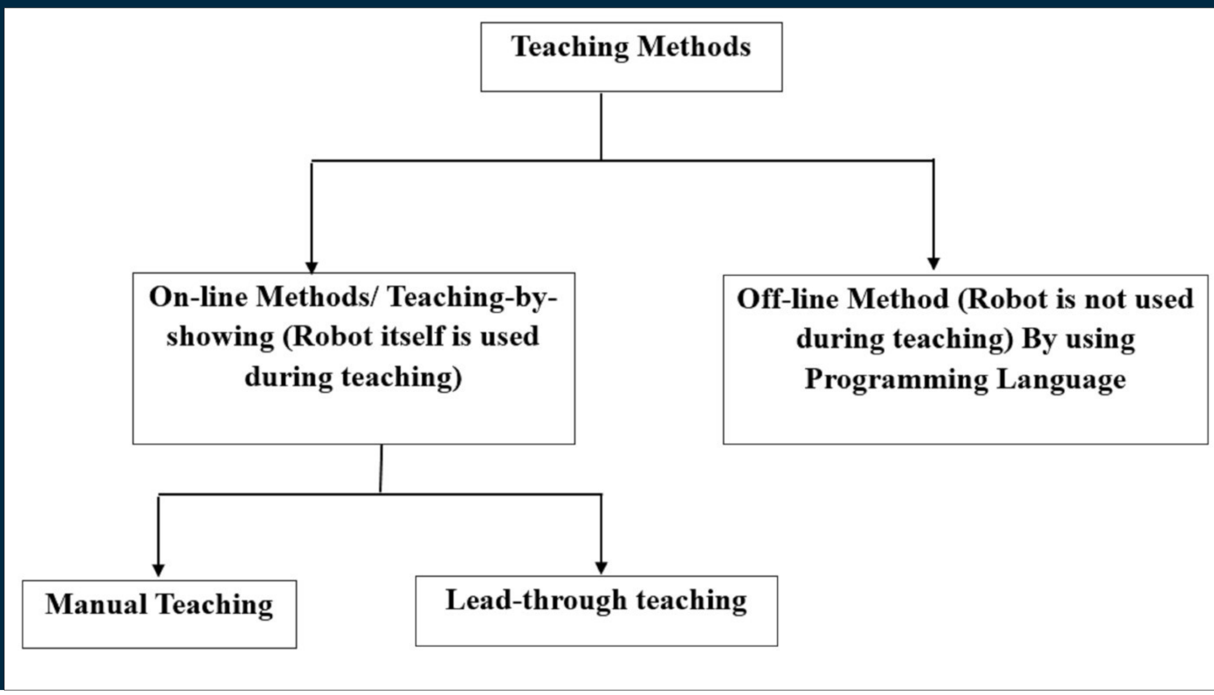


Figure 2: PUMA 560 Controller.[Ref.]



Manual Teaching

- It is suitable for point-to-point (PTP) tasks like spot welding, drilling holes at some pre-specified locations.

- Methods for manual teaching

1) Control handle/Joystick
2) Push buttons
3) Teach Pendant (works in Joint mode, World mode, Tool mode, Free mode)

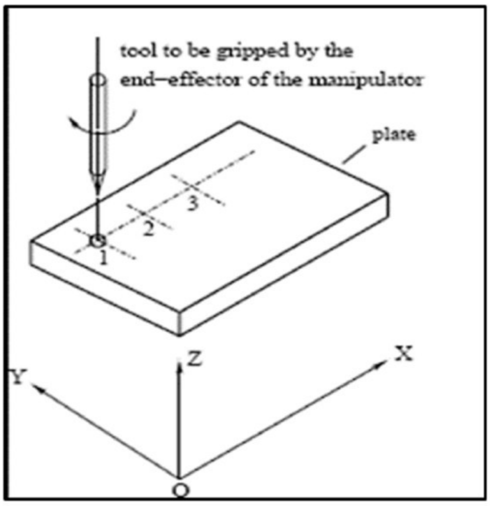


Fig. . Point-to-point (PTP) task.

Lead – Through Teaching

- It is suitable for continuous-path (CP) tasks like spray painting, arc welding, milling to generate complicated surface.

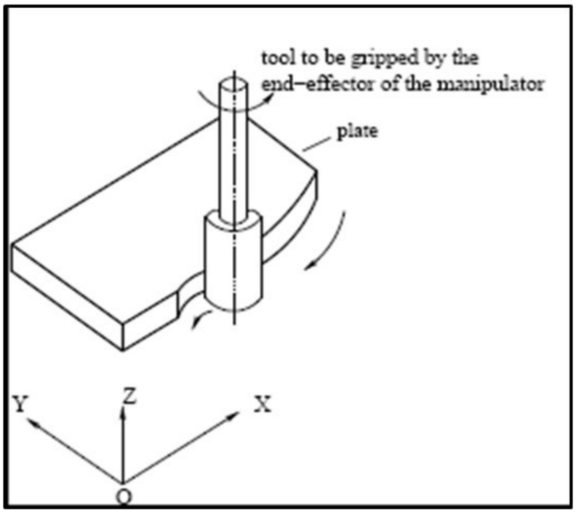


Fig. . Continuous-path (CP) task.

Robot Programming (off-line method) :

PUMA VAL Command Structure:

The PUMA robot will respond to a series of commands in a language called VAL II. There are two methods of sending the commands; first is from within a program, the other is by manually entering them into the computer.

Example: The command to make the arm go to the default position is READY. From within a program you can issue the command directly:

READY

From the terminal you must issue a sub-command to inform the robot to access the command structure, the sub-command is DO. To make the robot move to the default position from the terminal program you would enter:

DO READY

In the following text it will be presumed that the commands are being used from within a computer program. If you are entering them manually use the DO sub-command or you will get an error message.

List of VAL commands: The PUMA has several commands which are used in the creation of programs by the user. Here only a brief description of each of the major commands is listed to help you with making your own programs. For more detailed information you should download and read the VAL Programming Manual from referance tab:

CALI: Used for the calibration of robot.

DO READY: Takes the robot to home position from current location.

DO DRIVE: Used for moving individual joint.

HERE: Used to save robot current position MOVE: Used to command the end-effector to move form one pre-defined point to another.

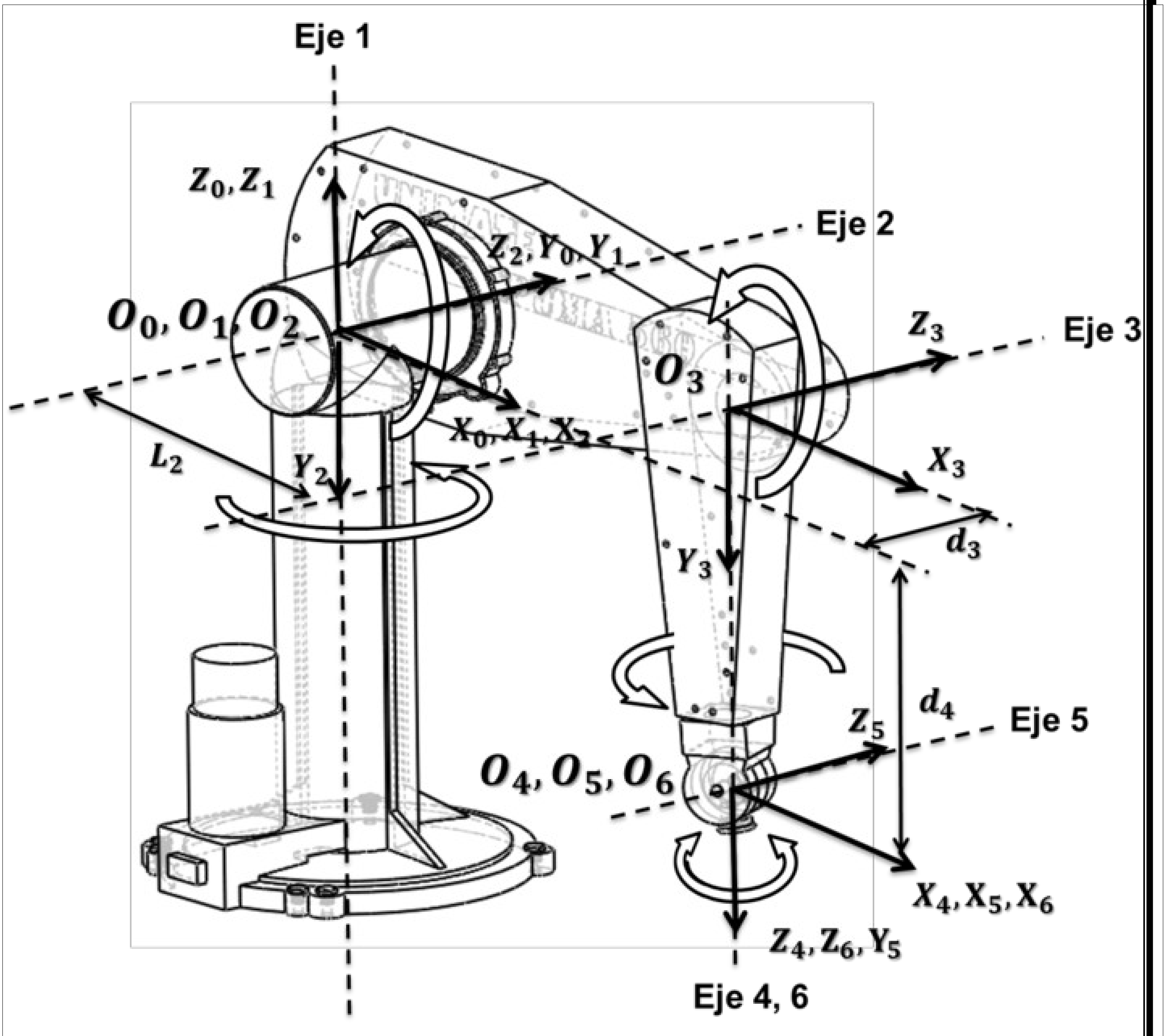
DO DRIVE Used to directly move a specified joint jt a specified number of degrees degrees and at a specified maximum speed speed. This command can be used to move from a known location such as the

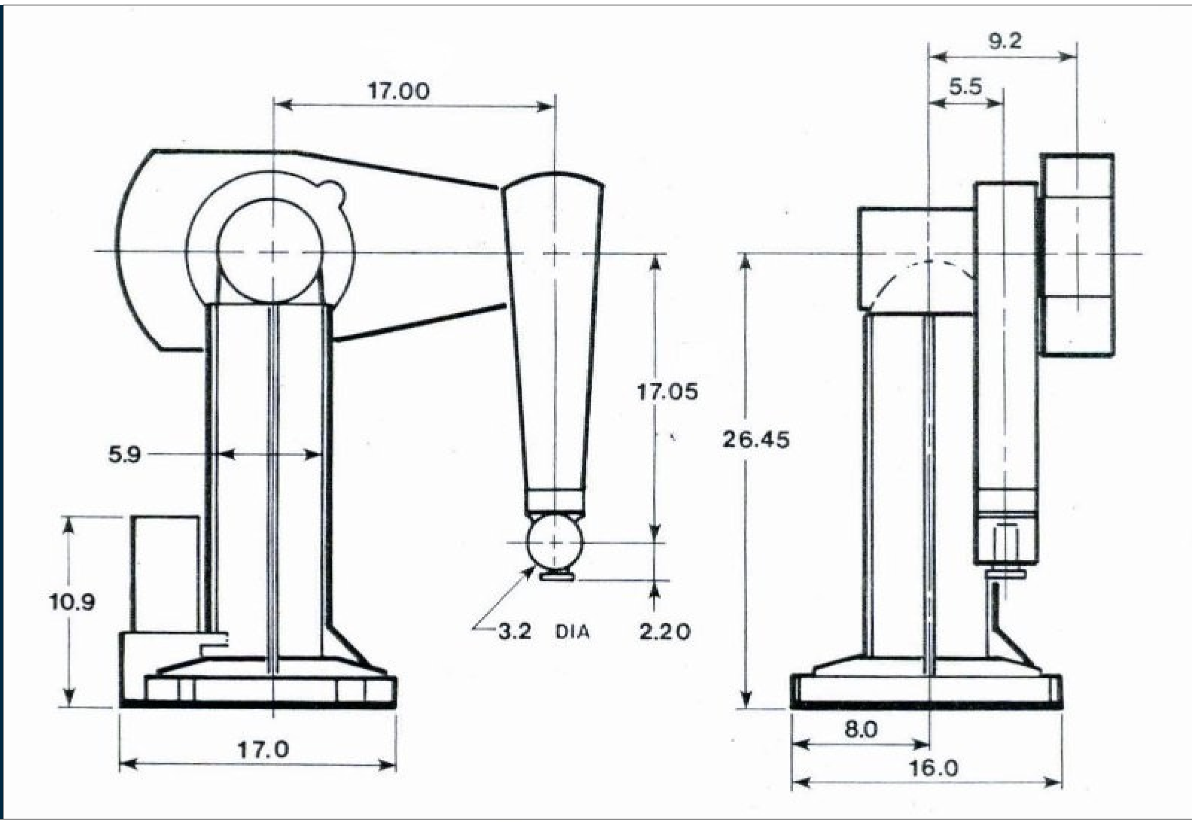
READY position to a new location in the initial setup of the machine, or it can be used to move a specific joint to assist in alignment.

Use: DO DRIVE JT, degrees, speed

Example: DO DRIVE 3, 40, 50

Puma kinematic diagrams:





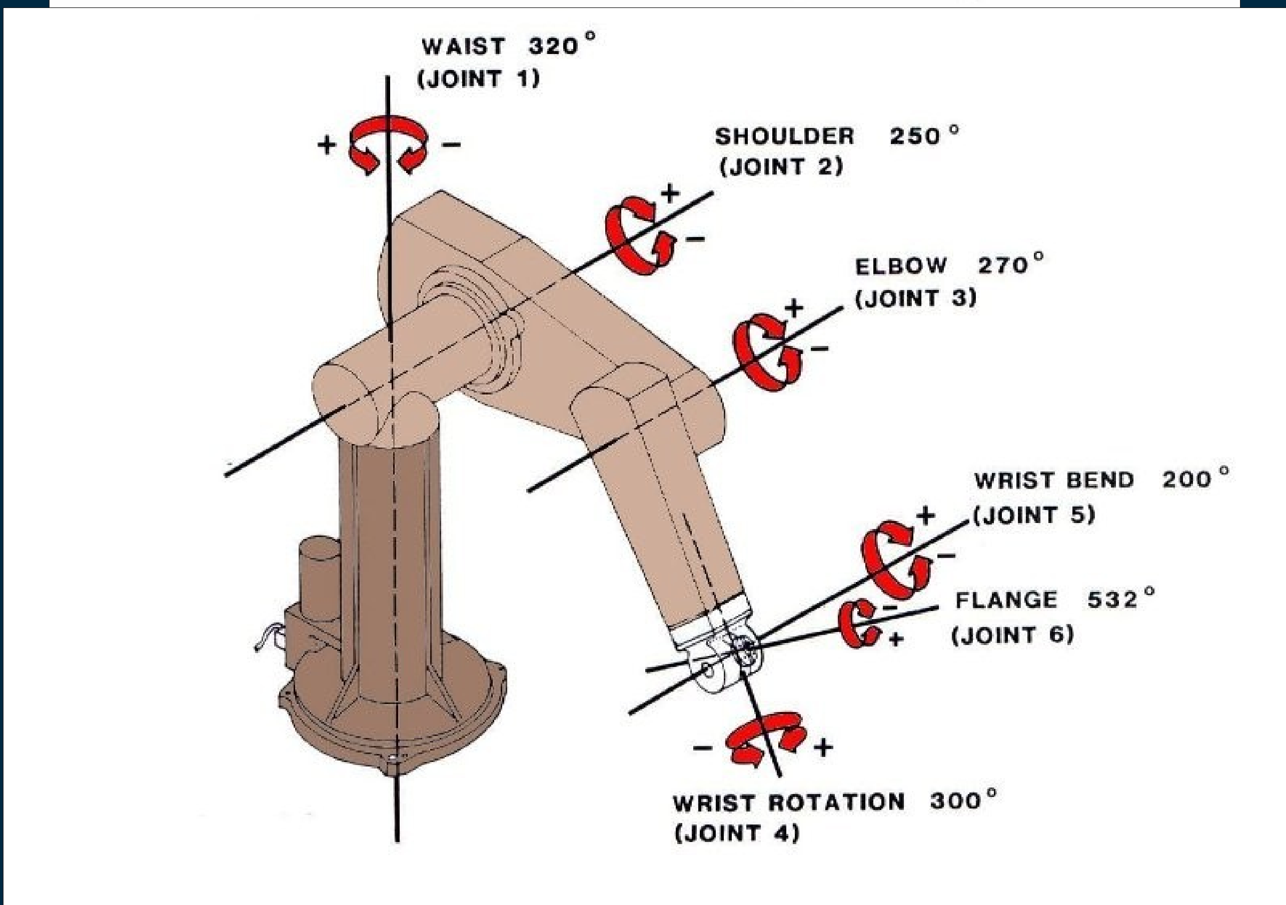


Table 1. Puma 560 D-H parameter table

`LINK_I`	`ALPHA_(I-1)`	`A_I-1`(M)	`D_I`(M)	`THETA_I`

1	0	0	0	`theta_1`
2	-90	0	0	`theta_2`
3	0	`a_2`	`d_3`	`theta_3`
4	-90	`a_3`	`d_4`	`theta_4`
5	90	0	0	`theta_5`
6	-90	0	0	`theta_6`

Transformation matrices of six joints for Puma 560 robot

`T_1 = [[cos \(theta_1\),-sin \(theta_1\),0,0], [sin \(theta_1\), cos \(theta_1\),0,0], [0,0,0,1], [0,0,0,1]]` `T_2 = [[cos \(theta_2\), -sin \(theta_2\),0,0], [0,0,1,0], [-sin \(theta_2\),-cos \(theta_2\),0,0], [0,0,0,1]]`

`T_3 = [[cos \(theta_3\),-sin \(theta_3\),0,a_2], [sin \(theta_3\),cos \(theta_3\),0,0], [0,0,1,d_3], [0,0,0,1]]` `T_4 = [[cos \(theta_4\),-sin \(theta_4\),0,a_3], [0,0,1,d_4], [-sin \(theta_4\), -cos \(theta_4\),0,0], [0,0,0,1]]`

`T_5 = [[cos \(theta_5\), -sin \(theta_5\),0,0], [0,0,-1,0], [sin \(theta_5\),cos \(theta_5\),0,0], [0,0,0,1]]` `T_6 = [[cos \(theta_6\),-sin \(theta_6\),0,0], [0,0,1,0], [-sin \(theta_6\),-cos \(theta_6\),0,0], [0,0,0,1]]`

Final Transformation Matrix `T = T_1*T_2*T_3*T_4*T_5*T_6`

The orientation and position of the end effector with reference to the base coordinate is obtain from the final matrix `T = [[n,s, a,p], [0,0,0,0]]=[[n_x, s_x, a_x, p_x], [n_y, s_y, a_y, p_y], [n_z, s_z, a_z, p_z], [0,0,0,1]]`

OBJECTIVE

- Familiarize with VAL Programming
- Formation of the transformation matrix though which a relationship is established between different links of the manipulator.
- Simulate the robot motion for various inputs of the joint angular value.
- To have a brief idea about the workspace through a 3D graph plot of manipulator position for various inputs.

PROCEDURE

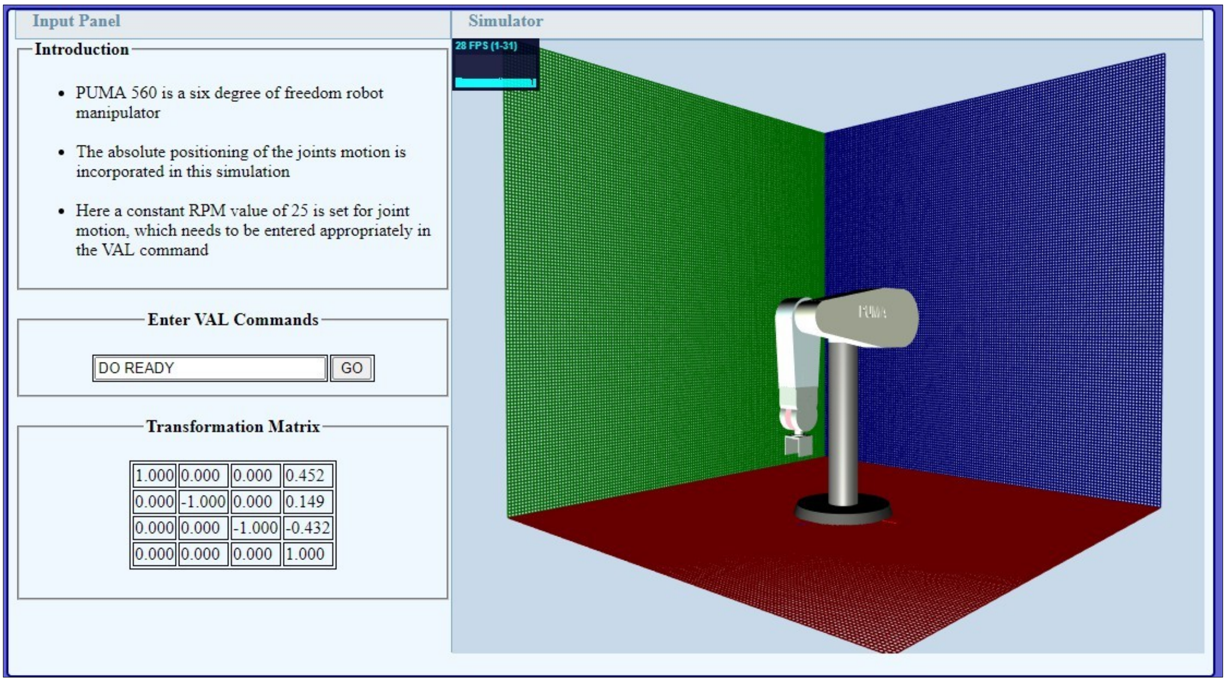
- First bring the robot in the ready configuration using DO READY command
- Do the calibration process using the CALI command
- Write the commands in the input pannel and click Go button for that command execution .
- Commands executed can be seen in the "command history" panel .
- The position and orientation of the robot end-effector is vizualized the Transformation matrix panel.
- The view can be rotated about a point by keeping the ***left mouse button*** pressed and rotating the mouse.
- The view can be translated by keeping the ***right mouse button pressed*** and translating the mouse in the desired direction.
- The ***scroll button*** or ***middle mouse button*** can be used for zooming.

http://vlabs.iitkgp.ac.in/mr/exp0/index.html#

SIMULATOR

This program simulates a 6 link 3D Puma Robot using the javascript program. The model and its movement of different links are encoded in javascript language. Model This program does not allow for the specification of angular speed or acceleration of the arms. Click on the screenshot given below to start the simulation.

Click on the screenshot to start the simulation



Simulator Screen shot

http://vlabs.iitkgp.ac.in/mr/exp0/Robot-teaching-of-puma-560.html

RESULT

Thus, the characteristics of Robot Teaching Using Val (Versatile Assembly Language) Programming was studied.

PROCESS CONTROL

CHARACTERISTICS OF AN LVDT

EXP NO :
Date :

AIM

To study the characteristics of an LVDT position sensor with respect to the secondary output voltage. And measure the voltage due to the residual magnetism .

APPARATUS REQUIRED

1. ITB-12-CE
2. LVDT setup
3. Multimeter (CRO)
4. Power Chord

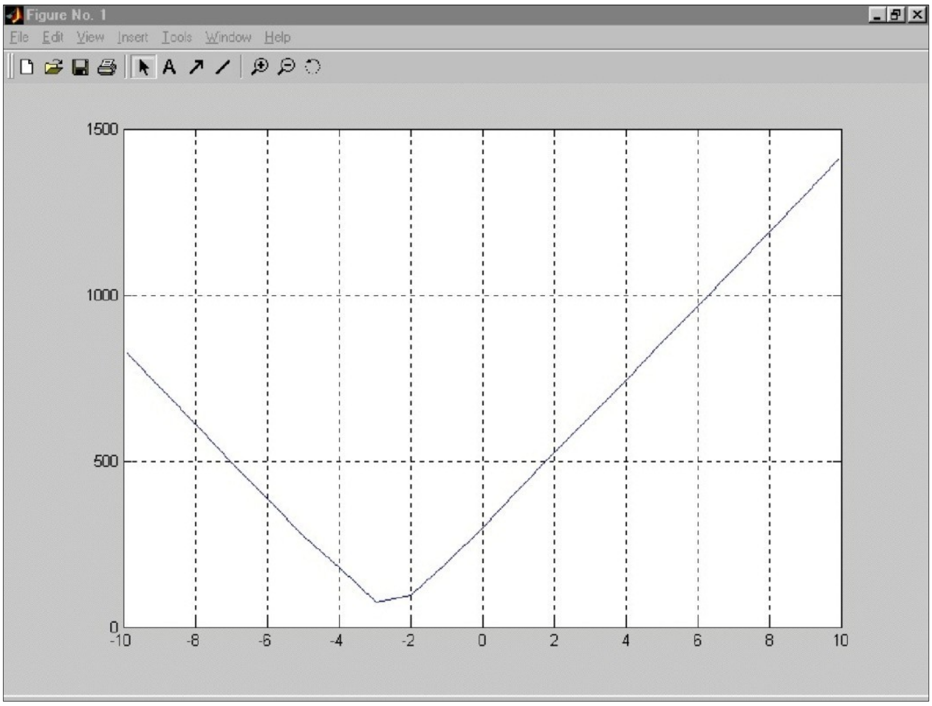
PROCEDURE

1. Install the LVDT position sensor and interface the 9 pin D connector with ITB-12-CE.
2. Switch ON the unit.
3. Connect the multimeter or CRO (in AC - mV mode)across the T4 and T7 for the secondary output voltage measurement.
4. Adjust the micrometer to 10 mm displacement and tune the zero adjustment POT to zero displacement on display.
5. Adjust the micrometer to 20 mm displacement and tune the gain adjustment POT to 10 on the display.
6. Repeat the zero and span calibration until the core displacement is 0.00mm for 10 mm displacement in micrometer and 10.00mm for 20 mm displacement in micrometer.
7. After completion of the calibration, give the displacement from the micrometer to the core of the LVDT sensor.
8. Gradually increase the micrometer displacement from 10 mm to 20 mm and note down the forward core displacement from zero mm to 10 mm on the display and secondary output voltage (mV) across T4 and T7.
9. Similarly, decrease the Micrometer displacement from 10 mm to zero mm and note down the reverse core displacement of zero to -10 mm on the display and secondary output voltage (mV) across T4 and T7.
10. Tabulate the readings of the core displacement, Micrometer displacement and secondary output voltage (mV).
11. Plot the graph between core displacement (mm) along x axis and secondary output voltage (mV) across y axis.

TABULATION

Micrometer displacement (mm)	Core displacement (mm)	Secondary Output voltage (mV)

MODEL GRAPH



RESULT

Thus, the characteristics of an LVDT position sensor with respect to the secondary output voltage was studied.

CHARACTERISTICS OF AN LVDT

EXP NO :
DATE :

AIM

To study the characteristics of an LVDT position sensor with respect to signal conditioned output voltage

APPARATUS REQUIRED

1. ITB-12-CE
2. LVDT setup
3. Multimeter (CRO)
4. Power Chord

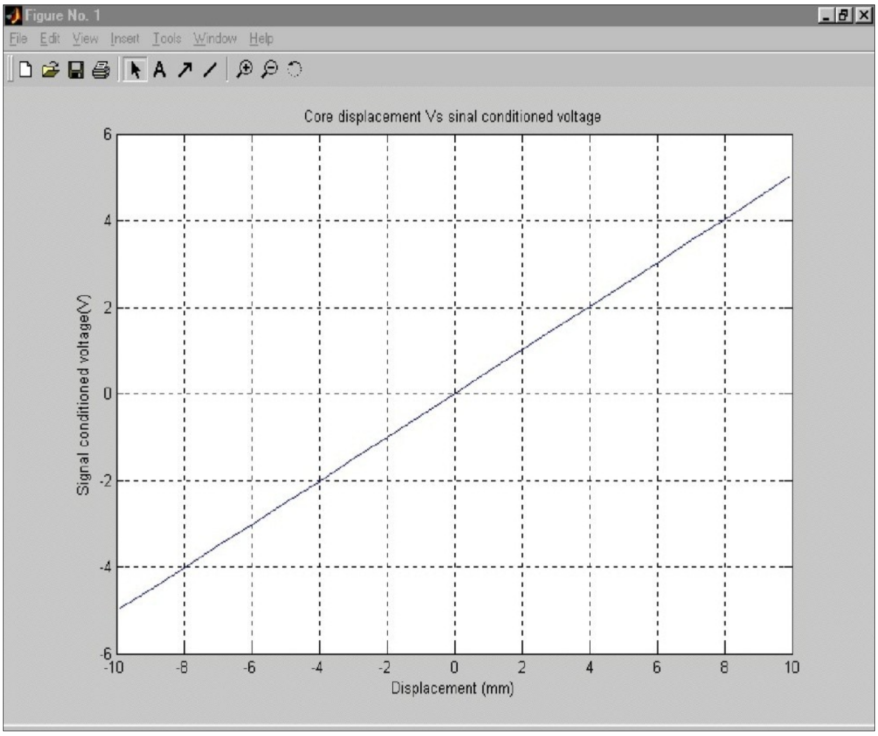
PROCEDURE

* Install the LVDT position sensor and interface the 9 pin D connector with ITB-12-CE.
* Switch ON the unit.
* Connect the multimeter or CRO (in DC-Volt mode) across T6 and T7 for signal conditioned output voltage measurement.
* Adjust the micrometer to 10 mm displacement and tune the zero adjustment POT to zero mm displacement on display. The voltage across the T6 and T7 should be zero volt.
* Adjust the micrometer to 20 mm displacement and tune the gain adjustment POT to 10 mm on the display. The voltage across the T6 and T7 should be 5 V.
* Repeat the zero and span calibration until the core displacement is 0.00 mm for 10 mm displacement in micrometer and 10.00mm for 20 mm displacement in the micrometer.
* After completion of the calibration, give the displacement from the micrometer to the core of the LVDT sensor.
* Gradually increase the micrometer displacement from 10 mm to 20 mm and note down the forward core displacement from zero mm to 10 mm on the display and signal conditioned output voltage (V) across T6 and T7.
* Similarly, decrease the Micrometer displacement from 10 mm to zero mm and note down the reverse core displacement of zero to -10 mm on the display and signal conditioned output voltage (V) across T6 and T7.
* Tabulate the readings of the core displacement, Micrometer displacement and signal conditioned output voltage (V).
* Plot the graph between core displacement (mm) along x-axis and the signal conditioned output voltage(V) along y-axis.

TABULATION

Micrometer displacement (mm)	Core displacement (mm)	Signal conditioned Output voltage (volt)

MODEL GRAPH



RESULT

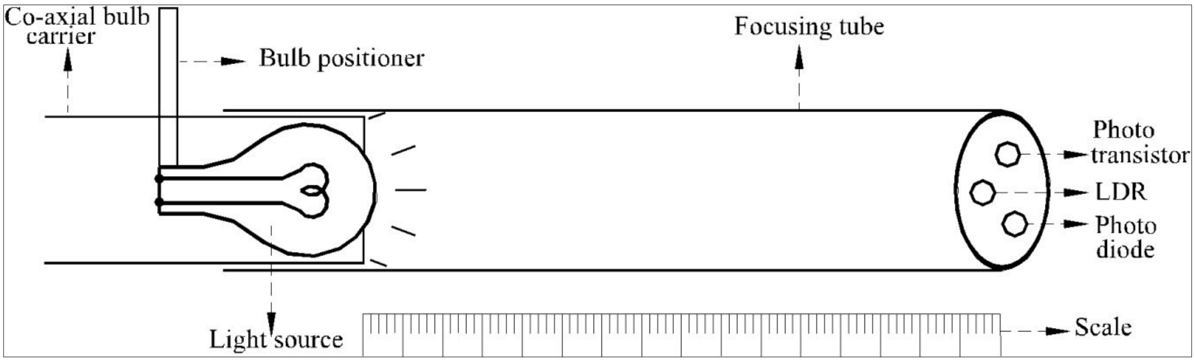
Thus the characteristics of an LVDT position sensor with respect to the signal conditioned output voltage was studied.

CHARACTERISTICS OF LDR

EXP No :
DATE :

AIM

To study the response of Distance versus Voltage in Light Dependent Resistors (LDR).



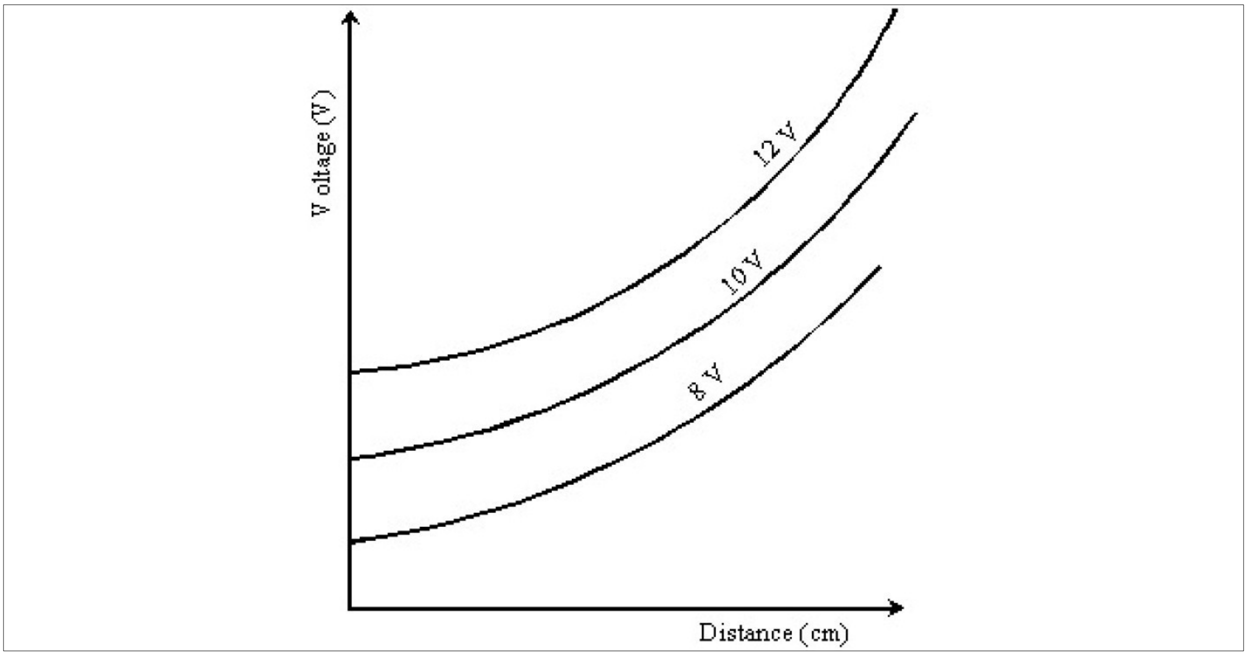
PROCEDURE

1. Position the pointer at 0 on the scale, when the bulb is at maximum distance away from the sensors.
2. Switch ON the supply to the unit.
3. To set 8V across T1, T2 terminals by adjusting the (0-12)VDC potentiometer.
4. To measure the voltage output across T5, T6 terminals at that time the switch is in V position.
5. Gradually move the bulb towards the sensor in steps of 5cm distance and note the corresponding voltage.
6. Repeat the steps 4 and 5 for 10V and 12V adjustments.
7. Tabulate the readings and plot the graph between distance and voltage.

TABULATION

Distance (cm)	Sensor Output Voltage (V)		
	8V	10V	12V

MODEL GRAPH



RESULT

Thus the response of Distance versus Voltage in Light Dependent Resistors (LDR) was studied.

CHARACTERISTICS OF LDR

EXP No :
DATE :

AIM

To study the response of Distance versus Resistance in Light Dependent Resistors (LDR).

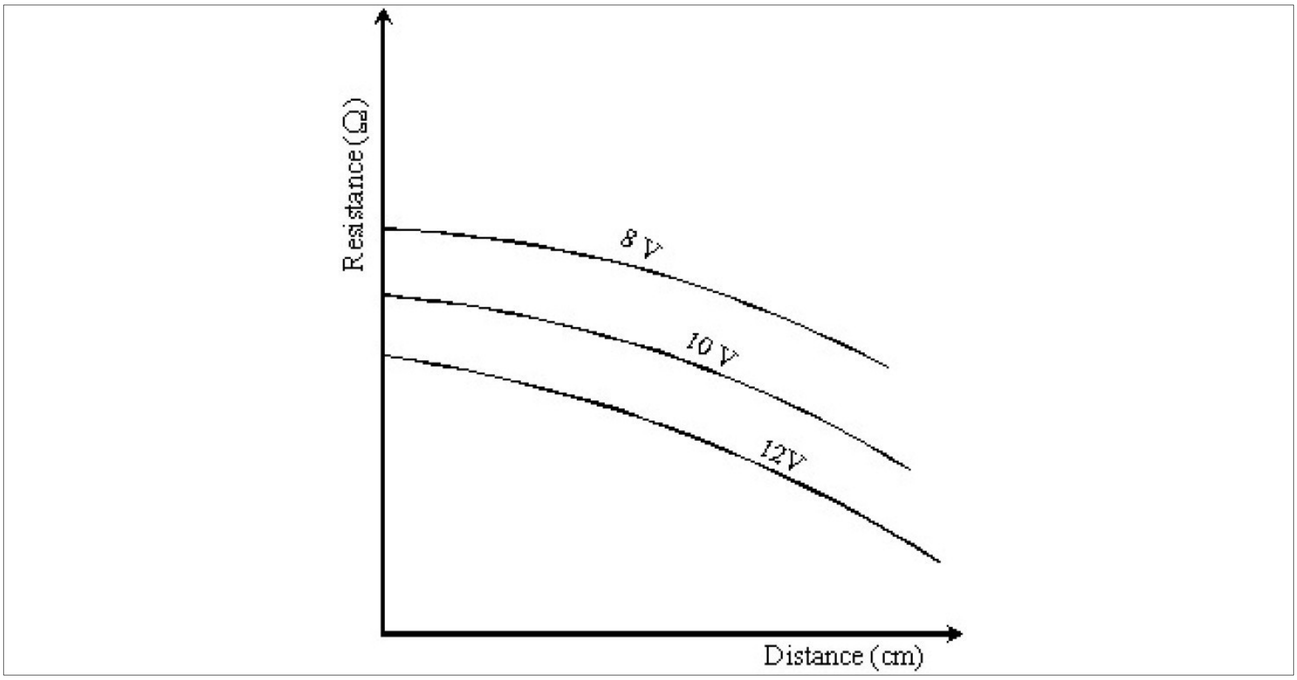
PROCEDURE

1. Position the pointer at 0 on the scale, when the bulb is at maximum distance away from the sensors.
2. Switch ON the supply to the unit.
3. To set 8V across T1, T2 terminals by adjusting the (0-12)VDC potentiometer.
4. To Measure the resistance output across T3, T4 terminals at that time the switch in R position.
5. Gradually move the bulb towards the sensor in steps of 5cm distance and note the corresponding resistance.
6. Repeat the steps 4 and 5 for 10V and 12V adjustments.
7. Tabulate the readings and plot the graph between distance and resistance.

TABULATION

Distance (cm)	Sensor Output Resistance (S)		
	8V	10V	12V

MODEL GRAPH



RESULT

Thus the response of Distance versus Resistance in Light Dependent Resistors (LDR) was studied.

CHARACTERISTICS OF THERMOCOUPLE

EXP No :
DATE :

AIM

To study the characteristics of thermocouple.

APPARATUS REQUIRED

i. ITB-05CE
ii. Thermocouple
iii. Water bath
iv. Thermometer
v. Digital multi meter
vi. Power Chord.

PROCEDURE

1. Patch the two terminals of the thermocouple across T1 & T2.
2. Insert the thermocouple and thermometer into the water bath.
3. Place the Multimeter (millivolts mode) across T3 and T4.
4. Switch ON the water bath and note the temperature in thermometer and mV in Multimerter.
5. Tabulate the readings temperature Vs mV and plot the graph.

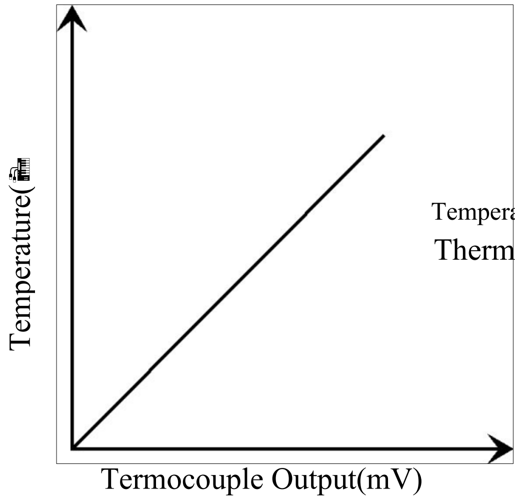
Tabular Column

Actual Temperature (°C)	Thermocouple Output (mV)

MODEL GRAPH

Temperature(

C) Vs Thermocouple Output(mV)



Temperature : 100 C

Thermocouple Output : 2.8mv

RESULT

Thus the characteristics of thermocouple was studied and graph is plotted.

CHARACTERISTICS OF THERMOCOUPLE

EXP No :
DATE :

AIM

To study the characteristics of thermocouple without compensation.

APPARATUS REQUIRED

i. ITB-05CE
ii. Thermocouple
iii. Water bath
iv. Thermometer
v. Digital multi meter
vi. Power Chord.

FORMULA

$$\% E \quad \frac{Displayed\ Temp - Actual\ Temp}{Actual\ Temp} \quad 100$$

PROCEDURE

1. Patch the two terminals of the thermocouple across T1 & T2.
2. Position the switch ‘SW1' towards ‘NO’.
3. Switch ‘ON’ the unit and note the displayed temperature.
4. If there is any difference in displayed temperature at room temperature, adjust the offset knob ‘Zero’ to set 0°C in display.
5. Insert the thermocouple and thermometer into the water bath.
6. Switch ‘ON’ the water bath.
7. Note the actual temperature in thermometer and displayed temperature simultaneously.
8. Tabulate the reading and calculate %Error using the above formula.
9. Plot the graph actual Temperature Vs% Error.

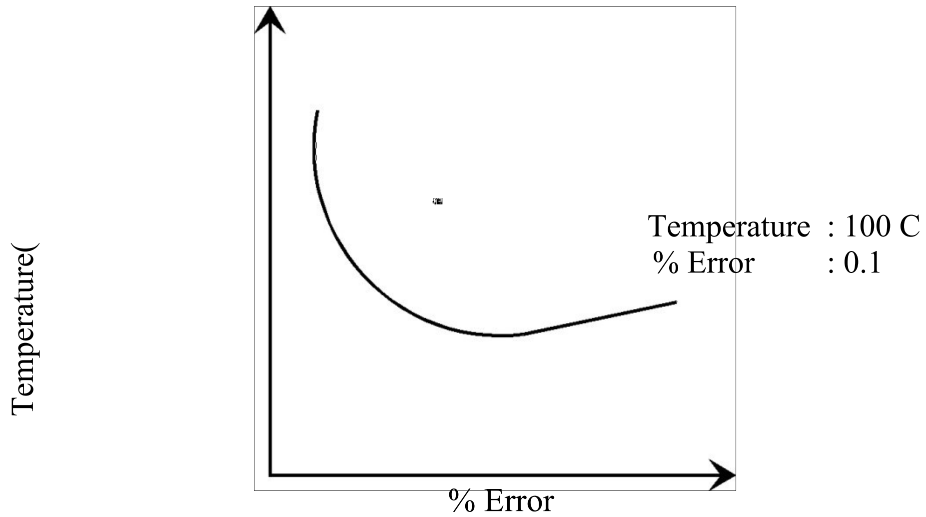
Tabular Column

Actual Temperature (°C)	Displayed Temperature (°C)	% Error

$$\% E = \frac{Displayed\ Temp - Actual\ Temp}{Actual\ Temp} \times 100$$

MODEL GRAPH

Temperature Vs Error



RESULT

Thus the characteristics of thermocouple without compensation was studied and graph is plotted.

CHARACTERISTICS OF THERMOCOUPLE

EXP No :
DATE :

AIM

To study the characteristics of thermocouple with compensation.

APPARATUS REQUIRED

i. ITB-05CE
ii. Thermocouple
iii. Water bath
iv. Thermometer
v. Digital multi meter
vi. Power Chord.

FORMULA

$$\% E = \frac{Displayed\ Temp - Actual\ Temp}{Actual\ Temp} \times 100$$

PROCEDURE

1. Patch the two terminals of the thermocouple across T1 & T2.
2. Position the switch ‘SW1' towards downwards.
3. Switch ‘ON’ the unit and note the displayed temperature.
4. If there is any difference in displayed temperature at room temperature, adjust the offset knob ‘Zero’ to set 0°C in display.
5. Insert the thermocouple and thermometer into the water bath.
6. Place the multimeter across T7 & T8
7. Position the switch ‘SW1' towards the ‘NC’
8. Switch ‘ON’ the water bath.
9. Note the actual temperature in thermometer, voltage in multimeter and displayed temperature simultaneously.
10. Tabulate the reading and calculate %Error using the above formula.

11. Plot the graph for

i. Actual Temperature Vs % Error.

ii. Actual Temperature Vs signal conditioner output.

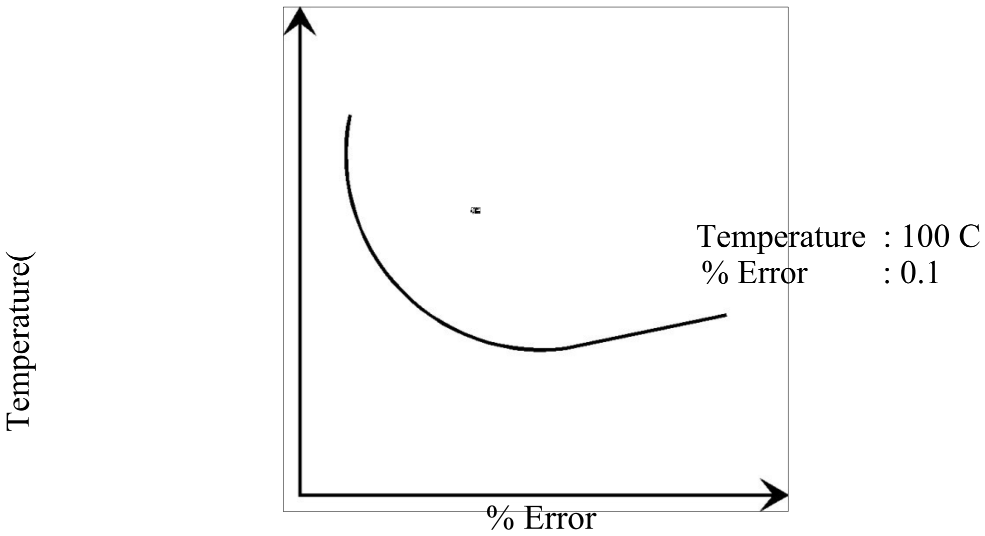
Tabular Column

Actual Temperature (°C)	Displayed Temperature (°C)	Signal conditioner output (V)	% Error

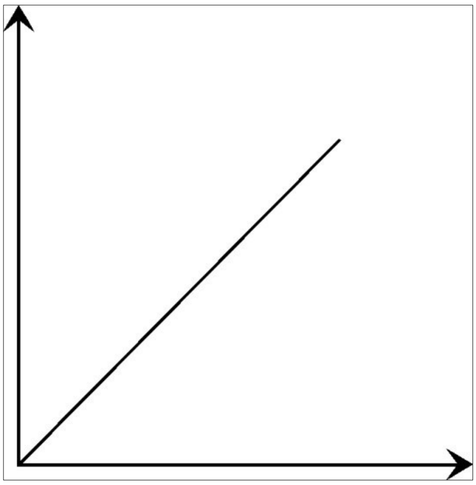
$$\% E = \frac{Displayed\ Temp - Actual\ Temp}{Actual\ Temp} \times 100$$

MODEL GRAPH

Temperature Vs Error



ii. TEMPERATURE Vs SIGNAL CONDITIONER OUTPUT VOLTAGE



Temperature(˚C)

Output Voltage(V)

Temperature:100˚C

Output Voltage: 5V

RESULT

Thus the characteristics of thermocouple with compensation was studied and graph is plotted.

CHARACTERISTICS OF RTD

EXP No :
DATE :

AIM

To study the temperature Vs resistance characteristics of RTD (Pt100)

APPARATUS REQUIRED

1. ITB-006CE
2. Water Bath
3. Thermometer
4. Multimeter

PROCEDURE

1. Patch the wires of RTD to the T1 and T2 terminals of the RTD input block and switch ON the unit.
2. Place the RTD and thermometer into the holes provides in the waterbath.
3. Keep the switch SW1 in right direction.
4. Place the multimeter in the resistance mode across T3 and T4 terminals.
5. Heat the waterbath and note the temperature in thermometer and corresponding resistance value in multimeter.
6. Repeat step 5 for different values of temperature and tabulate the readings.
7. Plot the temperature Vs resistance graph.
8. This gives the characteristic curve of the RTD. Refer to the model graph.

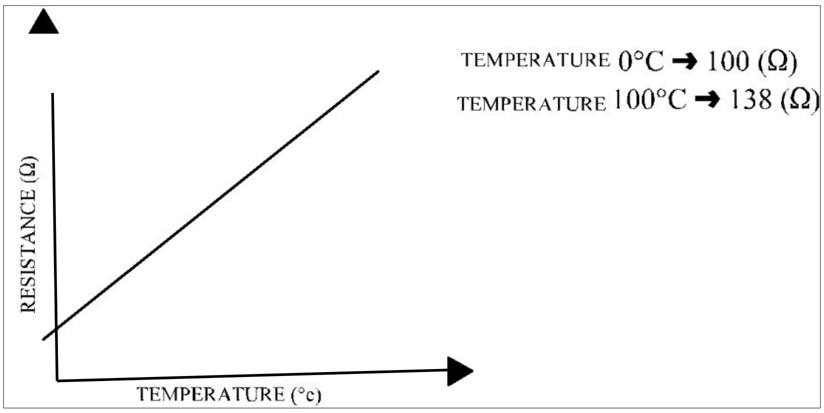
TABULAR COLUMN

Temperature (°C)	Resistance ( )
0°C	100
.	.
.	.
.	.
.	.
100°C	138.5

MODEL GRAPH

The graph between Temperature and Resistance are drawn.

TEMPERATURE (°c) VS RESISTANCE



SAMPLE READING

Temperature 0°C 100( )

Temperature 100°C 138.5( )

RESULT

Thus the study of Temperature Vs Resistance characteristics was studied and graph is plotted.

CHARACTERISTICS OF RTD

EXP No :
DATE :

AIM

To study the characteristics of temperature Vs voltage and the accuracy of the signal conditioning board.

APPARATUS REQUIRED

1. ITB-006CE Unit.
2. Water Bath.
3. Thermometer.
4. Multimeter.
5. Power Chord.

FORMULA TO BE USED

$$\% \ Error = \frac{Displayed\ Temperature - Actual\ Temperature}{Actual\ Temperature} * 100$$

PROCEDURE

1. Patch the wires of RTD to the T1 and T2 terminals of the RTD input block.
2. Switch ON the ITB -006CE Unit.
3. Keep the switch in left direction and switch SW2 in external mode.
4. Now adjust the the 'Zero' Potentiometer to read 0°C at the display. This is done for initial setup of the unit and this adjustment should be left undisturbed.
5. . Insert the RTD into the water bath and note the temperature without any heating at ambient condition.
6. Keep the switch SW1 in left direction and switch SW2 in internal mode.

7. Place the multimeter in voltage mode across the T6 and T7 terminals.

8. Now, gradually start heating the water bath and note down the actual temperature, output voltage of the unit and the displayed temperature simultaneously.

9. Repeat step 8 for different values of temperatures and tabulate the readings.

10.Plot the graph for Temperature Vs Voltage.

11. Calculate the % error and plot the graph for Temperature Vs %Error

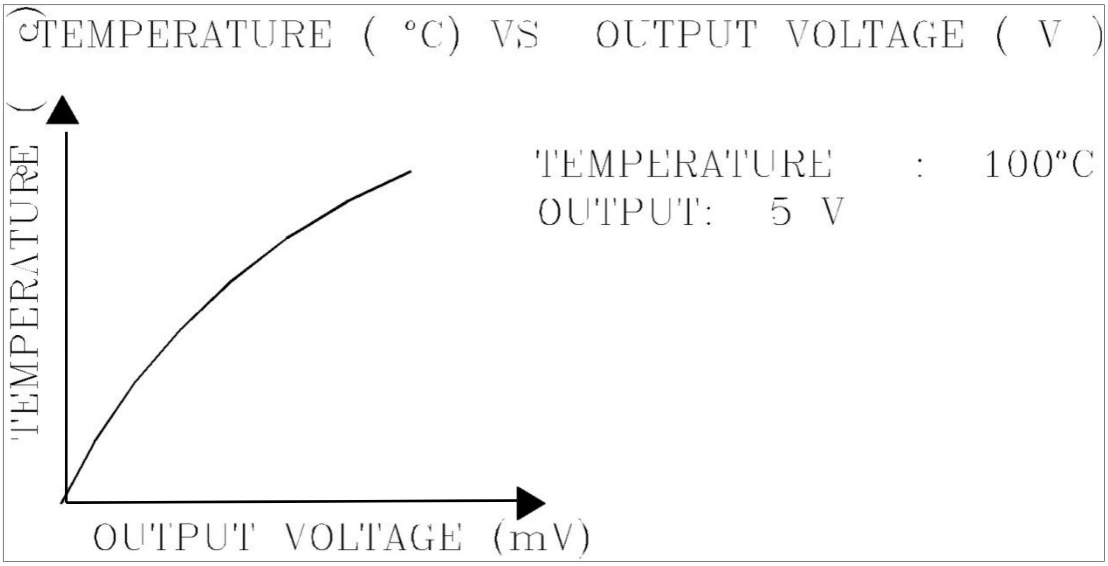
The first graph measures the linearity of the signal conditioning unit and the second graph measures the accuracy.

TABULAR COLUMN

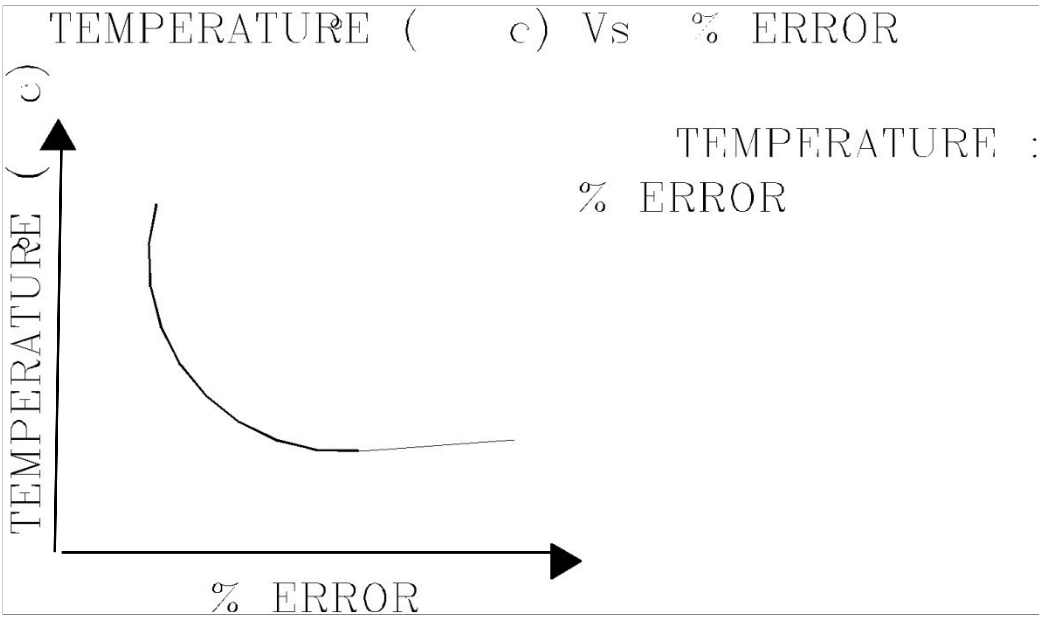
Actual Temperature (°C)	**Output Voltage (V)**	**Displayed Temperature (°C)**	**% Error**

MODEL GRAPH

1. The graph between temperature and voltage are drawn.



2. . The graph between temperature and % Error are drawn.



RESULT

Thus the study of Temperature Vs Voltage and the accuracy of signal conditioning board was studied and the graph is drawn.

CHARACTERISTICS OF THERMISTOR.

EXP No :
DATE :

AIM:

To study the temperature Vs resistance characteristics of Thermistor.

APPRATUS REQUIRED:

1. ITB-6A-CE
2. Water bath
3. Thermometer
4. Digital multimeter

PROCEDURE:

* Ensure that the power to the unit is switched off.

* Patch two wires of the Thermistor to the plus and minus terminals placed, in the Thermistor input block.

* Place an ohmmeter or a multimeter in resistance mode across the thermistor.

* Insert the Thermistor into the water bath and note the resistance offered at room temperature.

* Now, Gradually starts heating water bath and note the values of temperature and resistance.

* Repeat step 5 for different values of temperature and tabulate the readings.

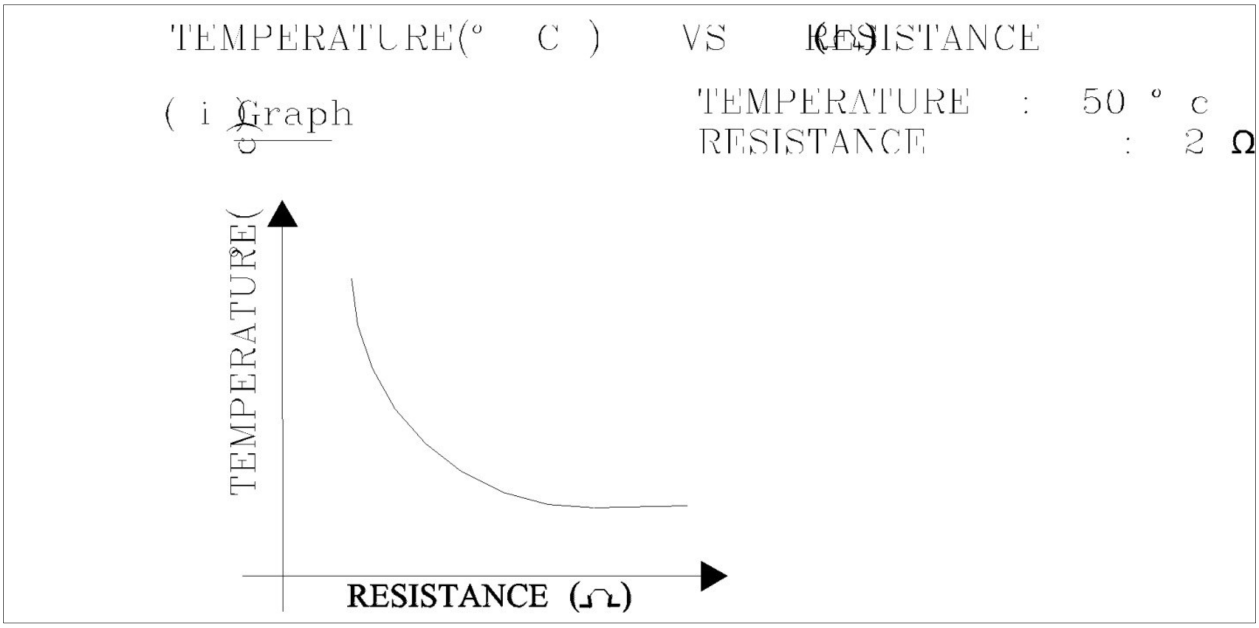
* The graph between temperature and resistance are drawn.

TABULAR COLUMN:

Temperature (°C)	Resistance (S)

MODEL GRAPH:

The graph between temperature and resistance are drawn.



RESULT:

Thus the study of temperature Vs resistance characteristics of thermister was studied and graph is plotted.

CHARACTERISTICS OF THERMISTOR.

EXP No :
DATE :

AIM:

To study the temperature Vs voltage and the accuracy of the signal conditioning board.

APPRATUS REQUIRED:

1. ITB-6A-CE
2. Water bath
3. Thermometer
4. Digital multimeter

PROCEDURE:

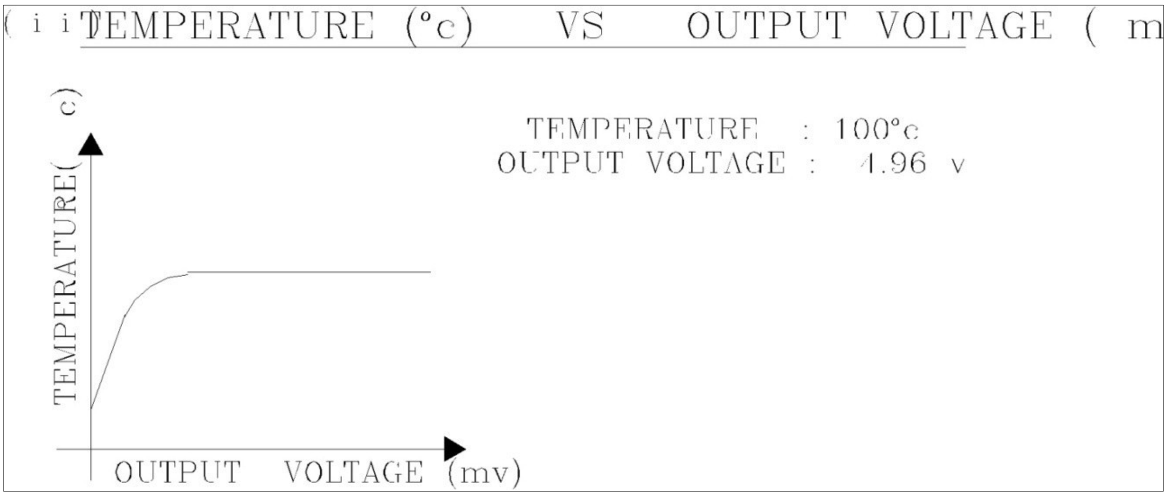
- Ensure that the power to the unit is switched OFF.
- Patch the wires of the Thermistor to the plus and minus terminals placed in the Thermistor input block.
- Switch on the power supply unit.
- Adjust offset knob to very display at room temperature.
- Insert the Thermistor into the water bath and note the temperature without any heating at ambient condition.
- If there is any difference in voltage between that noted and adjust the zero knob to vary the displayed voltage to tally with the actual voltage. Else, this knob may be left undisturbed.
- Now, gradually starts heating the water bath and note the actual temperature and output voltage of the unit.
- Repeat step 7 for different values of temperature and tabulate the readings.
- The graph between temperature and output voltage are drawn.

TABULAR COLUMN:

Actual Temperature (°C)	Output Voltage (V)

MODEL GRAPH:

The graph between temperature and output voltage are drawn.



RESULT:

Thus the study of temperature Vs voltage and the accuracy of signal conditioning board was studied and graph is plotted.

CHARACTERISTICS OF STRAIN GAUGE USING LOAD CELL

EXP No :
DATE :

AIM

To study the characteristics between strain applied to the cantilever strain sensor and the signal conditioned sensor output voltage.

APPARATUS REQUIRED

i. ITB-17 -CE Trainer kit

ii. Multimeter (V)

iii. Cantilever beam strain sensor setup

iv. Weights (100 gram × 10 Nos)

v. Power chord

FORMULA TO BE USED

$$\%_{e} = \frac{\text{Actual strain} - \text{Theoritical strain}}{\text{Theoritical strain}} * 100$$

Theoretical strain

$$= \frac{6PL}{B\,t^2\,Y} = \frac{6 \times 1 \times 21.58}{2.8 \times 0.25^2 \times 2 \times 10^6} = 370\mu \text{ strain}$$

Where,

Max. applied load (P) to beam : 1 Kg

Thick ness (t) of the beam : 0.25 cm

Breath (B) of the beam : 2.8 cm

Length (L) of the beam : 21.58 cm

Young's modulus (Y) : 2×10^6 kg /cm^2

PROCEDURE

1. Install the cantilever beam strain sensor setup and interface the 9 pin D connector with ITB-17-CE kit
2. . Connect the multimeter in Volt mode across T5 and GND for the signal conditioned sensor voltage measurement.
3. Switch "ON" the module.
4. Initially, unload the beam and nullify the display by using zero adjustment POT [zero calibration].
5. Apply the maximum load of 1Kg to the beam and adjust the display to 370 strain by using gain adjustment POT [gain calibration].
6. Now apply the load to the beam , a strain will develop on the beam and measure the signal conditioned sensor output voltage (V) across T5 and GND.
7. Gradually increase the load and note down the signal conditioned sensor output voltage (V) and actual strain.
8. Tabulate the values of theoretical strain, actual strain and signal conditioned sensor output voltage
9. Plot a graph between theoretical strain and signal conditioned sensor output voltage (V).

Note

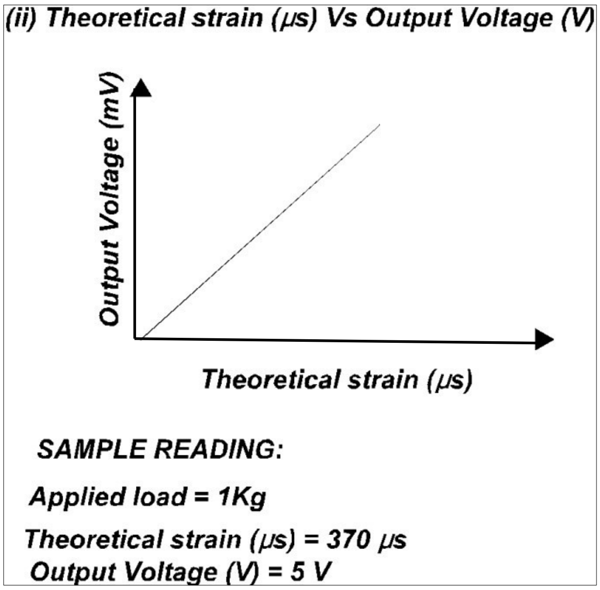
When 100 gram load is applied to the beam. The actual strain should be 37 s.

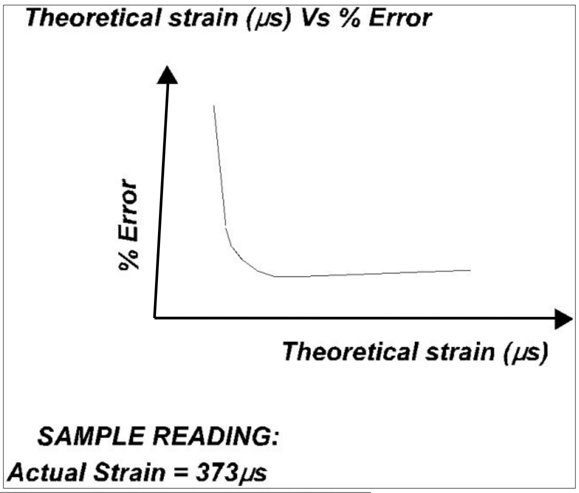
TABULATION

Theoretical strain (Strain)	**Signal conditioned sensor output voltage (V)**	**Actual strain (strain)**	**% Error**

MODEL GRAPH

1. The graph between theoretical strain and signal conditioned sensor output voltage (V)
2. The graph between theoretical strain and % Error





Theoretical strain (µs) =370 µs

% Error = 0.1

RESULT

Thus the characteristics between strain applied to the cantilever strain sensor and the signal conditioned output voltage was studied and graph was plotted.

CHARACTERISTICS OF TORQUE MEASUREMENT

EXP No :
DATE :

AIM

To study the relation between the load applied and to the final output voltage.

APPARATUS REQUIRED i.

ITB-13-CE trainer kit.

ii. Digital multimeter (V).

iii. Torque sensor setup.

iv. Weights (100gram × 10 Nos).

v. Power chord.

FORMULA TO BE USED

%Error= (Actual torque-Theoretical torque)/Theoretical torque *100

Theoritical torque = mass(m)*Acceleration due to gravity(g)*Radial distance(X)

= 1kg*9.81m/s^2* 1m

= 9.81 Nm

PROCEDURE

- Install the torque sensor setup and interface with ITB-13-CE kit.
- Switch "ON" the module.
- Connect the multimeter in volt mode across T5 and GND for sensor voltage measurement.
- First, unload the beam and nullify the display by using zero adjustment POT.
- Apply the maximum load of 1kg to the beam and adjust the display to 9.81Nm by using adjustment POT.
- By applying load the beam, torque will develop on the shaft and measure the signal conditioned sensor output voltage (V) across T5 and GND.

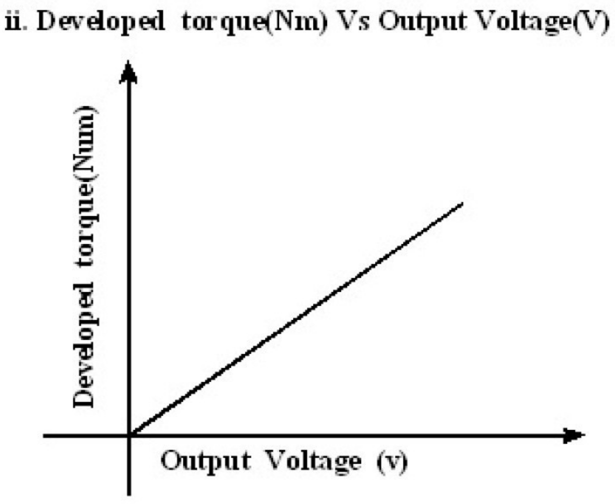
- Gradually increase the force by applying load and note down the signal conditioned sensor output voltage (V).
- Tabulate the readings and plot a graph between developed torque versus signal conditioned sensor output voltage(V).

Tabulate Column

S.No	Theoretical torque Nm	Output voltage (V)	Actual torque (Nm)	% Error

Model Graph

1. The graph between developed torque and output voltage(V).

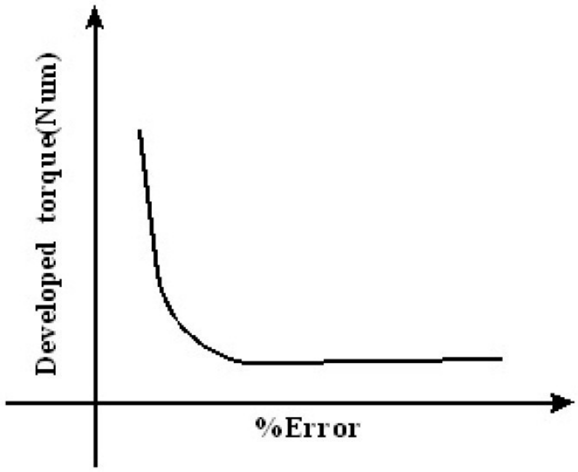


SAMPLE READING

Developed torque (Nm) = 9.81Nm

Output Voltage (V) = 5 V

ii. Developed torque(Nm) Vs Output Voltage(V)



SAMPLE READING

Developed torque (Nm) = 9.81Nm

% Error = 0.1

RESULT:

Thus the characteristics of the developed torque and the signal conditioned sensor voltage was studied and graph is plotted.

MEASUREMENT OF FLOW USING VENTURI METER

EXP No :
DATE :

AIM

To determine the co-efficient of discharge of an Venturi meter by measuring differential pressure.

REQUIREMENT

1. VFMT - 03
2. Stop watch

FORMULAE TO BE USED

THEORETICAL DISCHARGE

$$Q_{the} = \frac{a_1 \; a_o \sqrt{2gh}}{\sqrt{a_1^2 - a_0^2}} \; mm^3 / sec$$

ACTUAL DISCHARGE

$$Q_{act} = \frac{\text{Area of measuring tank} \times \text{height}}{\text{time}} \; mm^3 / sec$$

CO-EFFICIENT OF DISCHARGE

$$C_d = \frac{\text{Actual Discharge}}{\text{Theoretical Discharge}}$$

Where,
a_1=area of inlet(314.28 mm^2)
a_0=area of throat(62.09 mm^2)
g=acceleration due to gravity $9.81*10^3 mm/sec^2$
h=pressure in mm of water column
Area of measuring tank= 25457.14 mm^2

PROCEDURE

1. Switch ON the unit.
2. Set Rotameter to a particular flow(lph) using pump speed regulator knob.
3. Note down the pressure gauge G_1.
4. HV1 valve should be partially open.
5. Close HV2 and note down the time taken for a 100 mm (Δh) increase in height in the measuring tank.
6. Tabulate the readings and calculate co-efficient of discharge of Venturi meter.
7. Repeat the same procedures for different flow rate and calculate 'Cd'.
8. The mean value 'Cd' thus gives the co-efficient of discharge of the Venturi meter.

TABLE

Diameter of throat =8.89 mm

Diameter of inlet =20 mm

Diameter of Measuring Tank = 240 mm

Height (Δh) = ..100..mm

S. No	**Flow**	**Pressure gauge reading(G1)**	**Time taken**	**Theoretical Discharge**	**Actual Discharge**	**Cd**
Unit	LPH	mm of wc	sec	mm^3 / sec	mm^3 / sec	

RESULT

Thus the co-efficient of discharge of an venturi meter is determined by measuring differential pressure.

MEASUREMENT OF FLOW USING ORIFICE METER/ROTAMETER

EXP No :
DATE :

AIM

To determine the co-efficient of discharge of an Orifice Plate by measuring differential pressure.

REQUIREMENT

1. VFMT - 03
2. Stop watch

FORMULAE TO BE USED

THEORETICAL DISCHARGE

$$Q_{the} = \frac{a_1 \, a_o \sqrt{2gh}}{\sqrt{a_1^2 - a_0^2}} \ mm^3 / sec$$

ACTUAL DISCHARGE

$$Q_{act} = \frac{\text{Area of measuring tank} \times \text{height}}{\text{time}} \ mm^3 / sec$$

CO-EFFICIENT OF DISCHARGE

$$C_d = \frac{\text{Actual Discharge}}{\text{Theoretical Discharge}}$$

Where,

a_1 = Area of pipe

a_0 = Area of Orifice

= Acceleration due to gravity 9.81×10^3 mm/sec^2

= Pressure in mm of water column

PROCEDURE

1. Switch ON the unit.
2. Set Rotameter to a particular flow(lph) using pump speed regulator knob.
3. Note down the head(h) developed (in mm of Hg) in the manometer.
4. Close HV2 and note down the time taken for a 100 mm ()h) increase in height in the measuring tank.
5. Tabulate the readings and calculate co-efficient of discharge of Orifice Plate.
6. Repeat the same procedures for different flow rate and calculate ‘Cd’.
7. The mean value ‘Cd’ thus gives the co-efficient of discharge of the Orifice Plate.

TABLE

Diameter of Orifice = 8.5 mm

Diameter of Pipe = 13 mm

Diameter of Measuring Tank = 240 mm

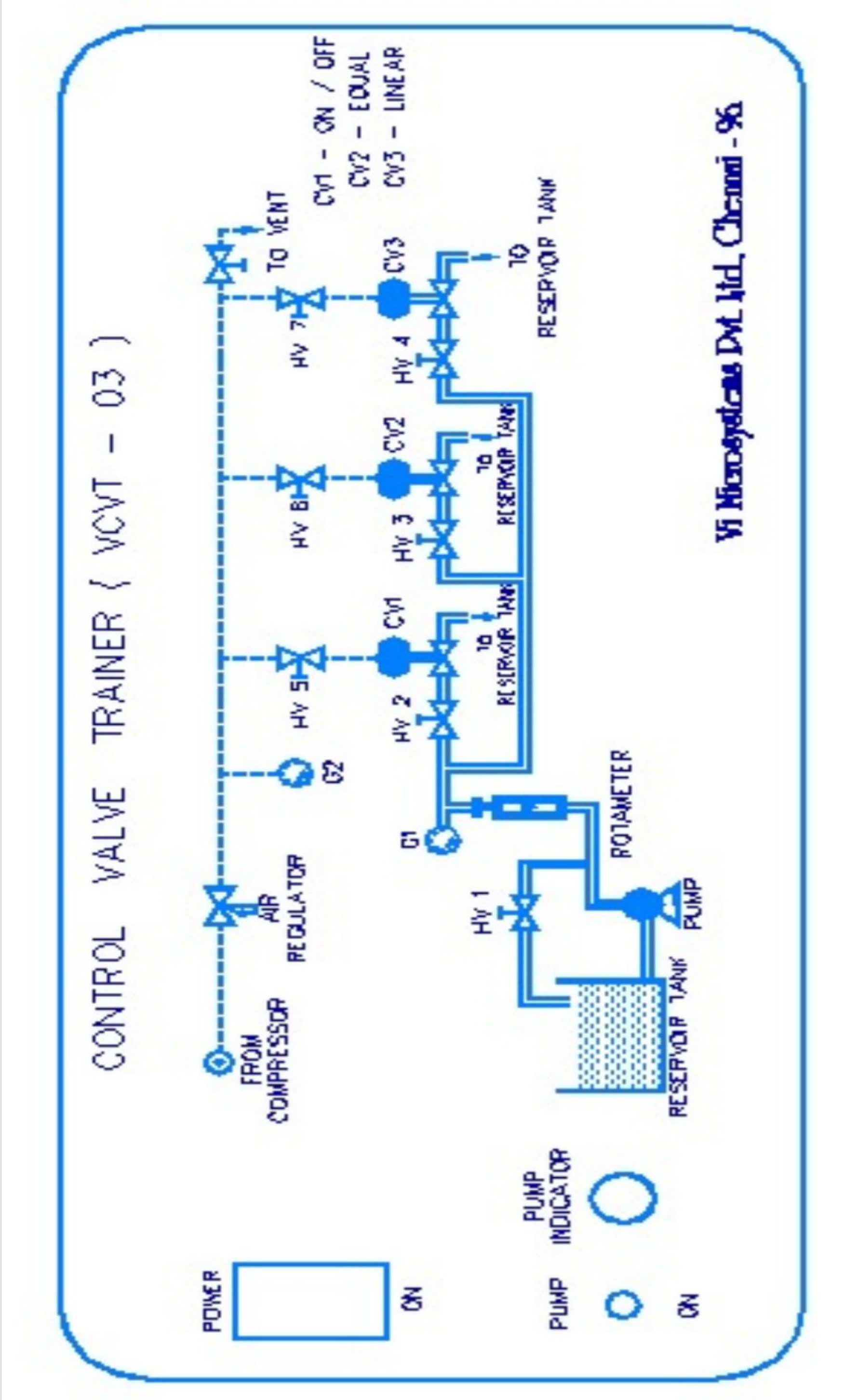
Height ()h) = ..100..mm

S. No	Flow	Head	Time taken	Theoretical Discharge	Practical Discharge	Cd
Unit	LPH	(×13.6) mm of wc	sec	mm^3 / sec	mm^3 / sec	

RESULT

Thus the co-efficient of discharge of an Orifice Plate is determined by measuring head.

FRONT PANNEL:



CHARACTERISTICS OF QUICK OPENING (ON/OFF) VALVE

EXP No :
DATE :

AIM

To study the characteristics of quick opening (ON/OFF) control valve.

APPARATUS REQUIRED

* VCVT-03A

PROCEDURE

* Before conducting the experiment, make sure that availability of water in reservoir tank. Fill clean and soft water in the reservoir.
* Connect air supply pipe to the regulator. Confirm there is no loose connection.
* Hand valve settings for ON/OFF control valve characteristics study; HV2 (the regulating valve, which is provided at the inlet of control valve) and HV5 should be fully open. Regulating valves of other control valves should be fully closed.
* Initially, set the output pressure of air regulator to 15 Psi by varying the knob. The quick opening valve is fully open.
* Keep partially open the vent valve (HV8), when air regulator lifts to its maximum range.
* Switch on the unit. Set the maximum flow in the rotameter by adjusting the bypass valve (HV1) and inlet regulating valve (HV2).
* Maintain the pressure drop across the control valve in pressure gauge (G1) (e.g. 1/1.5/2 Psi) remains constant by varying the hand valve (HV2). Note the pressure drop across the valve at fully open (G1).
* Never disturb the hand valve (HV2), once it is adjusted for particular opening.
* Observe flow and inlet pressure variations. Note down the air regulator pressure (G2), rotameter flow, and stem position in control valve.
* Decrease the pressure in air regulator to 12 Psi, at same time, pressure across the control valve slightly increases, adjust hand valve (HV1) to maintain predefined pressure in G1.
* Note the flow in rotameter and stem position in control valve, air regulator pressure.
* Slowly decrease/increase the air pressure regulator for achieving different stem positions till the valve is fully closed/open.
* Tabulate the rotameter flow, air regulator pressure and stem position.
* Plot the graph between rotameter flow in the y-axis and stem position in x-axis.

TABULATION

PRESSURE DROP ACROSS CONTROL VALVE(ΔP)=

Actuator pressure (Psi)	Stem position (%)	Rotameter flow (LPH)

*   Calculate the control valve co-efficient from the table,

CONTROL VALVE CO-EFFICIENT

The no of Us gallons of water/min that flow through a fully open valve with a Δp

Of 1psi.

$$C_v = Q\sqrt{\frac{G}{\Delta p}}$$

Where,

Q = flow rate in GPM (1 GPM=227.1247LPH) G=

specific gravity of water (=1)

Î

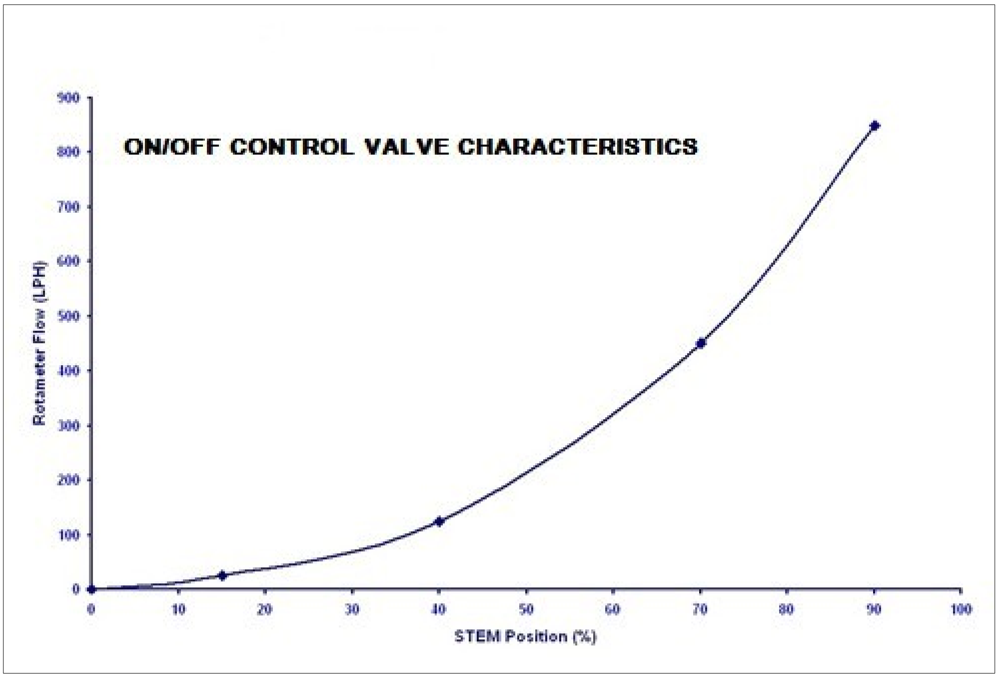
p = pressure drop across the control valve in Psi

Determine the control valve gain,

$$Gain = \frac{\text{Change in flow rate}}{\text{Change in pressure}}$$

$$\text{Hysteresis} = \frac{\text{Cv at decreasing pressure - Cv at increasing pressure}}{\text{Maximum Cv}}$$

MODEL GRAPH:



RESULT:

Thus, the characteristic of quick opening (ON/OFF) valve was studied.

CHARACTERISTICS OF EQUAL % CONTROL VALVE

EXP No :
DATE :

AIM

To study the characteristics of equal percentage control valve.

APPARATUS REQUIRED

* VCVT-03A

PROCEDURE

* Before conducting the experiment, make sure that availability of water in reservoir tank. Fill clean and soft water in the reservoir.

* Connect air supply pipe to regulator. Confirm there is no loose connection.

* Hand valve settings for equal percentage control valve characteristics study; HV3 (the regulating valve, which is provided at the inlet of control valve) and HV6 should be fully open. Regulating valves of other control valves should be fully closed.

* Initially, set the output pressure of air regulator to 15 Psi by varying the knob. The equal percentage valve is fully open.

* Keep partially open the vent valve (HV8), when air regulator lifts to its maximum range.

* Switch on the unit.

* Set the maximum flow in the rotameter by adjusting the bypass valve (HV1) and inlet regulating valve (HV3).

* Maintain the pressure drop across the control valve in pressure gauge (G1)(e.g. 1/1.5/2 Psi) remains constant varying the hand valve (HV3). Note the pressure drop across the valve at fully open (G1).

* Never disturb the hand valve (HV3), once it is adjusted for particular opening.

* Observe flow and inlet pressure variations. Note down the air regulator pressure (G2), rotameter flow, and stem position in control valve.

* Decrease the pressure in air regulator to 12 Psi, at same time, pressure across the control valve slightly increases, adjust bypass valve (HV1) to maintain predefined pressure in G1.

* Note the flow in rotameter and stem position in control valve, air regulator pressure.

* Slowly decrease/increase the air pressure regulator for achieving different stem positions till the valve is fully closed/open.

* Tabulate the rotameter flow, air regulator pressure and stem position.

* Plot the graph between rotameter flow in the y-axis and stem position in x-axis.

* Calculate the control valve co-efficient from the table,

CONTROL VALVE CO-EFFICIENT

The no of Us gallons of water/min that flow through a fully open valve with a Δp of 1psi.

$$Cv = Q \sqrt{\frac{G}{\Delta p}}$$

Where,

Q = flow rate in GPM (1 GPM=227.1247LPH) G =
Î specific gravity of water (=1)
p = pressure drop across the control valve in Psi

Determine the control valve gain,

$$Gain = \frac{\text{Change in flow rate}}{\text{Change in pressure}}$$

$$\text{Range ability} = \frac{\text{Cv (max)}}{\text{Cv(min)}}$$

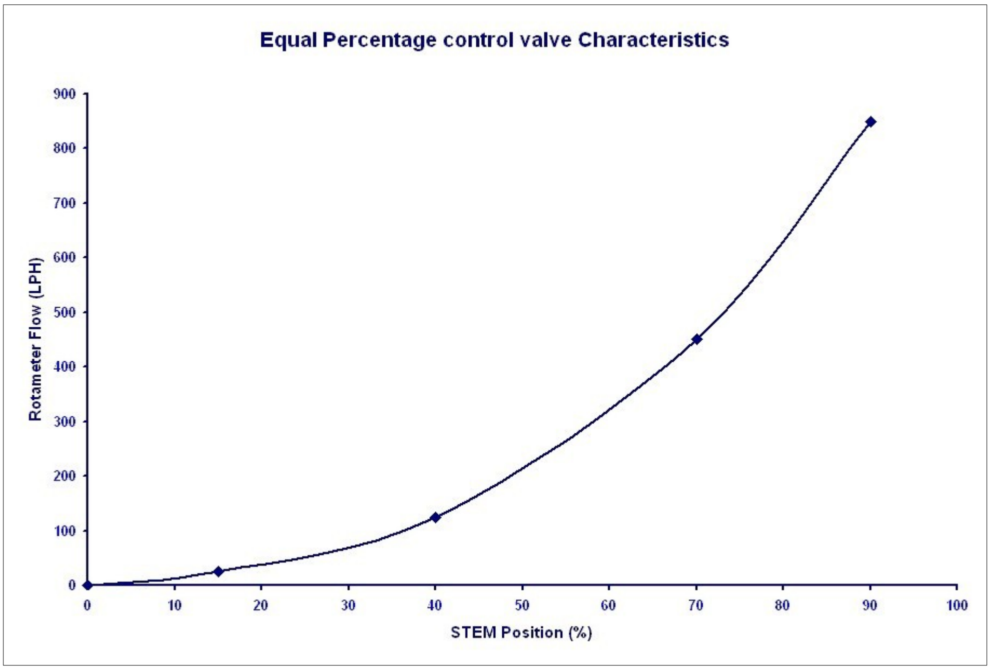
$$\text{Hysteresis} = \frac{\text{Cv at decreasing pressure - Cv at increasing pressure}}{\text{Maximum Cv}}$$

TABULATION:

Pressure drop across control VALVE (ΔP) =

Actuator pressure (Psi)	Stem position (%)	Rotameter flow (LPH)

MODEL GRAPH:



RESULT

Thus, the characteristic of equal opening valve was studied.

CHARACTERISTICS OF LINEAR CONTROL VALVE WITHOUT POSITIONER

EXP No :
DATE :

AIM

To study the characteristics of linear control valve without positioner.

APPARATUS REQUIRED

VCVT-03A

PROCEDURE

* Before conducting the experiment, make sure that availability of water in reservoir tank. Fill clean and soft water in the reservoir.
* Connect air supply pipe to regulator. Confirm there is no loose connection.
* Control valve positioner should be in “bypass” mode
* Hand valve settings for linear control valve characteristics study; HV4(the regulating valve, which is provided at the inlet of control valve) and HV7 should be fully open. Regulating valves of other control valves should be fully closed.
* Initially, set the output pressure of air regulator to 15 Psi by varying the knob. The linear valve is fully open.
* Keep partially open the vent valve (HV8), when air regulator lifts to its maximum range.
* Switch on the unit.
* Set the maximum flow in the rotameter by adjusting the bypass valve (HV1) and inlet regulating valve (HV4).
* Maintain the pressure drop across the control valve in pressure gauge (G1)(e.g. 1/1.5/2 Psi) remains constant varying the bypass valve (HV4). Note the pressure drop across the valve at fully open (G1).
* Never disturb the hand valve (HV4), once it is adjusted for particular opening.
* Observe flow and inlet pressure variations. Note down the air regulator pressure (G2), rotameter flow, and stem position in control valve.
* Decrease the pressure in air regulator to 12 Psi, at same time, pressure across the control valve slightly increases, adjust bypass valve (HV1) to maintain predefined pressure in G1.
* Note the flow in rotameter and stem position in control valve, air regulator pressure.

* Slowly decrease/increase the air pressure regulator for achieving different stem positions till the valve is fully closed/open.

* Tabulate the rotameter flow, air regulator pressure and stem position.

* Plot the graph between rotameter flow in the y-axis and stem position in x-axis.

TABULATION:

Pressure drop across control VALVE(ΔP)=

Actuator pressure (Psi)	Stem position (%)	Rotameter flow (LPH)

CONTROL VALVE CO-EFFICIENT

The no of Us gallons of water/min that flow through a fully open valve with a Δp of 1psi.

$$Cv = Q\sqrt{\frac{G}{\Delta p}}$$

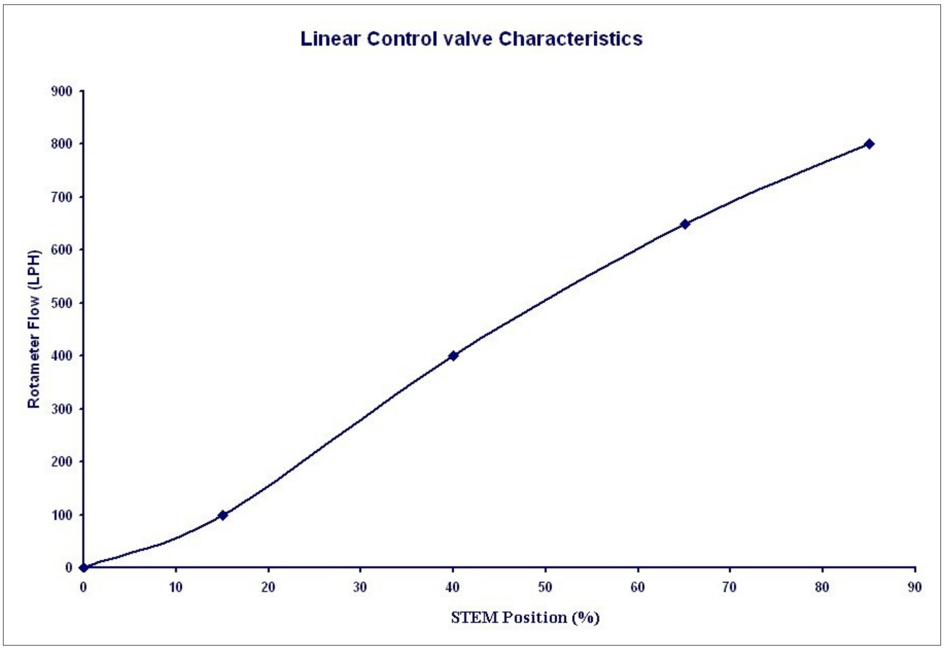
Where,

Q= flow rate in GPM (1 GPM=227.1247LPH) G=specific
gî ravity of water (=1)
p=pressure drop across the control valve in Psi

Determine the control valve gain,

$$Gain = \frac{\text{Change in flow rate}}{\text{Change in pressure}}$$

MODEL GRAPH



RESULT

Thus, the characteristic of linear valve without positioner was studied.

CHARACTERISTICS OF LINEAR CONTROL VALVE WITH POSITIONER:

EXP No :
DATE :

AIM

To study the characteristics of linear control valve with positioner.

APPARATUS REQUIRED

VCVT-03A

PROCEDURE

- Before conducting the experiment, make sure that availability of water in reservoir tank. Fill clean and soft water in the reservoir.
- Connect air supply pipe to regulator. Confirm there is no loose connection.
- Initially, set the output pressure of air regulator(G3) to 20 Psi by varying the knob..
- Control valve positioner should be in "auto" mode
- Hand valve settings for linear control valve characteristics study; HV4(the regulating valve, which is provided at the inlet of control valve) and HV7 should be fully open. Regulating valves of other control valves should be fully closed.
- Set the output pressure of air pressure to 15 Psi by varying the knob. The linear valve is fully open.
- Keep partially open the vent valve (HV8), when air regulator lifts to its maximum range.
- Switch on the unit.
- Set the maximum flow in the rotameter by adjusting the bypass valve (HV1) and inlet regulating valve (HV4).
- Maintain the pressure drop across the control valve in pressure gauge (G1)(e.g. 1/1.5/2 Psi) remains constant varying the hand valve (HV4). Note the pressure drop across the valve at fully open (G1).
- Never disturb the hand valve (HV4), once it is adjusted for particular opening.
- Observe flow and inlet pressure variations. Note down the air regulator pressure (G2), rotameter flow, and stem position in control valve.
- Decrease the pressure in air regulator to 12 Psi, at same time, pressure across the control valve slightly increases, adjust bypass valve (HV1) to maintain predefined pressure in G1.
- Note the flow in rotameter and stem position in control valve, air regulator pressure.
- Slowly decrease/increase the air pressure regulator for achieving different stem positions till the valve is fully closed/open.

- Tabulate the rotameter flow, air regulator pressure and stem position.

- Plot the graph between rotameter flow in the y-axis and stem position in x-axis.

TABULATION:

Pressure drop across control VALVE(ΔP)=

Actuator pressure (Psi)	Stem position (%)	Rotameter flow (LPH)

* Calculate the control valve co-efficient from the table,

CONTROL VALVE CO-EFFICIENT

The no of Us gallons of water/min that flow through a fully open valve with a Δp of 1psi.

$$Cv = Q\sqrt{\frac{G}{\Delta p}}$$

Where,

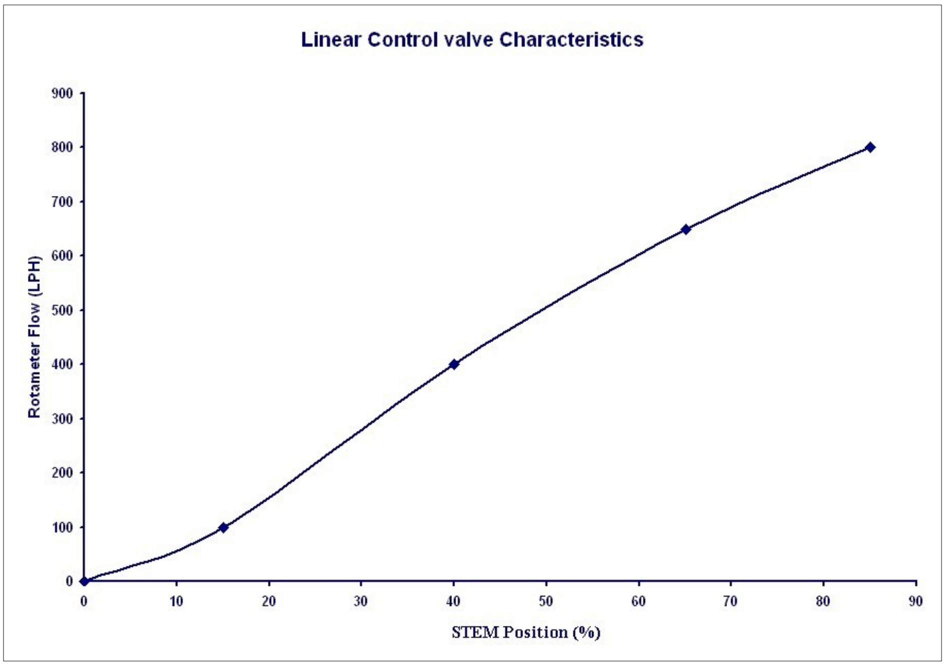
Q = flow rate in GPM (1 GPM=227.1247LPH) G =
Î specific gravity of water (=1)
p = pressure drop across the control valve in Psi

Determine the control valve gain,

$$Gain = \frac{\text{Change in flow rate}}{\text{Change in pressure}}$$

$$\text{Hysteresis} = \frac{\text{Cv at decreasing pressure - Cv at increasing pressure}}{\text{Maximum Cv}}$$

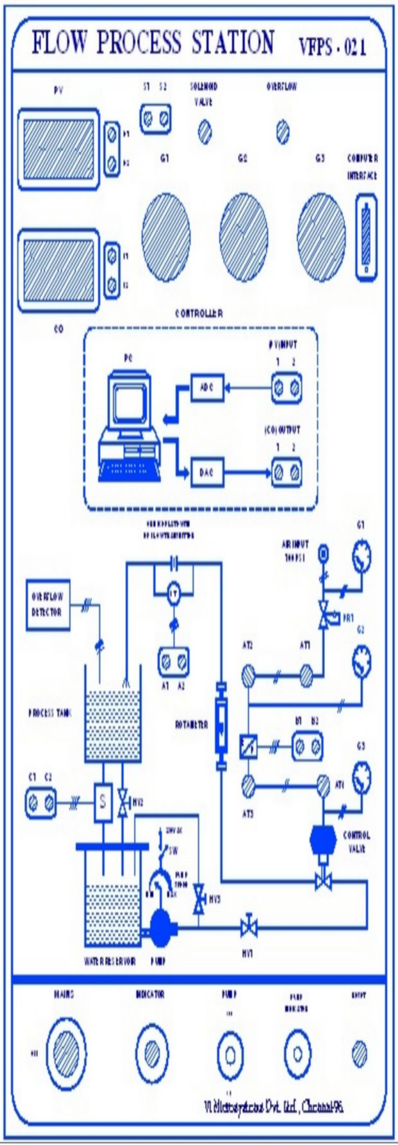
MODEL GRAPH



RESULT:

Thus, the characteristics of linear valve with positioner valve was studied

FRONT PANEL DIAGRAM:



FLOW PROCESS STATION
CHARACTERISTICS AND CONTROL ACTION OF ON/OFF

EXP No :
DATE :

AIM

To study the characteristics and a control action of ON/OFF on the Flow Process Station.

APPARATUS REQUIRED

i. VFPS-021 unit

ii. PC

iii. Data Acquisition Card (VAD-104) with software

iv. Patch Chords

v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator input should be more than 25 psi and maintain the air regulator output pressure (G2) to 20 psi by varying the air regulator knob.
4. Switch ON the VFPS-021 and Data Acquisition Card (VAD-104).
5. Position the Hand valve (HV1) fully open and (HV2) fully opened & (HV3) in the mid position.
6. Invoke " process control" software in PC and select 'Process station >> Flow".
7. Select "Control >> ON-OFF".
8. Select "settings >> parameters" and enter values for each parameters (i.e SP-500 Dead Band-20 & Delay).
9. Select "File >> Start"
10. Before switch ON the pump, check the control valve opening. Check whether the controller output is 100%.
11. For getting a desired response, tune the process parameter to optimum values.
12. Now, study the response of ON-OFF control action for various values of set point, Dead band.

1. Stop the process (Click "File>>stop").

14. Save the file in desired file name(Click “File>>Save”).

15. Open the existing file(Click “File >>Load”). Observe the response of the process in graphical format.

16. If you want to view the report or printout select

    “File>>Load>>option>>report”.
    “File>>Load>>option>>print”.

RESULT

Thus the characteristics and control action of ON/OFF on the Flow Process Station was studied.

FLOW PROCESS STATION
PROPORTIONAL CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL CONTROL" for Flow process station using process control software.

APPARATUS REQUIRED

i. VFPS-021

ii. PC

ii. Data Acquisition Card (VAD-104) with software

iii. Patch Chords

iv. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator input should be more than 25 psi and maintain the air regulator output pressure (G2) to 20 psi by varying the air regulator knob.
4. Switch ON the VFPS-021 and Data Acquisition Card (VAD-104).
5. Position the Hand valve (HV1) fully open and (HV2) fully open & (HV3) in the mid position.
6. Invoke “ Process control” software in PC and select “Process station >> Flow
7. Select “control >> proportional”.
8. Select “settings >> parameters” and enter values for each parameters (i.e Sp, Kp & Delay).
9. Select “File >> Start”.
10. Before switch ON the pump, check the control valve is opening.
11. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the proportional band without any oscillation.

12. Now, study the response of P control action for various values of set point, Kp.

13. Stop the process(Click “File>>stop”).

14. Save the file in desired file name(Click “File>>Save”).

15. Open the existing file(Click “File >>Load”). Observe the response of the process in graphical format.

16. If you want to view the report or printout select

    “File>>Load>>option>>report”.
    “File>>Load>>option>>print”.

RESULT

Thus the characteristics and control action of proportional control on the Flow Process Station was studied.

FLOW PROCESS STATION
PROPORTIONAL PLUS INTEGRAL CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL PLUS INTEGRAL CONTROL" for a Flow process using Process control software.

APPARATUS REQUIRED

i. VFPS-021 unit

ii. PC

iii. Data Acquisition Card (VAD-104) with software

iv. Patch Chords

v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator input should be more than 25 psi and maintain the air regulator output pressure (G2) to 20 psi by varying the air regulator knob.
4. Switch ON the VFPS-021 and Data Acquisition Card (VAD-104).
5. Position the Hand valve (HV1) fully open and (HV2) fully open & (HV3) in the mid position.
6. Invoke “Process control” software in PC and select “Flow”.
7. Select “control >> "Proportional Plus Integral Control”.
8. Select “settings >> parameters” and enter values for each parameters (i.e Sp, Kp, Ki & Delay).
9. Select “File >> Start”.
10. Before switch ON the pump, Check the control valve opening check whether the controller output is 100%.
11. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the

proportional band without any oscillation. To change the proportional gain (Kp) and Tune the integral gain (Ki) to maintain the process variable at set point

12. Now, study the response of PI control action for various values of set point, Kp, Ki

13. Stop the process(Click “File>>stop”).

14. Save the file in desired file name(Click “File>>Save”).

15. Open the existing file(Click “File >>Load”). Observe the response of the process in graphical format.

16. If you want to view the report or printout select

    “File>>Load>>option>>report”.
    “File>>Load>>option>>print”.

RESULT

Thus the characteristics and control action of PI on the Flow Process Station was studied.

FLOW PROCESS STATION
PROPORTIONAL PLUS DRIVATIVE CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL PLUS DERIVATIVE CONTROL" for a Flow process using Process Control Software.

APPARATUS REQUIRED

- i. VFPS-021 unit
- ii. PC
- iii. Data Acquisition Card (VAD-104) with software
- iv. Patch Chords
- v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig.2 shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator input should be more than 25 psi and maintain the air regulator output pressure (G2) to 20 psi by varying the air regulator knob.
4. Switch ON the VFPS-021 and Data Acquisition Card (VAD-104) unit.
5. . Position the Hand valve (HV1) fully open and (HV2) fully open & (HV3) in the mid position.
6. Invoke " Process control" software in PC and select " Process station >> Flow".
7. Select "Control >> Proportional Plus Derivative Control".
8. Select "settings >> parameters" and enter values for each parameters (i.e Sp, Kp, Kd, & Delay)
9. Select "File >> Start"
10. Before switch ON the pump, check whether the controller output is 100%.

11. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the proportional band without any oscillation. To change the proportional gain (Kp) and Tune the derivative gain (Kd) to maintain the process variable at set point.

12. Now, study the response of PD control action for various values of set point, Kp & Kd.

13. Stop the process (Click “File>>stop”).

14. Save the file in desired file name (Click “File>>Save”).

15. Open the existing file(Click “File >>Load”). Observe the response of the process in graphical format.

16. If you want to view the report or printout select

“File>>Load>>option>>report”.
“File>>Load>>option>>print”.

RESULT

Thus the characteristics and control action of PD on the Flow Process Station was studied.

FLOW PROCESS STATION
PROPORTIONAL PLUS INTEGRAL PLUS DERIVATIVE CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL PLUS INTEGRAL PLUS DERIVATIVE CONTROL" for a Flow process using Process Control Software.

APPARATUS REQUIRED

i. VFPS-021 unit
ii. PC
iii. Data Acquisition Card (VAD-104) with software
iv. Patch Chords
v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator input should be more than 25 psi and maintain the air regulator output pressure (G2) to 20 psi by varying the air regulator knob.
4. Switch ON the VFPS-021 and Data Acquisition Card (VAD-104).
5. Position the Hand valve (HV1) fully open and (HV2) fully open & (HV3) in the mid position.
6. Invoke “Process control” software in PC and select “Process station >> Flow”
7. Select “control >> Proportional Plus Integral Plus Derivative Control”.
8. Select “settings >> parameters” and enter values for each parameters (i.e Kp, Ki, Kd & Delay)
9. Select “File >> Start”.
10. Before switch ON the pump, Check the control valve opening.

11. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the proportional band without any oscillation. To change the proportional gain (Kp) and Tune the integral gain (Ki) and derivative gain (Kd) to maintain the process variable at set point

12. Now, study the response of PID control action for various values of set point, Kp, Ki, & Kd.

13. Stop the process(Click “File>>stop”).

14. Save the file in desired file name(Click “File>>Save”).

15. Open the existing file(Click “File >>Load”). Observe the response of the process in graphical format.

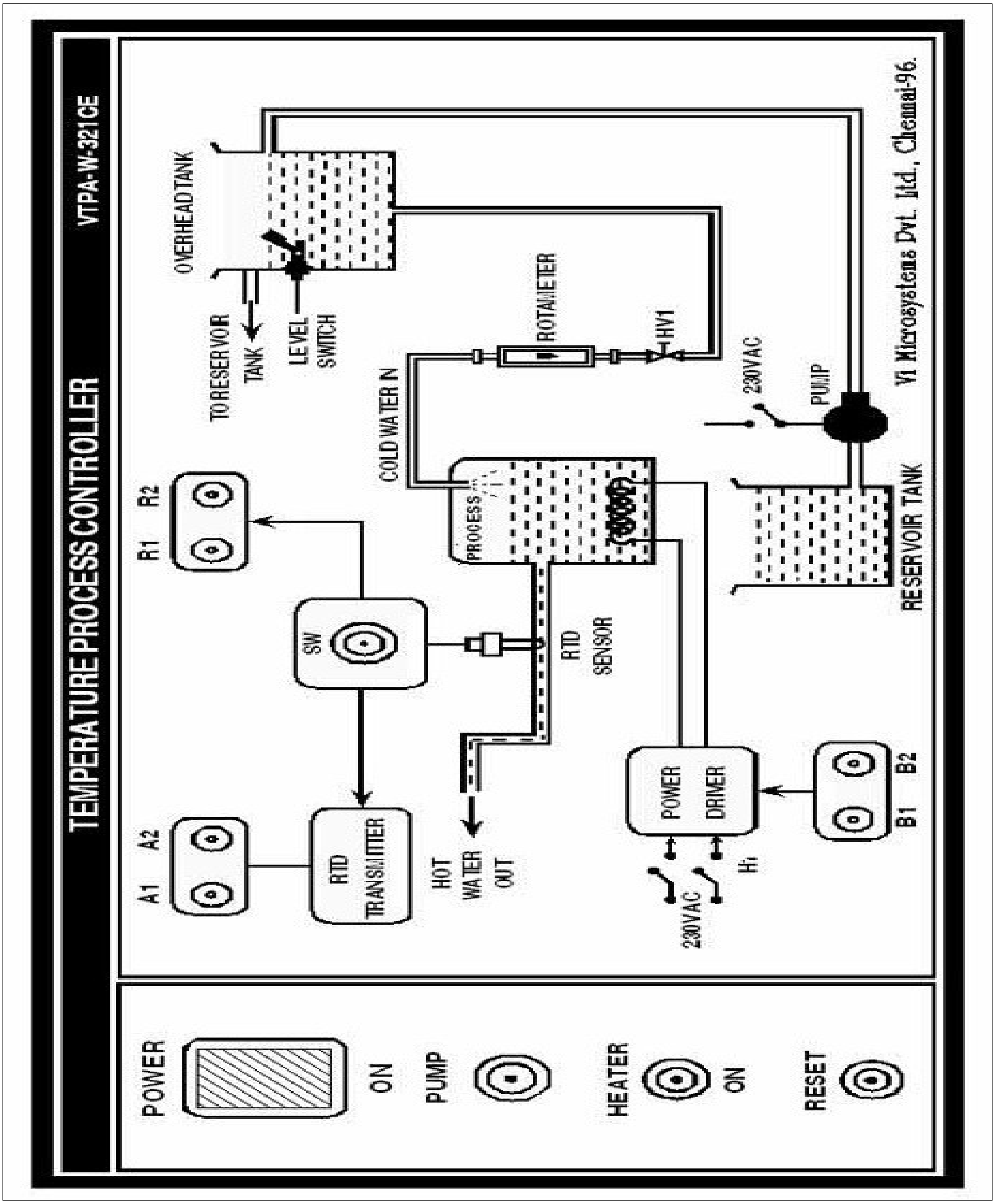
16. If you want to view the report or printout select

    “File>>Load>>option>>report”.
    “File>>Load>>option>>print”.

RESULT

Thus the characteristics and control action of PID on the Flow Process Station was studied.

FRONT PANNEL:



RESISTANCE-TEMPERATURE CHARACTERISTICS OF RTD

EXP No :
DATE :

AIM

To study the resistance-temperature characteristics of RTD.

APPARATUS REQUIRED

1. VTPA-W-321CE.
2. Data Acquisition card with cable
3. Multimeter (in resistance mode).
4. PC with Process control software.
5. Patch chords.

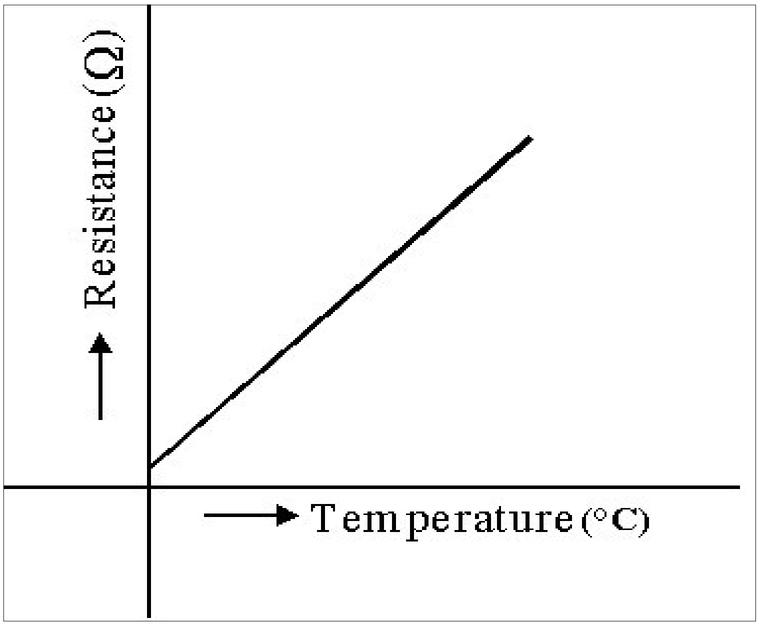
PROCEDURE

1. Ensure the availability of water.
2. Interface the PC with the Unit and Data Acquisition card.
3. Connect the pump plug and Heater plug to the respective sockets provided at the back panel
4. Connect the sensor terminals and level switch terminals to the respective connectors provided at the back panel.
5. Keep the switch ‘S2' in the right position (towards 2).
6. Connect the multimeter in resistance mode to the R1-R2 terminals.
7. Patch A1-A2 & B1-B2 using patch chords.
8. Switch on the unit.
9. Switch on the Pump.
10. Set the rotameter at some minimum flow rate (say 40Lph) by adjusting hand valve.
11. Switch on the heater.
12. Note down the resistance for different temperatures and tabulate.
13. Plot the graph between temp Vs Resistance.
14. Switch OFF the heater and pump.

TABULATION

Sl. No.	Temperature (°C)	Resistance (Ω)

MODEL GRAPH



RESULT

Thus the characteristic of the RTD was studied.

TEMPERATURE PROCESS
PERFORMANCE OF ON/OFF/P/PI/PD/PID CONTROLLERS

EXP No :
DATE :

AIM

To study the performance of ON-OFF/P/PI/PD/PID controllers on temperature process.

APPARATUS REQUIRED

1. VTPA-W-321CE.
2. Data Acquisition card with cable
3. PC with Process control software.
4. Patch chords.

PROCEDURE

1. Ensure the availability of water.
2. Interface the PC with the Unit and Data Acquisition card.
3. Connect the pump plug and Heater plug to the respective sockets provided at the back panel
4. Connect the sensor terminals and level switch terminals to the respective connectors provided at the back panel.
5. Keep the switch ‘S2' in left position (towards 1)
6. Patch R1-R2, A1-A2, B1-B2, using patch chords.
7. Switch on the unit with PC and Data Acquisition card.
8. Switch on the pump.
9. Set rotameter at some minimum flow rate (say 40Lph).
10. Select “Temperature << control << ON/OFF/P/PI/PD/PID”.
11. Switch ON the heater.

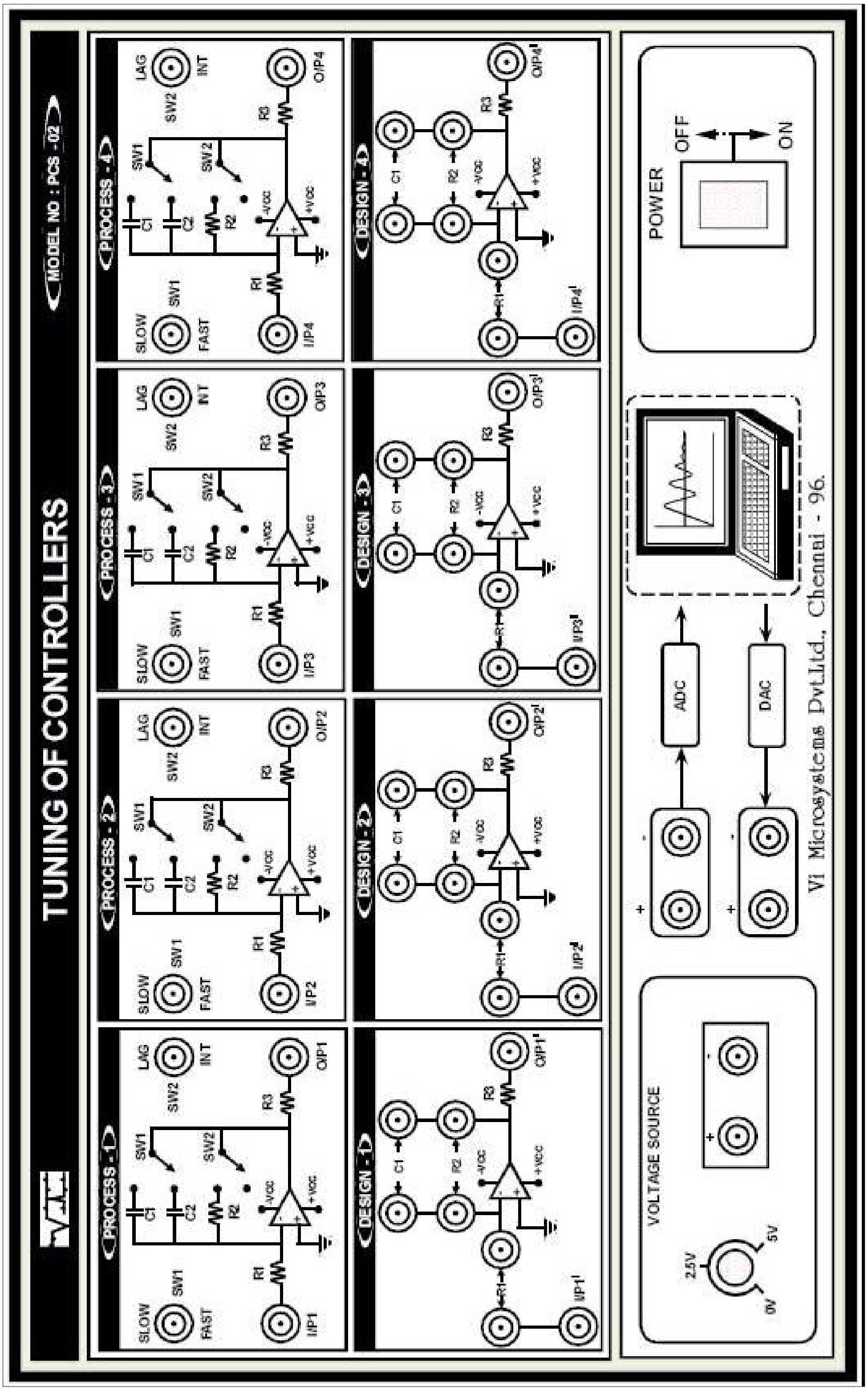
12. Enter desired parameters and observe the response by saving the graph.

13. Switch OFF the heater and pump.

RESULT

Thus the performance of ON-OFF/P/PI/PD/PID controllers on temperature process was studied.

FRONT PANEL DIAGRAM:



TUNING OF CONTROLLER BY PROCESS REACTION CURVE METHOD

EXP No :
DATE :

AIM

The objective of this experiment is to analyze the plant dynamic response using process reaction curve method.

APPARATUS REQUIRED

* Tuning of controllers (PCS-02) Unit.
* Data Acquisition Card (VAD -104).
* Process control software
* Patch chords.
* IBM - PC.

PROCEDURE

* Connections are made as per the circuit diagram.
* Switch ON the main unit and VAD-104 Cards power supply.
* Involve the ***"Tuning of controller"*** software.
* Select control 5 Manual mode 5
* Software displays CP value in the text box & enter the step input value in the range of 0 - 100%.
* Now, input and output are displayed in graphical form on the screen.
* Save the curJrent file, load theJ file & using two point methods to determine, the delay (dead) time $_d$, time constant ( ) of the process.

* Substitue the calculate $_d$ J value into the ZN proposal
* Find out the K_P, K_I, K_D value are entered into the text box.
* Start the simulation process and see the response of an appropriate controller

CALCULATION:

Step Input(ΔU):
Steady state output (ΔY_{ss}):
Find the gain (K) value by using the formula: ($\Delta Y_{ss}/\Delta U$)
From the ΔY_{ss} value find,

0.632 ΔY_{ss} :
0.283 ΔY_{ss} :

From the graph note down the t1 and t2 values and find τ and τ_d value by using the following formula.

i. The $\tau = 3/2\ (t2-t1)$
ii. The $\tau_d = (t2-\tau)$

Set point value

Tabulate the value by using calculation

TABULATION

CONTROLLER	GAIN (K_C)	INTEGRAL TIME (T_I)	DERIVATIVE TIME (T_D)
P		-	-
PI			-
PID			

RESULT

Thus, the dynamic response of the plant was analysed, using process reaction curve method.

CONTINUOUS OSCILLATION METHOD

EXP No :
DATE :

AIM:

The objective of this experiment is to investigate the dynamic response of the plant using continuous oscillation method.

APPARATUS REQUIRED

i. Tuning of controllers Unit (PCC2)

ii. Date Acquisition card (VAD104)

iii. Process control software

iv. Patch Cards

v. I B M P C

PROCEDURE

* Connections are made as per the circuit diagram.
* Switch ON the main unit and VAD-104 Cards power supply.
* Involve the ***"tuning of controller"*** software.
* Select control 5 proportional control 5
* Enter the K_P value form minimum to K_{cu}. At one particular value of K_{cu} output waveform attains the sustained oscillation.
* Now, input and output are displayed in graphical form on the screen.
* Save the current file, load the file & using continues oscillation method to determine, the K_{cu} and T_u value.
* Substitute the calculate K_{cu} and T_u values into the ZN proposal.
* Find the values of K_P, K_I, K_D and enter into the text box.
* Start the simulation process and see the response of an appropriate controller.

Calculations:

K_{cu} =

T_u =

Tabulation:

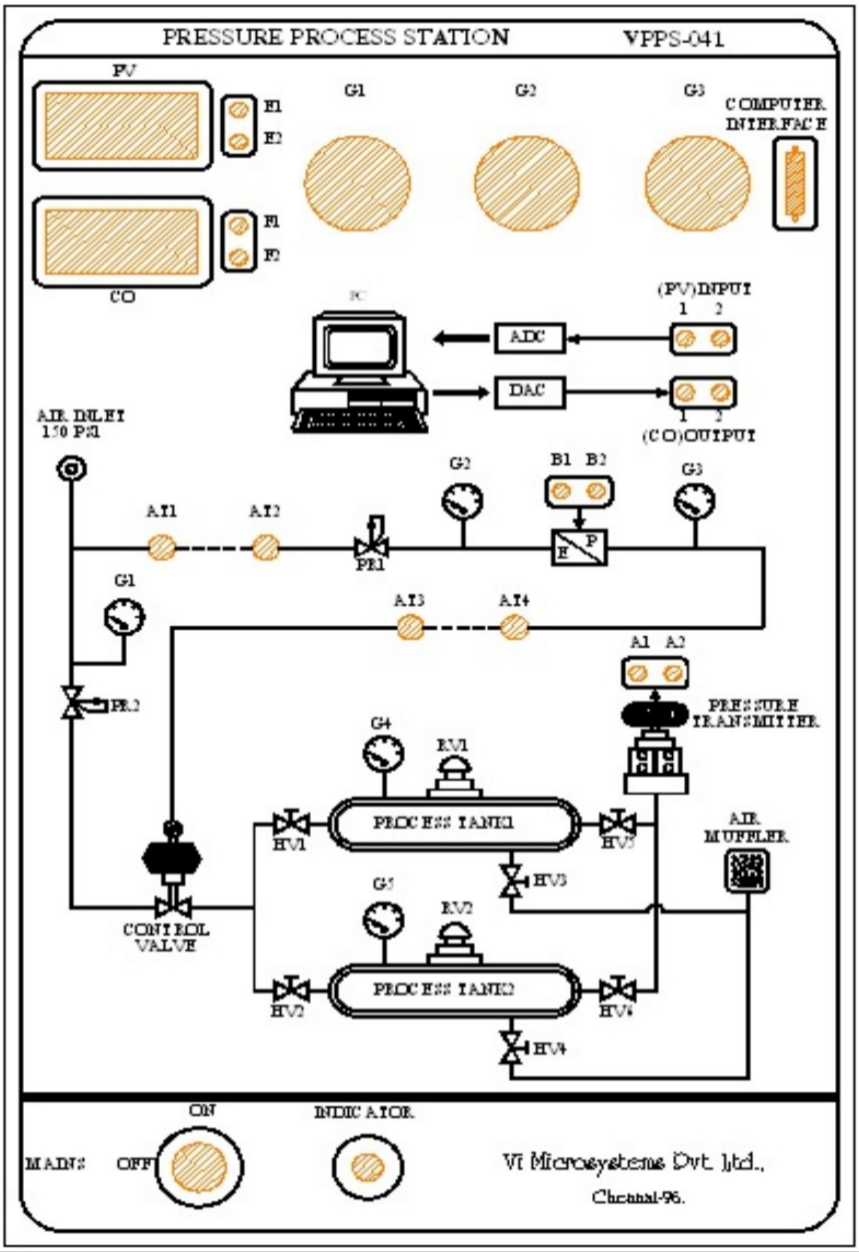
SL. NO	SET POINT	K_{cu}	T_u

CONTROLLER	GAIN (K_C)	INTEGRAL TIME (T_I)	DERIVATIVE TIME (T_D)
P		-	-
PI			-
PID			

RESULT

Thus, the time dynamic response of plant was investigated using continuous oscillation method.

FRONT PANNEL DIAGRAM:



PRESSURE PROCESS STATION
ON/OFF

EXP No :
DATE :

AIM

To study the characteristics and a control action of ON/OFF on the Pressure Process Station.

APPARATUS REQUIRED

i. VPPS-041 unit
ii. PC
iii. Data Acquisition Card (VAD-104) with software
iv. Patch Chords
v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig 2 shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator (1) input should be more than 25 psi and maintain the air regulator (1) output pressure (G2) to 20 psi by varying the air regulator knob.
4. Air pressure regulator (2) input should be more than 100psi and maintain the air regulator (2) output pressure 100psi by vary the air regulator knob.
5. Switch ON the VPPS-041 and Data Acquisition Card (VAD-104).
6. Position the Hand valve (HV1, HV5) fully open, (HV3) in the mid position.
7. Invoke " process control" software in PC and select 'Process station >> Pressure".
8. Select "Control >> ON-OFF".
9. Select "settings >> parameters" and enter values for each parameters (i.e SP-35 Dead Band-20, Delay).
10. Select "File >> Start"
11. Check the control valve opening. Check whether the controller output is 100%,
12. For getting a desired response, tune the process parameter to optimum values.
13. Now, study the response of ON-OFF control action for various values of set point, Dead band.
14. Stop the process(Click "File>>stop").

15. Save the file in desired file name(Click “File>>Save”).

16. Open the existing file(Click “File >>Load”). Observe the response of the process in graphical format.

17. If you want to view the report or printout select

    “File>>Load>>option>>report”.
    “File>>Load>>option>>print”.

RESULT

Thus the characteristics and control action of ON/OFF on the Pressure Process Station was studied.

PRESSURE PROCESS
PROPORTIONAL CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL CONTROL" for a Pressure process using Process Control Software.

APPARATUS REQUIRED

i. VPPS-041
ii. PC
iii .Data Acquisition Card (VAD-104) with software
iv. Patch Chords
v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig 2 shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator (1) input should be more than 25 psi and maintain the air regulator (1) output pressure (G2) to 20 psi by varying the air regulator knob.
4. Air pressure regulator (2) input should be more than 100psi and maintain the air regulator (2) output pressure 100psi by vary the air regulator knob.
5. Switch ON the VPPS-041 and Data Acquisition Card (VAD-104).
6. Position the Hand valve (HV1, HV2, HV5, HV6) fully open & (HV3, HV4) in the mid position.
7. Invoke “Process control” software in PC and select “Process station >> Pressure”
8. Select “control >> Proportional Control”.
9. Select “settings >> parameters” and enter values for each parameters (i.e Kp Delay).
10. Select “File >> Start”.
11. Check the control valve opening.
12. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the proportional band without any oscillation. To change the proportional gain (Kp) to maintain the process variable at set point

13. Now, study the response of P control action for various values of set point, Kp.

14. Stop the process (Click “File>>stop”).

15. Save the file in desired file name (Click “File>>Save”).

16. Open the existing file(Click “File >>Load”). Observe the response of the process in graphical format.

17. If you want to view the report or printout select

“File>>Load>>option>>report”.
“File>>Load>>option>>print”

RESULT

Thus the characteristics and control action of Proportional control on the Pressure Process Station was studied.

PRESSURE PROCESS
PROPORTIONAL PLUS INTEGRAL CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL PLUS INTEGRAL CONTROL" for a Pressure process using Process Control Software.

APPARATUS REQUIRED

i. VPPS-041
ii. PC
iii. Data Acquisition Card (VAD-104) with software
iv. Patch Chords
v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig 2 shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator (1) input should be more than 25 psi and maintain the air regulator (1) output pressure (G2) to 20 psi by varying the air regulator knob.
4. Air pressure regulator (2) input should be more than 100psi and maintain the air regulator (2) output pressure 100psi by vary the air regulator knob.
5. Switch ON the VPPS-041 and Data Acquisition Card (VAD-104).
6. Position the Hand valve (HV1, HV2, HV5, HV6) fully open & (HV3, HV4) in the mid position.
7. Invoke "Process control" software in PC and select "Process station >> Pressure"
8. Select "control >> Proportional Plus Integral Control".
9. Select "settings >> parameters" and enter values for each parameters (i.e Kp, Ki Delay).
10. Select "File >> Start".
11. Check the control valve opening.

12. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the proportional band without any oscillation. To change the proportional gain (Kp) and Tune the integral gain (Ki) to maintain the process variable at set point

13. Now, study the response of PI control action for various values of set point, Kp, Ki.

14. Stop the process (Click “File>>stop”).

15. Save the file in desired file name (Click “File>>Save”).

16. Open the existing file (Click “File >>Load”). Observe the response of the process in graphical format.

17. If you want to view the report or printout select

    “File>>Load>>option>>report”.
    “File>>Load>>option>>print”.

RESULT

Thus the characteristics and control action of PI on the Pressure Process Station was studied.

PRESSURE PROCESS
PROPORTIONAL PLUS DERIVATIVE CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL PLUS DERIVATIVE CONTROL" for a Pressure process using Process Control Software.

APPARATUS REQUIRED

i. VPPS-041
ii. PC
iii. Data Acquisition Card (VAD-104) with software
iv. Patch Chords
v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig 2 shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator (1) input should be more than 25 psi and maintain the air regulator (1) output pressure (G2) to 20 psi by varying the air regulator knob.
4. Air pressure regulator (2) input should be more than 100psi and maintain the air regulator (2) output pressure 100psi by vary the air regulator knob.
5. Switch ON the VPPS-041 and Data Acquisition Card (VAD-104).
6. Position the Hand valve (HV1, HV2, HV5, HV6) fully open & (HV3, HV4) in the mid position.
7. Invoke “Process control” software in PC and select “Process station >> Pressure”
8. Select “control >> Proportional Plus Integral Plus Derivative Control”.
9. Select “settings >> parameters” and enter values for each parameters (i.e Kp, Kd Delay).
10. Select “File >> Start”.
11. Check the control valve opening.

12. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the proportional band without any oscillation. To change the proportional gain (Kp) and derivative gain (Kd) to maintain the process variable at set point

13. Now, study the response of PD control action for various values of set point, Kp, Kd.

14. Stop the process(Click “File>>stop”).

15. Save the file in desired file name(Click “File>>Save”).

16. Open the existing file(Click “File >>Load”). Observe the response of the process in graphical format.

17. If you want to view the report or printout select

    “File>>Load>>option>>report”.
    “File>>Load>>option>>print”.

RESULT

Thus the characteristics and control action of PD on the Pressure Process Station was studied.

PRESSURE PROCESS
PROPORTIONAL PLUS INTEGRAL PLUS DERIVATIVE CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL PLUS INTEGRAL PLUS DERIVATIVE CONTROL" for a Pressure process using Process Control Software.

APPARATUS REQUIRED

i. VPPS-041
ii. PC
iii. Data Acquisition Card (VAD-104) with software
iv. Patch Chords
v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig 2 shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator (1) input should be more than 25 psi and maintain the air regulator (1) output pressure (G2) to 20 psi by varying the air regulator knob.
4. Air pressure regulator (2) input should be more than 100psi and maintain the air regulator (2) output pressure 100psi by vary the air regulator knob.
5. Switch ON the VPPS-041 and Data Acquisition Card (VAD-104).
6. Position the Hand valve (HV1, HV2, HV5, HV6) fully open & (HV3, HV4) in the mid position.
7. Invoke “Process control” software in PC and select “Process station >> Pressure”
8. Select “control >> Proportional Plus Integral Plus Derivative Control”.
9. Select “settings >> parameters” and enter values for each parameters (i.e Kp, Ki, Kd, Delay).
10. Select “File >> Start”.
11. Check the control valve opening.
12. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the Proportional band without any oscillation. To change the proportional gain (Kp) and Tune the integral gain (Ki) and derivative gain (Kd) to maintain the process variable at set point

13. Now, study the response of PID control action for various values of set point, Kp, Ki, Kd.

14. Stop the process(Click “File>>stop”).

15. Save the file in desired file name(Click “File>>Save”).

16. Open the existing file(Click “File >>Load”). Observe the response of the process in graphical format.

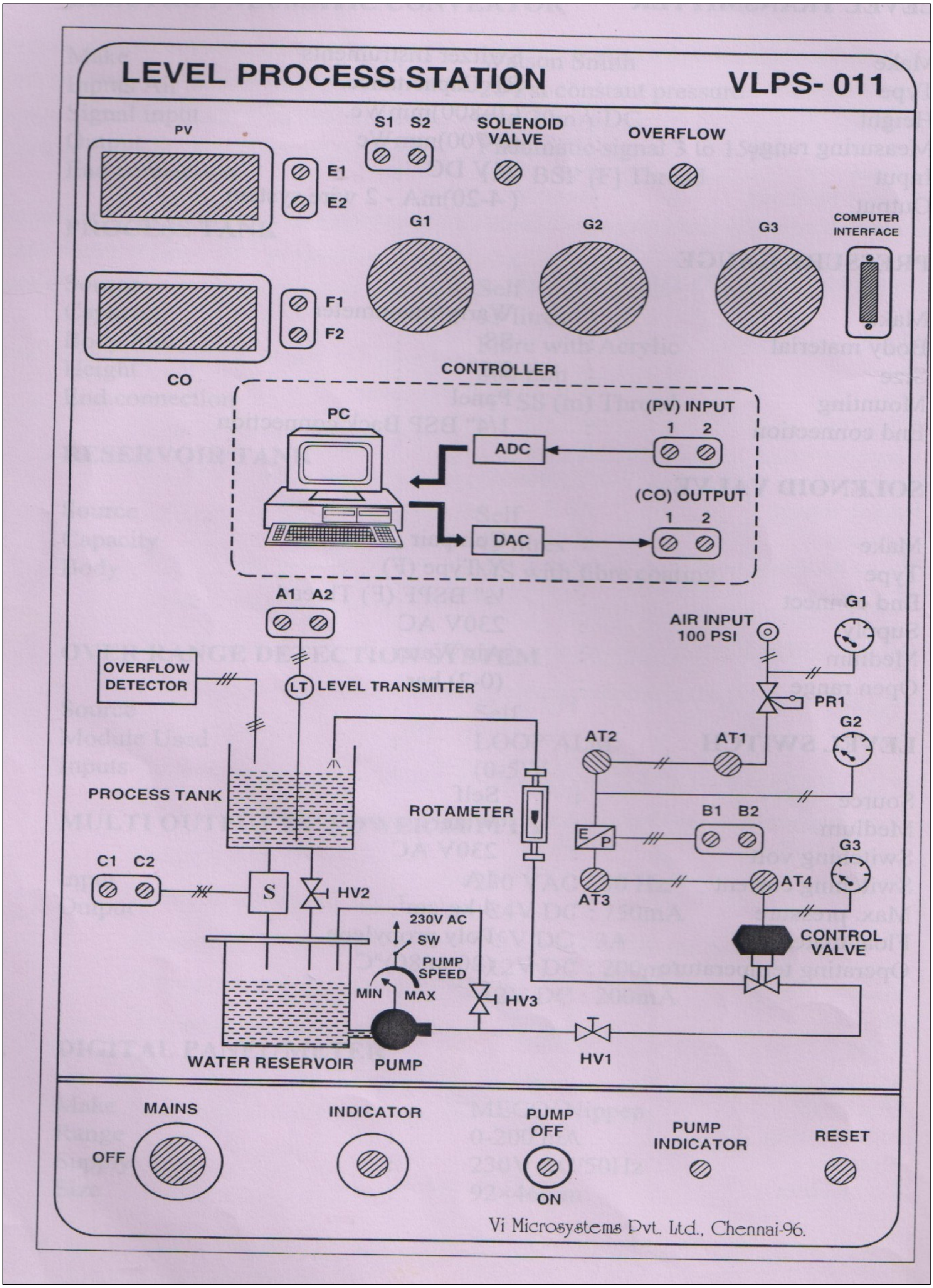
17. If you want to view the report or printout select

“File>>Load>>option>>report”.
“File>>Load>>option>>print”.

RESULT

Thus the characteristics and control action of PID on the Pressure Process Station was studied.

FRONT PANEL:


LEVEL PROCESS STATION
VLPS- 011
PV
E1
E2
S1 S2
SOLENOID VALVE
OVERFLOW
G1
G2
G3
COMPUTER INTERFACE
F1
F2
CO
CONTROLLER
PC
(PV) INPUT
1 2
ADC
(CO) OUTPUT
1 2
DAC
A1 A2
AIR INPUT 100 PSI
G1
OVERFLOW DETECTOR
LT
LEVEL TRANSMITTER
PR1
G2
AT2
AT1
PROCESS TANK
ROTAMETER
B1 B2
E
P
G3
C1 C2
S
HV2
AT3
AT4
230V AC
SW
PUMP SPEED
MIN
MAX
CONTROL VALVE
HV3
WATER RESERVOIR
PUMP
HV1
MAINS
OFF
INDICATOR
PUMP OFF
ON
PUMP INDICATOR
RESET
Vi Microsystems Pvt. Ltd., Chennai-96.

LEVEL PROCESS STATION
ON/OFF

EXP No :
DATE :

AIM

To study the characteristics and a control action of ON/OFF on the Level Process Station.

APPARATUS REQUIRED

i. VLPS-011

ii. PC

iii. Data Acquisition Card (VAD-104) with software

iv. Patch Chords

v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig 2 shown.

2. Interfacing connection should be given as per a fig.1 shown.

3. Air Pressure regulator input should be more than 25 psi and maintain the air regulator output pressure (G2) to 20 psi by varying the air regulator knob.

4. Switch ON the VLPS-011 and Data Acquisition Card (VAD-104).

5. Position the Hand valve (HV1) fully open and (HV2) & (HV3) in the mid position.

6. Invoke " process control" software in PC and select 'Process station >> Level".

7. Select "Control >> ON-OFF".

8. Select "settings >> parameters" and enter values for each parameters (i.e SP-35 Dead Band-20).

9. Select "File >> Start"

10. Before switch ON the pump, check the control valve opening. Check whether the controller output is 100%, before you switch on the pump.

11. Switch ON the pump.

12. For getting a desired response, tune the process parameter to optimum values.

13. Now, study the response of ON-OFF control action for various values of set point, Dead band.

RESULT

Thus the characteristics and control action of ON/OFF on the Level Process Station was studied.

LEVEL PROCESS
PROPORTIONAL CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL CONTROL" for a Level Process using process Control software.

APPARATUS REQUIRED

i. VLPS-011
ii. PC
iii. Data Acquisition Card (VAD-104) with software
iv. Patch Chords
v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator input should be more than 25 psi and maintain the air regulator output pressure (G2) to 20 psi by varying the air regulator knob.
4. Switch ON the VLPS-011 and Data Acquisition Card (VAD-104).
5. Position the Hand valve (HV1) fully open and (HV2) & (HV3) in the mid position.
6. Invoke " Process control" software in PC and select "Process station >> Level".
7. Select "control >> proportional".
8. Select "settings >> parameters" and enter values for each parameters (i.e Sp, Kp).
9. Select "File >> Start".
10. Before switch ON the pump, check the control valve opening in before you switch on the pump.
11. Switch ON the pump.
12. For getting a desired response, tune the process parameter to optimum values.Tune the proportional gain to maintain the process variable within the proportional band without any oscillation.
13. Now, study the response of P control action for various values of set point, Kp.

RESULT

Thus the characteristics and control action of proportional control on the Level Process Station was studied.

LEVEL PROCESS
PROPORTIONAL PLUS INTEGRAL CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL PLUS INTEGRAL CONTROL" for a Level process using Process control software.

APPARATUS REQUIRED

i. VLPS-011
ii. PC
iii. Data Acquisition Card (VAD-104) with software
iv. Patch Chords
v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig 2 shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator input should be more than 25 psi and maintain the air regulator output pressure (G2) to 20 psi by varying the air regulator knob.
4. Switch ON the VLPS-011 and Data Acquisition Card (VAD-104).
5. Position the Hand valve (HV1) fully open and (HV2) & (HV3) in the mid position.
6. Invoke “Process control” software in PC and select “Level”.
7. Select “control >> "Proportional Plus Integral Control”.
8. Select “settings >> parameters” and enter values for each parameters (i.e Sp, Kp, Ki)
9. Select “File >> Start”.
10. Before switch ON the pump, Check the control valve opening check whether the controller output is 100%, before you switch on the pump.
11. Switch ON the pump.

12. For getting a desired response, tune the process parameter to optimum values.Tune the proportional gain to maintain the process variable within the proportional band without any oscillation. To change the proportional gain (Kp) and Tune the integral gain (Ki) to maintain the process variable at set point

13. Now, study the response of PI control action for various values of set point, Kp, Ki.

RESULT

Thus the characteristics and control action of PI on the Level Process Station was studied.

LEVEL PROCESS
PROPORTIONAL PLUS DERIVATIVE CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL PLUS DERIVATIVE CONTROL" for a Level process using Process Control Software.

APPARATUS REQUIRED

i. VLPS-011
ii. PC
iii. Data Acquisition Card (VAD-104) with software
iv. Patch Chords
v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig.2 shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator input should be more than 25 psi and maintain the air regulator output pressure (G2) to 20 psi by varying the air regulator knob.
4. Switch ON the VLPS-011 and Data Acquisition Card (VAD-104) unit.
5. . Position the Hand valve (HV1) fully open and (HV2) & (HV3) in the mid position.
6. Invoke “Process control” software in PC and select “Process station” >> Level.
7. Select “control >> Proportional Plus Derivative Control”.
8. Select “settings >> parameters” and enter values for each parameters (i.e Sp, Kp, Kd)
9. Select “File >> Start”
10. Before switch ON the pump, check whether the controller output is 100%.
11. Switch ON the pump.

12. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the band w i t h o u t any oscillation. To change the proportional gain (Kp) and Tune the derivative gain (Kd) to maintain the process variable at set point.

13. Now, study the response of PD control action for various values of set point, Kp, Kd.

RESULT

Thus the characteristics and control action of PD on the Level Process Station was studied.

LEVEL PROCESS
PROPORTIONAL PLUS INTEGRAL PLUS DERIVATIVE CONTROL

EXP No :
DATE :

AIM

To study the action of "PROPORTIONAL PLUS INTEGRAL PLUS DERIVATIVE CONTROL" for a Level process using Process Control Software.

APPARATUS REQUIRED

i. VLPS-011
ii. PC
iii. Data Acquisition Card (VAD-104) with software
iv. Patch Chords
v. Loop cable

PROCEDURE

1. Electrical and Pneumatic connections should be given as per fig 2 shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Air Pressure regulator input should be more than 25 psi and maintain the air regulator output pressure (G2) to 20 psi by varying the air regulator knob.
4. Switch ON the VLPS-011 and Data Acquisition Card (VAD-104).
5. Position the Hand valve (HV1) fully open and (HV2) & (HV3) in the mid position.
6. Invoke "Process control" software in PC and select "Process station >> Level"
7. Select "control >> Proportional Plus Integral Plus Derivative Control".
8. Select "settings >> parameters" and enter values for each parameters (i.e Kp, Ki,Kd)
9. Select "File >> Start"

10. Before switch ON the pump, Check the control valve opening.

11. Switch ON the pump.

12. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the proportional band without any oscillation. To change the proportional gain (Kp) and Tune the integral gain (Ki) and derivative gain (Kd) to maintain the process variable at set point

13. Now, study the response of PID control action for various values of set point, Kp, Ki, Kd.

RESULT

Thus the characteristics and control action of PID on the Level Process Station was studied.