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Kinematic Analysis andSimulation of 6Dof KukaKr5 Robot For Welding Application.

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ABSTRACT
The end-effectors of the manipulator are required to move in a particular fashion to accomplish a specified task. The execution of the specific task requires the manipulator to follow a preplanned path, which is the larger problem of motion or trajectory planning and motion control for the manipulator. The goal of trajectory planning is to describe the requisite motion of the manipulator as a time sequence of joints/link/end-effectors locations and derivatives of locations,in our work we aim to design a serial robot which is suitable for welding application for a curved profiles , where forward kinematics ,inverse kinematics are calculatedand simulation of end effector is done for given joint and link parameters and final work space of arm is identified and graphs related to motion of manipulator as a time sequence of joints ,links are achieved using roboanalyzer software.
***Key words**: end-effector, trajectory, robo-analyzer*

1. LITERATURE SURVEY:

Kinematic analysis of serial robots are discussed in the journals [1] contributors had discussed about the work space, kinematics, dimensions and the type of mechanisms that are held in kuka robot. The analysis of the workspace singularities for three-axesPositioning manipulator is given in the work of Angeles[5].In this paper we are presenting the kinematic analysis and link , joint parameters graphs using robo-analyzer.2-D Work space of end effector issimulated.:

Robot welding is a relatively new application of robotics even though robots were first introduced into US industry during the 1960s. The use of robots in welding did not take off until the 1980s, when the automotive industry began using robots extensively for spot welding. Since then, both the number of robots used in industry and the number of their applications has grown greatly. In 2005, more than 120,000 robots were in use in North American industry, about half of them for welding.] Growth is primarily limited by high equipment costs, and the resulting restriction to high-production applications.

Robot arc welding has begun growing quickly just recently, and already it commands about 20% of industrial robot applications. The major components of arc welding robots are the manipulator or the mechanical unit and the controller, which acts as the robot's "brain". The manipulator is what makes the robot move, and the design of these systems can be categorized into several common types, such as the scararobot,Cartesian coordinate robot use different coordinate systems to direct the arms of the machine.

The robot may weld a pre-programmed position, be guided by machine vision, or by a combination of the two methods. in this paper we presented the simulation of a kuka kr5 robot which is used for welding purpose. The work space to be welded or the trajectory planning of a robot for welding a speciedwork space and also presented graphs regarding the velocities, accelerations and forces of the links and joints and their variations are also presented. The Schematic diagram of a welding to welded by robot is as follows

2.INTRODUCTION:

The motion subsystem is the physical structure of the robot that carries out a desired motion similar to human arms as illustrated below. The elements of the motion subsystem are Manipulator,end effector:

Manipulator is the physical structure which moves around. It comprises of links and joints normally connected in series. Each link is made of steel or aluminum. Other materials can also be used depending on the Requirements. The joints are generally rotary or translator types. In the study of the robotics and mechanisms these joints are referred as revolute and prismatic joints. A robot manipulator has three parts mainly arm, wrist and the hand. The function of the arm is to place an object in a certain location in the three dimensional Cartesian space, where the wrsit orients it. For 6 DOF robots the first three links and joints form the arm and the last three mutually in intersecting joints made a wrist

Endeffector is a part attached at the end of the manipulator and so it is named. This is equivalent to the human hand. An end effector could be mechanical hand that manipulates an object or holds it before they are moved by the robot arm. Also specialized tools like the welding electrode, a gas cutting torch attached to the end of the manipulator arm for performing tasks are also considered. as end-effectors

3.DENAVIT AND HARTENBERG (DH) PARAMETERS:

The DenavitHartenberg parameters(also called DH parameters) are the four parameters associated with a particular convention for attaching reference frames to the links of a spatial kinematic chain, or robot manipulator
1) Joint offset(b): length of intersections of common normal on joint axis

2) Joint angle (θ): angle between the orthogonal projections of te common normal to the plane normal to the joint axes.

3) Link length (a): measured as the distance between the common normals to the axis.

4) Twist angle (α): the angle between the orthogonal projections of the joint axes onto a plane normal to the common normal.

so for the given type of joint i.e. revolute or prismatic one of the DH parameters is variable which is called the joint variable, whereas the other three remaining parameters are constant and are called link parameters

4. Forward Kinematics

Forward kinematics is the mathematics behind the process of taking joint angles and specified link lengths and calculating the position of the end effector in the universe frame. To calculate the position of the end effector in the universe frame a series of matrix calculations must be performed that find the position of the end effector relative to each robotic joint. The universe coordinate frame (frame U) is considered to be non-moving and to be located concurrent with the Joint 1 frame which is at the shoulder of the robot. In our robot design joints one and two are also coincident with one another. Although joint two is coincident to joint one, its frame is negatively rotated by 90degrees about the x-axis. The matrix that describes the position and orientation of joint 1 in universe is designated as "T1toU." Similarly, joint two's rotation and translation into the joint 1 frame is T2to1.

To get to Joint three's frame in the universe frame a translation was made along the x-axis and z-axis, known as T3to2. Once all the rotations and translations have been placed in a 4X4 matrix for each joint, they are then multiplied together in the following order:
Toolin U=T1toU*T2to1*T3to2
This series of matrix multiplications gives the position and orientation of the end-effector (the tool) in the universe frame. Each rotational joint has a specific "joint angle" which is the angle of rotation of the joint axis from its home position. Each joint angle is designated using the Greek letter θ followed by the joint number.DH formula for calculating forward kinematics:

$$\begin{bmatrix} \cos\theta_i & -\cos\alpha_i\cdot\sin\theta_i & \sin\alpha_i\cdot\sin\theta_i & a_i\cdot\cos\theta_i \\ \sin\theta_i & \cos\alpha_i\cdot\cos\theta_i & -\sin\alpha_i\cdot\cos\theta_i & a_i\cdot\sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

4.1 Forward position analysis

In the forward or direct kinematics for positions, the joint positions of the revolute joints and the displacement of the prismatic joints are prescribed. The task is to find the end effectors pose i.e. its position and orientation from yhr closure equations as explained in the following steps:

According to the rules attach a coordinate frame to each of the n + 1 links of the robot with frame1 being attached to the fixed frame, and frame n+1 to the end effectors or the nth body
Define the Denavit and Hartenberg parameters as presented.
Write the homogenous transformation matrices for i= 1… n, represents the transformation of the body i or frame i+1 with respect to its previous body i-1 or the frame attached to it i.e. frame i
The homogeneous transformation matrix of the end effector frame with respect to frame1 i.e. is now obtained by post-multiplication of the above individual homogeneous transformation Ti, for i=1…..n.
Q= Q1Q2……Qn

P=a1+Q1a2+…….+Qn-1an

Q=orientation of the end effector with respect to the fixed frame
P=position of the origin of the frame attached to the end effector

5. Inverse Kinematic analysis:

The reverse process that computes the joint parameters that achieve a specified position of the end effector is known as inverse kinematics. Inverse kinematics refers to the use of the kinematics equations of a robot to determine the joint parameters that provide a desired position of the end-effector.[1] Specification of the movement of a robot so that its end-effector achieves a desired task is known as motion planning. Inverse kinematics transforms the motion plan into joint actuator trajectories for the robot. The movement of a kinematic chain whether it

is a robot or an animated character is modeled by the kinematics equations of the chain. These equations define the configuration of the chain in terms of its joint parameters. Forward kinematics uses the joint parameters to compute the configuration of the chain, and inverse kinematics reverses this calculation to determine the joint parameters that achieves a desired configuration. For example, inverse kinematics formulas allow calculation of the joint parameters that position a robot arm to pick up a part. Similar formulas determine the positions of the skeleton of an animated character that is to move in a particular way.
To know the end effector of the kuka robot not only by using the theoretical methods but also by using robo- analyzer we can analyze and get the end effector position as well as work space of the kuka robot. The DH parameters of the kuka robot.

GENERAL MODEL OF KUKA ROBOT KR5:

COURTESY FROM: Visual servoing on unknown objects[3

6.kinematic analysisof kukarobot

The DH parameters of a kuka robot at initial stage as follows:

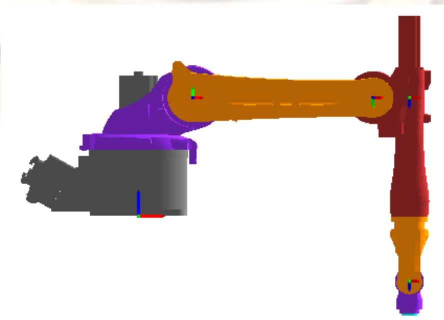
D-H Parameters

Robot
Select DOF: 6
Select Robot: KUKA KI
OK

Joint No	Joint Type	Joint Offset (b) mm	Joint Angle (theta) deg	Link Length (a) mm	Twist Angle (alpha) deg	Initial Value (JV) deg or mm	Final Value (JV) deg or mm
1	Revolute	400	Variable	180	90	0	60
2	Revolute	135	Variable	600	180	0	60
3	Revolute	135	Variable	120	-90	0	60
4	Revolute	620	Variable	0	90	0	60
5	Revolute	0	Variable	0	-90	0	60
6	Revolute	0	Variable	0	0	0	60

And the KUKA KR5 robot the designed and general model before giving no values is as follows:

FRONT VIEW OF KUKA KR5 ROBOT:



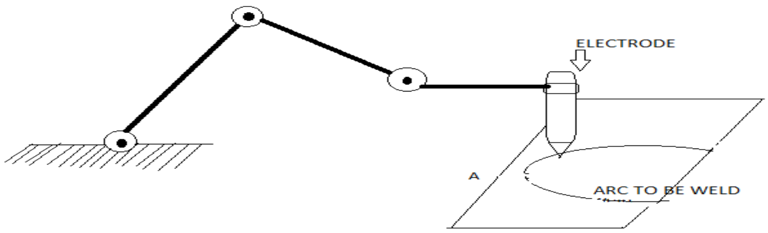
As per our requirements we can give values of link lenth,linktwist,joint parameters.we can get the end effectorpostion as well as the work space to be done by kuka robot.
AND AFTER CHANGING THE VALUES THE DH PARAMETRS,3D MODEL AND GRAPHS OF LINKS AND JOINTS OF THE ROBOT ARE AS FOLLOWS:

D-H Parameters

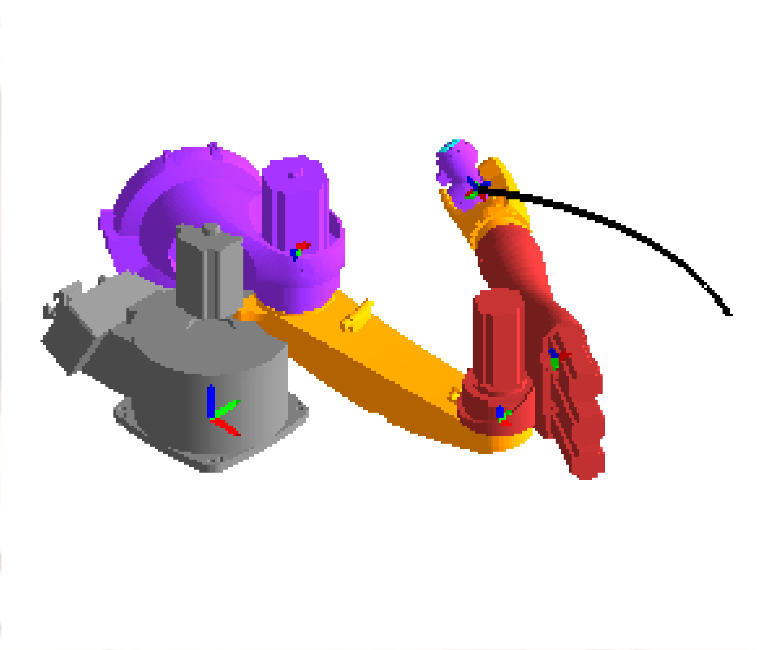
Robot
Select DOF: 6
Select Robot: KUKA KI
OK

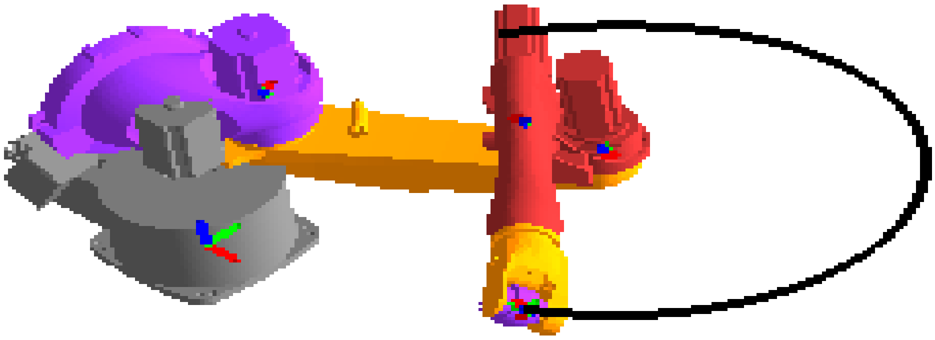
Joint No	Joint Type	Joint Offset (b) mm	Joint Angle (theta) deg	Link Length (a) mm	Twist Angle (alpha) deg	Initial Value (JV) deg or mm	Final Value (JV) deg or mm
1	Revolute	400	Variable	180	180	20	60
2	Revolute	135	Variable	600	180	30	60
3	Revolute	135	Variable	120	-90	0	60
4	Revolute	620	Variable	0	90	45	60
5	Revolute	0	Variable	0	-90	0	60
6	Revolute	0	Variable	0	0	50	60

WELDING PATH :

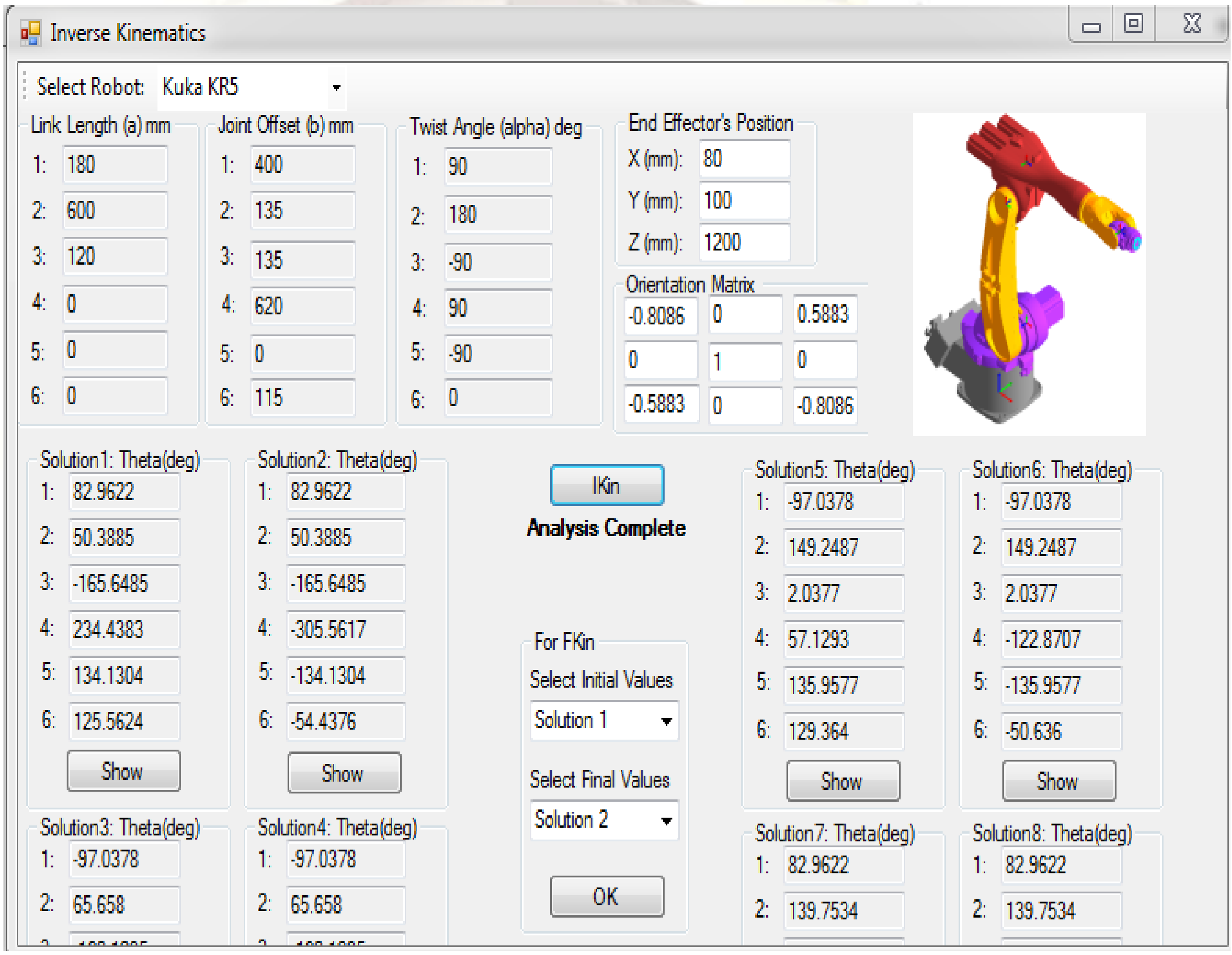


End effector simulation /work space after changing DH parameters forward and inverse kinematics.



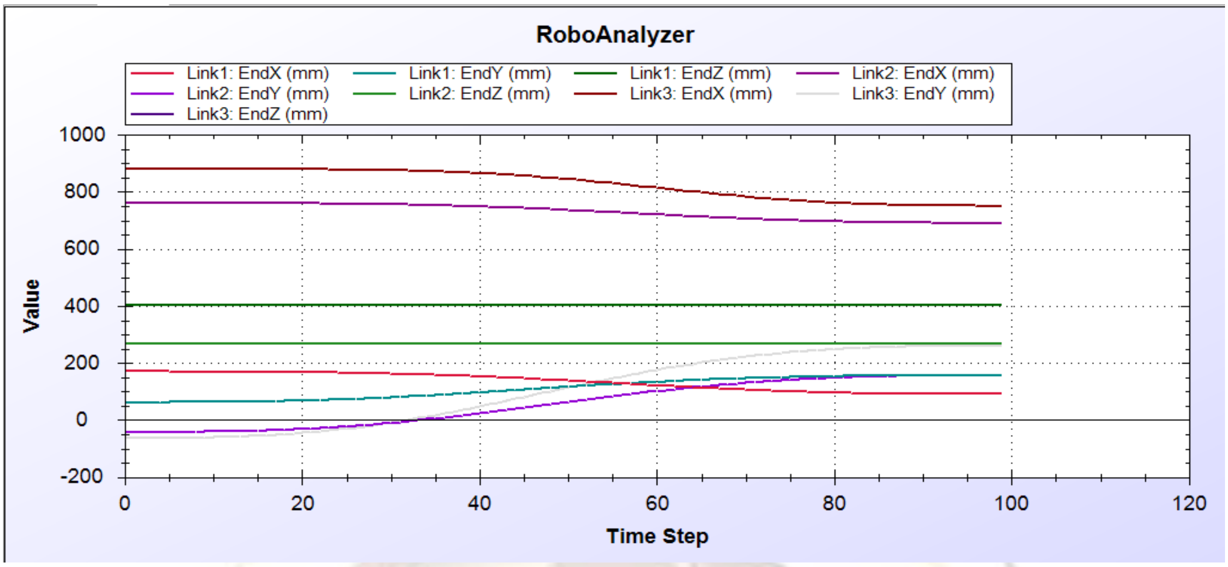


7.INVERSE KINEMATICS:

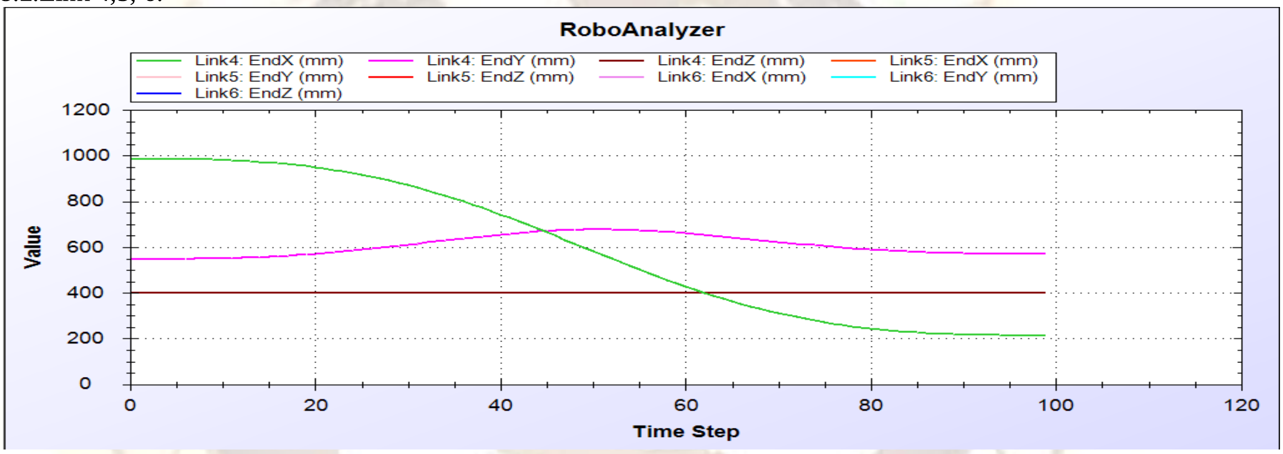


8. GRAPHS REGARDING LINKS OF KUKA KR5 ROBOT AFTER CHANGING DH PARAMETERS ARE AS FOLLOWS:

8.1.LINK 1,2, 3



8.2.Link 4,5, 6.



9.AND LINK CONFIGURATIONS ARE AS FOLLOWS:

LINK1:

0.500004	0.866023	0	90.000716
0.866023	-0.500004	0	155.884159
0	0	-1	400
0	0	0	1

LINK 2:

0.500003	0.866024	0	300.00179
0.866024	-0.500003	0	519.614209
0	0	-1	135
0	0	0	1

LINK 3:

0.500006	0	-0.866022	60.000716
0.866022	0	0.500006	103.922635
0	-1	0	135
0	0	0	1

LINK 4:

0.500001	0	0.866025	0
0.866025	0	-0.500001	0
0	1	0	620
0	0	0	1

:

LINK 5:

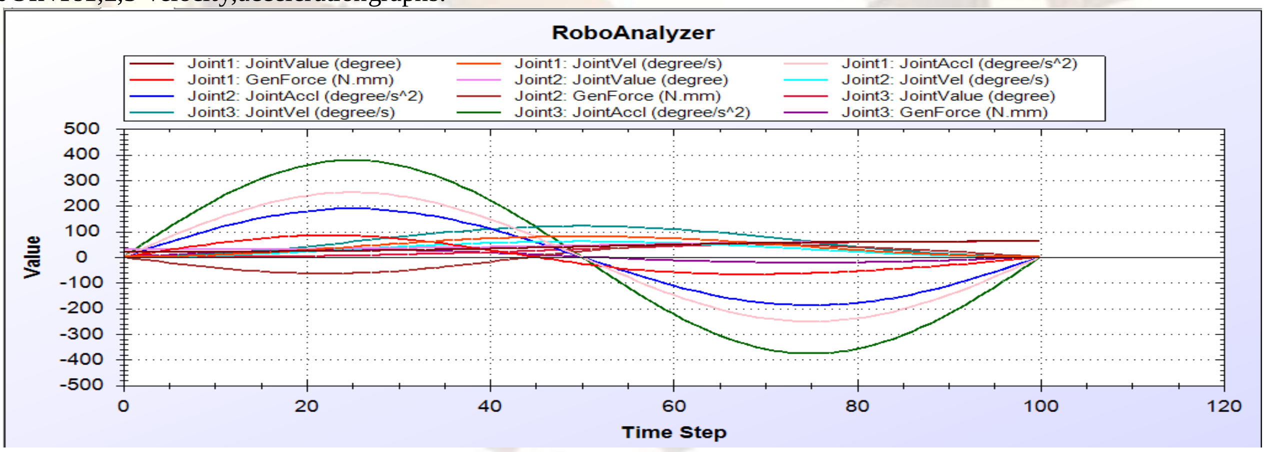
0.500006	0	-0.866022	0
0.866022	0	0.500006	0
0	-1	0	0
0	0	0	1

LINK 6 :

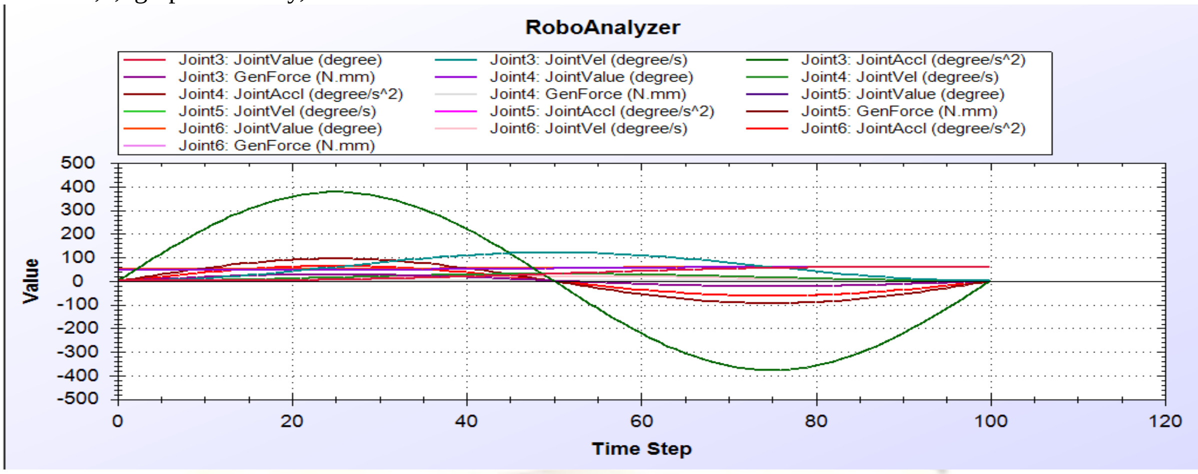
0.500001	-0.866025	0	0
0.866025	0.500001	0	0
0	0	1	0
0	0	0	1

9.1.GRAPHS REGARDING JOINTS OF KUKA ROBOT ARE AS FOLLOWS:

JOINTs1,2,3-velocity,accelerationgraphs:



JOINT:4,5,6graphs-velocity,accelaration.



These graphs give us the details regarding links velocity, acceleration. Whereas the joint graphs give us the info on joint velocity, joint value, joint acceleration and force with torque.

10.CONCLUSION:

The theoretical approach only gives theforward kinematics values and inverse kinematics values.but to find individual velocity,force,torque values of each link and joint it is complicated. By using roboanalyzer we can easily identify velocity acceleration graphs and their values regarding the joints and links and simulation of robot end effector can be done. Proposed serial manipulator is not suitable for medical applications as work volume is large in case of surgical applications limited work volume and effective control of robot is preferred. Serial robot is suitable for welding curved paths.

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