DESIGN AND ANALYSIS OF AN ARTICULATED ROBOT ARM

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ABSTRACT:

Nowadays Robots play a vital role in all the activities in human life including industrial needs. In modern industrial manufacturing process consists of precise and fastest proceedings. Human operations are needed to perform a variety of tasks in a robotic system such as set-up, programming, trouble shooting, maintenance and error handling activities. Hazardous conditions exist when human operators intervene into the robotic work zones. Human perception, decision making, and action strategies need to be studied to prevent robot-related accidents. System designers and technology managers are required to consider the limitations of operator perceptual process in design and layout of robotic system. The ultimate object is to save human lives in addition to increasing productivity and quality of high technology work environments. Effective safety training programs for work with industrial robots should be developed. The objective of this project is to design, analysis of a Generic articulated robot Arm. Articulated robot has been noted for application in traversing and performing manipulation in nuclear reactor facilities. Some aspects of the articulated Robot that are anticipated as useful are its small cross section and its projected ability to change elevation and maneuver over obstacle. The small cross section and the loads associated with suspension of the Robot while changing elevation or maneuvering over obstacles require large joint torque to weight rations for joint actuation. A novel joint actions actuation scheme is described and its implementation detailed in this project.

In this project by using CAD-tool (creo-2) we created 2 different robots. One is circular arm robot and another is square shape arm robot models and analysed with real time boundary conditions with 3 different materials (steel, al-356, ARAMID epoxy) and calculated results of deformation and stress, and shear stress and strain values for both models. From all these results here we are going to conclude which material has less weight and which material has fewer amounts of stress values. From all these results we can get an idea which robot with which material we should use for different conditions like less weight or less stress producing robots.

Keywords: *Articulated robot, CREO, ANSYS, Manipulation, Novel joint, obstacles, robotic work zones.*

1.0 INTRODUCTION

The application of robotics field is broadly used in the field of research, laboratory based work, industrial work to automate process and reduce the human errors. This project is describing the design of mechanical structure of a robotic arm. This robotic arm is often indicated to move an object from one place to another place. One kind of example of this application is in an industrial area where need to move a weighable object like tank or container or other object. The advantage of automated process results is faster completion time with lowest errors. This project also describes the implementation of a robotic arm with switching controlled. The application of the force controlled function can be seen in the industrial/manufacturing environments.

In the field of robotics the beginner can contribute many functional operations in the world. This arm can solve many human's limitations. Many people cannot move from one place to another place for their limitation but they have needed to move for collect something like mug, jog, and so on. For that they require getting help from other persons. When they use this type of robot they can solve their problem easily without help other person for its easy operation system. For an example when a person has needed to carry an object from drawing room to bed room he can use this robot. It can move surround also collect photo and other information. When earthquake will be occurred by using these types of robot people can unseat many weight full objects from destroyed area to a safety place.

Researchers developing robots often work with articulated robots when they want to engage in activities like teaching robots to walk and developing robotic arms. The joints in the robot can be programmed to interact with each other in addition to activating independently, allowing the robot to have an even higher degree of control. Many next generation robots are articulated because this allows for a high level of functionality. 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.

CLASSIFICATIONS OF ROBOTS:

- Cylindrical
- Polar
- Articulated
- Scara
- Cartesian

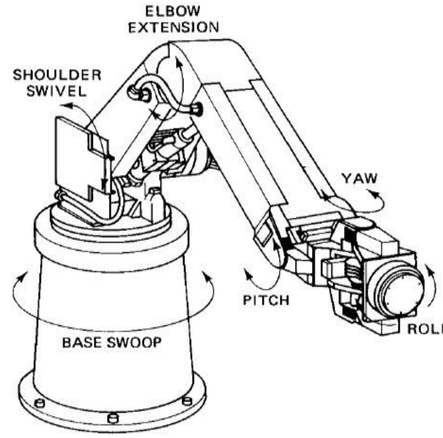


Figure 1: robot parts

The ODIS robot is designed for under-vehicle inspection and has been successfully employed by troops at checkpoints in Iraq and Afghanistan. The robotic arm and controller described in this paper is built to mount on ODIS. A video camera is mounted on the end of the arm to facilitate vehicle inspection, but the concepts presented in this paper are equally applicable to a claw or other end-effectors. The arm has three degrees of freedom which allow the linkages to move in a vertical plane. The standard ODIS model camera on a tilt-mount is removed when this robotic arm with camera is installed. Out-of-plane motion of the camera or end effector is achieved by ODIS pivoting in place thereby eliminating the need for a hip joint in the robotic arm. The robotic arm has its own controls and power for easy transfer to platforms other than ODIS. the design of the robotic arm. The arm has three revolute joints with horizontal axes parallel to each other a shoulder joint, an elbow joint, and a wrist joint. The shoulder joint is actuated by two servomotors in parallel mechanically. The two shoulder joint motors and the elbow joint motor are "quarter-scale" servomotors, so called because of the intended use in quarter-scale aircraft hobby models.

2.0 LITERATURE REVIEW

Early research efforts in legged locomotion focused on statically stable gaits in which robot's centre of gravity is always kept over the polygon formed by the supporting feet [1]. Raibert, around 1985, set the stage with his ground-breaking work on dynamic legged locomotion [2], which resulted in one of the most advanced quadrupeds, Boston Dynamics' BigDog that can control its forward speed, and although it moves with static stable gaits, it can achieve a dynamically balanced trot gait when moving at human walking speeds [3]. Boston Dynamics' statically stable LittleDog, is a quadruped walking robot with 12 degrees of freedom, used as an algorithm test bed. A different design and control approach is followed in Scout II [4] and in the NTUA Quadruped Robot [5, 6], which use only one actuator and a spring per leg to realise dynamically stable running with speed control. While the Scout requires a time-consuming trial-and-error controller parameter determination to achieve a given speed, the NTUA quadruped control algorithm does not need empirical gain tuning. Quadruped robots like Kotetsu [7] that employ Central Pattern Generator (CPG) based controllers and KOLT [8] that uses a fuzzy controller are different approaches towards achieving dynamic stable gaits. Recent research efforts by the Autonomous System Lab at ETH [9] and the Advanced Robotics Department at IIT [10] are aiming at making a step forward from LittleDog and BigDog respectively. Generally, the tendency for the new robotic quadrupeds is to aim for very fast, rapidly accelerated, able to make tight turns robots with flexible spine, articulated legs, possibly including head and tail, such as the Boston Dynamics' Cheetah concept. Lygorouas et al. [11] developed a computer-controlled lightweight mechanical arm. This mechanical arm was a selfcontained, autonomous system capable of executing high-level commands from a supervisory computer. The actuators of the joints were permanent magnet type dc motors driven by servoamplifiers via Pulse Width Modulation. Aung [12] designed and implemented a controller circuit based on PIC microcontroller and H bridge circuit to control the motion of a Wheeled Mobile Robot (WMR). He used MATLAB software for the modeling of the total system. Silva [13] applied fuzzy logic at several hierarchical levels of a typical robotic control system. For controlling robotic manipulators, Moosavian [14] used transpose jacobian (TJ) control. Arciniegas et al. [15] developed neural network based adaptive control system to control the flexible robotic arm. Tseng [16] developed a DSP based instantaneous torque controller to control the manipulator. Rogers [17] designed a microcontroller circuit for interfacing joint sensor to control robotic arm. A simple structured linked model of the articulated limb was developed where the model is manipulated in simulation to 'pull' the end of the limb towards the desired destination position and orientation [18]. Hisham [19] developed a PIC 16F877 microcontroller based system where an articulated robot arm having six degrees of freedom was controlled [19]. In this present work, an ATmega32L microcontroller based controller circuit has been designed to control the three degrees of freedom of an articulated robot arm.

AIM OF THE PROJECT

1) The main goal of the project is to design and analysis of an articulated robot arm for inspection purpose.
2) To design the robotic arm using analytical calculation
3) To achieve computer aided modeling of this robot arm using solid works software.
4) To perform the Finite Element Analysis of the designed robot arm for the selected dynamic condition using the ANSYS software.

3.0 DESIGN

Computer aided design (cad) is defined as any activity that involves the effective use of the computer to create, modify, analyze, or document an engineering design. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as cad system. The term CAD/CAM system is also used if it supports manufacturing as well as design applications.

DESIGN OF ARTICULATED INSPECTION ARM (AIA)

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.

Calculations:

Volume of the shaft, V

V =π/4(do2 - di2) x Length Considering,
k= di /do = 0.75
di = 0.75 do

Volume, V= π/4 (do 2-0.5625 do2) x 4
V=1.37 do2 m3 ---------- Eqn. 1

Mass of the shaft,

m Mass = volume x density = 1.37 do2 x 1.1x 103 [Considering, density of nylon = 1.1x103 kg/m3]
Mass, m=1507 do2 ----------- Eqn. 2

Force Acting On the Shaft, F

Force, f =mass x acceleration due to gravity =1507 do2 x 9.81
F = 14783.67 do2 ----------- Eqn. 3

Power of the motor, P

P = (length of the shaft from the motor x speed of the motor x load acting) 60
P = 4x 10x14783.67 do2/60
P = 9855.78 do2 KW ---------- Eqn. 4

1. Motor
2. Camera
3. Knuckle Joint
4. Weight of the shaft

Figure 3.1 shows explode view of robot arm

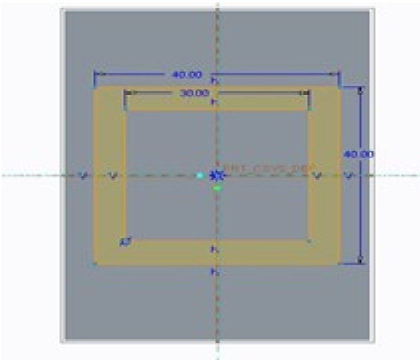


Figure 3.2 Square arm robot

Figure 3.3 Individual parts in assembly window

Figure 3.4 Circular arm robot assembly

Figure 3.5 final design of robot arm

4.0 ANALYSIS

In general, there are three phases in any computer-aided engineering task:

- Pre-processing – defining the finite element model and environmental factors to be applied to it
- Analysis solver – solution of finite element model
- Post-processing of results using visualization tools

The ANSYS program allows engineers to construct computer models or transfer CAD models of structures, products, components, or systems, apply loads or other design performance conditions and study physical responses such as stress levels, temperature distribution or the impact of lector magnetic fields.

In some environments, prototype testing is undesirable or impossible. The ANSYS program has been used in several cases of this type including biomechanical applications such as high replacement intraocular lenses.

ANSYS design optimization enables the engineers to reduce the number of costly prototypes, tailor rigidity and flexibility to meet objectives and find the proper balancing geometric modifications.

Competitive companies look for ways to produce the highest quality product at the lowest cost. ANSYS (FEA) can help significantly by reducing the design and manufacturing costs and by giving engineers added confidence in the products they design. FEA is most effective when used at the conceptual design stage. It is also useful when used later in manufacturing process to verify the final design before prototyping.

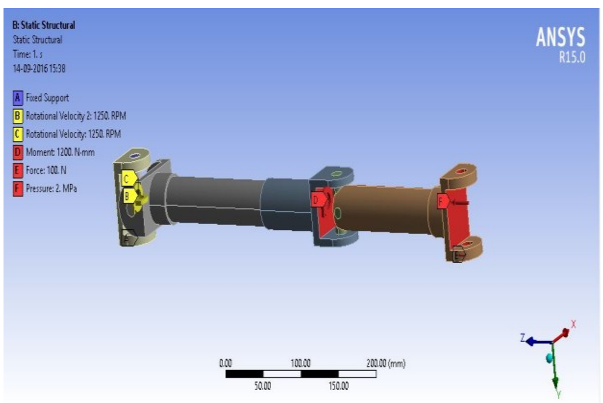


Figure 4.1 static structural assign material properties with steel

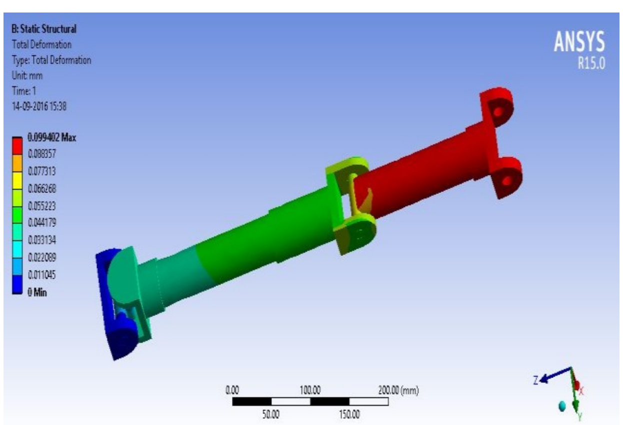


Figure 4.2 deformation of robotic arm with steel

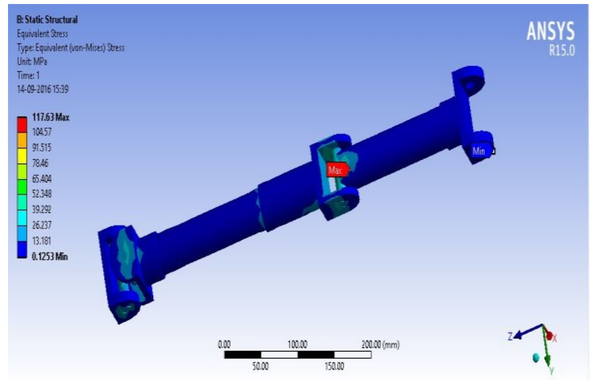


Figure 4.3 equivalent stresses of robotic arm with steel

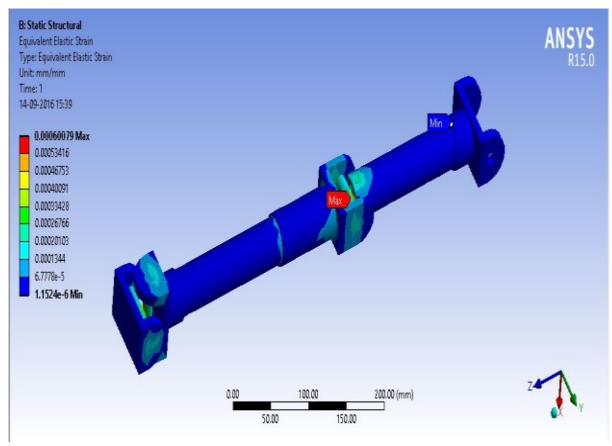


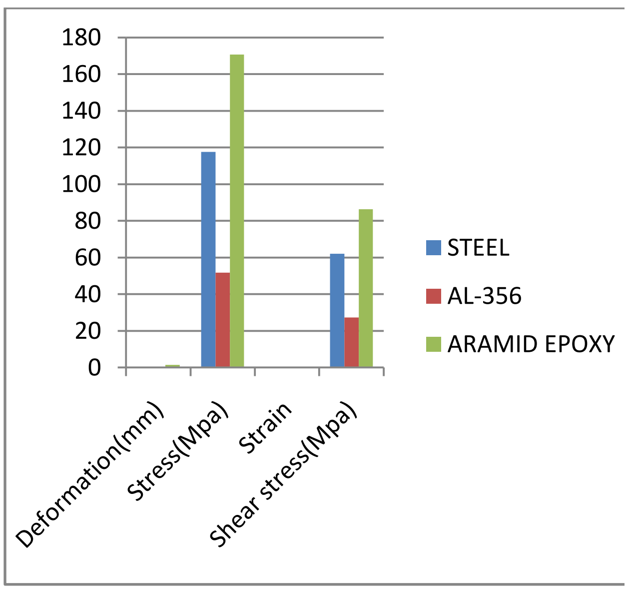
Figure 4.4 equivalent strain of the robotic arm with steel

5.0 RESULTS AND DISCUSSION

The maximum displacements of the circular and rectangular sections are 26.638mm and 26.03mm during the first load step i.e., while considering the position of the base arm is at 30 degrees. Considering the 4000mm length of the arm, the deflection is 0.66% in case of circular and 0.65% in case of rectangular section arm. It cumulates to a maximum of 159.83mm in circular and 156.18mm in rectangular section arm. But this is only an elevated estimate since the bending moment and force acting on the arm will also decrease linearly (5-n) with the nth position of the five arms from the base arm. This deflection is negligible and can be controlled while programming the controller for precision. Hence both the models are eligible for further studies.

Table Circular arm robot

Parameters	STEEL	AL-356	ARAMID EPOXY
Deformation (mm)	0.099402	0.12171	1.4472
Stress(Mpa)	117.63	51.715	170.67
Strain	0.00060079	0.00072088	0.010939
Shear stress(Mpa)	61.987	27.234	86.4



Graph 5.1 parameters variation for different materials

6.0 CONCLUSION & FUTURE SCOPE

In this project by using CAD-tool (creo-2) we created 2 different robots. One is circular arm robot and another is square shape arm robot models and analyzed with real time boundary conditions with 3 different materials (steel, al-356, ARAMID epoxy) and calculated results of deformation and stress, and shear stress and strain values for both models.

The completed project will consist of a robot arm. While analyzing models with different materials we got different weights and different stress and different strain values. From all these results we can say, if we compare both robots by materials we can say that steel square arm robot will reduce overall stress by 16% compare with circular arm robot with steel material. But in al-356 material we reducing only 2% of stress compare with circular arm. And in ARAMID epoxy produces much more stress compare with other 2 materials. And we know that composite materials generally high strength materials and also expensive. By comparing both circular and square arm robots here we observe that square shape arms have more weight compare to circular arm robots.

FUTURE SCOPE:

The scope of the project includes the designing and building of the hardware and software for a comparable robot arm. This Robotic arm is very useful for the society and also in industrial application and it works successfully at the time of demonstration. A humanoid robotics is a new challenging field. To co-operate with human beings, humanoid robots not only have to feature human like form and structure, but more importantly, they must prepared human like behavior regarding the motion, communication and intelligence.

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