Review on Dynamic Analysis of Articulated Robotic ARM

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Abstract— Articulated robotic arm plays very important role in nuclear power plants. In nuclear reactors, because of nuclear reactions that produce a radiation in reactors which is harmful for humans. To protect workers in highly contaminated areas or hostile environments in nuclear plants, ARA robot can be used in nuclear power plants to reduce human exposure not only to radiation, but also to hot, humid and oxygen-deficient atmosphere. Firstly derive the suitable configuration of articulated robotic arm for applications in nuclear reactors and other uses. Here four configurations are considered of five degree of freedom of articulated robotic arm. Then derived DH parameters for each of them. And also generate creo models of them.

Key words: Articulated Robotic ARM, Multicasting Routing Protocols

I. Introduction

A robotic arm is a robotic manipulator, usually programmable, with similar functions to a human arm .Servo motor is used for joint rotation. It has about same number of degree of freedom as in human arm. Humans pick things up without thinking about the steps involved. In order for a robot or a robotic arm to pick up or move something, someone has to tell it to perform several actions in a particular order — from moving the arm, to rotating the "wrist" to opening and closing the "hand" or "fingers." .So, we can control each joint through computer interface. Industrial robot manipulators are indispensable for achieving productivity and flexibility in automated production lines, where they are used for a wide variety of tasks, ranking from material handling and assembly to cutting, welding, and painting. To improve the performance and accuracy of the robot manipulator, several efforts have been made in past for developing methods to identify the factors influencing the performance. Dynamic robot models are the most important in these developments. The search for the optimal dynamic performance of a robot's arm emerges as a challenging task due to highly non-linear and strongly coupled characteristics of robot manipulator.

At present, the main interest is to protect nuclear workers in highly contaminated areas or hostile environments, robots can be used in nuclear power plants to reduce human exposure not only to radiation, but also to hot, humid and oxygen-deficient atmosphere researchers in the field of robotics are proposing a great variety of robots configurations and functional capabilities to be used in nuclear power plants. Wheeled robots and tracked vehicles are the common configurations for mobile robots. In mobile robot, the robotic system is made up of three main sub-systems: sensory head; teleportation and control panel; and mobile robot, vision, sound and temperature cover 90% of all inspections tasks required in nuclear power plants pan-tilt mechanism. So it can be easily plugged into different mechanical robots. Video camera used inspection purpose, stereo vision equipment, produced by stereo graphics, has been integrated in the tele-operation panel. This stereo system is of great use in guiding the mechanical robot through cloistered areas. The tele-presence is completed with a stereophonic bidirectional audio set, which also provides signals for sound inspection. A close inspection task of the vacuum vessel first wall using a long reach robot is called the "Articulated Inspection Arm" (AIA). Significant stress and high deformations in bending and torsion occur in the structure depends on the articulated structure. And the model has to be realistic to have a good knowledge of the end-effectors position. The model of the complete robot is the assembly of the five elementary models. It gives the deformation and position of the structure for any given joint position and loads. The calculation is iterative due to the non-linarite induced by the large displacements and the cumulative effect of the deformations. The Industrial manipulators coming evolving a lot lately. They are no longer just in the manufacturing industry, carrying pieces of one side to another. Now also perform welding in automobile production lines, are present in industries of electronics and are being used even in medical fields. That is, these robots, currently, must be more precise than before. The accuracy of movements to be performed on the trajectory of robot manipulators is the key performance requirements that must be taken into account. Thus, the industrial automation assumes role of paramount importance, since it allows to perform operations in less time and with higher quality. As today's automation is present in virtually all large companies, the difference is, this can offer the quality and reliability of its products. Since to increase these characteristic, should increase the accuracy of the manipulators who produce it. For example, manipulators that perform welding on a production line for an automotive manufacturer cannot introduce any inaccuracy. A poorly solder made commits the entire structure of the automobile.

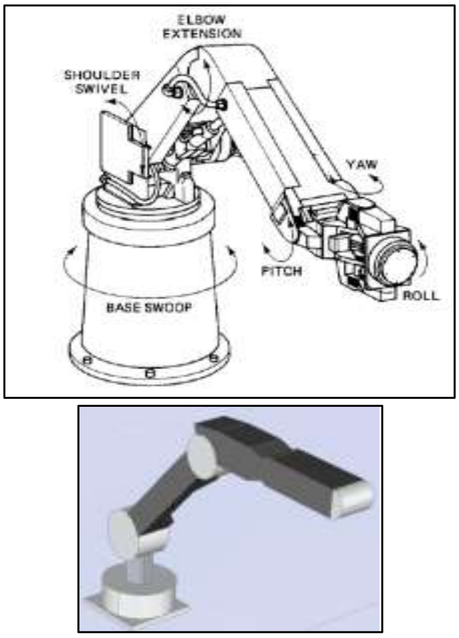

Fig. 1: Articulated robotic arms[2]

Arms are typically defined by fourteen different parameters:

1) Number of Axes – Two axes are needed to reach any point in a plane. Three are required to reach a point in space. Roll, pitch, and yaw control are required for full control of the end manipulator.
2) Degrees of Freedom – Number of points a robot can be directionally controlled around. A human arm has seven degrees; articulated arms typically have up to 6.
3) Working Envelope – Region of space a robot can encompass.
4) Working Space – The region in space a robot can fully interact with.
5) Kinematics – Arrangement and types of joints (Cartesian, Cylindrical, Spherical, SCARA, Articulated, Parallel)
6) Payload – Amount that can be lifted and carried
7) Speed – May be defined by individual or total angular or linear movement speed
8) Acceleration – Limits maximum speed over short distances. Acceleration is given in terms of each degree of freedom or by axis.
9) Accuracy – Given as a best case with modifiers based upon movement speed and position from optimal within the envelope.
10) Repeatability – More closely related to precision than accuracy. Robots with a low repeatability factor and high accuracy often need only to be recalibrated.
11) Motion Control – For certain applications, arms may only need to move to certain points in the working space. They may also need to interact with all possible points.
12) Power Source – Electric motors or hydraulics are typically used, though new methods are emerging and being tested.
13) Drive – Motors may be hooked directly to segments for direct drive. They may also be attached via gears or in a harmonic drive system
14) Compliance – Measure of the distance or angle a robot joint will move under a force.

II. CONFIGURATION AND CALCULATION

Industrial robot manipulators are indispensable for achieving productivity and flexibility in automated production lines, where they are used for a wide variety of tasks, ranking from material handling and assembly to cutting, welding, and painting. To improve the performance and accuracy of the robot manipulator, several efforts have been made in past for developing methods to identify the factors influencing the performance. Dynamic robot models are the most important in these developments. The search for the optimal dynamic performance of a robot's arm emerges as a challenging task due to highly non-linear and strongly coupled characteristics of robot manipulator.

For five degree of freedom articulated robotic arm I considered following configurations:

- TRRRR
- RRRRR
- RTRRR
- RRTRR

III. LITERATURE SURVEY

Hatem A. Al-Dois[1] had work on determination of the parameters influencing the dynamic performance of 3-RRR planar & articulated robot manipulators. Two 3-RRR robot configurations planar and articulated arms are considered here to study. The robots kinematic and dynamic models are symbolically formulated. A simulation program has been developed to measure the dynamic performance of the robot manipulators under different combinations of control and noise factors. A fractional factorial Design of Experiment (DoE) approach is utilized to identify the significant factors and their interactions on the performance of the manipulators while moving through different trajectories.

V.Srinivasan et al.[2] had worked on design and analysis of an articulated robot arm. The challenge of designing a robot stems from anticipating and controlling the system dynamics. This report outlines the dynamic behaviour of robotic arms and spatial transformations used to determine position. Path planning, curve tracking, and inverse transformation solution methods are also discussed. Definition of link coordinate frames considering the shapes, sizes, deflections during working and stresses occurring, both the AIAs are workable comparatively. Considering the manufacturability, ease of transport, assembly, and weight, the circular section AIAs are preferred over the rectangular section AIAs.

S.Pachaiyappan et al.[3] had worked on design and analysis of an articulated robot arm for various industrial application. In this report the design calculations are done using basic formulae from strength of materials. The lengths of the AIAs are calculated considering the distance of the control panels from the core, diameter of the core to be inspected and height of the core. This length is considered invariant with respect to the robot designed. The two variants of cross sections considered are hollow square and hollow circular. Since the electrical and control system wiring to the various motors in the robotic assembly are required to pass through the hollow portion of the arm the inner and hence the outer dimensions are first considered. The analysis has been done by considering 5DoF RRRRR configurations of articulated robot arm.

Felipe Costa Cardoso et al.[4] had worked on kinematic and dynamic behaviour of articulated robot manipulators by two bars. Making an initial analysis of these results, they arrive at a preliminary conclusion that the maximum torque always happen when the bar is at an angle of zero degree with respect to a horizontal reference. Another conclusion is that the torque is higher in the first joint, followed by the second joint torque, and the smallest one in the third joint. This happens because the engine of the first joint has to realize a torque that must balance the weight of the three bars plus the payload, the engine of the second joint must balance the weight of two bars more the payload and finally the torque on the last joint is smaller, because it only needs to lift the weight of a bar plus the payload.

Jamshed Iqbal et al.[5] had worked on modelling and analysis of a 6 DOF robotic arm manipulator. The robotic platform used in this work is a 6 DOF robotic arm manipulator ED7220C. It is basically a serial manipulator having all joints as revolute. The arm geometrical configuration is made up of waist, shoulder, elbow and wrist in correspondence with the human arm joints (Figure 11). Each of these joints except the wrist has a single DOF. Wrist can move in two planes (roll and pitch). In this report analytical approach has been followed to develop IK model of ED7220C. This approach ensures that for any object within robotic arm workspace, the model determines correct joint angles. The first four joint angles i.e. waist, shoulder, elbow and tool pitch are calculated using this approach while tool roll is directly given by the desired orientation for object manipulation.

T.C. Manjunath[6] had worked on kinematic modelling and manoeuvring of a 5-Axes articulated robot arm. This paper features the kinematic modelling of a 5-axis stationary articulated robot arm which is used for doing successful robotic manipulation task in its workspace. 5-axis articulated robot was designed entirely from scratch and from indigenous components and a brief kinematic modelling was performed and using this kinematic model. The pick and place task was performed successfully in the work space of the robot. A user friendly GUI was developed in C++ language which was used to perform the successful robotic manipulation task using the developed mathematical kinematic model. This developed kinematic model also incorporates the obstacle avoiding algorithms also during the pick and place operation. Unique 5-axes articulated system was used to obtain the kinematic model of the same and was used to perform a successful pick and place task using a user-friendly developed graphical user interface and real time implementation. The simulated results were exactly verified with implementation results, thus demonstrating effective PNP manipulation.

Gabriel Munteanu[7] had worked on analysis of the accuracy parameters for the articulated arm industrial robot using modern instruments and software. The current paper indicates the results of an analysis of the mechanical system of the articulated robot 5R arm, performed using state of the art software and virtual instruments. In this report the target to obtain lighter structures to achieve high speeds and accelerations but also to reach the target in very small tolerances is possible only by considering optimization criteria. Lighter structures have normally lower stiffness and are more flexible structures to the gravitational and inertial forces determined by an increased acceleration. The static analysis comprises an assessment of the total deformation and directional displacement, shear stress, principal stress and equivalent stress under the load. Preliminary, an analysis of non-operational robot was done only considering the gravitational forces. The inertial forces were introduced as well, to show a complete static analysis of the operational robot.

M. Y. Ibrahim[8] had worked on dynamic performance of robot manipulators. In this report a comprehensive study was conducted to analyse the dynamic characteristics of robot manipulators under different operational conditions and various structural and geometrical configurations. Therefore, both kinematic and dynamic modelling were extensively used in both iterative and closed form. The analysis was applied on both types of widely used industrial robots, a SCARA type robot and articulated robot PUMA 560.

R. Nigam et al.[9] had worked on an efficient formulation of robot arm dynamics for control analysis and manipulator design. This paper presents the development of the generalized d'Alembert equation of motion for application to robot manipulators with rotary joints. These equations, when applied to a robot arm, result in an efficient and explicit set of closed form second order nonlinear differential equations with vector cross product terms. They give well-structured equation of motion suitable for state-space control analysis. The interaction and coupling reaction forces/torques between the neighbouring joints of a manipulator can be easily identified as coming from the translational and rotational effects of the links. With this information, either a simplified dynamic model can be developed or an appropriate controller can be designed to compensate the nonlinear effects. Application to obtaining simplified dynamic model is discussed together with the computational complexities of the dynamic coefficients in the generalized d'Alembert equation of motion. The dynamic equations of the first three links of a PUMA robot are worked out to illustrate the method.

Keller Delphine et al.[10] had worked on an ITER relevant robot for remote handling: on the road to operation on tore supra. The AIA robot carrier is composed of a set of 5 modules and a pushing system (Deployer). The payload is supported by the end effecter. Because of the high cantilever structure (9.5m), the robot elements are submitted to high forces and torques. Tubes and clevis are made of titanium for its mechanical properties even under high temperature. Rods are made of bearing steel for its high mechanical resistance in traction. Each module is a two DoF mechanism: 2 rotary joints (horizontal and vertical axis) with a four-bar mechanism composed of the rods, the base clevis, the tube and the head clevis. The initial objective of the project is to demonstrate the feasibility of close inspection task. In-Service use of a RHE as a routine inspection tool on a tokomak will provide a lot of lessons very precious to follow up the demand for high performance remote maintenance required to operate the next tokomaks expected to support the future Fusion experiments.

IV. CONCLUSION

In nuclear reactors, because of nuclear reactions that produce a radiation in reactors which is harmful for humans. To protect workers in highly contaminated areas or hostile environments in nuclear plants, ARA robot can be used in nuclear power plants to reduce human exposure not only to radiation, but also to hot, humid and oxygen-deficient atmosphere. This issue solves by defining articulated robotic arm for industrial application such as inspection, welding, and other operations in nuclear reactors.

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