ANNA UNIVERSITY-CHENNAI

MADRAS INSTITUTE OF TECHNOLOGY

CHROMPET, CHENNAI – 600 044

DEPARTMENT OF PRODUCTION TECHNOLOGY

MR7211-AUTOMATION LABORATORY

NAME	
REG NO	
YEAR	
SEMESTER	
BRANCH	**ME MECHATRONICS**
DATE OF END SEM EXAMINATION	

BONAFIDE CERTIFICATE

NAME :

REGISTER NO. :

SUBJECT : **MR7211-AUTOMATION LABORATORY**

DEPARTMENT :

Certified to be bonafide record of practical work done by

Mr./Miss. .... **in the**

AUTOMATION LABORATORY during the period .... **2016.**

Date: **Staff-In-Charge**

Submitted for the practical examination held on …………….

LIST OF EXPERIMENTS

COMPUTER AIDED INSPECTION

CNC AND WATER JET MACHINING

ROBOT MODELING AND PROGRAMMING

COMPUTER AIDED INSPECTION

STUDY AND EXPERIMENTATION OF TOOL MAKER'S MICROSCOPE

AIM:

To study and experiment on a tool maker's microscope.

APPARATUS USED:

Tool maker's microscope, specimen.

INTRODUCTION:

The tool maker's microscope is a versatile instrument that measures by optical means with no pressure being involved, thus very useful for measurement on small and delicate parts. It is designed for:

a) Measurement on parts of complex form e.g. - profile of external thread, tool, templates, gauges, etc.

b) Measuring centre to centre distance of holes in any plane.

c) A variety of linear measurements.

d) Accurate angular measurements.

Fig.1. Tool makers microscope

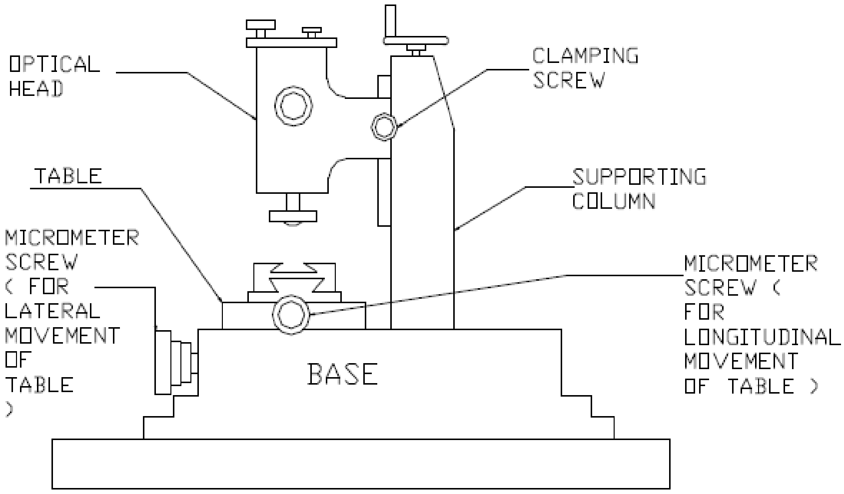


Fig.2. Tool makers microscope

Tool maker's microscope is shown in fig.1&2. The optical head can be moved up or down the vertical column and can be clamped at any height by means of clamping screw. The table which is mounted on the base of the instrument can be moved in two mutually perpendicular horizontal directions (longitudinal and lateral) by means of accurate micrometer screw having thimble scale and verniers.

PRINCIPLE OF MEASUREMENT:

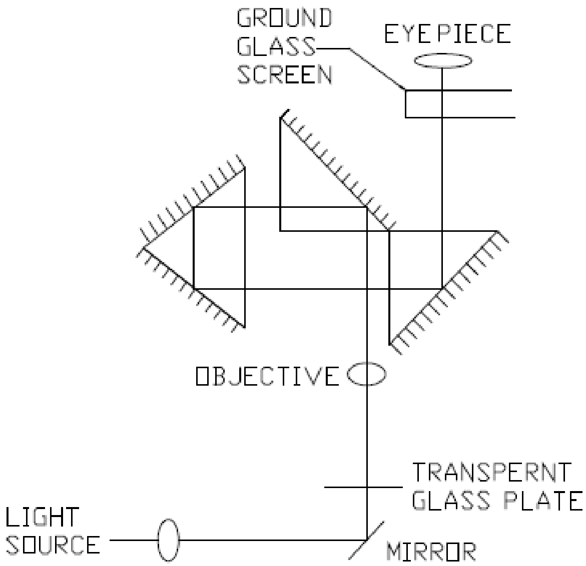


Fig.3. Principle of measurement

A ray of light from a light source is reflected by a mirror through 90'. It then passes through a transparent glass plate (on which flat parts may be placed). A shadow image of the outline or counter of the workspaces passes through the objective of the optical head and is projected by a system of three prisms to a ground glass screen. Observations are made through an eyepiece. Measurements are made by means of cross lines engraved on the ground glass screen. The screen can be rotated through 360', the angle of rotation is read through an auxiliary eyepiece.

PROCEDURE:

A) Pitch Measurement:

1. Take the hacksaw blade and mount on the moving blade of tool maker's Microscope in horizontal position.
2. Focus the microscope on the blade.
3. Make the cross line in the microscope coincided with one of the edge of the blade.
4. Take a reading on ground glass screen, this is the initial reading.
5. The table is again moved until the next edge of the blade coincides with the cross-line on the screen and the final reading takes.
6. The difference between initial and final reading gives pitch of the blade.

B) Teeth Angle:

1. Place the blade on the table in same position.
2. Rotate the screen until a line on the angle of screen rotation is noted.
3. Take the angular reading, the initial one.
4. Again rotate the screen until the same line coincides with the other flank of the tooth.
5. Take the final angular reading.
6. The teeth angle of blade in the difference between the two angular readings.

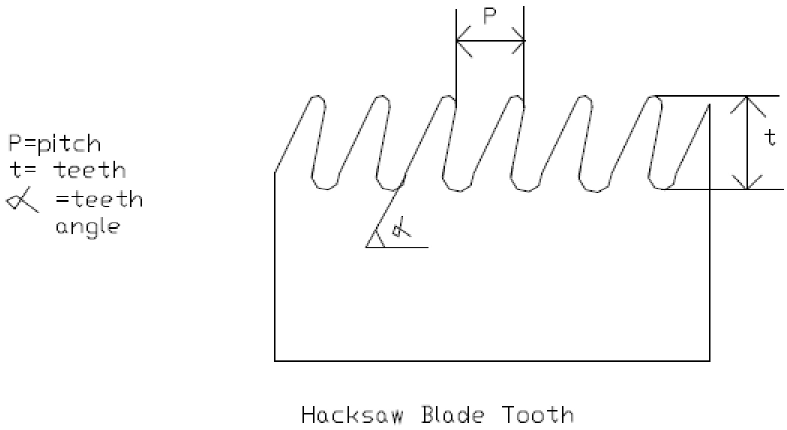


Fig.4. Hacksaw blade tooth

RESULT:

Thus the tool maker's microscope was studied and experimented.

MEASUREMENT USING CMM
(COORDINATE MEASURING MACHINE)

AIM:

To study the construction and operation of co-ordinate measuring machine and to measure the specified dimensions of the given component.

INSTRUMENTS USED:

Coordinate measuring machine, Vernier calipers.

THEORY:

A coordinate measuring machine (CMM) is a 3D device for measuring the physical geometrical characteristics of an object. This machine may be manually controlled by an operator or it may be computer controlled. Measurements are defined by a probe attached to the third moving axis of this machine, X, Y and Z. A coordinate measuring machine (CMM) is also a device used in manufacturing and assembly processes to test a part or assembly against the design intent. By precisely recording the X, Y, and Z coordinates of the target, points are generated which can then be analyzed via regression algorithms for the construction of features. These points are collected by using a probe that is positioned manually by an operator or automatically via Direct Computer Control (DCC). DCC CMMs can be programmed to repeatedly measure identical parts, thus a CMM is a specialized form of industrial robot.

PARTS:

Coordinate-measuring machines include three main components:

1. The main structures which include three axes of motion.
2. Probing system.
3. Data collection and reduction system - typically includes a machine controller, desktop computer and application software.

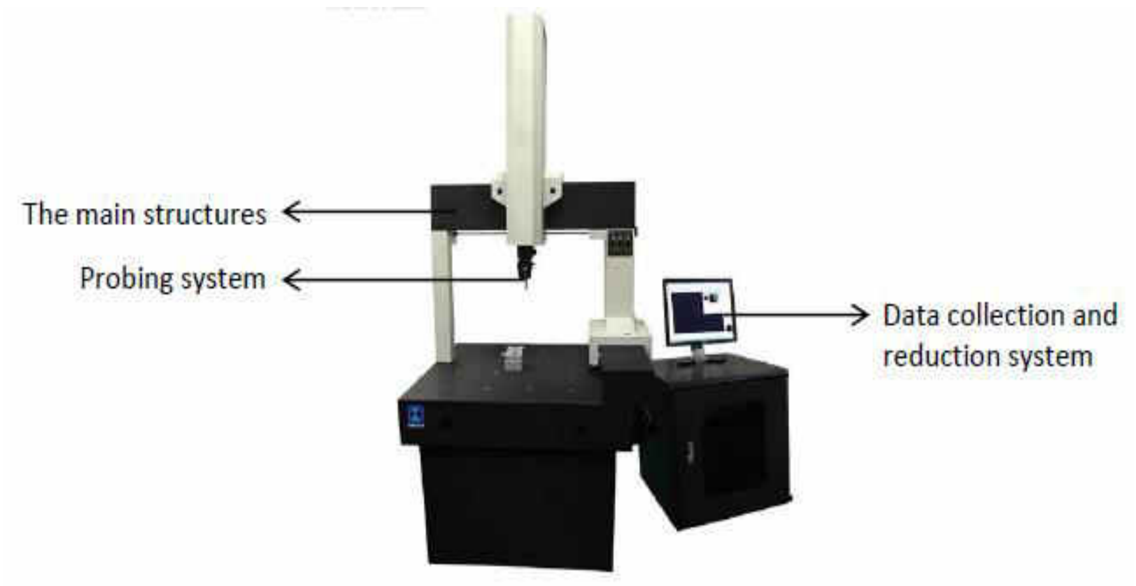


Fig.1.Coordinate Measuring Machine

MACHINE DESCRIPTION:

- In modern machines, the gantry type superstructure has two legs and is often called a bridge. This moves freely along the granite table with one leg following a guide rail attached to one side of the granite table. The opposite leg simply rests on the granite table following the vertical surface contour.
- Air bearings are the chosen method for ensuring friction free travel. Compressed air is forced through a series of very small holes in a flat bearing surface to provide a smooth but controlled air cushion on which the CMM can move in a frictionless manner.
- The movement of the bridge along the granite table forms one axis of the XY plane. The bridge of the gantry contains a carriage which traverses between the inside and outside legs and forms the other X or Y horizontal axis.
- The third axis of movement (Z axis) is provided by the addition of a vertical quill or spindle which moves up and down through the center of the carriage. The touch probe forms the sensing device on the end of the quill.
- The movement of the X, Y and Z axes fully describes the measuring envelope. Some touch probes are themselves powered rotary devices with the probe tip able to swivel vertically through 90 degrees and through a full 360 degree rotation.

MECHANICAL PROBE:

In the early days of coordinate measurement mechanical probes were fitted into a special holder on the end of the quill. A very common probe was made by soldering a hard ball to the end of a shaft. This was ideal for measuring a whole range of flat, cylindrical or spherical surfaces. These probes were physically held against the workpiece with the position in space being read from a 3-Axis digital readout (DRO) or in more advanced systems, being logged into a computer by means of a footswitch or similar device. Measurements taken by this contact method were often unreliable as machines were moved by hand and each machine operator applied different amounts of pressure on the probe or adopted differing techniques for the measurement. Operators no longer had to physically touch the machine but could drive each axis using a hand box with joysticks. Measurement accuracy and precision improved dramatically with the invention of the electronic touch trigger probe. Although still a contact device, the probe had a spring-loaded steel ball (later ruby ball) stylus. As the probe touched the surface of the component the stylus deflected and simultaneously sent the X,Y,Z coordinate information to the computer. Measurement errors caused by individual operators became fewer and the stage was set for the introduction of CNC operations and the coming of age of CMMs.

USES:

They are generally used for:

- Angularity or orientation measurement
- Dimensional measurement
- Profile measurement
- Depth mapping
- Digitizing or imaging
- Shaft measurement

PROCEDURE:

1) Calibration of machine is done using a sphere ball attached to the granite table. Take at least 8 point on sphere.
2) Fix the object whose dimension needs to be measured using the jigs and fixtures.
3) Using joystick, move the probe whose tip is made of ruby slowly and carefully to the surface whose measurements have to be taken.
4) For measurement of a line, the probe is touched at 2 places (starting and ending point).
5) For measuring circular profile, probe is touched at 3 points, for cylinder it is touched at 8 points.
6) Same profiles are again measured with Vernier calipers (length of line, circle diameter, Cylinder diameter) to compare the two readings.

ADVANTAGES:

- High precision and accuracy.

- Accurate dimensions can be obtained by knowing the coordinates and distance between the two reference points.
- Robustness against external force and error accumulation.

DISADVANTAGES:

- The Coordinate measuring machines are very costly and less portable.
- If the operating software cracks down it is difficult to restart the entire system.
- It needs to construct some feature on its own as some parts of the workpiece are unreachable by the probe.

RESULT:

Thus the dimensions of a given component were measured and it was found that the coordinate measuring machine gives much more accurate value.

MEASUREMENT OF SURFACE ROUGHNESS

AIM:

To obtain the value of roughness of a specimen by the center line average (CLA) or roughness average (Ra) method by using a Computerized Roughness Measuring Machine and to compare the value of roughness of a specimen by the Center Line Average (CLA) and average roughness (Ra) method and to study the causes of different value of roughness of a specimen between CLA and Ra method and to study the necessary precaution needed for this experiment.

SPECIMEN AND EQUIPMENT USED:

a) Specimen - piston cylinder

b) A computerized surface roughness machine

c) Ruler

d) Digital Planimeter

INTRODUCTION:

Roughness is something that we calculate from the texture of the specimen and the entire thing in this world have the roughness but in different value of roughness. The surface for specimen are not always been smooth even the mirror have the roughness. The roughness can be quantified by the deviation, more high the deviation more roughs the surface. Roughness also is important in determining the surface of specimen reaction with the environment. The specimen that has more interaction with the environment has more roughness surface than the smooth surface that has a low reaction with the environment.

THEORY:

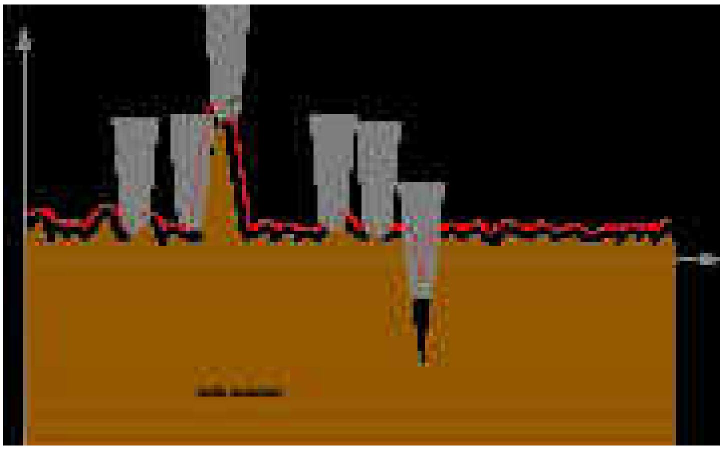


Fig.1. Roughness Identification

A surface never be smooth even the mirror, and still have the two components that is roughness and waviness. ISO and CLA are the methods that use to measure the surface finish. During experiment several sampling of length can be taken and the average result will give the actual value of the surface component.

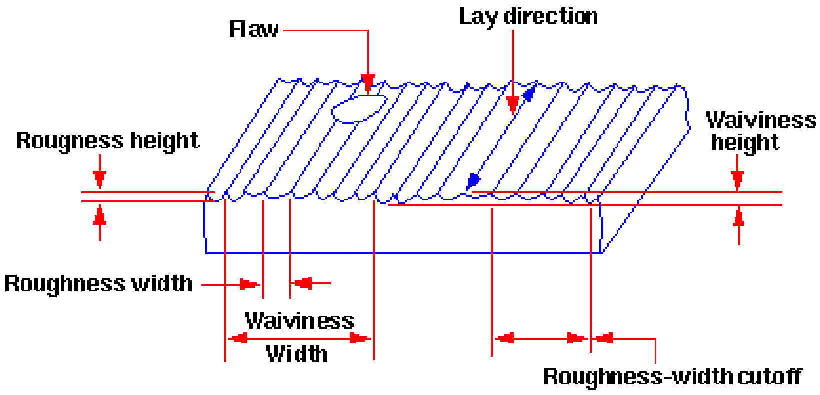
$$\boldsymbol{CLA = \sum \frac{A}{(Lx\;Mv)}}$$

where,

$\sum A$ = surface of area above and below the center

L = sample length (graph)

Mv = Vertical Magnification



Surface characteristics (Courtesy, ANSI B46.1 - 1962)

WAVINESS HEIGHT:

This refers to the irregularities which are outside the roughness width cut off values. Waviness is the widely spaced component of the surface texture. This may be the result of work piece or tool deflection during machining, vibrations or tool run out. Waviness is the measure of the more widely spaced component of surface texture. It is a broader view of roughness because it is more strictly defined as "the irregularities whose spacing is greater than the roughness sampling length". It can occur from machine or work deflections, chatter, residual stress, vibrations, or heat treatment.

ROUGHNESS WIDTH:

The roughness width is the distance parallel to the nominal surface between successive peaks or ridges which constitute the predominate pattern of the roughness. It is measured in millimeters.

ROUGHNESS HEIGHT:

It is the height of the irregularities with respect to a reference line. It is measured in millimeters or microns or microfiches. It is also known as the height of unevenness.

WAVINESS WIDTH:

Waviness height is the peak to valley distance of the surface profile, measured in millimeters.

ROUGHNESS WIDTH CUT OFF:

Roughness width cut off is the greatest spacing of respective surface irregularities to be included in the measurement of the average roughness height. It should always be greater than the roughness width in order to obtain the total roughness height rating

PROCEDURE:

Procedure on machining process:

1. A cut off wavelength of 0.8mm by 8 sections was selected on the machine. The machine was set to a vertical magnification to AUTO and horizontal magnification to 100.
2. The component on the auto leveling table was placed at a suitable position such that when pick up head is lowered, its stylus contacts the surface of the specimen.
3. The machine was set; ready to record the measurement.
4. The roughness profile graph for the specimen was obtained.

Fig.2. Computerized Surface Roughness machine

Procedure on manual process:

1. Each group had to select three peaks on the graph.
2. Two vertical lines were drawn for the three peaks.
3. The value of ‘L’ within the three peaks was found in (cm).
4. A centerline (CLA) was drawn somewhere in the middle.
5. The starting point and turning point were pointed on the graph.
6. The areas above and below the CLA was measured using the digital planimeter.
7. Three different reading were measured by three different persons in the group and the average of the reading was calculated.
8. The value of the CLA was calculated.
9. The manual result was compared with the computerized result for CLA.

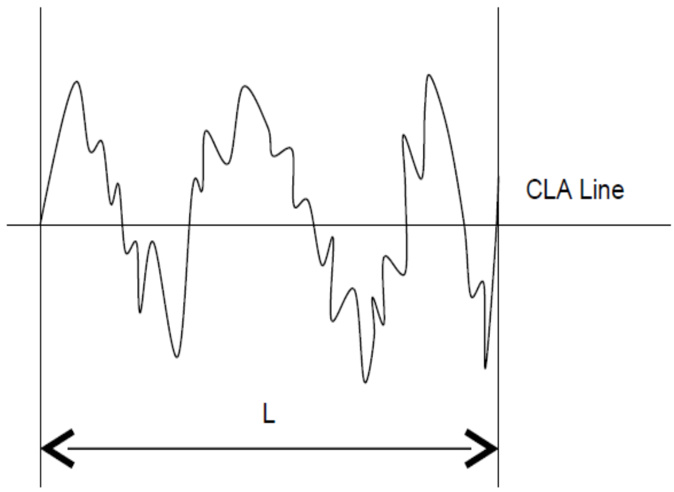


Fig.3. Roughness Profile

RESULT:

Thus the value of the roughness of a specimen by Roughness Average (R_a) method by using a computerized Roughness Measuring Machine was found and for the manual calculation, we calculate the Center Line Average (CLA) from the reading of the Digital Planimeter.

CNC AND WATER JET MACHINING

PROGRAMMING FOR PROFILE MILLING OPERATION, CIRCULAR INTERPOLATION AND NC CODE GENERATION

AIM:

To generate a program for performing a profile milling operation for a given workpiece.

SOFTWARE USED:

PCNC 24

INTRODUCTION:

The term “CNC” is a generic term which can be used to describe many types of device, this would include plotters, vinyl cutters, 3D printers, milling machines and others. CNC stands for Computer Numerically Controlled and basically means that the physical movements of the machine are controlled by instructions, such as co-ordinate positions that are generated using a computer.

The term “CNC Machine” is typically used to refer to a device which uses a rotating cutting tool which moves in 3 or more axes (X, Y and Z) to cut-out or carve parts in different types of materials.

G-CODE:

G - CODE	DESCRIPTION
G00	Rapid Traverse
G01	Linear Interpolation
G02	Circular Interpolation (CW)
G03	Circular Interpolation (CCW)
G04	Dwell time
G17	X, Y Plane selection
G18	X, Z Plane selection
G19	Y, Z Plane selection
G20, G70	Units in Inches
G21, G71	Units in mm
G28	Return to home position
G40	Cutter compensation cancel
G41	Cutter compensation left
G42	Cutter compensation right
G73	Drill cycle with chip Breaks
G74	Tapping cycle LH
G76	Boring cycle with orient &rapid Retract
G80	Canned cycle cancel
G81	Drilling cycle
G82	Drilling cycle with Dwell
G83	Peck Drilling cycle
G90	Absolute coordinate s/m
G91	Incremental coordinate s/m

M- CODE (Miscellaneous/Machine Code):

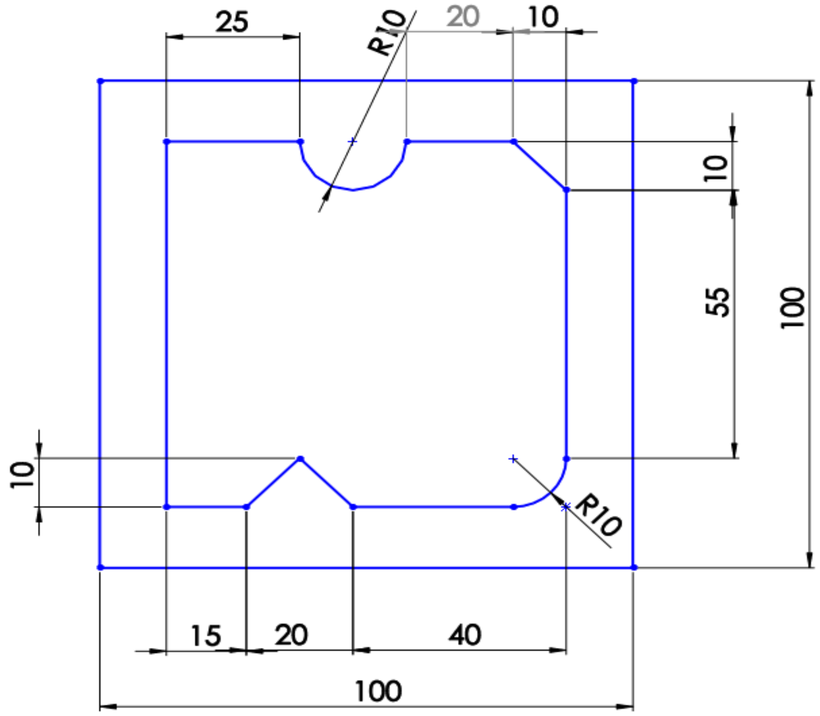
M - CODE	DESCRIPTION
M00	Unconditional Program stop
M01	Optional program stop
M02	Program end
M03	Spindle ON clockwise
M04	Spindle ON CCW
M05	Spindle ON
M06	Automatic Tool Change (ATC)
M07, M08	Coolant ON
M09	Coolant OFF
M30	Program end and reset
A	Angular co-ordinate around (Rotation on) X-axis
B	Angular co-ordinate around (Rotation on) Y-axis
C	Angular co-ordinate around (Rotation on) Z-axis
F	Feed rate (mm/min) or (rev/min)
G94	Constant surface feed (mm/min)
G96	Constant surface feed (rev/min)
H	Tool height length compensation or Tool height offset
I	Incremental distance to arc center along X-axis
J	Incremental distance to arc center along Y-axis
K	Incremental distance to arc center along Z-axis
L	No. of times to loop a canned cycle
N	Sequence Number (N10, N20, N30…)
O	Program Name (or) program address
P	Dwell timing
Q	Pick depth
S	Spindle speed
T	Tool Identification (or) Tool designation
R	Retraction

MILLING OPERATION:

Write a program using G-codes and M-codes to perform the following milling operation on a given blank with:

Blank thickness – 25mm

Depth – 2mm



SOLUTION:

PROCEDURE:

1. Open PCNC 24 software .
2. Click File→New.
3. Type the below program in the editor window.
4. Update tool path.
5. Save and Close.

PROGRAM:

O 0001;

G21 G90;

M06 T01;

M03 S1500;

M07;

G00 X0 Y0 Z0;

G00 X0 Y0 Z5;

G01 Z-25 F100;

G01 X100 Y0;

G01 X100 Y100;

G01 X0 Y100;

G01 X0 Y0;

G00 Z5;

G40;

G00 X12.5 Y12.5;

M05;

MO6 T02;

M03 S750;

G01 Z-2 F100;

G01 X27.5 Y12.5;

G01 X37.5 Y22.5;

G01 X47.5 Y12.5;

G01 X77.5 Y12.5;

G03 X87.5 Y22.5 R10;

G01 X87.5 Y77.5;

G01 X77.5 Y87.5;

G01 X57.5 Y87.5;

G02 X37.5 Y87.5 R10;

G01 X12.5 Y87.5;

G01 X12.5 Y12.5;

G00 Z5;

M05 M02;

RESULT:

Thus the program for performing a profile milling operation for a given workpiece is generated and made.

EXPERIMENTATION ON EDM & ECM

I. ELECTRICAL DISCHARGE MACHINING (EDM)

AIM:

To study and experiment the process of Electro Discharge Machining (EDM).

APPARATUS REQUIRED:

Electrical Discharge Machine

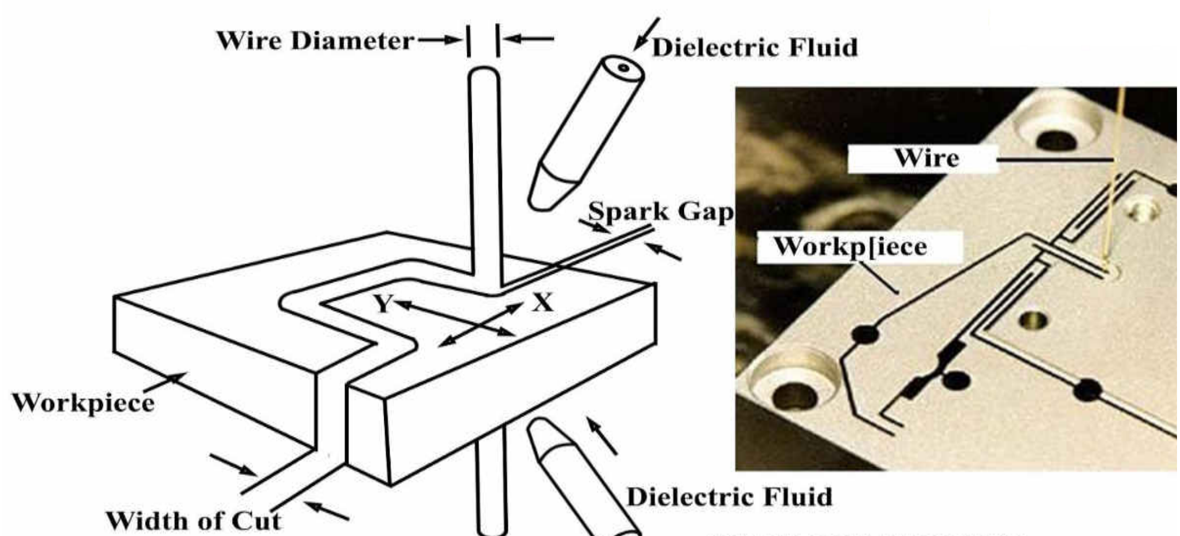
PRINCIPLE:

Electrical discharge machining involves two metal objects positioned opposite each other that are submerged in a liquid such as water or oil. An electrical spark is ignited between the objects to generate the heat used to melt and shape the metal. When a spark is ignited in the liquid, the metal struck by the spark is melted. The melted portion is then cooled by the liquid at rapid speed and dispersed. The melted part is whisked away, leaving behind dimpled pockets on the surface of the metal, resembling the craters on moon! This process of machining metals by melting, cooling, and scattering metal particles repeatedly using intermittent bursts of electrical discharges is known as electrical discharge machining.

WORKING PRINCIPLE:

Electrical discharge machining (EDM), sometimes colloquially also referred to as spark machining, spark eroding, burning, die sinking, wire burning or wire erosion, is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks). Material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the "tool" or "electrode", while the other is called the workpiece - electrode, or "work piece". The process depends upon the tool and work piece not making actual contact.

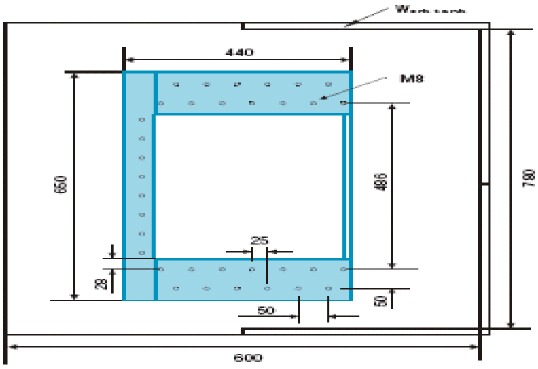
When the voltage between the two electrodes is increased, the intensity of the electric field in the volume between the electrodes becomes greater than the strength of the dielectric (at least in some point(s)), which breaks, allowing current to flow between the two electrodes. This phenomenon is the same as the breakdown of a capacitor (condenser) (see also breakdown voltage). As a result, material is removed from both electrodes. Once the current stops (or is stopped, depending on the type of generator), new liquid dielectric is usually conveyed into the inter-electrode volume, enabling the solid particles (debris) to be carried away and the insulating properties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as "flushing". Also, after a current flow, the difference of potential between the electrodes is restored to what it was before the breakdown, so that a new liquid dielectric breakdown can occur.

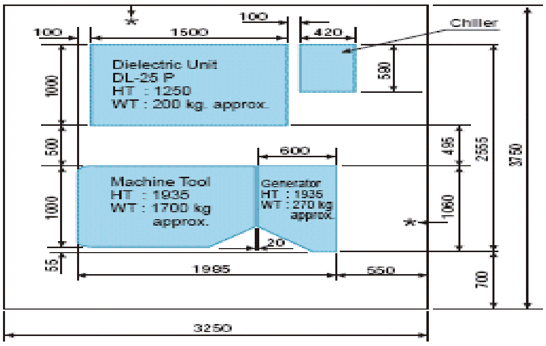


WIRE CUT PROCESS

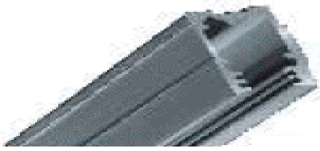
SPECIFICATION OF EDM:

- 4 axes CNC
- Precision LM guide ways for all axes
- Max. Cutting speed : 160mm/min
- 0.25 special soft brass wire on 50 mm thick HCHCr (steel) work piece)
- Best surface finish : 0.8 Ra (surface roughness)
- Taper : 30/ 50 mm
- E pulse technology
- Elcam - Powerful part programming software
- Table size - 440 X 650 mm
- Complex profile cutting
- Auto job setting parameters



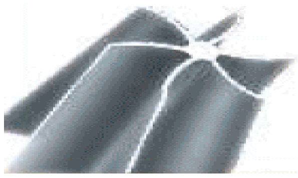


- 4 axes CNC
- Precision LM guideways for all axes
- Max. cutting speed :
  - 160 mm²/ min.
    (With Ø 0.25 special soft brass wire on 50 mm thick HCHCr (steel) workpiece)
  - 140 mm²/ min. [With Ø 0.25 plain brass wire (Bravocut plus) on 50 mm thick HCHCr (steel) workpiece]
- Best surface finish : 0.8 μ Ra
- Taper : ± 30⁰/ 50 mm
- *e*Pulse technology
- ELCAM - Powerful part programming software



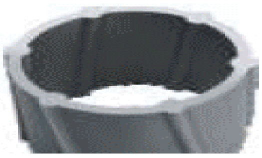
Speed in Aluminium cutting

Material	: Aluminium
Height	: 180 mm
No. of cuts	: 1+ 2
Machining time	: 2 hrs. 52 min.
Surface finish	: 1.2 μ Ra



Independent X, Y, u, v control

Material	: HCHCr (steel)
Height	: 70 mm
No. of cuts	: 3 (1 rough + 2 trimcut)
Machining time	: 4 hrs. 50 min.
Surface finish	: 1.0 to 1.2 μ Ra



Helical cutting :

Material	: HCHCr (Steel)
Height	: 50 mm
No. of cuts	: 1+2
Machining time	: 3 hrs. 30 min.
Surface finish	: 1.0 μ Ra

Sprintcut EDM

RESULT:

Thus, the Electrical Discharge Machining process is studied and experimented.

II.ELECTRO CHEMICAL MACHINING (ECM)

AIM:

To study and experiment the process of Electro Chemical Machining (ECM).

APPARATUS REQUIRED:

Electrical Discharge Machine

SOFTWARE USED:

Hyper 2 GUI

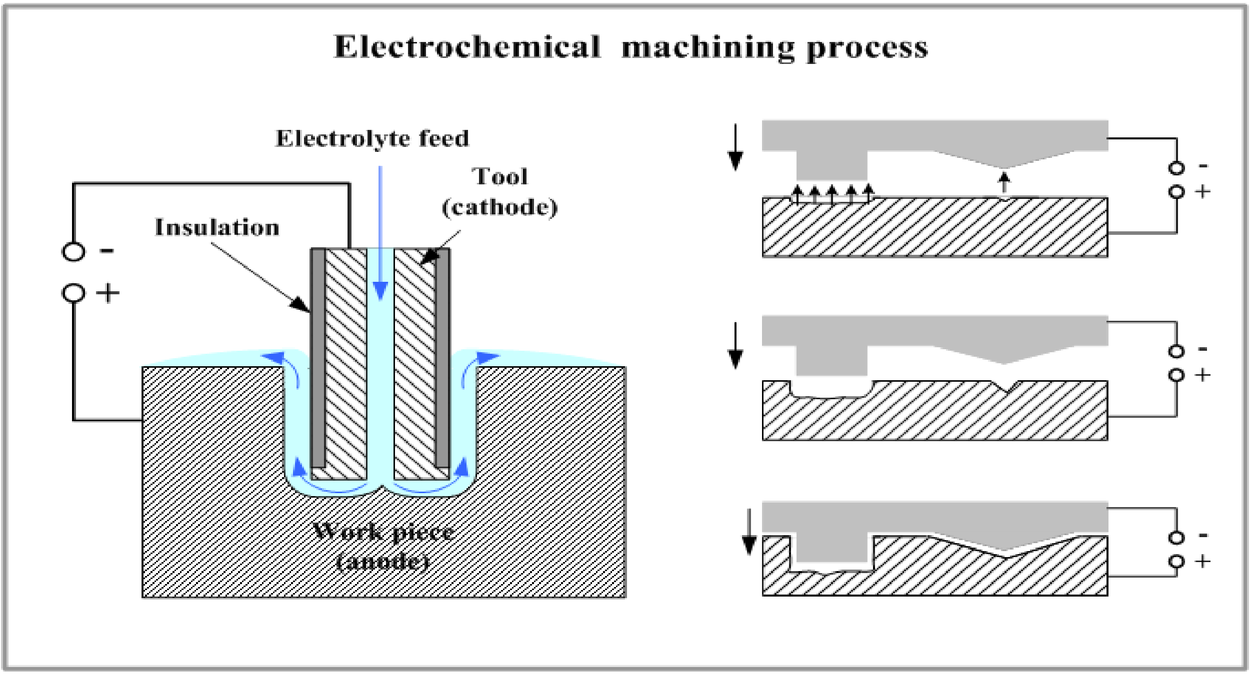
PRINCIPLE:

During the process the metal work piece is dissolved (Machining) locally through electricity (Electro) and chemistry (Chemical) until it reaches the required complex 3D end shape.

WORKING PRINCIPLE:

During the ECM process metal is dissolved from a work piece with direct current at a controlled rate in an electrolytic cell. The work piece serves as the anode and is separated by a gap (which can be as small as 10 μm) from the tool, which serves as the cathode. Therefore, the work piece and the work tool do not touch in any moment. The electrolyte, usually a salt solution in water, is pumped under pressure through the inter-electrode gap, thus flushing away metal dissolved from the work piece. As the electrode tool moves towards the work piece to maintain a constant gap, the work piece is machined into the complementary shape of the tool.

ECM resembles electroplating in reverse: instead of adding material, ECM removes it. The technique can also be described as the opposite of electrochemical or galvanic coating or deposition process. Due to the non-contact principle of the process, no mechanical or thermal stress is exercised on the work piece.



Electro Chemical Machining (ECM) process

Material removal rate (MRR) is an important characteristic in evaluating the efficiency of the non-traditional machining processes. In ECM, material removal takes place due to the atomic dissolution of the work material. In addition, unlike the previous generations of ECM machines, the current ECM technique benefits from pulsating power supply and a vibrating axis. This concept enables processing even products with a minimum process-gap of just a few micrometers, as well as shaping complex forms both internally and externally.

RESULT:

Thus, the Electro Chemical Machining process is studied and experimented.

EXPERIMENTATION ON WATER JET CUTTING

AIM:

To perform an experimentation on Abrasive Water Jet Machining (AWJM).

BASIC COMPONENTS AND OPERATION:

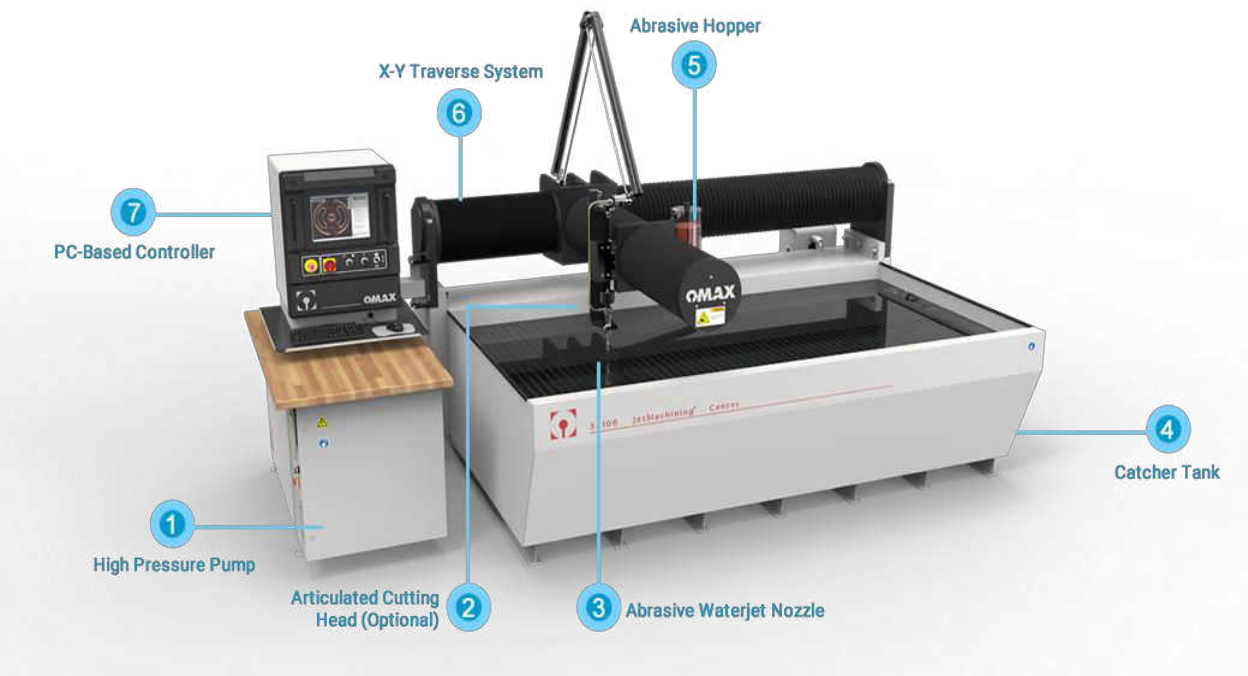


Fig.1. Abrasive Water Jet Machine (AWJM)

High Pressure Pump:

The pump generates a flow of pressurized water for the cutting process.

Articulated Cutting Head:

As an add-on option to OMAX waterjets, this computer-controlled multi-axis cutting head permits angled cuts and can be used to automatically minimize taper for precise vertical cuts.

Abrasive Waterjet Nozzle:

Inside the nozzle the pressurized water passes through a small-diameter orifice and forms a coherent jet of water. The jet then passes through a venturi section where a metered amount of granular abrasive is drawn into the water stream. The mixture of water and abrasive particles passes through a special ceramic mixing tube and the resulting abrasive/water slurry exits the nozzle as a coherent cutting stream of abrasive particles travelling at very high speed.

Catcher Tank:

The water-filled catcher tank dissipates the energy of the abrasive jet after it has cut through the material being machined.

Abrasive Hopper:

The abrasive hopper and associated abrasive flow control system provide a metered flow of granular abrasive to the nozzle.

X-Y Traverse System:

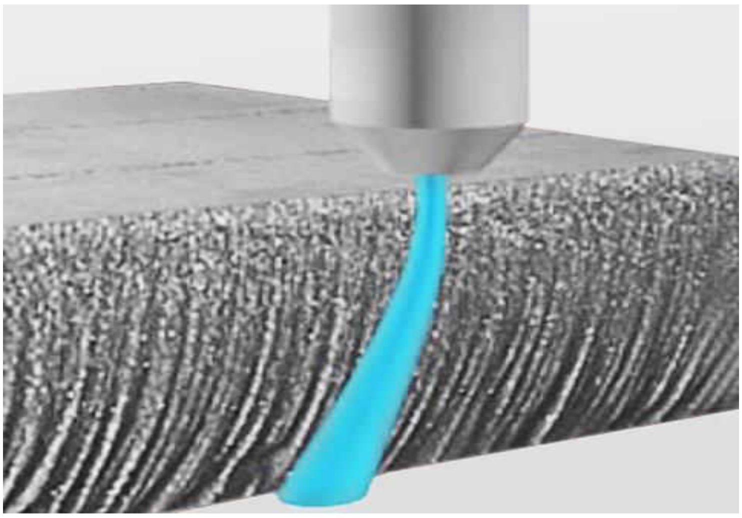
A precision X-Y motion system is used to accurately move the nozzle to create the desired cutting path.

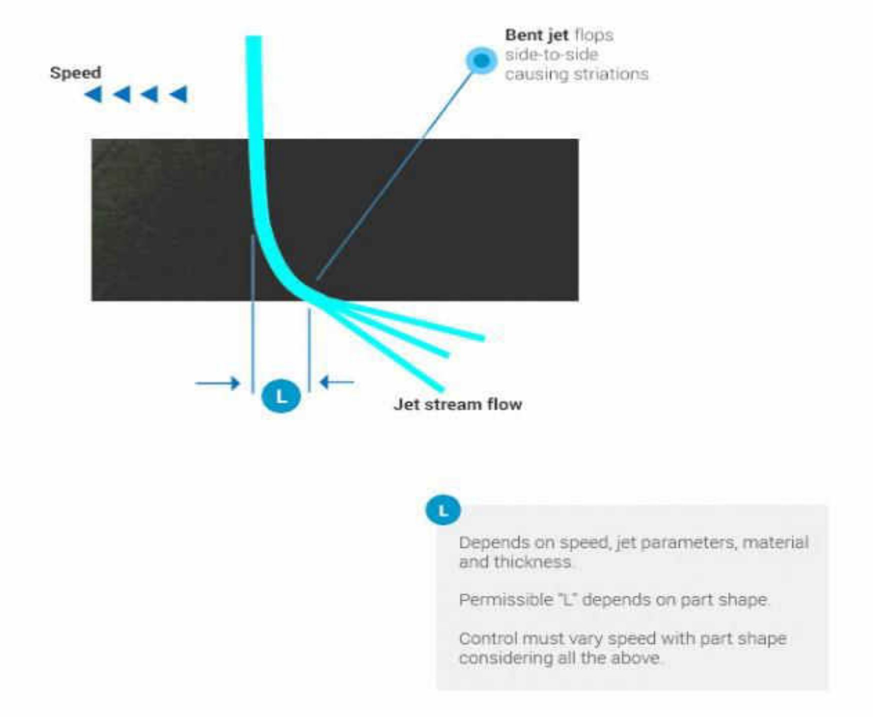
PC-based Controller:

Advanced motion controllers for abrasive waterjet systems are PC-based and permit production of accurate parts with minimal operator experience.

Motion Control:

The motion control system is an essential element in an abrasive waterjet cutting system because the cutting stream bends as it cuts. This means that a waterjet tends to undercut corners and swing wide on curves when moved as one would move a traditional rigid cutting tool. OMAX eliminates this issue by using an advanced computer model to accurately predict the motion and shape of the cutting stream and then by using a PC-based motion control system to compensate for undesired jet motion. The result is a fast, accurate part the first time. No trial and error and no need for an experienced programmer because the experience and the knowledge is in the control software.

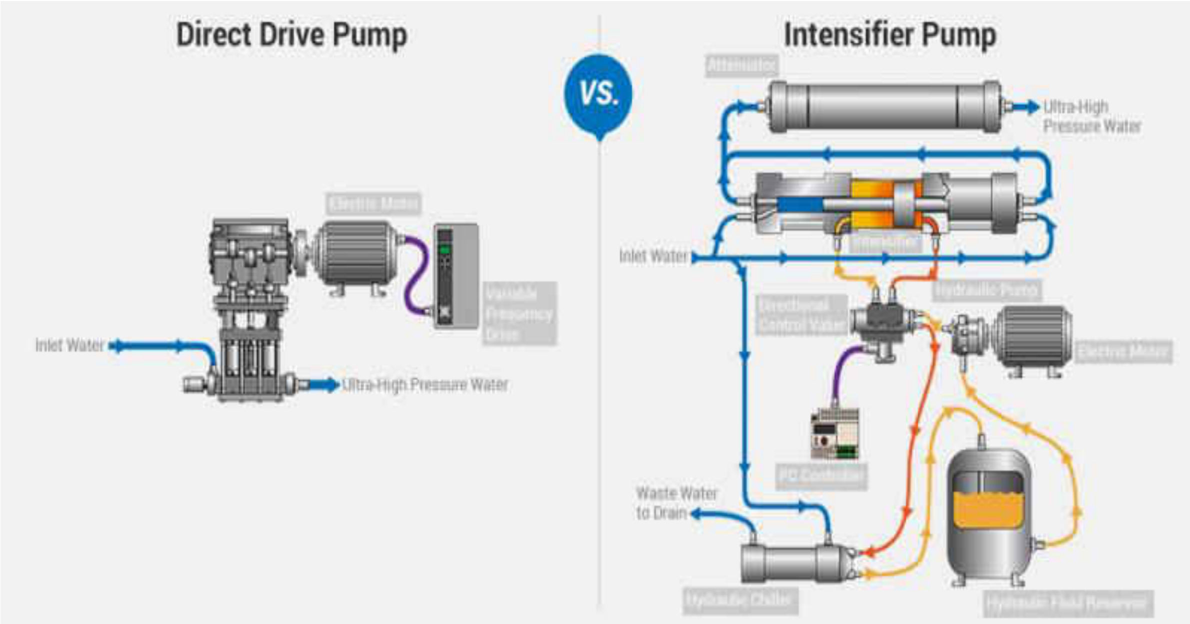




Pumps:

Waterjet cutting systems utilize either the older, more complex hydraulic intensifier pump or the newer, simpler crankshaft-driven triplex plunger pump. Crankshaft pumps are inherently more efficient than intensifier pumps because they do not require a power-robbing hydraulic system. The crankshaft drive is a purely mechanical direct-drive system with minimal friction losses and so efficiencies between 85% and 90% are typical. This means that 85% or more of the electric power supplied to the drive motor can actually be delivered to the cutting nozzle, compared to the typical 65% or less of an intensifier. Historically intensifier pumps had an advantage of longer seal and check-valve life, but ongoing improvements in seal designs and materials and the wide availability and reduced cost of ceramic valve components now make it possible to operate a crankshaft pump in the 60,000 PSI (4,137 bar) range with long maintenance intervals and excellent reliability.

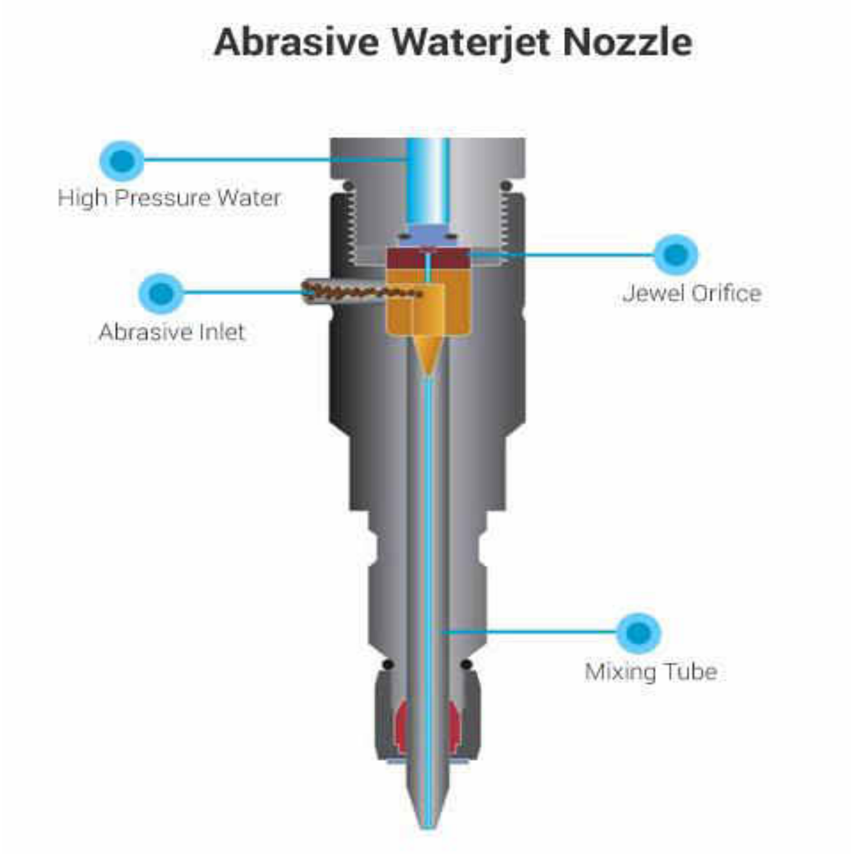
OMAX uses high-efficiency crankshaft-driven direct-drive pumps exclusively for all of its systems. A direct-drive pump is more efficient than a traditional hydraulic intensifier pump and so it can deliver more net power to the cutting nozzle, resulting in faster cutting. It is quiet and clean, with no risk of messy hydraulic leaks. In addition, a direct-drive pump is simple to understand, to troubleshoot and to maintain. The OMAX Enduromax pump features a preventative maintenance interval of 1000 hours, offering the ultimate in reliable low-cost operation.



Nozzle:

All abrasive waterjet nozzles use the basic operating principle of the aspiration nozzle, first patented in 1937 (Patent 2,131,660) and shown in its modern configuration in the diagram on the right. Note that for water-only nozzle designed for cutting of soft material, the venturi section and mixing tube are eliminated and the coherent jet of water alone cuts the material.

In order for the aspiration nozzle to cut efficiently and with long component life, it is critical that the orifice be carefully aligned with the centerline of the mixing tube. All OMAX nozzles are factory-aligned and individually tested to assure efficient cutting and long life.



FEATURES & BENEFITS

- Fast cutting speeds and high precision that is backed by our exclusive Intelli-MAX® Software with real world cutting data
- Programmable Motorized Z-Axis with a precision OMAX MAXJET®5i Nozzle boosts productivity and process efficiency
- Drive system protected against water, dirt, and grit
- Powerful all-in-one controller computer with large 23" screen
- Highly efficient, industry-proven direct drive pumps available up to 40 hp with operating efficiencies up to 85%
- Free Intelli-VISOR® SE System Monitoring simplifies routine maintenance planning to minimize downtime
- Optional Rapid Water Level Control for quiet submerged cutting
- Optional Bulk Abrasive Feed Assembly transports garnet from the assembly's large hopper into the Zero Downtime Hopper located at the Programmable Motorized Z-Axis
- Optional Variable Speed Solids Removal System (VS-SRS) designed for industrial use increases uptime through automated solids removal
- Factory tested as a complete system before shipping

- Machines a wide range of materials and thicknesses, from metals and composites to glass and plastics
- Designed and manufactured at the OMAX factory in Kent, Washington, USA
- Does not create heat-affected zones or mechanical stresses
- No tool changes & minimal fixturing dramatically reduce setup
- Convenient controller storage drawers keep essential tools and spares close by to maintain machine uptime
- Uses substantially less cooling water than inefficient hydraulic intensifier pumps
- Small, efficient footprint for minimal floor space utilization
- Lowest electrical consumption compared to other pump technology
- Leaves behind a satin-smooth edge, reducing secondary operations
- No noxious fumes, liquid or oils used in, or caused by, the machining process
- Environmentally "green" system uses only natural garnet abrasive and water in the cutting process.

MACHINE DIMENSIONS

Footprint (without controller)	9'3" x 10'10" (2,819 mm x 3,302 mm)
Weight (tank empty)	3,000 lb (1,361 kg)
Height (with whip plumbing)	10'6" (3,200 mm)
Operating Weight (with water in tank)	10,500 lb (4,763 kg)

WORK ENVELOPE

X-Y Cutting Travel*	5'2" x 5'2" (1,575 mm x 1,575 mm)
Z-Axis Travel*	12" (305 mm)
Table Size*	7'4" x 5'8" (2,248 mm x 1,740 mm)

DRIVE DESCRIPTION

- Brushless servo motors
- Stainless steel hardened precision ground shaft ways
- Real-time closed loop feedback with digital drives
- Bridge-style Y-Axis
- Intelli-*TRAX* drive technology with precision linear encoders
- Precision Programmable Motorized Z-Axis

STANDARD MODEL SPECIFICATIONS

OPTIONAL ACCESSORIES

- A-Jet 5-Axis Cutting Head with Smart Taper Control
- Rapid Water Level Control for submerged cutting
- Intelli-VISOR EX Monitoring Expansion Package

Material Support Slats	20 4" x 14Ga Galvanized Steel (102 mm x 2 mm)
Maximum Supported Material Load	300 lbs/sq ft (1,465 kg/sq meter)
Electrical Requirements	3-Phase, 380-480 VAC ±10%, 50-60 Hz
Speed	500 in/min (12,700 mm/min)
Accuracy	±0.003" (±0.076 mm)
Repeatability	±0.001" (±0.025 mm)

- OMAX Mini MAXJET 5i Nozzle
- 7/15 Mini MAXJET5 Nozzle
- Bulk Abrasive Delivery Assembly
- Terrain Follower/A-Jet
- Collision Sensing Terrain Follower
- Manual Tilt Z-Axis
- Material Holding Kit
- Waterjet Brick Kit
- High Pressure Universal Plumbing
- Bridge-mounted Pause Button and USB Port
- DualPUMP Package (redundant pump option up to 80 hp)
- Additional Seats of Intelli-MAX Software Suite
- Variable Speed Solids Removal System (VS-SRS)
- Water-only MAXJET 5 Nozzle
- Laser Feature Finder
- Z-Axis Pneumatic Drill
- Splash Shield Kit
- Water Resistant Keyboard and Mouse
- Access Control Circuit Interface for safety interlocks
- Catcher Tank Armor Plating
- Extended Slat Package
- Laminar Filter
- Air and Water Conditioning Kit
- Water Recycling System

RESULT:

Thus the experimentation on Abrasive Water Jet Machining was performed.

ROBOT MODELING AND PROGRAMMING

MODELING & SIMULATION OF ARTICULATED ROBOT CONFIGURATION

AIM:

To model and simulate the Articulated (TRR) configuration of robots using Matlab.

INTRODUCTION:

An articulated robot is one which uses rotary joints to access its work space. Usually the joints are arranged in a “chain”, so that one joint supports another further in the chain. An articulated robot’s joints are all revolute, similar to a human’s arm. It is a TRR configuration of robot. It is used for assembly operations, die-casting, fettling machines, gas welding, arc welding and spray painting. It's a robot whose arm has at least three rotary joints.

PROCEDURE:

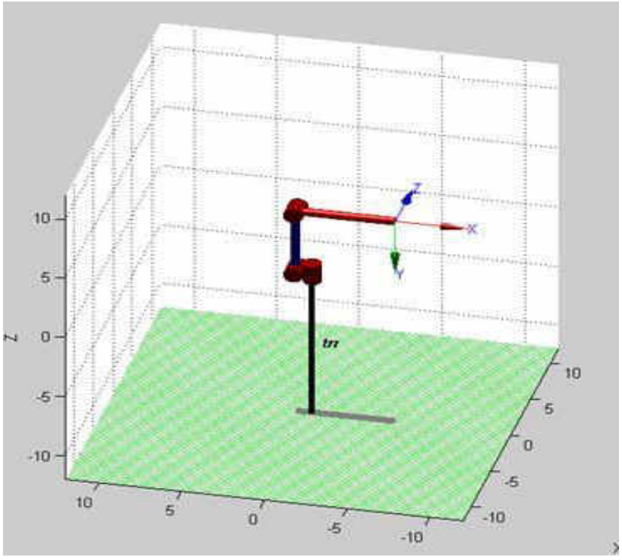
MATLAB is a powerful environment for linear algebra and graphical presentation that is available on a very wide range of computer platforms. The core functionality can be extended by application specific toolboxes. The Robotics Toolbox provides many functions that are required in robotics and addresses areas such as kinematics, dynamics, and trajectory generation. The Toolbox is useful for simulation as well as analyzing results from experiments with real robots, and can be a powerful tool for education.

S.no	Symbol	Description
1	α	Link twist angle (rad)
2	a	Link length
3	θ	Joint angle (rad)
4	d	Link offset
5	σ	Joint type; 0 for revolute, non-zero for prismatic

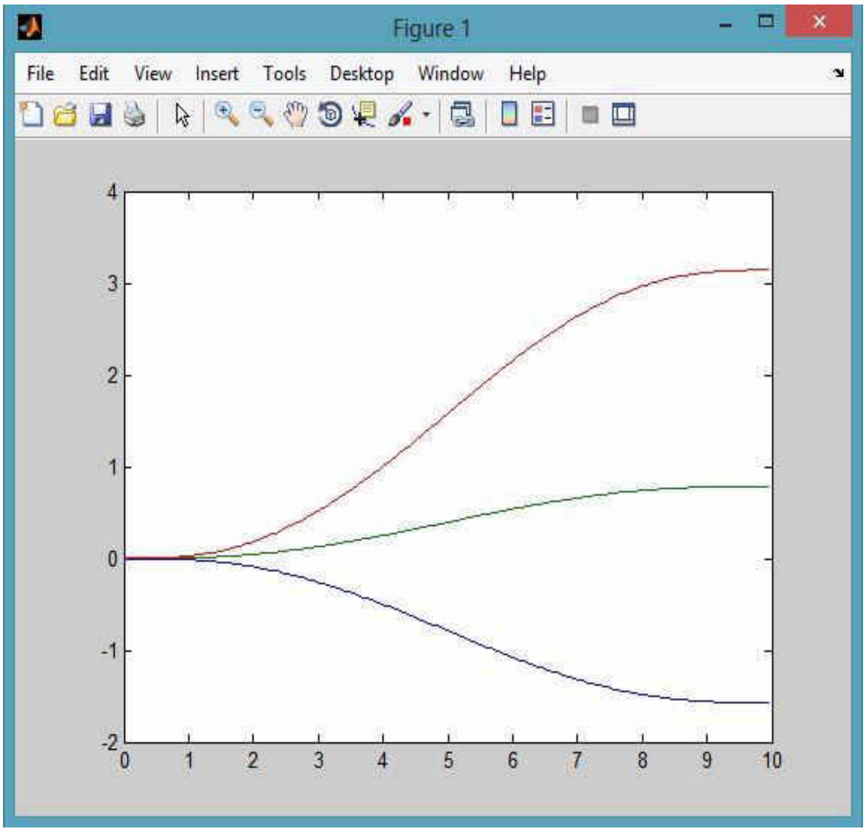
MATLAB CODE:

```
l1=Link([0 0 1 pi/2]);
l2=Link([0 0 5 0]);
l3=Link([0 0 6 0]);
arm=SerialLink([l1,l2,l3],'name','trr');
q1=[0,0,0];
q2=[pi/2,0,0];
q=(1:1:100);
traj=jtraj(q1,q2,q);
arm.plot(traj)
q1=[pi/2,0,0];
q2=[pi/2,pi/2,pi/2];
q=(1:1:100);
traj=jtraj(q1,q2,q);
arm.plot(traj)
```

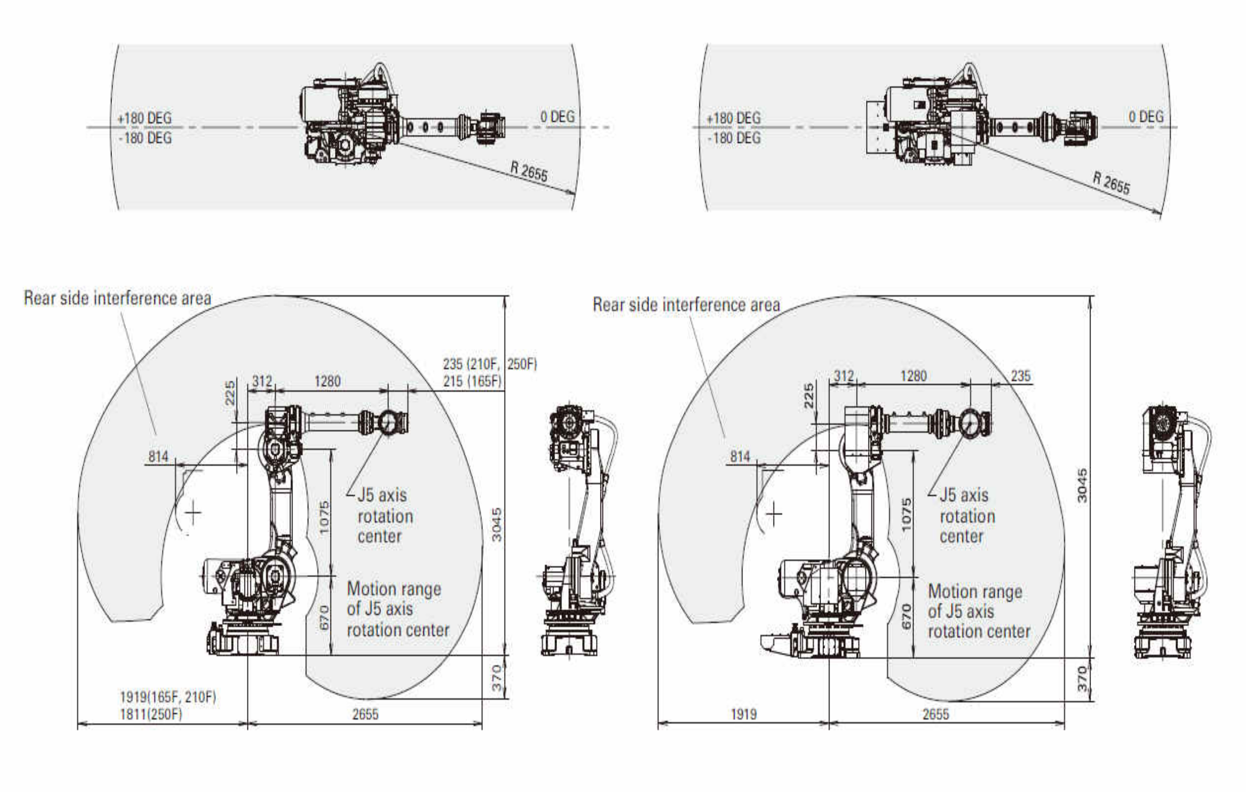
SIMULATION OUTPUT:

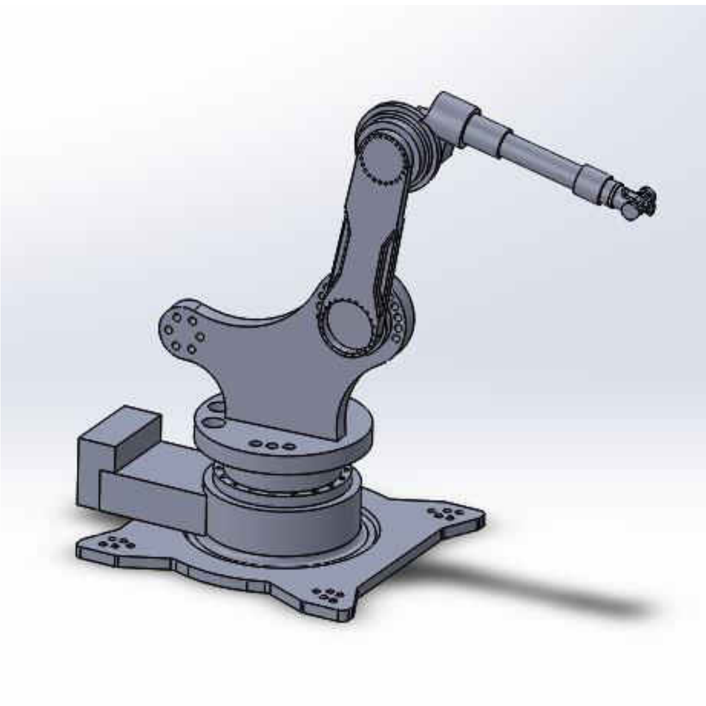


TRR configuration



DATA SHEET:

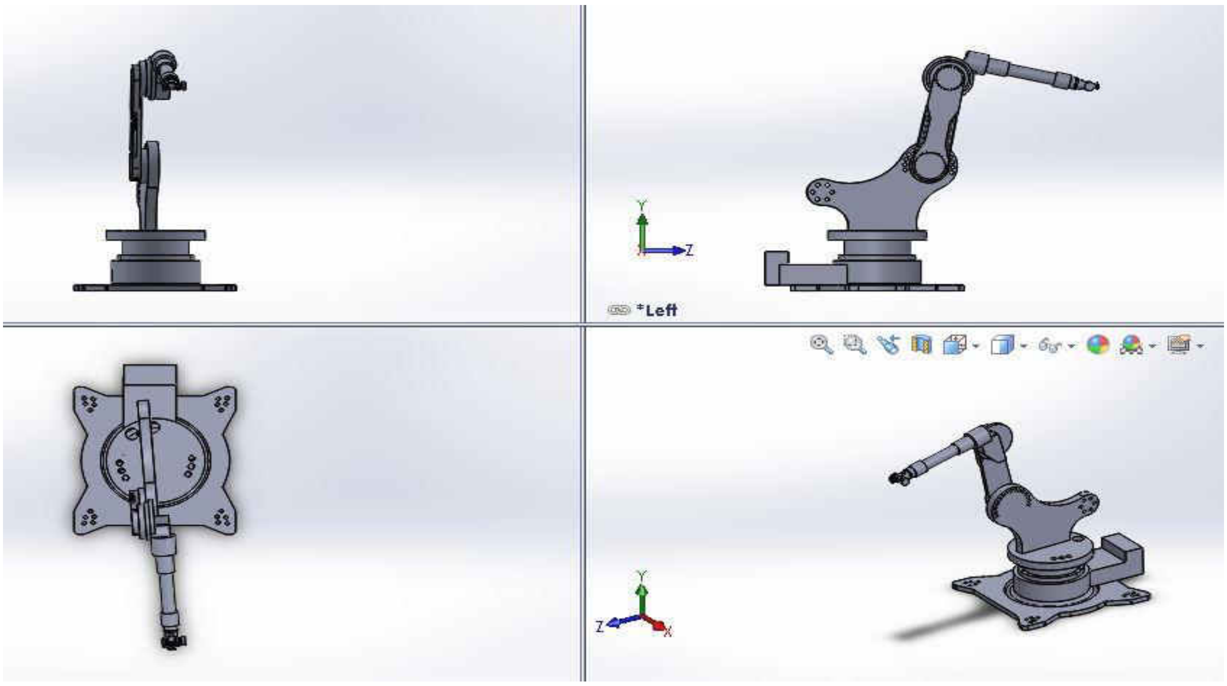

+180 DEG
-180 DEG
0 DEG
R 2655
+180 DEG
-180 DEG
0 DEG
R 2655
Rear side interference area
235 (210F, 250F)
215 (165F)
225
312
1280
814
J5 axis
rotation
center
1075
3045
Motion range
of J5 axis
rotation center
670
370
1919(165F, 210F)
1811(250F)
2655
Rear side interference area
312
1280
235
225
814
J5 axis
rotation
center
1075
3045
Motion range
of J5 axis
rotation center
670
370
1919
2655



Specifications

Item		Specifications			
		R-2000iB/165F	R-2000iB/210F	R-2000iB/250F	R-2000iB/210WE
Type		Articulated type			
Controlled axes		6 axes (J1, J2, J3, J4, J5, J6)			
Reach		2.66m	2.66m	2.66m	2.66m
Installation		Floor			
Motion range (Maximum speed) Note 1)	J1 axis rotation	360° (110°/s) 6.28rad (1.92rad/s)	360° (95°/s) 6.28rad (1.66rad/s)	360° (95°/s) 6.28rad (1.66rad/s)	360° (95°/s) 6.28rad (1.66rad/s)
	J2 axis rotation	136° (110°/s) 2.37rad (1.92rad/s)	136° (90°/s) 2.37rad (1.57rad/s)	136° (85°/s) 2.37rad (1.48rad/s)	136° (90°/s) 2.37rad (1.57rad/s)
	J3 axis rotation	362° (110°/s) 6.32rad (1.92rad/s)	362° (95°/s) 6.32rad (1.66rad/s)	357° (88°/s) 6.23rad (1.54rad/s)	362° (95°/s) 6.32rad (1.66rad/s)
	J4 axis wrist rotation	720° (150°/s) 12.57rad (2.62rad/s)	720° (120°/s) 12.57rad (2.09rad/s)	720° (120°/s) 12.57rad (2.09rad/s)	720° (120°/s) 12.57rad (2.09rad/s)
	J5 axis wrist swing	250° (150°/s) 4.36rad (2.62rad/s)	250° (120°/s) 4.36rad (2.09rad/s)	250° (120°/s) 4.36rad (2.09rad/s)	250° (120°/s) 4.36rad (2.09rad/s)
	J6 axis wrist rotation	720° (220°/s) 12.57rad (3.84rad/s)	720° (190°/s) 12.57rad (3.32rad/s)	720° (190°/s) 12.57rad (3.32rad/s)	720° (190°/s) 12.57rad (3.32rad/s)
Max load capacity at wrist		165kg	210kg	250kg	210kg
Max load capacity at J2 base		550kg	550kg	550kg	550kg
Max load capacity on J3 arm		25kg	25kg	25kg	25kg
Allowable load moment at wrist	J4 axis	921N・m 94kgf・m	1333N・m 136kgf・m	1382N・m 141kgf・m	1333N・m 136kgf・m
	J5 axis	921N・m 94kgf・m	1333N・m 136kgf・m	1382N・m 141kgf・m	1333N・m 136kgf・m
	J6 axis	461N・m 47kgf・m	706N・m 72kgf・m	715N・m 73kgf・m	706N・m 72kgf・m
Allowable load inertia at wrist	J4 axis	78.4kg・m^2 800kgf・cm・s^2	141.1kg・m^2 1440kgf・cm・s^2	225.4kg・m^2 2300kgf・cm・s^2	141.1kg・m^2 1440kgf・cm・s^2
	J5 axis	78.4kg・m^2 800kgf・cm・s^2	141.1kg・m^2 1440kgf・cm・s^2	225.4kg・m^2 2300kgf・cm・s^2	141.1kg・m^2 1440kgf・cm・s^2
	J6 axis	40.2kg・m^2 410kgf・cm・s^2	78.4kg・m^2 800kgf・cm・s^2	196kg・m^2 2000kgf・cm・s^2	78.4kg・m^2 800kgf・cm・s^2
Drive method		Electric servo drive by AC servo motor			
Repeatability		±0.2mm	±0.3mm	±0.3mm	±0.3mm
Mass Note 2)		1,170kg	1,240kg	1,270kg	1,280kg
Installation environment		Ambient temperature : 0~45°C Ambient humidity : Normally 75%RH or less (No dew, nor frost allowed) Short term Max. 95%RH or less (within one month) Vibration : 0.5G or less			

SOLIDWORKS MODEL:



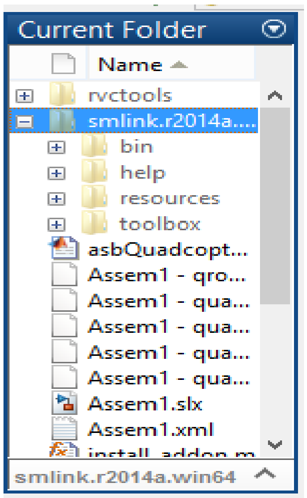
INTERFACING SOLIDWORKS & MATLAB:

1. Go to maths works website and download solid works interface add-on with your suitable operating system.

in.mathworks.com/products/simmechanics/download_smlink_confirmation.html?elqsid=1460435344681&potential_use=Student&country_code=IN

SimMechanics Link 4.2	
Win32 (PC) Platform	smlink.r2013a.win32 install_addon.m
Win64 (PC) Platform	smlink.r2013a.win64 install_addon.m
UNIX (64-bit Linux)	smlink.r2013a.glnxa64 install_addon.m
Mac OS X (64-bit Intel)	smlink.r2013a.maci64 install_addon.m

2. Matlab version, you have to remember that your matlab and solid works are same version.
3. After downloading add-on, open the matlab, copy the download file put into bin and set to path.



4. Enter the matlab comment window install _add-on (‘enter zip file name’).

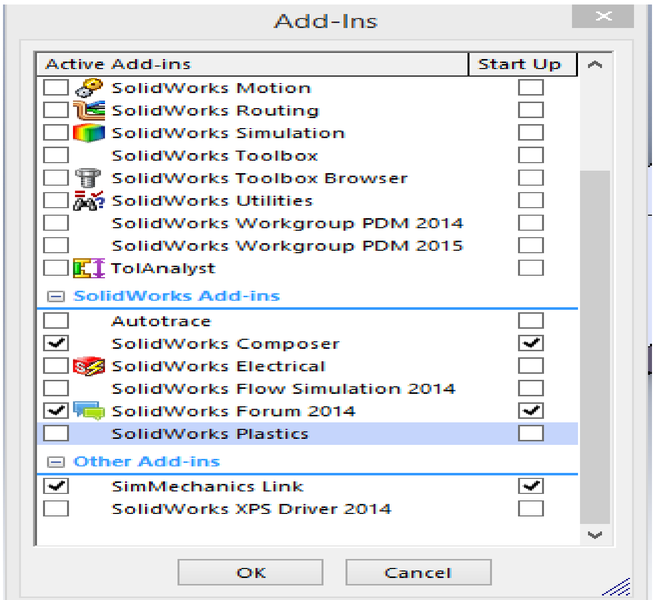
```
>> install_addon('smlink.r2014a.win64.zip')
Installing smlink...
Extracting archive smlink.r2014a.win64.zip to C:\Program Files\MATLAB\R2014a...
```

5. Then after extracting the file enter smlink_linksw.

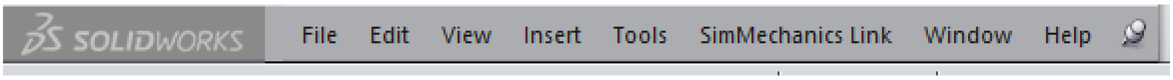
```
smlink_linksw
Installation of smlink complete.

To view documentation, type "doc smlink".
Registering dll: regsvr32 "C:\Program Files\MATLAB\R2014a\bin\win64\cl_sldwks2sm.dll"
```

6. Go to solid works option add-on and select simmechanics add-on present just you have to enable the icon.

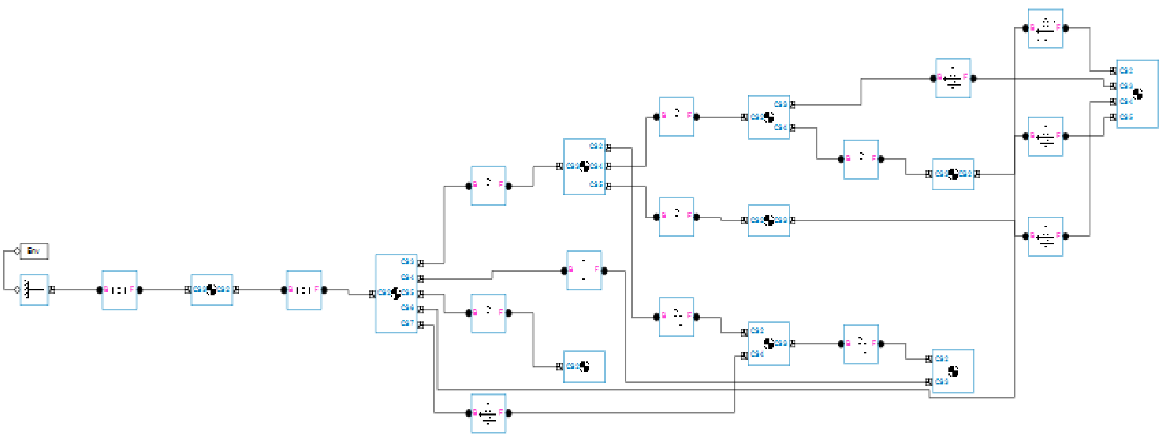


7. After adding it will indicate in assemble window now you can export your model. to matlab.

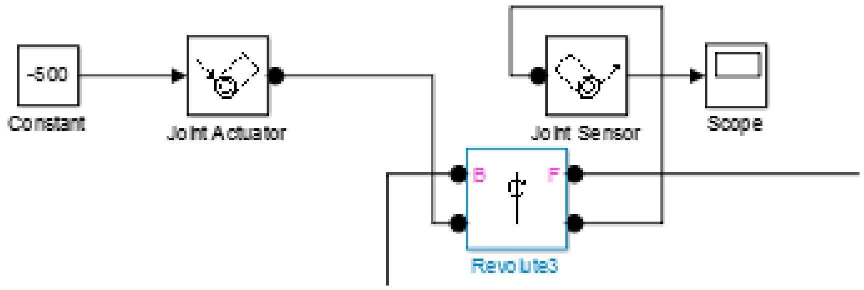


8. Simple constrains only export to matlab or else it will show error.
9. Now you can design to model export to matlab.
10. After export to matlab it will save in the form of xml file then it will open in matlab Simulink now it will show in the form of block that block contain joints, revolute ,fixer, weld like that block.

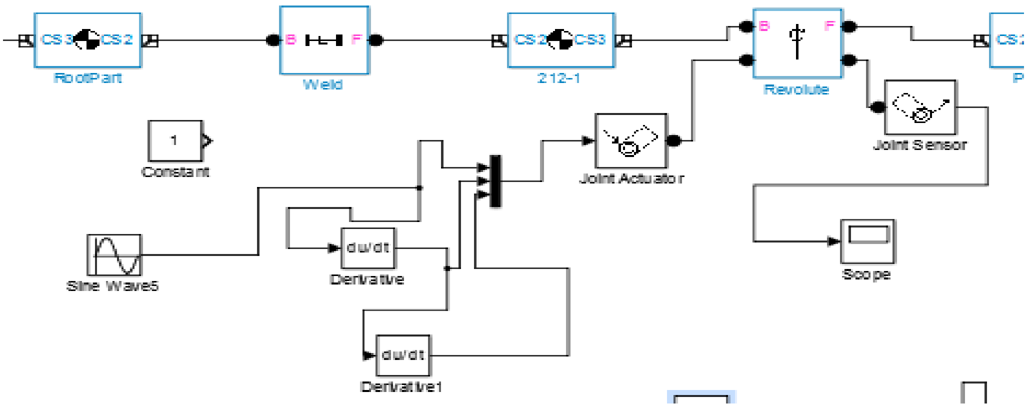
```
mech_import('power window.xml')
```



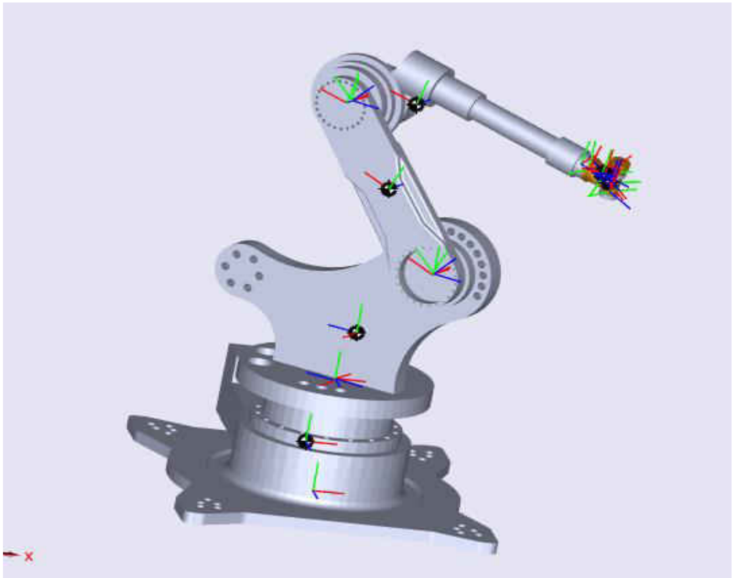
11. Now you can control the joint using Simulink block.
12. Double click the revolute joint it will show the port number if you increase the port numbers it will show in respective input and out puts.



13. In that input device you can connect first joint actuator out put joint sensors ,after joint actuator block you can connect the controlling block like step ,ramp, pid, sine using this you can control the joints.



INTERFACING RESULTS:



ADVANTAGES OF ARTICULATED ROBOTS:

- The advantages of a vertically articulated robot are its flexibility and dexterity. Articulated robot use in pick and place operation with the dexterity of the vertically articulated robot, you can use the robot to pick up and re-orient the part. Five- and six-axis articulating robots also are more adaptable to variations or changes during a project, and offer more flexibility during and after a program. There are always changes in design and process.
- Covers a large work space relative to volume of robots.
- Revolute joints are easy to seal.
- Suits electric motors.

DISADVANTAGES OF ARTICULATED ROBOTS:

- Complex kinematics.
- Difficult to visualize.
- Control of linear motion is difficult.

RESULT:

Thus the Articulated robot was modeled and simulated using Solidworks & Matlab.

MODELING & SIMULATION OF SPHERICAL ROBOT CONFIGURATION

AIM:

To model and simulate the Spherical (TRL) configuration of robots using Matlab.

INTRODUCTION:

Spherical robots are also known as polar robots. They have spherical work envelopes that can be positioned in a polar coordinate system. These robots are more sophisticated than Cartesian and cylindrical robots, while control solutions are less complicated than those of articulated robot arms. This may be the reason why sometimes they are used as a base for robot kinematics exercises.

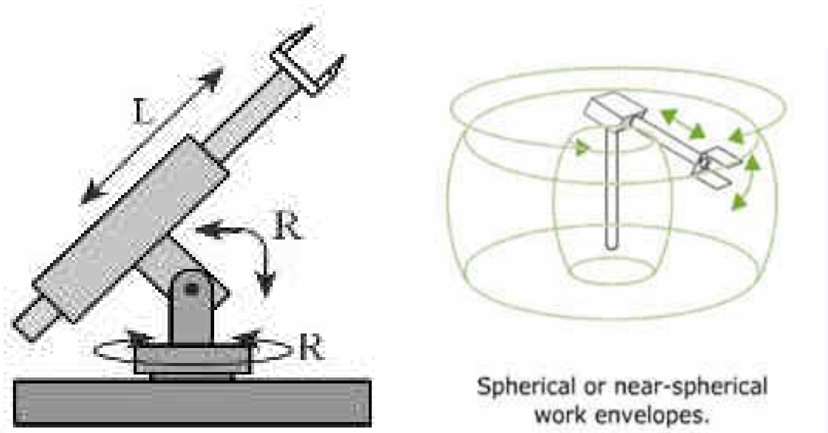


Fig.1.Spherical robot configuration

The spherical robots structure is seen in fig1. It has one twisting joint, one rotary joint and one linear. Thus a spherical work envelope is formed. It is not a sphere, but reachable places can still be calculated in a polar coordinate system. As you can understand, there can be more than three joints. However, these three are the basic ones that form the work envelope. Further joints would add more flexibility, but wouldn't radically change the reachable area. For example, if the gripper could rotate, this would be a 4-axis robot while the work envelope wouldn't change at all. Robots of this kind have a near-spherical work envelope. Most modern industrial robots are derivatives of this type.

PROCEDURE:

MATLAB is a powerful environment for linear algebra and graphical presentation that is available on a very wide range of computer platforms. The core functionality can be extended by application specific toolboxes. The Robotics Toolbox provides many functions that are required in robotics and addresses areas such as kinematics, dynamics, and trajectory generation. The Toolbox is useful for simulation as well as analyzing results from experiments with real robots, and can be a powerful tool for education.

S.no	Symbol	Description
1	α	Link twist angle (rad)
2	a	Link length
3	θ	Joint angle (rad)
4	d	Link offset
5	σ	Joint type; 0 for revolute, non-zero for prismatic

MATLAB CODE:

```
l1=Link('d', 1.2, 'a', 0.3, 'alpha', pi/2);
l2=Link([0 0 1 0]);
l3=Link([0 0 1 0]);
y=SerialLink([l1 l2 l3],'name','trl');
q=[1:1:100];
q1=[0,0,0];
q2=[2*pi,-pi/4,pi/2];
traj=jtraj(q1,q2,q);
y.plot(traj);
plot(traj);
title('Joint Trajectory Path')
xlabel('step size') % x-axis label
ylabel('step angle') % y-axis label
legend('link 1','link 2','link 3')
```

SIMULATION OUTPUT:

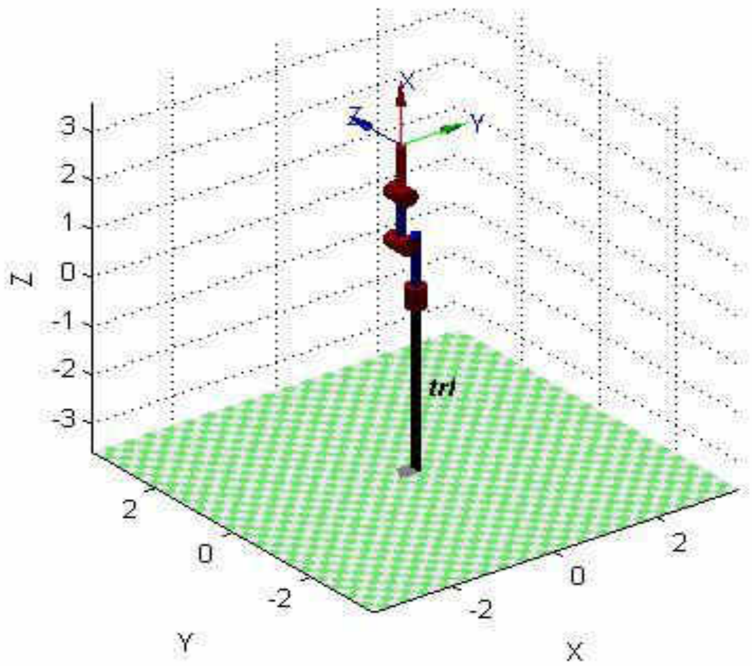
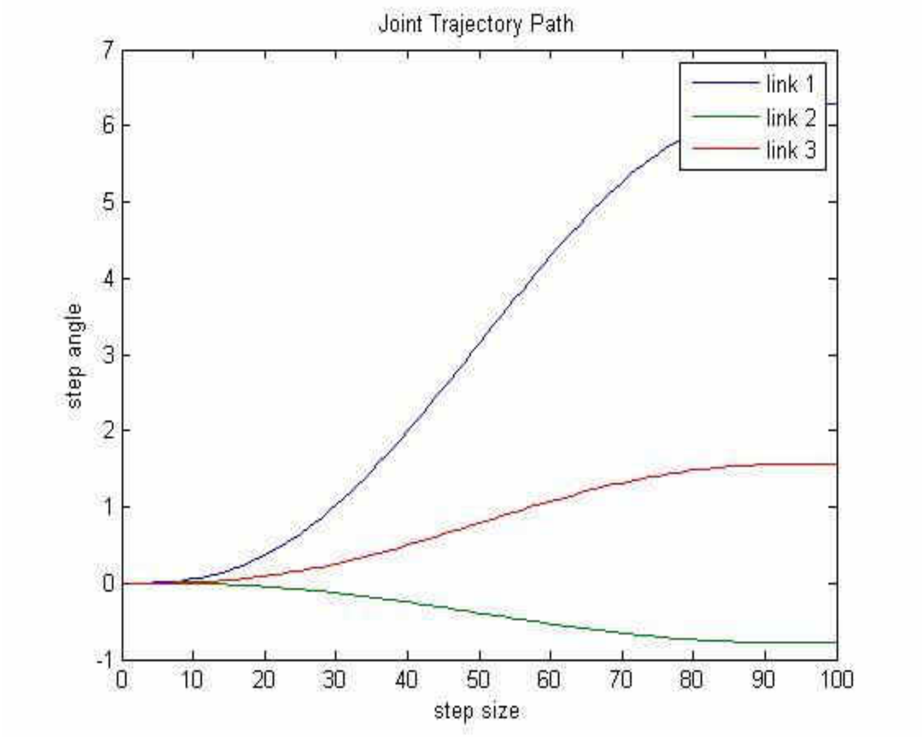
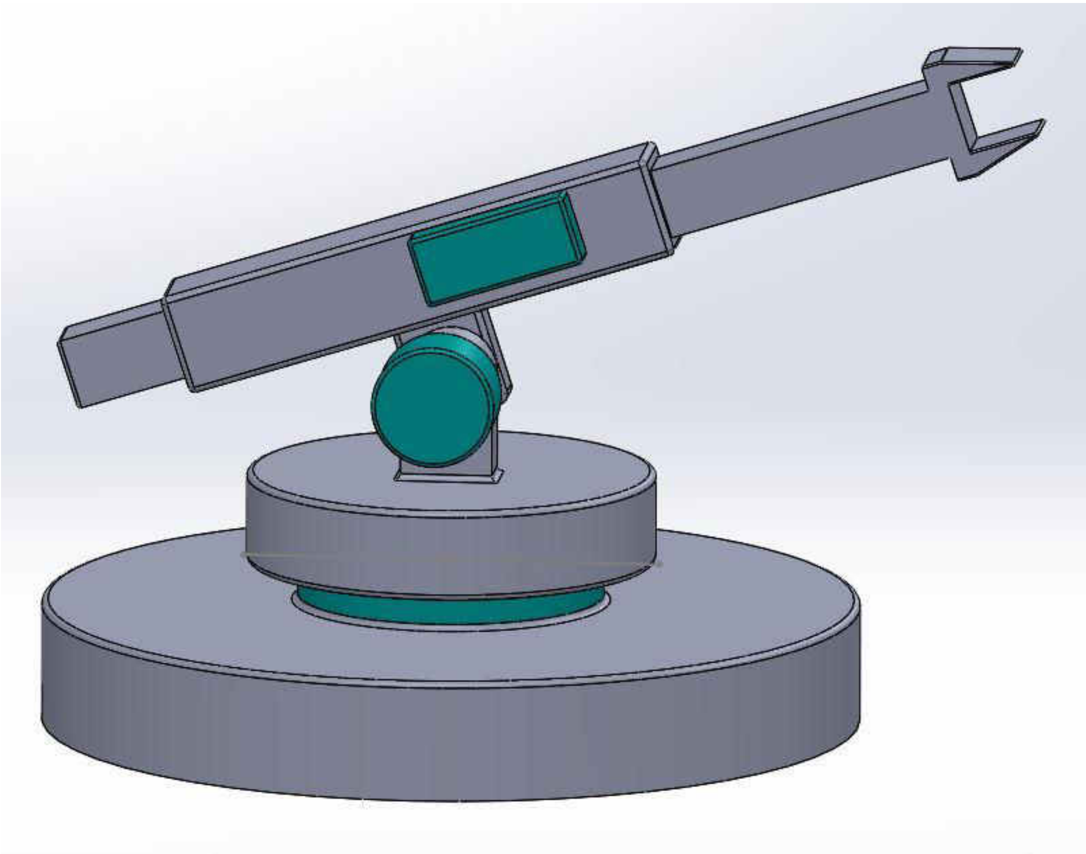


Fig.2. TRL configuration robot



SOLIDWORKS MODEL:



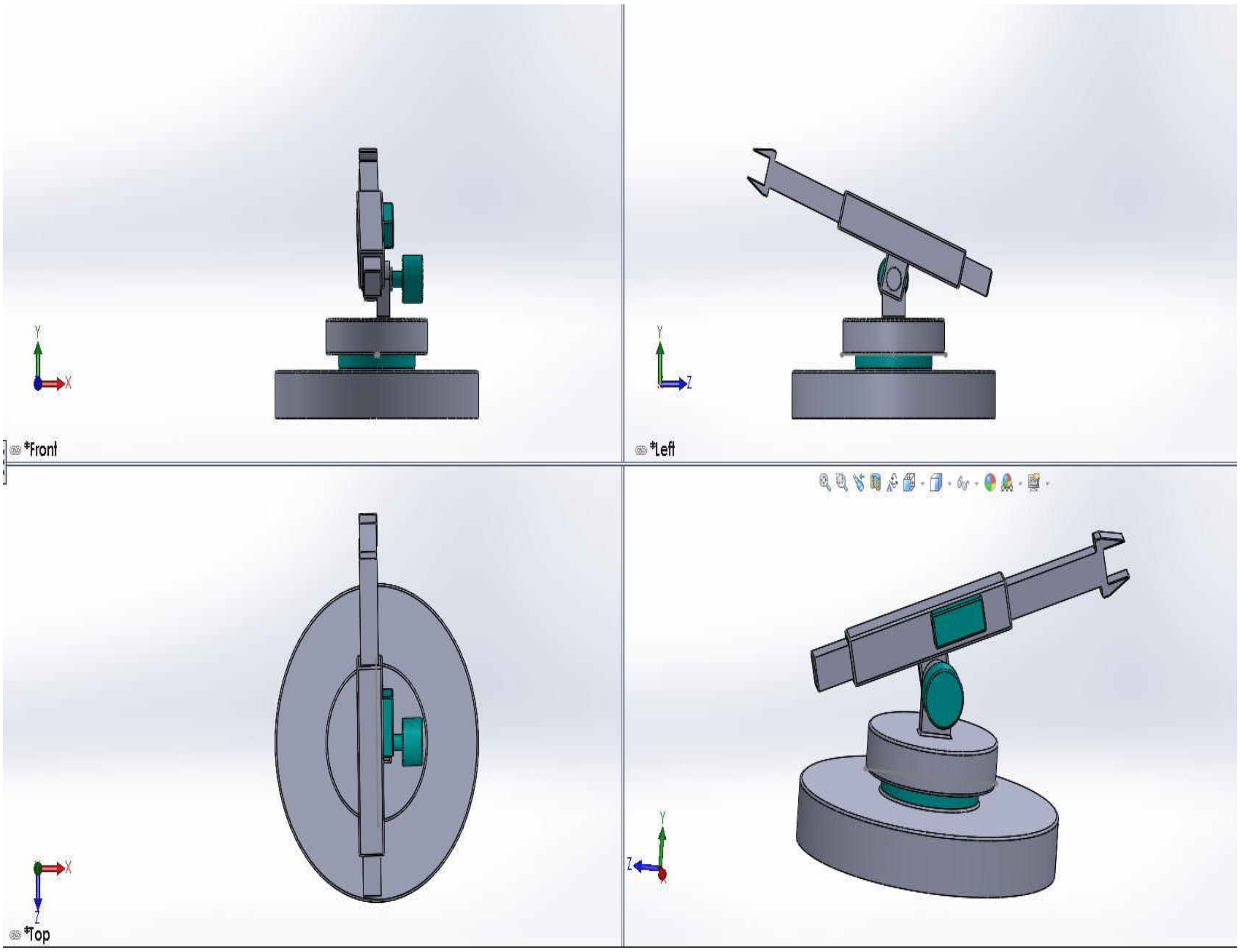


Fig.3. Spherical robots

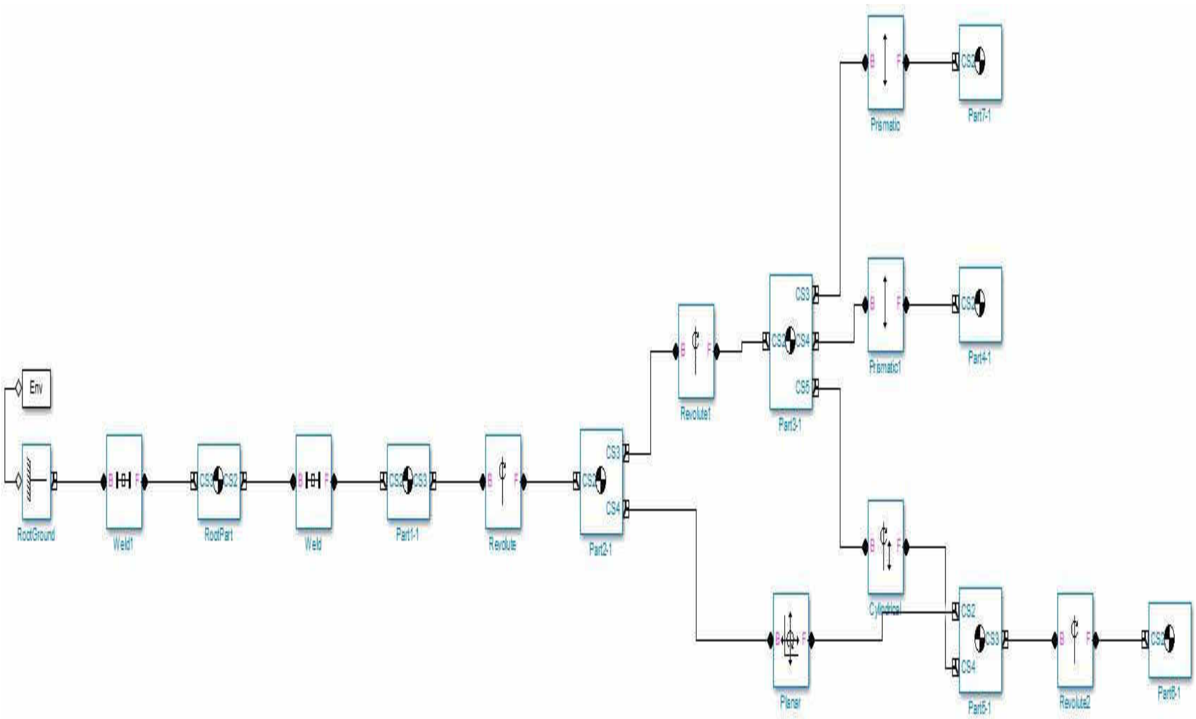
DATA SHEET:

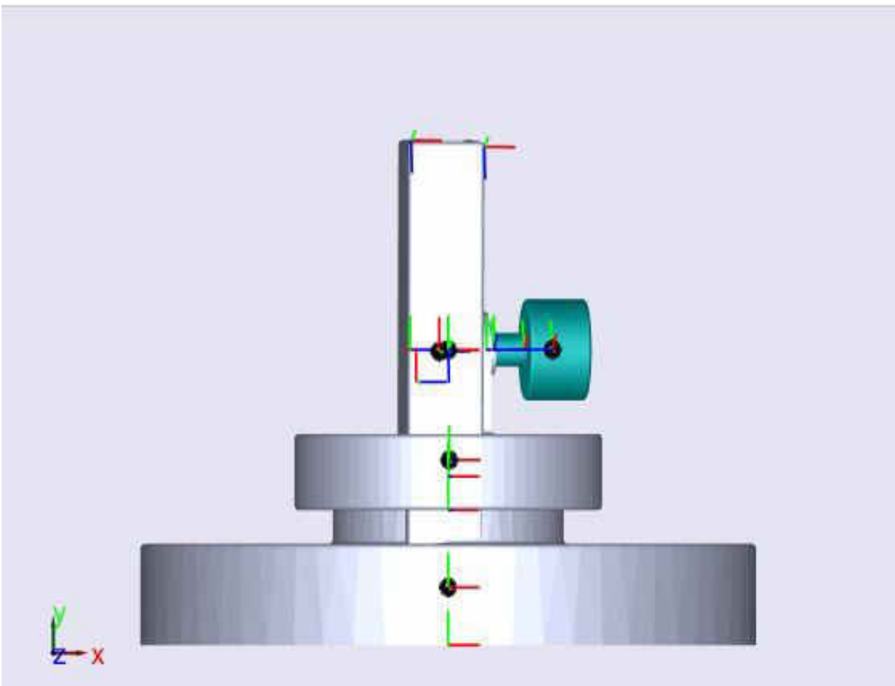
NAME - SPHERICAL ROBOTS

PARAMETERS	DIMENSIONS
Fixed Base	Diameter = 400 mm
	Extruded value = 150 mm
Link1	Diameter = 200 mm
	Extruded value = 45 mm
	Connecting member = 45*90*25 mm
	Hole diameter = 20 mm
Link 2	Top member = 250*50*7.5 mm
	Square shaped hole = 35*35 mm
	Bottom member = 45*100*25 mm
	Hole diameter = 20 mm
Link 3	35*450*35
Screw	Shank diameter = 20 mm
	Head diameter = 30 mm
Provision for motor	150 mm
Work-envelope	Spherical or near spherical
Work volume	Moves 600 mm linearly from base centre and twists with base at 360^{o}
	Link 2 rotates 60^{o} vertically

Angle of twist	360^{o}
Angle of rotation	60^{o}

RESULTS OF INTERFACING SOLIDWORKS WITH MATLAB:





ADVANTAGES OF SPHERICAL ROBOTS:

There are many advantages to a spherical robot design. First of all, they are very maneuverable. They can move in any direction. This increases the options for navigating around objects and prevents the robot from getting stuck in corners. Traditional wheeled robots have the ability to be rendered useless if they land upside-down. This is not the case with a spherical robot. Stairs and ledges are also a problem for traditional robots, and a spherical robot can overcome these conditions very well. This feature also allows them to be thrown or dropped. They have a great capability to recover from collisions with obstacles. The sensors, electronics, and mechanisms are all protected. This would be useful in a swarm application.

DISADVANTAGES OF SPHERICAL ROBOTS:

Spherical robots cannot be overturned.

RESULT:

Thus, the spherical configurations of robot were modeled and simulated using Solidworks & Matlab.

MODELING & SIMULATION OF SCARA ROBOT CONFIGURATION

AIM:

To model and simulate the SCARA configuration of robots using Matlab.

INTRODUCTION:

SCARA Stands for **S**elective **C**ompliance **A**ssembly **R**obot **A**rm. It has at least two Parallel revolute joints and having one Linear joint for the position of the wrist. But for SCARA all three joint axes are Vertical.

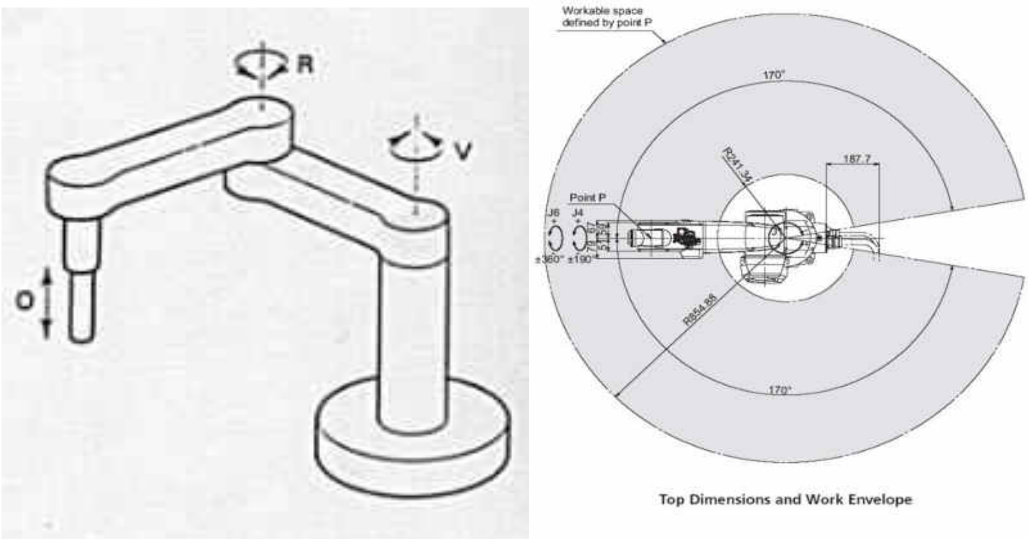


Fig.1.SCARA robot configuration

By virtue of the SCARA's parallel-axis joint layout, the arm is slightly compliant in the X-Y direction but rigid in the ‘Z’ direction, hence the term: Selective Compliant. This is advantageous for many types of assembly operations, i.e., inserting a round pin in a round hole without binding. The second attribute of the SCARA is the jointed two-link arm layout similar to our human arms, hence the often-used term, Articulated. This feature allows the arm to extend into confined areas and then retract or “fold up” out of the way. This is advantageous for transferring parts from one cell to another or for loading/ unloading process stations that are enclosed.

PROCEDURE:

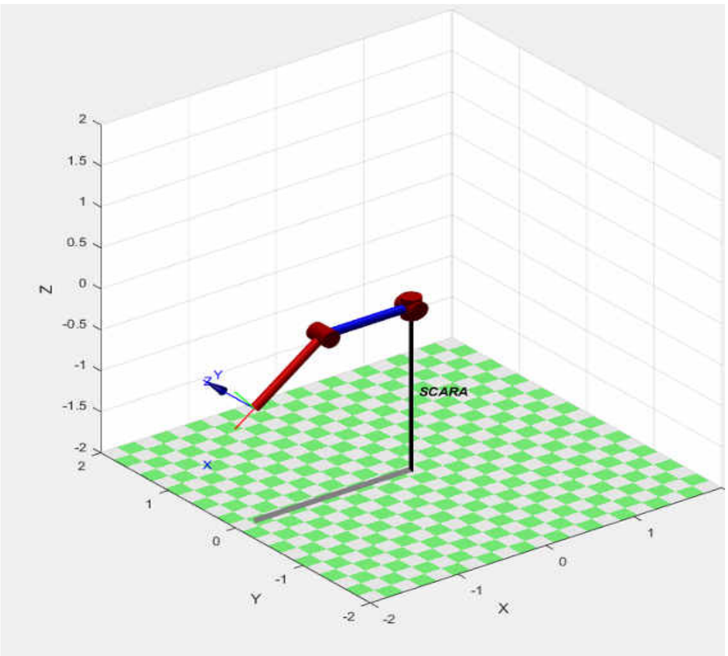
MATLAB is a powerful environment for linear algebra and graphical presentation that is available on a very wide range of computer platforms. The core functionality can be extended by application specific toolboxes. The Robotics Toolbox provides many functions that are required in robotics and addresses areas such as kinematics, dynamics, and trajectory generation. The Toolbox is useful for simulation as well as analyzing results from experiments with real robots, and can be a powerful tool for education.

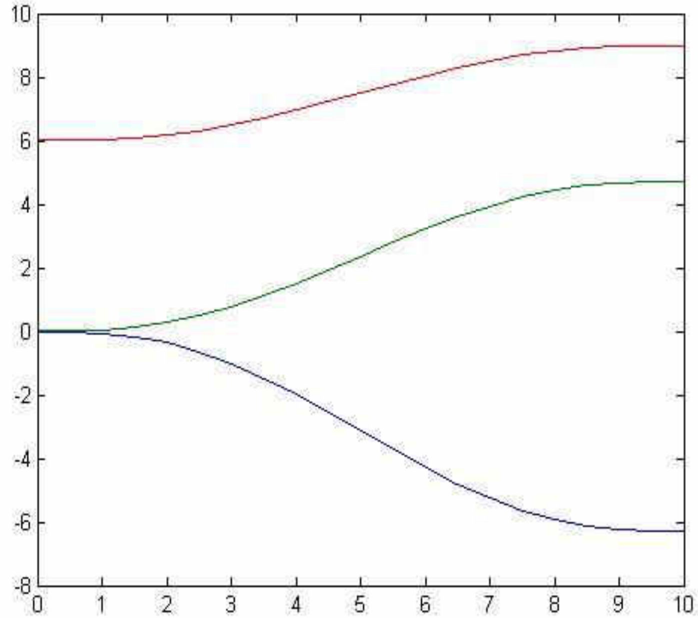
S.no	Symbol	Description
1	α	Link twist angle (rad)
2	a	Link length
3	θ	Joint angle (rad)
4	d	Link offset
5	σ	Joint type; 0 for revolute, non-zero for prismatic

MATLAB CODE:

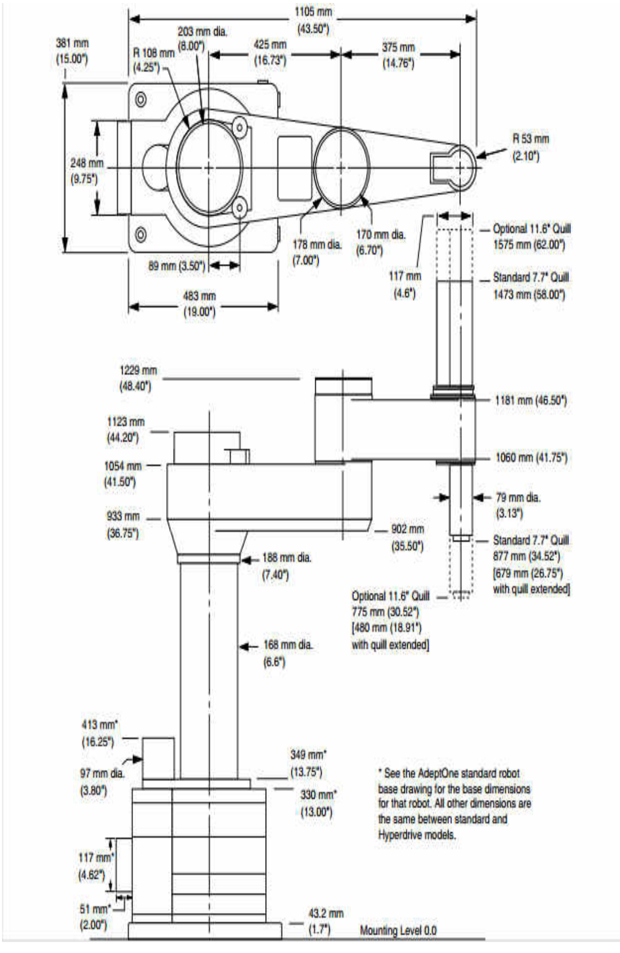
```
function scara
l1=Revolute('d', 0, 'a', 0, 'alpha', pi/2);
l2=Link([0 0 1 0]);
l3=Link([0 0 1 0]);
scara=SerialLink([l1 l2 l3],'name','SCARA');
q=[1:1:100];
q1=[0,0,0];
q2=[-pi,0,0];
traj=jtraj(q1,q2,q);
scara.plot(traj);
q=[1:1:100];
q1=[-pi,0,0];
q2=[-pi,0,-pi/2];
traj=jtraj(q1,q2,q);
scara.plot(traj);
```

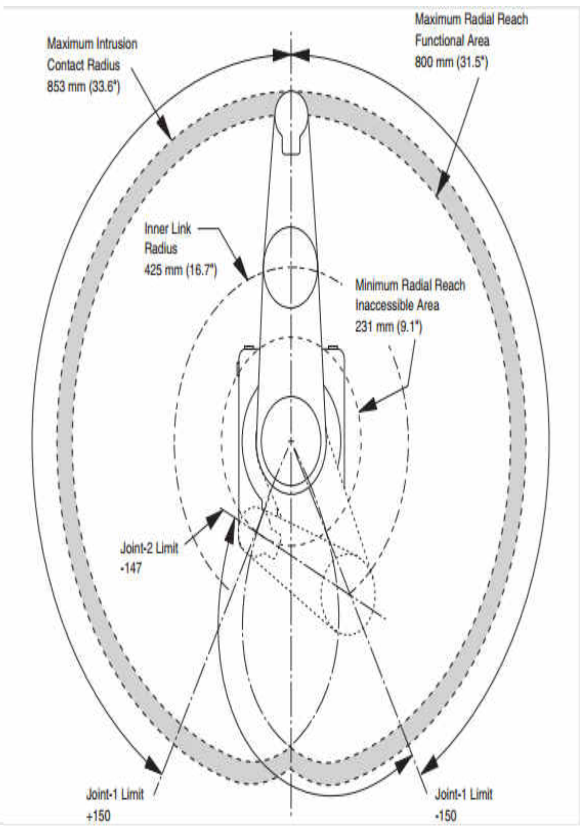
SIMULATION OUTPUT:




10
8
6
4
2
0
-2
-4
-6
-8
0
1
2
3
4
5
6
7
8
9
10

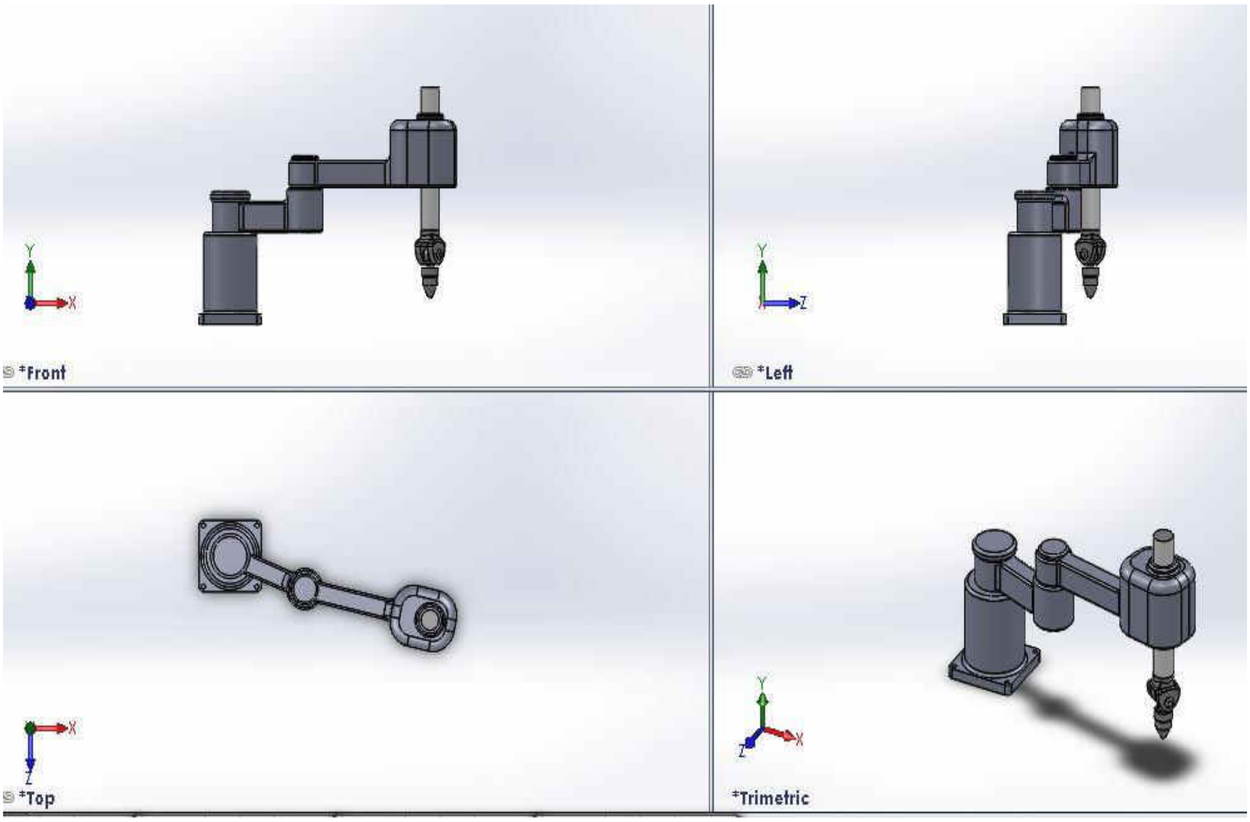
DATA SHEET:


1105 mm
(43.50")
381 mm
(15.00")
203 mm dia.
(8.00")
R 108 mm
(4.25")
425 mm
(16.73")
375 mm
(14.76")
R 53 mm
(2.10")
248 mm
(9.75")
178 mm dia.
(7.00")
170 mm dia.
(6.70")
89 mm (3.50")
483 mm
(19.00")
117 mm
(4.6")
Optional 11.6" Quill
1575 mm (62.00")
Standard 7.7" Quill
1473 mm (58.00")
1229 mm
(48.40")
1181 mm (46.50")
1123 mm
(44.20")
1060 mm (41.75")
1054 mm
(41.50")
79 mm dia.
(3.13")
933 mm
(36.75")
902 mm
(35.50")
Standard 7.7" Quill
877 mm (34.52")
[679 mm (26.75")
with quill extended]
188 mm dia.
(7.40")
Optional 11.6" Quill
775 mm (30.52")
[480 mm (18.91")
with quill extended]
168 mm dia.
(6.6")
413 mm*
(16.25")
349 mm*
(13.75")
97 mm dia.
(3.80")
330 mm*
(13.00")
* See the AdeptOne standard robot base drawing for the base dimensions for that robot. All other dimensions are the same between standard and Hyperdrive models.
117 mm*
(4.62")
51 mm*
(2.00")
43.2 mm
(1.7")
Mounting Level 0.0


Maximum Intrusion
Contact Radius
853 mm (33.6")
Maximum Radial Reach
Functional Area
800 mm (31.5")
Inner Link
Radius
425 mm (16.7")
Minimum Radial Reach
Inaccessible Area
231 mm (9.1")
Joint-2 Limit
-147
Joint-1 Limit
+150
Joint-1 Limit
-150

ITEM		SPECIFICATION	
MODEL		**ADEPT ONE**	**OMRON ADEPT 800**
TYPE		SCARA	
REACH		800 mm	800 mm
PAYLOAD MAX		9.1 Kg	9.1 Kg
MOMENT OF INERTIA		3000 $Kg\text{-}cm^2$	450 $Kg\text{-}cm^2$
JOINT RANGES	JOINT 1	$\pm 150^{\circ}$	$\pm 105^{\circ}$
	JOINT 2	$\pm 147^{\circ}$	$\pm 157.5^{\circ}$
	JOINT 3	195 mm	210 mm
	JOINT 4	$\pm 277^{\circ}$	$\pm 360^{\circ}$
JOINT SPEED	JOINT 1	540°/ Sec	386°/ Sec
	JOINT 2	540°/ Sec	720°/ Sec
	JOINT 3	500 mm/Sec	1100 mm/Sec
	JOINT 4	3600°/ Sec	1200°/ Sec
REPEATABILITY	XY	± 0.025 mm	± 0.017 mm
	Z	± 0.050 mm	± 0.003 mm
	THETA	$\pm 0.05^{\circ}$	$\pm 0.019^{\circ}$
DIGITAL I/O	INPUT	12	12
	OUTPUT	8	8
ENVIROINMENT REQUIRED	TEMPERATURE	$5 - 40^{\circ}C$	$5 - 40^{\circ}C$
	HUMIDITY	5 – 90%	5 – 90%
POWER REQUIREMENT	AC	200-240 V; 8.5 A	200-240 V; 10 A
	DC	24 V; 5A	24 V; 5A

SOLIDWORKS MODEL:



ADVANTAGES OF SCARA ROBOTS:

- SCARAs are generally faster and cleaner than comparable Cartesian robot systems.
- Their single pedestal mount requires a small footprint and provides an easy, unhindered form of mounting.
- Best suited for point-to-point movements – pick and place, assembly, and packaging applications.
- It offers 6-axes of movement and more flexibility.
- The limited, compact structure of SCARA is often preferred for small spaces and parts.

DISADVANTAGES OF SCARA ROBOTS:

- SCARAs can be more expensive than comparable Cartesian systems
- Controlling software requires inverse kinematics for linear interpolated moves.
- SCARA robots are based on serial architectures that the first motor should carry all other motors

RESULT:

Thus the SCARA configurations of robot were modeled and simulated using Solidworks & Matlab.

MODELING & SIMULATION OF CARTESIAN ROBOT CONFIGURATION

AIM:

To model and simulate the Cartesian configuration of robots using Matlab.

INTRODUCTION:

A Cartesian coordinate robot also called linear robot is an industrial robot whose three principal axis of control are linear (i.e. they move in a straight line rather than rotate) and are at right angles to each other. The three sliding joints correspond to moving the wrist up-down, in-out, back-forth. Among other advantages, this mechanical arrangement simplifies the Robot control arm solution. Cartesian coordinate robots with the horizontal member supported at both ends are sometimes called Gantry robots. They are often quite large.

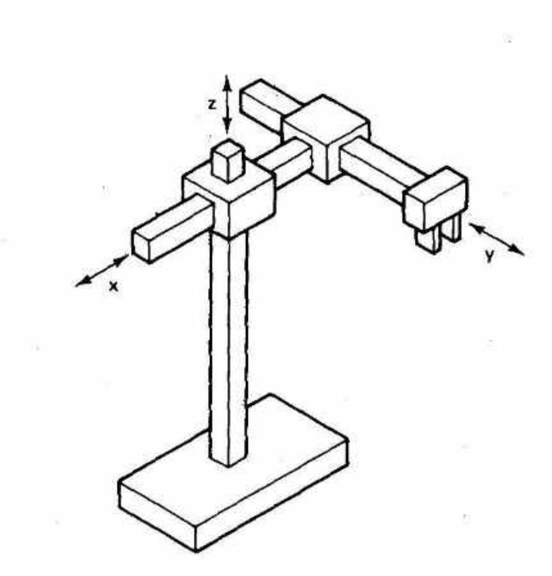


Fig.1. Cartesian robot configuration

The Cartesian robots structure is seen in fig1. Cartesian robots have three linear joints that use the Cartesian coordinate system (X, Y, and Z). They also may have an attached wrist to allow for rotational movement. The three prismatic joints deliver a linear motion along the axis. Payloads and speeds vary based on axis length and support structures. CCRs are also typically very repeatable, have better inherent accuracy than a SCARA or jointed arm, and perform 3D path-dependent motions with relative ease. However, the CCR's key feature is its configurability – the ability you have to configure and size the CCR to best meet your application needs.

A gantry robot is a special type of Cartesian robot whose structure resembles a gantry. This structure is used to minimize deflection along each axis. Many large robots are of this type. The X, Y, and Z coordinates of a gantry robot can be derived using the same set of equations used for the Cartesian robot.

PROCEDURE:

MATLAB is a powerful environment for linear algebra and graphical presentation that is available on a very wide range of computer platforms.

We create a tool for simulating a Cartesian Robot. The MATLAB code for this tool box is given below. Save the below Matlab code as ‘cart.m’ and add it the Matlab programs path.

MATLAB SOURCE CODE:

```
function v = cart
    global p;
    global n;
    global r;
    p = 8;
    n = 180;
    r = p/n;
    v.pram = @pram;
    v.fkine = @fkine;
    v.ikine = @ikine;
    v.rtraj = @rtraj;
    v.otraj = @otraj;
    v.track = @track;
    format compact
    show()
end

function pram(a,b)
    global p;
    global n;
    p = a;
    n = b;
    r = p/n;
    show()
end

function [x,y,z] = fkine(a,b,c)
    global p;
    global n;
    x = (p/n)*a;
    y = (p/n)*b;
```

```
    z = (p/n)*c;
end

function [a,b,c] = ikine(x,y,z)
    global p;
    global n;
    a = x/(p/n);
    b = y/(p/n);
    c = z/(p/n);
end

function show
    global p;
    global n;
    fprintf('\tCartesian Robot Parameters\n')
    fprintf('\t  Lead Screw Pitch = %d \n',p)
    fprintf('\t  Motor steps/rev = %d \n',n)
    fprintf('\t  Resolution = %f \n',p/n)
    fprintf('\t  Work Volume = 1000 x 1000, 600 mm^3\n')
end

function [x,y,z] = rtraj(a,b)
    global r;

    if (a(1)<b(1))
        x = a(1):r:b(1);
    else
        x = sort(b(1):r:a(1),'descend');
    end



    if (a(3)<b(3))
        z = a(3):r:b(3);
    else
        z = sort(b(3):r:a(3),'descend');
    end

    if (a(2)<b(2))
        y = a(2):r:b(2);
    else
        y = sort(b(2):r1:a(2),'descend');
    end
end
```

```
function [x,y,z] = otraj(a,b)
    global r;

    if (a(1)<b(1))
        x = a(1):r:b(1);
    else
        x = sort(b(1):r:a(1),'descend');
    end

    y = (zeros(1,length(a(1):r:b(1))))+a(2);
    z = (zeros(1,length(a(1):r:b(1))))+a(3);

   if (a(2)<b(2))
        y = [y a(2):r:b(2)];
    else
        y = [y sort(b(2):r:a(2),'descend')];
    end

    x = [x ((zeros(1,length(a(2):r:b(2))))+b(1))];
    z = [z ((zeros(1,length(a(2):r:b(2))))+a(3))];

    if (a(3)<b(3))
        z = [z a(3):r:b(3)];
    else
        z = [z sort(b(3):r:a(3),'descend')];
    end

    x = [x ((zeros(1,length(a(3):r:b(3))))+b(1))];
    y = [y ((zeros(1,length(a(3):r:b(3))))+b(2))];

end

function track(x,y,z)
    axis('square')
    grid on
    grid minor
    title('Cartesian Robot Path')
    xlabel('x'); ylabel('y'); zlabel('z')
    h = animatedline;
    axis([0,1000,0,1000,0,1000])
    view(44,12);
    for k = 1:length(x)
```

```
            addpoints(h,x(k),y(k),z(k));
            drawnow
        end
    end
```

FUNCTIONS AVAILABLE:

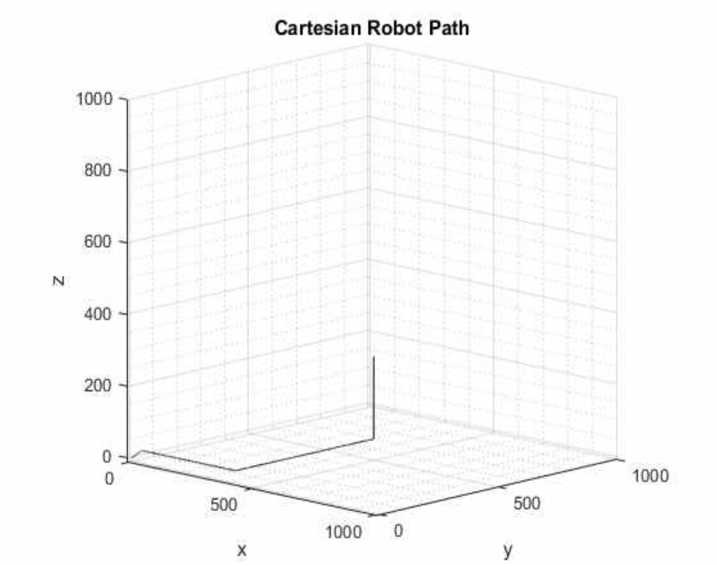
FUNCTION	DESCRIPTION	USAGE
`cart`	This function creates a template of a Cartesian coordinate robot. ‘a’ is an variable which has the details of the robot	a = cart;
`pram`	This function can be used to change the default parameters of the cartesian robot. Use the dot(‘.’) operator to this function. Set the pitch and steps/rev through ‘p’ and ‘n’ respectively.	a.pram(p,n)
`fkine`	This function returns the end position of the robot for a given no of steps given to the robot. x, y, z store the respective coordinates of the end effector. i, j, k are the steps actuated by each actuator.	[x y z] = a.fkine(i,j,k)
`ikine`	This function returns the no of steps taken by each actuator to reach the given position of the end effector.	[i j k] = a.ikine(x,y,z)
`rtraj`	This function gives the trajectory for the shortest path between two points. x, y ,z stores the trajectory points of the corresponding coordinates.[a b c] and [d e f] are the start and end points respectively.	[x y z] = rtraj([a b c],[d e f])
`otraj`	This function gives the trajectory for the orthogonal path between two points. x, y ,z stores the trajectory points of the corresponding coordinates.[a b c] and [d e f] are the start and end points respectively.	[x y z] = otraj([a b c],[d e f])
`track`	This function gives the path traced by the end effector. This function uses the trajectory points obtained by rtraj or otraj function.	a.track(x,y,z)

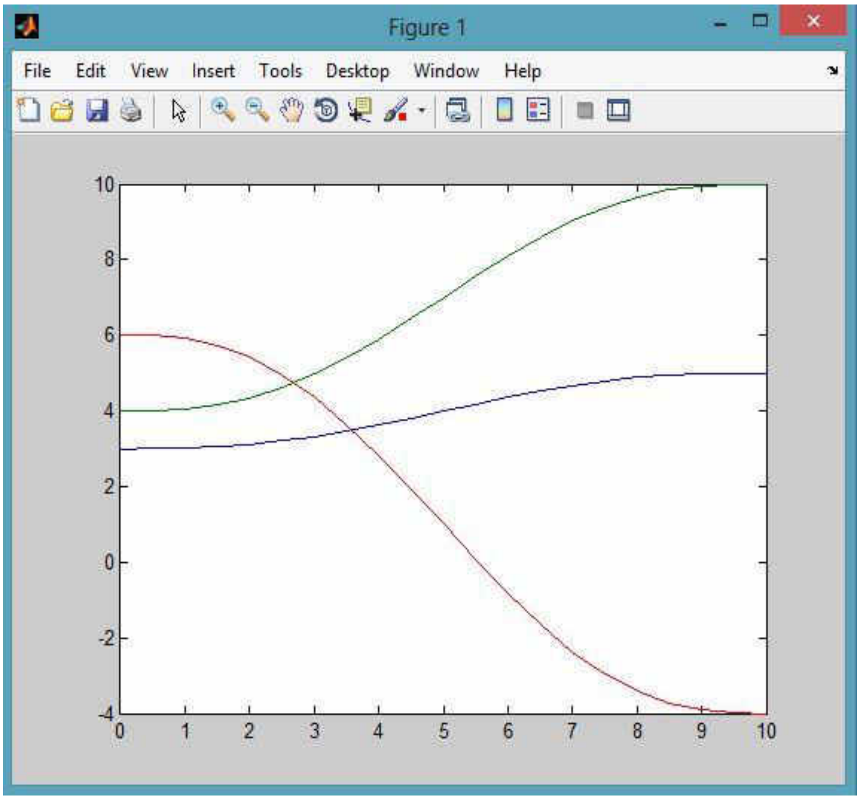
MATLAB CODE:

```
a = cart();                        % create robot
a.pram(10,50);                     % pitch = 10 mm, Steps/rev = 50
[x,y,z] = a.fkine(100,100,100);    % get postion for 100 steps
[q,r,s] = a.rtraj([0 0 0],[x y z]); % trajactory from origin
m = [x,y,z];                       % store postion
n = [400,600,250];                 % store required position
[i,j,k] = a.otraj(m,n);            % get orthogonal trajactory
i = [q i];                         % combine x trajactory
j = [r j];                         % combine y trajactory
```

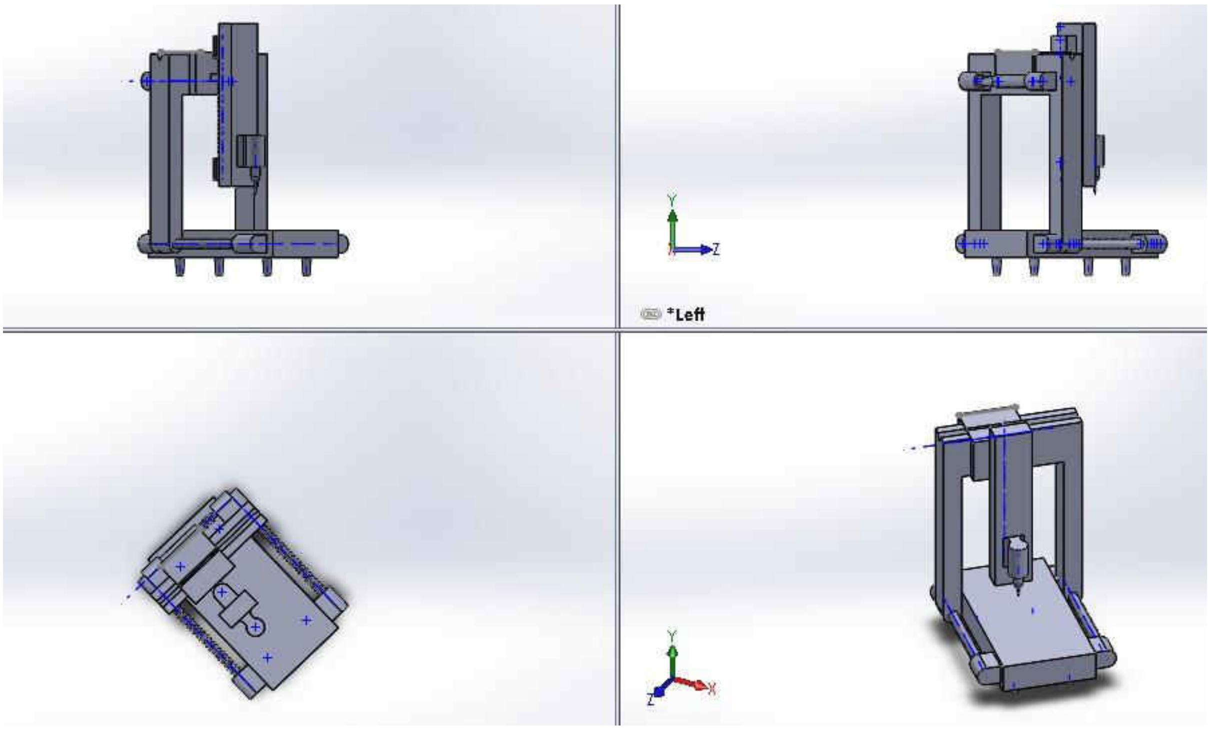
```
k = [s k];                         % combine z trajectory
a.track(i,j,k);                    % plot the end effector's path
```

SIMULATION OUTPUT:

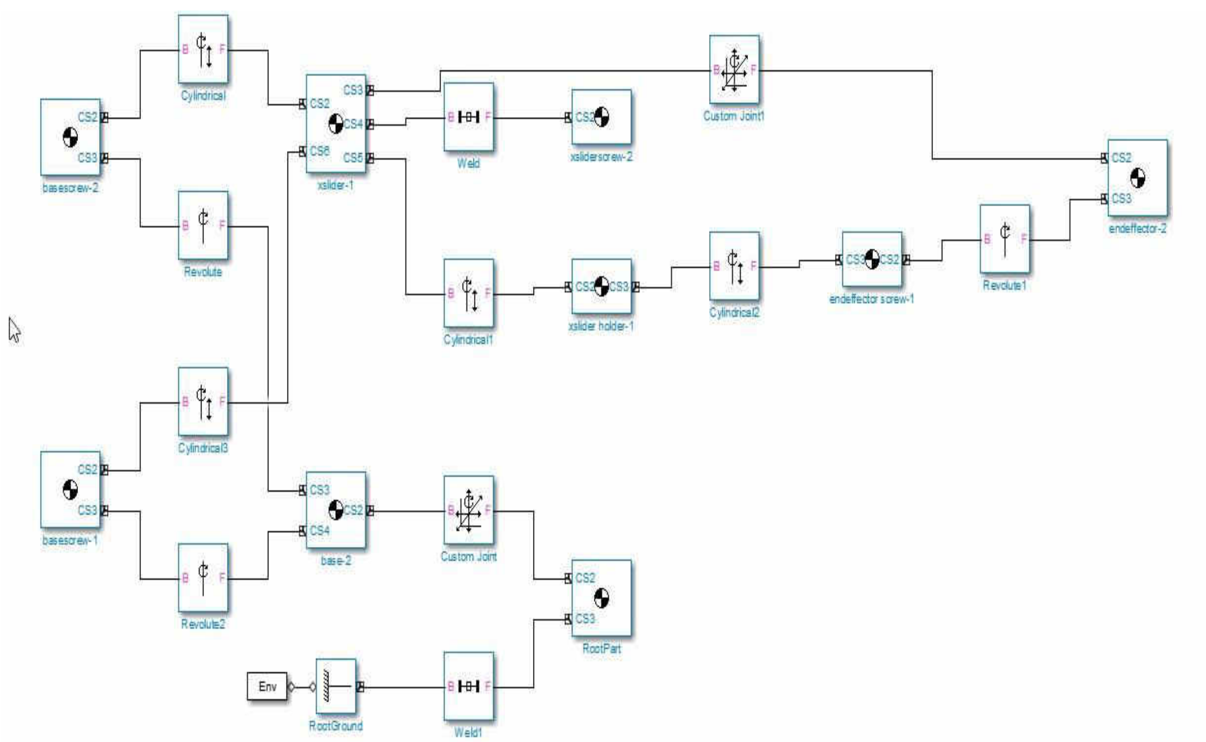


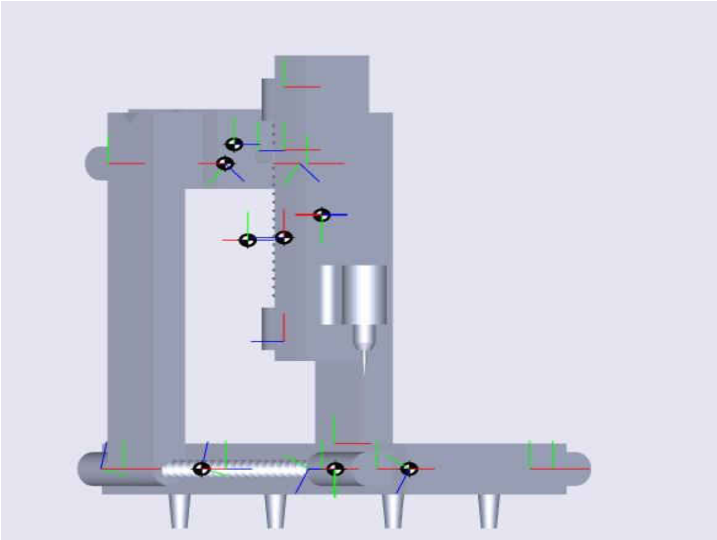


SOLIDWORKS MODEL:



RESULTS OF INTERFACING SOLIDWORKS WITH MATLAB:





ADVANTAGES OF CARTESIAN ROBOTS:

- Can be designed as center-stacked, cantilevered or in a gantry assembly.
- Very versatile.
- Simplifies robot and master control systems.
- Large work envelope.
- High accuracy**.**
- Overhead mounting is possible.

DISADVANTAGES OF CARTESIAN ROBOTS:

- Access to the work envelope by overhead crane or other material-handling equipment may be impaired.
- Maintenance may be difficult.

APPLICATIONS OF CARTESIAN ROBOTS:

- Materials handling.
- Parts handling related to machine loading/unloading supply bins.
- Assembly of small systems.
    - Example: Electronic printed circuit board assembly.

RESULT:

Thus the Cartesian coordinate configurations of robot were modeled and simulated using Solidworks & Matlab.

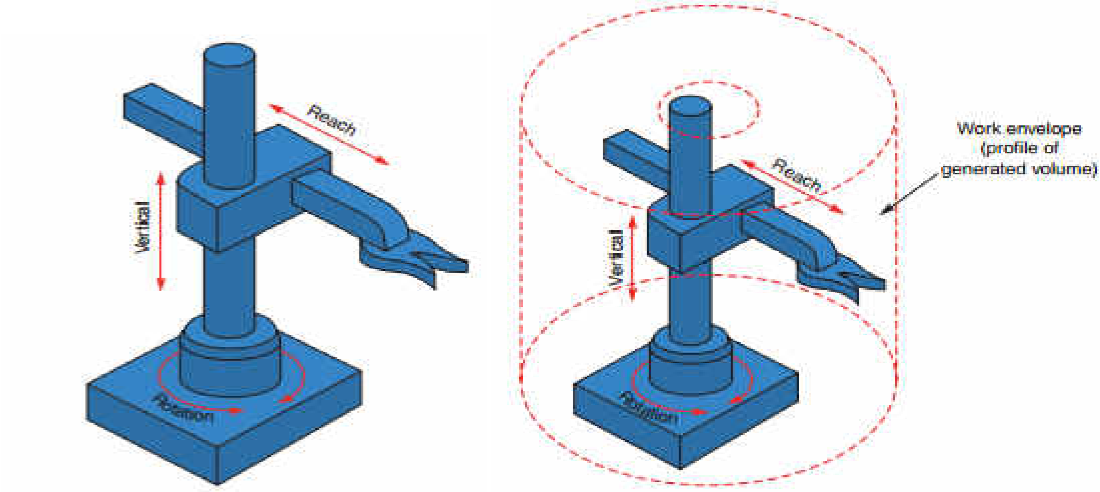
MODELING & SIMULATION OF CYLINDRICAL ROBOT CONFIGURATION

AIM:

To model and simulate the cylindrical configuration of robots using Matlab.

INTRODUCTION:

Cylindrical Configuration A cylindrical configuration consists of two orthogonal slides, placed at a 90° angle, mounted on a rotary axis. Reach is accomplished as the arm of the robot moves in and out. For vertical movement, the carriage moves up and down on a stationary post, or the post can move up and down in the base of the robot. Movement along the three axes traces points on a cylinder, as shown in fig. A cylindrical configuration generally results in a larger work envelope than a Cartesian configuration. These robots are ideally suited for pick-and place operations.



Typical applications for cylindrical configurations include the following: • Machine loading and unloading • Investment casting • Conveyor pallet transfers • Foundry and forging applications.

PROCEDURE:

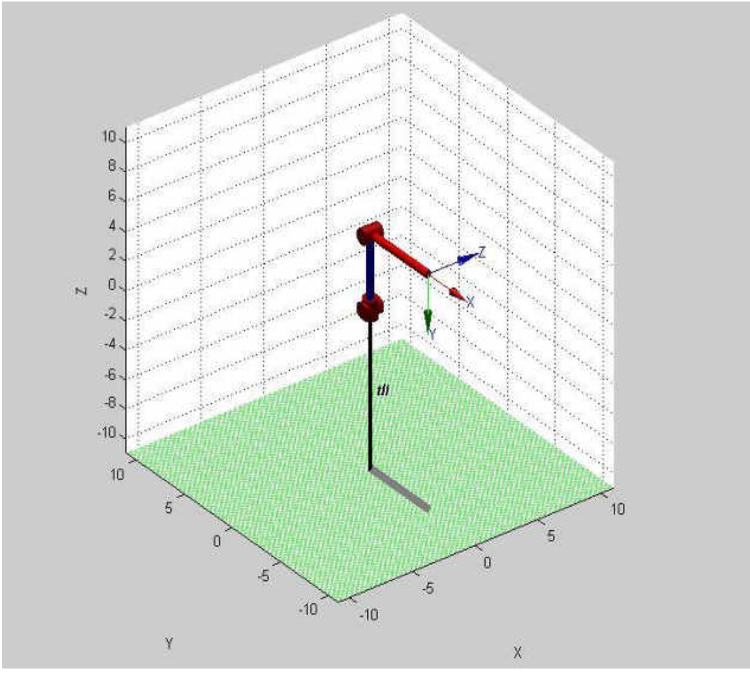
MATLAB is a powerful environment for linear algebra and graphical presentation that is available on a very wide range of computer platforms. The core functionality can be extended by application specific toolboxes. The Robotics Toolbox provides many functions that are required in robotics and addresses areas such as kinematics, dynamics, and trajectory generation. The Toolbox is useful for simulation as well as analyzing results from experiments with real robots, and can be a powerful tool for education.

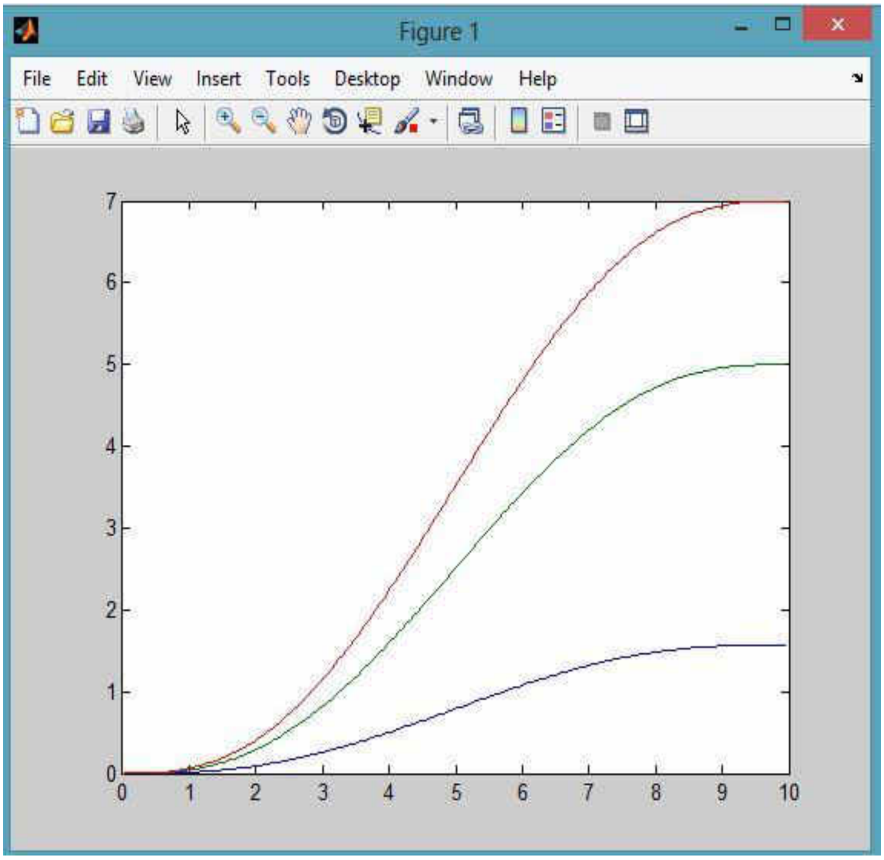
S.no	Symbol	Description
1	α	Link twist angle (rad)
2	a	Link length
3	θ	Joint angle (rad)
4	d	Link offset
5	σ	Joint type; 0 for revolute, non-zero for prismatic

MATLAB CODE:

```
function tll
l1=Link([0 0 0 pi/2]);
l2=Link([0 0 5 0]);
l3=Link([0 0 6 0]);
arm=SerialLink([l1,l2,l3],'name','tll');
q1=[0,0,0];
q2=[pi/2,0,0];
q=(1:1:100);
traj=jtraj(q1,q2,q);
arm.plot(traj)
q1=[pi/2,0,0];
q2=[pi/2,0,pi/4];
q=(1:1:100);
traj=jtraj(q1,q2,q);
arm.plot(traj)
q1=[pi/2,0,pi/4];
q2=[pi/2,pi/2,pi/2];
q=(1:1:100);
traj=jtraj(q1,q2,q);
arm.plot(traj)
```

SIMULATION OUTPUT:





SOLIDWORKS MODEL:

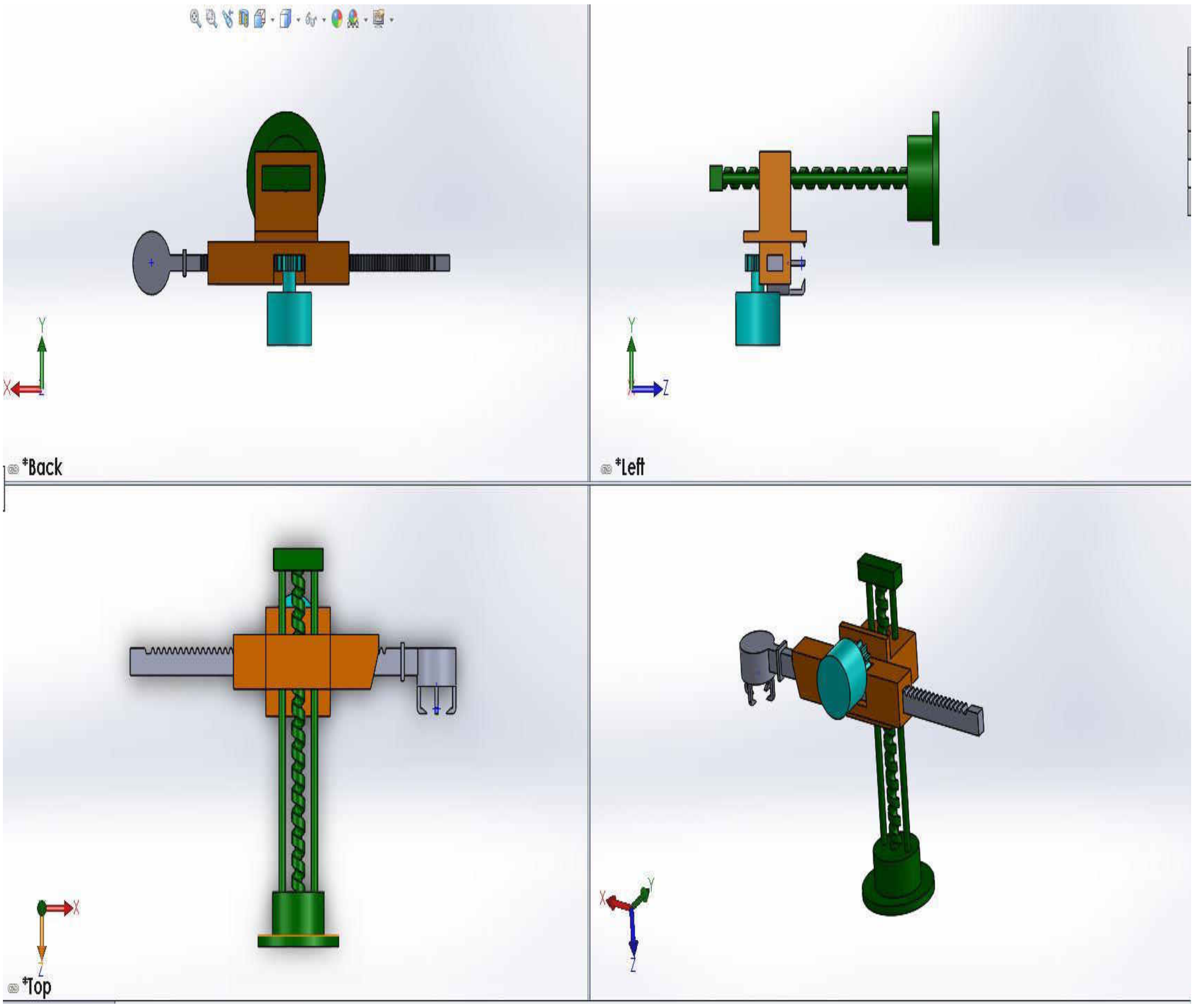


PLATE CRANE EX – CYLINDRICAL ROBO SPECIFICATION:

Plate Capacity: Up to 450 plates without lids or up to 275 plates with lids.

Plate Format: Portrait & Landscape – (Rotary Gripper)

Plate Storage Device: 2 removable stacks (expandable up to 15)

Housing Material: Painted steel covering cast aluminum housing.

Gripper Material: Black anodized aluminum; textured neoprene rubber inserts.

Arm Mechanism: Ball bearing axis with high-speed screw rail; mechanical stops to prevent continuous rotation (345° maximum).

Rotary Travel: 345° ¨

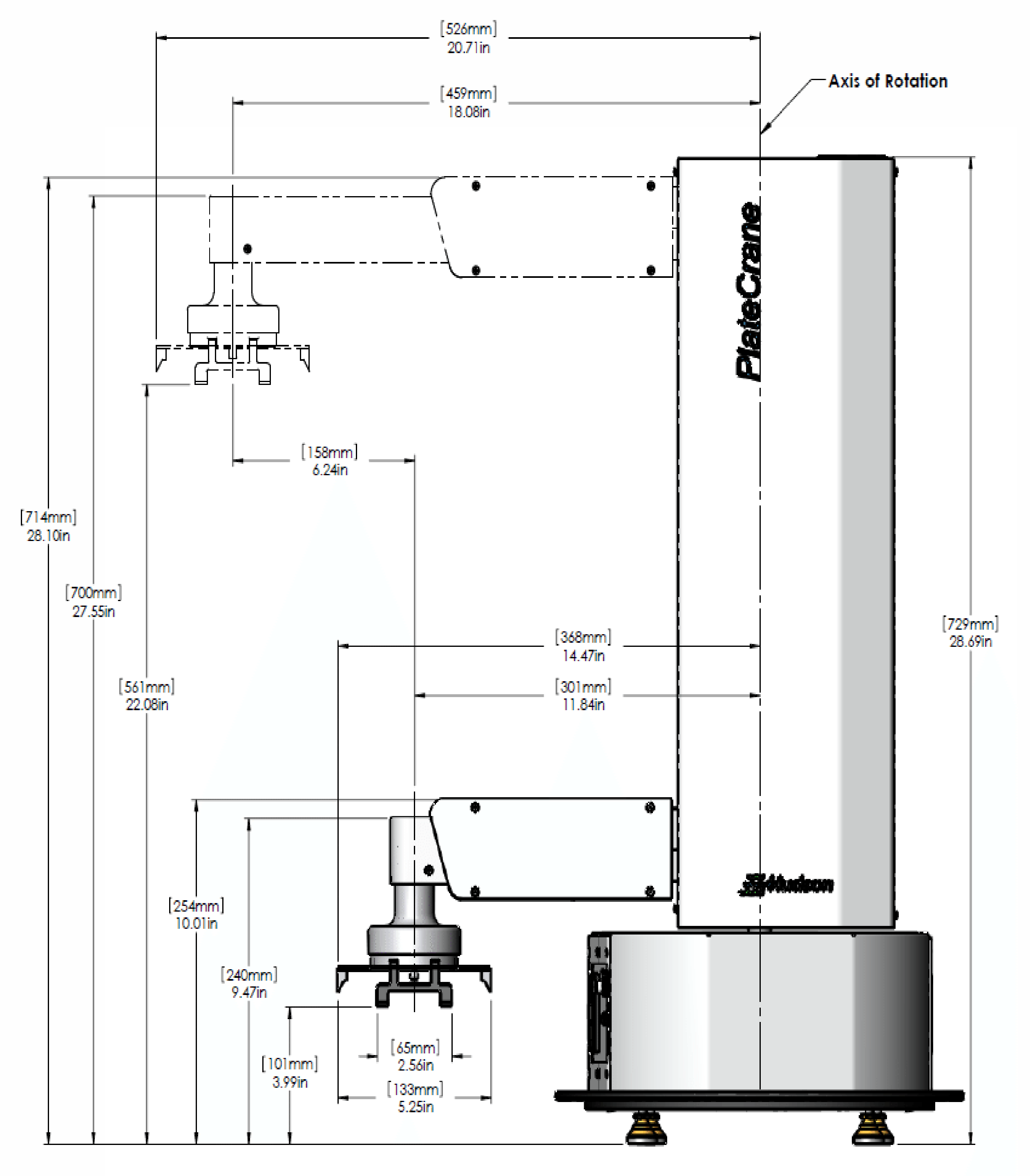
Horizontal Reach: From center of vertical axis: 12″ – 18″ radius

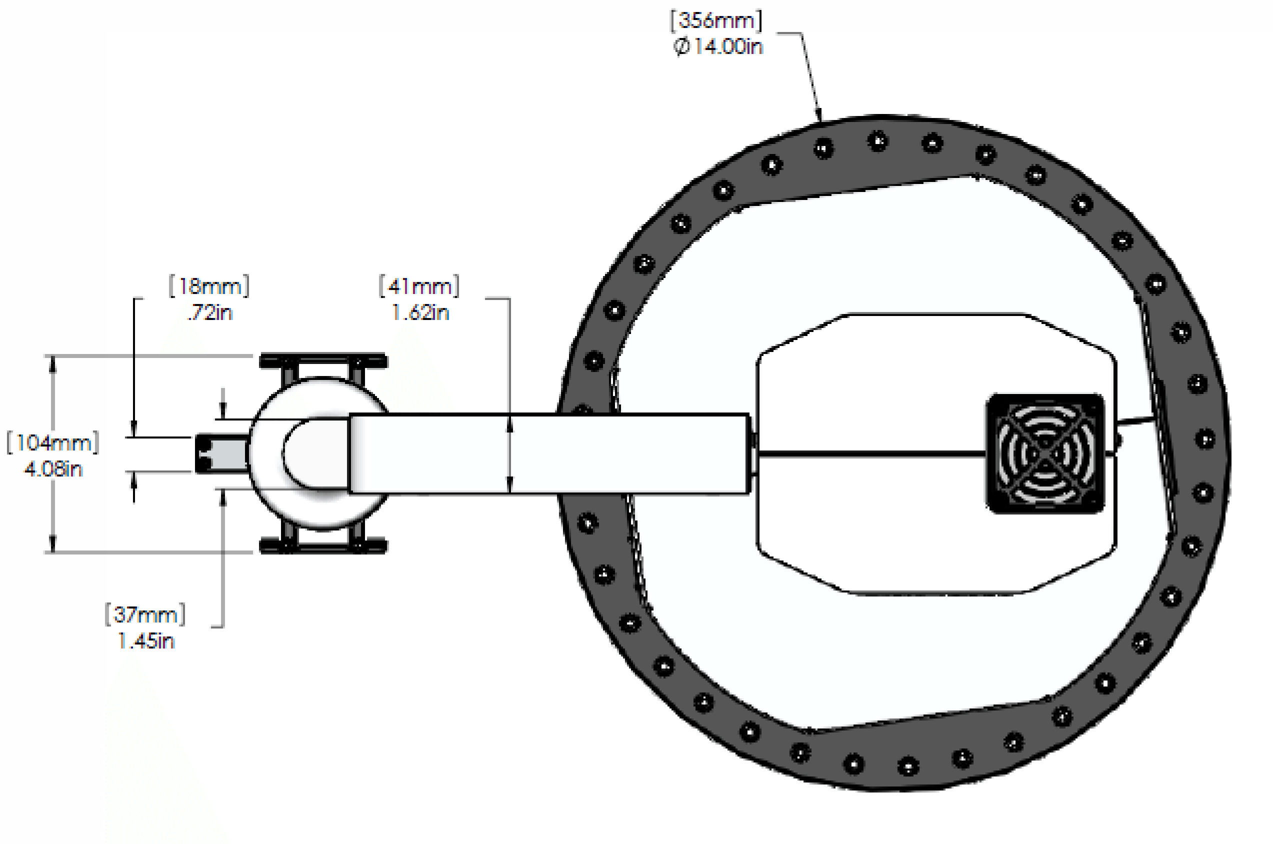
Vertical Reach: Maximum 22.75 in. from table, minimum 4.25 in. from table, total 18.0 in. vertical travel distance.

Size (H x W x D): 27 in. x 19 in. x 27 in.

Weight: about 45 lbs.

Computer Interface: RS-232 serial cable





ADVANTAGES OF SPHERICAL ROBOTS:

A cylindrical configuration generally results in a larger work envelope than a Cartesian configuration. These robots are ideally suited for pick-and place operations.

DISADVANTAGES OF SPHERICAL ROBOTS:

Their overall mechanical rigidity is reduced because robots with a rotary axis must overcome the inertia of the object when rotating. Their repeatability and accuracy is also reduced in the direction of rotary movement. The cylindrical configuration requires a more sophisticated control system than the Cartesian configuration.

RESULT:

Thus, the cylindrical configurations of robot were modeled and simulated using Solidworks & Matlab.