ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

Design and fabrication of Multipurpose Manual Controlled Robotic Arm (MMCRA)

B. Kiran Kumar[1,*],

[1] Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh 522302, India

K. Venkatesan[2],

[2] Department of Automobile Engineering, Bharath Institute of Higher Education and Research, Chennai, Tamil Nadu, India

B Saikrishna Srikar[3]

[3]Tata Consultancy Services, Adibatla, Hyderabad, Telangana

*Corresponding author; E-mail: buragaddakirankumar15@gmail.com

Abstract:

With the increasing technology, the industries are moving from the current state to automation in Industry 4.0 to maximize productivity and maintain consistency in quality. A robotic manipulator with 3 to 5 degrees of freedom is the most frequently employed robot in the industry. They have movable joints and links suitable for industrial and household applications. This work presents a design and fabrication of a multipurpose manual controlled robotic arm (MMCRA) and its control is as simple as operating with a remote. Its applications will exist at pick and place, painting, drilling operations by changing the end effector or gripper of the arm. In the first phase of this study, the modelling and finite element analysis is done by using Unigraphics NX software. In the second phase, the materials are selected by comparing their nodal stresses, deflections of different elements, and a prototype is fabricated. It is validated through real-time applications.

Keywords: Robotic manipulator, DOF, Kinematic chain, End effector, Finite element analysis.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

1. Introduction

Mechanical engineering is one of the branches of engineering and technology related to machinery based on its design, manufacturing, and application. Robotics is also a part of mechanical engineering that embeds software, electronics, and mechanics. The main scope of today's robotics and its development is towards the systems that reveal modularity, extended software environment, fault-tolerance, redundancy, flexibility, and smooth, logical connectivity with other machines. In most routine and often carried out industrial tasks, automation plays a critical role in saving human effort. The flexible and generally high cost of automation systems is used in big industries used for several tasks [5].

The robots are broadly divided into industrial and service robots. International Federation of Robotics (IFR) defines a service robot as a robot based on a semi or fully automated service that benefits human well-being and equipment, excluding manufacturing operations. Those robots are used in various applications, including office, military areas, hospitals, agriculture.

Moreover, particular jobs such as picking up explosive chemicals, defusing bombs, selecting and putting the bomb somewhere for containment, and repeating pick and place activity in industries may be challenging or risky for people. As a result, humans can take the position of robots in the workplace. In some layouts, links can be compared with human anatomy as wrist, upper arm, and forearm with the joint at shoulder and elbow. A wrist joint connects to an end effector at the end of the arm, which may be a tool or a gripper or end effector, or any other device to work [1][2].

A robotic manipulator is a programmed mechanical arm that performs functions similar to a human arm. The links of those manipulators are connected by joints permitting either rotational motion or translational displacement [6][7].

Degrees Of Freedom (DOF) refers to the freedom of movement of a rigid body in 3D space. There is a total of 6 degrees of freedom i.e., three rotation moments, and three linear movements along the x, y, and z axes [8][9]. The Kinematic chain of the manipulator can be expressed as a combination of links. The end effector is a replica of the human hand that serves as the final link in the manipulator's kinematic chain. [10]. An end effector may be created to do any activity, including gripping, welding, and spinning. It contains various sensors based on the task in which it is used [2][5][8].

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

2. Literature Review

Ghadge et al. (2018) [5] proposed the fabrication of a robotic arm that can pick and place items using Node MCU controller based on microchip technology as the control system to guide the device. The input signal is sent from the android application to MCU, and the arm reacts according to it. Gautam et al. (2017) [6] discussed industrial robots in the areas such as wood, consumer goods, plastic, food, etc. His approach is to develop a lightweight robot by using carbon fiber and aluminum material and with the help of a stepper motor for movements. Yusoff et al. (2012) [7] presented the wireless mobile robotic arm for pick and place operations using the wireless PS2 controller. The Arduino Mega interface platform is used in the development of an arm and is intended to solve the challenges of item placing and picking. Singh et al. (2013) [8] carried the Design of a Robotic Arm with a gripper & end effector for Spot Welding using an AC motor along with spur gear and threaded shaft arrangements. The end effectors of his design are used for various tasks like holding, picking, grasping objects, and spot welding with a fixed base. Mourya et al. (2015) [9] prosed a design and implementation of a 4-DOF pick and placed robotic arm. This model is self-operational in controlling simple tasks like lifting, gripping, and placing. It consists of revolute links for angular motion and four serial servo motors are used to perform four degrees of freedom.

Abdulkareem et al. (2019) [10] reported the design and implementation of a robotic arm used for pick and place tasks. Its control is based on the Arduino microcontroller having a slave configuration. The model is developed by using various motors and tracked wheels for the transportation of the arm. Omijeh et al. (2014) [11] worked on a Design Analysis of a Remote Controlled "Pick and Place" Robotic Vehicle. It is used for handling some objects and specific tasks in hazardous environments. This model contains a 5-DOF arm with a base resting on the vehicle. Liang et al. (2018) [12] presented a Soft Robotic Arm (SRA), which is a potential alternative for a domestic robotic arm, as it is constructed of low-cost fabrics and flexible plastics. It contains two joints and a gripper. They characterized the force output of the bending modality and demonstrated the result of the SRA in object manipulation. Kumar et al. (2016) [13] worked on the design and execution of a mechanical and vacuum gripper-based multi-handling pick and place robotic arm. It is a self-operated device used for lifting, sucking, and placing. The angular movement between adjacent is incubated by using revolute

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

joints. Wongphati et al. (2012) [14] shared their views on how the robotic arm is used in daily lives.

They surveyed to know the people thinking about the use of a robotic arm worldwide and concluded that most of the people suggested use in the workplace and the household. Kadir et al. (2012) [15] presented an Internet Controlled Robotic Arm and arm movement that is controlled with the help of Arduino Uno by using the internet.

It is clear from the literature review that robotics has a wide range of applications. This study's goal is to improve the robotic arm and broaden its range of applications.

3. Design Steps of Robotic Arm

Figure.1 illustrates the multiple steps involved in the creation of a Robotic arm.

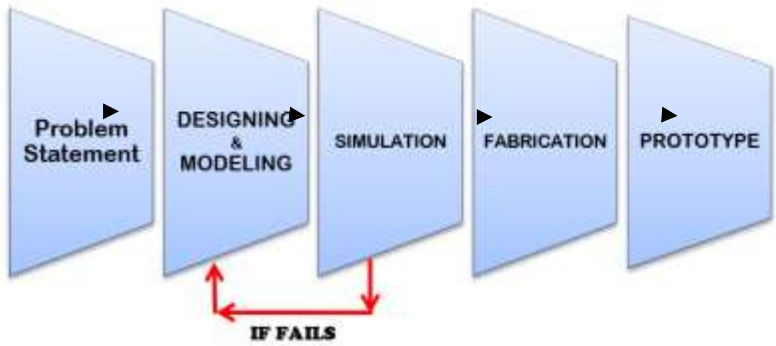

Figure.1: Various steps of designing a Robotic Arm

Problem Statement

The robotic arms are fit for industrial and household applications. Some of the inconveniences caused by modern industrial robotic manipulators are listed below.

- Very expensive and require additional maintenance
- Need a skilled person to operate
- Fixed and cannot be moved
- Program is mandatory for the robotic arm
- Not intelligent or sentient

A design of a new robotic manipulator will be useful to overcome the disruptions

ISSN PRINT 2319 1775 Online 2320 7876

Research paper © 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

Design of Robotic Arm

The proposed Multipurpose Manual Controlled Robotic Arm (MMCRA) is designed by using the elements viz., Motor, Controller & Controller Casing, Motor Couplings, Outer Shaft, Screw

Coupling, Stud & Nut, Inner Shaft, Nut Holding Coupling, Clearance Reducer Coupling, Elbow Coupler, Elbow and Gripper. It is aimed to operate manually.

Modeling of Robotic Arm

All the elements of the Robotic arm are designed and assembled by using NX Design Software. Figure.2 depicts the proposed Robotic Arm, which was created using NX. The telescopic arrangement with nut and bolt principle between outer and inner shafts.

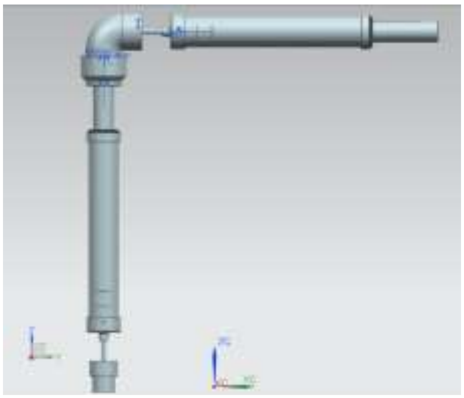

Figure.2: Assembly model of Robotic Arm

Simulation of Robotic Arm Elements

Simulation is an approximate analysis of the body at any instant point of time due to structural, thermal, and vibration behaviour, i.e., the application of loads, temperature, noise. Using this type of analysis, the approximate lifetime of the body, occurrence of failure in the region and strength will be known [4].

Materials for Robotic Arm elements

While choosing the materials for the prototype of a robotic arm, the mechanical properties, manufacturing characteristics, appearance, and cost are to be considered [9][10]. The mechanical properties of the materials include: Density, Strength, Elasticity, Hardness & Toughness,

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

Durability & Malleability, Temperature and moisture resistance, Corrosion & Wear resistance.The most commonly used Metallic and Non-metallic materials are Aluminum, Mild steel, Stainless steel, and ABS plastic, PVC respectively.

Theoretical analysis

In this study, a comparison of nodal stress and deformation values obtained from the theoretical calculation and NX software is done to confirm the closeness of their values and to find the location of major stress-induced on a simple cantilever.

In this simulation, Aluminium specimen of size 100 * 20 * 5mm is considered

Deflection in beam (δ) = $\frac{F L^3}{3EI}$

where F = Load applied, L = Length of material, E= Young's Modulus, and I = Moment of Inertia

$$\delta = \frac{40 * 100^3}{3 * 68 * 10^3 * \mathbf{208.33}} = 0.9411\text{mm}$$

Max stress-induced (σ) = $\frac{y * M}{I}$

where y = Vertical distance away from the neutral axis, M = Bending Moment and I = Moment of Inertia

$$\sigma = \frac{2.5 * 40 * 10^2}{208.33} = 48.0379 \text{ MPa}$$

The Displacement and Nodal stress simulations are shown in Figure.3 and Figure.4 respectively. Table. 1 depicts the values obtained from both theoretical and analysis by NX software.

Table.1: Deflection and Stress values

Solutions	Theoretical	NX Software
Max Deflection (mm)	0.9411	0.829052
Max Stress (MPa)	48.0379	48.9305

ISSN PRINT 2319 1775 Online 2320 7876

Research paper **UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019**

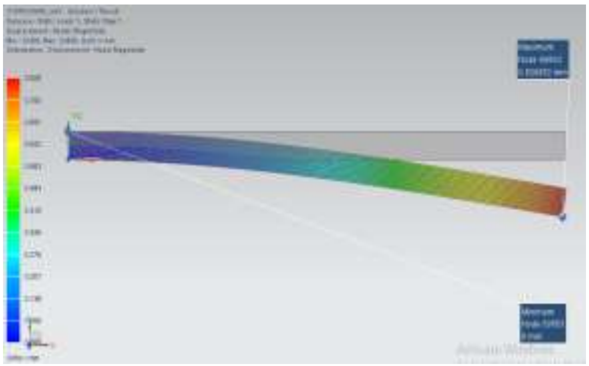	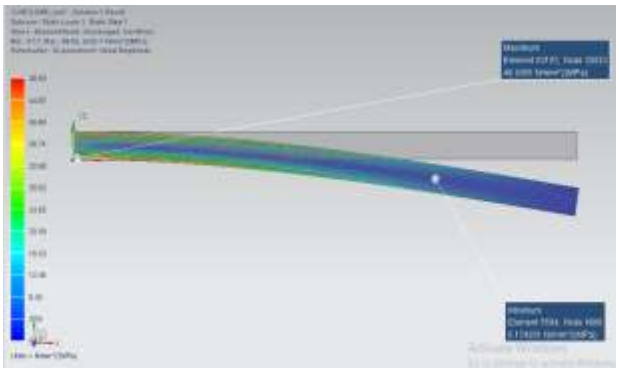
Figure.3: Displace simulation of Aluminium beam	**Figure.4:** Nodal Stress simulation of Aluminium beam

By comparing the solutions of theoretical and NX software values, it is clear that they are very close. Hence, it is concluded that NX data can be taken directly for further study. It reflects that the failure occurs at the constrained location or position and needs to be more focused on the constrained area.

In the design of the Robotic arm, a motor coupling connects the motor with the outer shaft. Study includes material selection and design of a motor coupling. Four different kinds of Motor coupling designs and Five materials (i.e, Metallic and non-metallic materials) are considered for the simulation purpose.

Motor Coupling materials and Loads considered

The total load is the sum of self-load and a payload of 400gms will be acting on a motor coupling. The self-load is mainly dependent on the properties of material like density and volume of the arm. Table.2 shows different kinds of motor coupling materials, properties, and the loads applied on them.

ISSN PRINT 2319 1775 Online 2320 7876

 UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

Table.2: Motor Coupling materials and loads

S. No.	Materials	Density (Kg/m^3)	Max Tensile Strength (MPa)	Young Modules (GPa)	Load Applied (N)
1	Aluminum	2707	90	68	80
2	ABS Plastic	1050	60	-	30
3	PVC	1380	62	190	40
4	Mild Steel	7850	490	215	240
5	Stainless Steel	7850	540	190	240

Motor Coupling Design

Table.3 lists four different motor coupling designs for simulation purposes.

Table.3: Different design of Motor couplings

Design	I	II	III	IV
3D Drawing of the coupling				

Simulation for Displacement and Nodal Stress

Simulation carried on all four designs of Motor couplings for displacement and Nodal stress values by using NX software. It is carried for all five different kinds of materials listed in Table.2. Figure.5 and Figure.6 shows simulations for the Aluminium material. For all twenty models (i.e., 4 designs x 5 materials) the Displacement and Nodal stress values obtained from NX software are tabulated in Table.5 and Table.6 respectively.

ISSN PRINT 2319 1775 Online 2320 7876

  UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

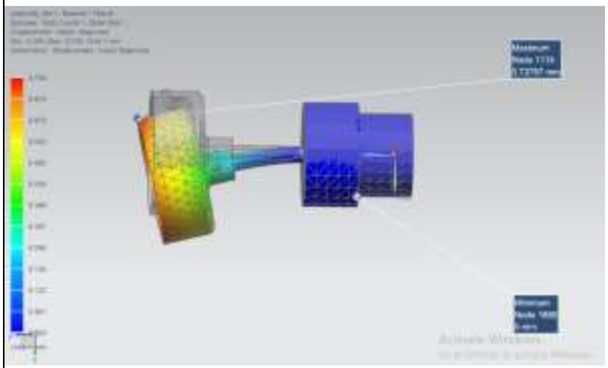

Figure.5: Simulation for Displacement on Aluminium Design I coupling

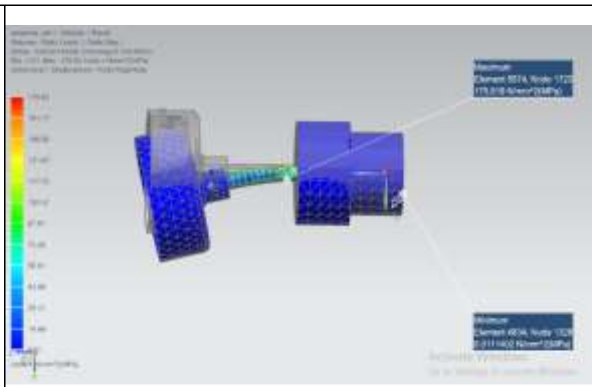

Figure.6: Simulation for Nodal Stress on Aluminium Design I coupling

Table.4: Displacement values of twenty models

Displacement (in mm)										
Design/ Material	Aluminium		ABS		PVC		Mild Steel		Stainless Steel	
	min	max	min	max	min	max	min	max	min	max
I	0	0.7376	0	0.3635	0	0.4595	0	2.109	0	2.101
II	0	1.2407	0	0.8221	0	0.9745	0	3.602	0	3.619
III	0	1.1562	0	0.6128	0	0.74862	0	3.4004	0	3.39232
IV	0	1.9295	0	0.9081	0	0.85291	0	5.5363	0	5.65878

Table.5: Nodal Stress values of twenty models

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

Nodal Stress values (in MPa)										
Design / Material	Aluminum		ABS		PVC		Mild Steel		Stainless Steel	
	min	max	min	max	min	max	min	max	min	max
I	0.0114	175.82	0.005	65.626	0.00557	87.9093	0.03756	525.01	0.0375	525.009
II	0.0135	178.89	0.005	67.083	0.0067	89.441	0.04045	536.67	0.0405	536.665
III	0.0189	176.84	0.004	66.875	0.0049	89.1972	0.03931	535.3	0.04852	530.531
IV	0.0201	236.73	0.008	88.775	0.00582	98.1094	0.04513	782.44	0.05624	710.199

By referring to the values of Table.4 & Table.5, it is found that ABS material has less deformation and stress values for Design I. This motor coupling is fabricated by a 3D printing process.

7. Proposed Robotic Arm Prototype

As per the design shown in Section 4, all the elements are suitably fabricated as per the design and assembled. The prototype of the proposed Multipurpose Manual Controlled Robotic Arm with a controller is depicted in Figure.7.

Figure.7: Prototype of a Multipurpose Manual Controlled Robotic Arm

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

This arm is the combination of cartisian and articulated robotic arm in which each link has both linear and rotary motion simultaneously. The control is done manually by the person operating it. The nut and bolt mechanism is employed for cartisian motion and different capacity gear motors for the articulated motion. This arm can used for various purposes by changing the end effector i.e., mechanical gripper, vacuum gripper or any other types of customized grippers.

9. Conclusion

The progression of robotic arm will increase the aptness of its applications in Manufacturing, Health care, Agriculture, Space Exploration. Based on the application the gripper needs to be altered.

- The objective of this study is to provide a design and prototype implementation of a Multipurpose Manual Controlled Robotic Arm (MMCRA) that increases its versatility. This arm combines the features of both Cartesian and Articulated Mechanical Arms**.**
- It is proved that the nodal stress and deformation values obtained from theoretical and analytical methods are very close and concluded that analytical value could be taken for further study.
- Also concluded that ABS is the best material in the fabrication of motor coupling.
- Having both linear and rotary movements at each link of the arm, facilitates in increasing the suitability of its application.

References

[1] Robotic Engineering by Richard D.Klafter, Prentice-Hall, Tata Mc Graw-Hill, 1995.

[2] Industrial Robotics by Mikell P.Groover, Tata Mc Graw-Hill, 1986.

[3] Bansal, R. K. (2008). A Textbook of Strength of Materials. Laxmi Publications (P) Ltd, https://books.google.com/books?id=2IHEqp8dNWwC&pgis=1

[4] Reddy, G. R., & Eranki, V. K. P. (2016). Design and Structural Analysis of a Robotic Arm. 101.

[5] Ghadge, K., More, S., Gaikwad, P., & Chillal, S. (2018). Robotic ARM for pick and place application. International Journal of Mechanical Engineering and Technology, 9(1), 125–133.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

[6] Gautam, R., Gedam, A., Zade, A., & Mahawadiwar, A. (2017). Review on Development of Industrial Robotic Arm. International Research Journal of Engineering and Technology (IRJET), 4(3), 1752–1755.

[7] Yusoff, M. A. K., Samin, R. E., & Ibrahim, B. S. K. (2012). Wireless mobile robotic arm. Procedia Engineering, 41(Iris), 1072–1078. https://doi.org/10.1016/j.proeng.2012.07.285

[8] Singh, P., Kumar, A., & Vashisth, M. (2013). Design of a Robotic Arm with Gripper & End Effector for Spot Welding. Universal Journal of Mechanical Engineering, 1(3), 92–97.

[9] Mourya, R., Shelke, A., Satpute, S., Kakade, S., & Botre, M. (2015). Design and Implementation of Pick and Place Robotic Arm. International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME), 2(1), 232–240.

[10] Abdulkareem, A., Ladenegan, O., Agbetuyi, A. F., & Awosope, C. O. A. (2019). Design and implementation of a prototype remote-controlled pick and place robot. International Journal of Mechanical Engineering and Technology, 10(2), 235–247.

[11] Omijeh, B. O., Uhunmwangho, R., & Ehikhamenle, M. (2014). Design Analysis of a Remote Controlled Pick and Place Robotic Vehicle. International Journal of Engineering Research and Development, 10(5), 2278–67.

[12] Liang, X., Cheong, H., Sun, Y., Guo, J., Chui, C. K., & Yeow, C. H. (2018). Design, Characterization, and Implementation of a Two-DOF Fabric-Based Soft Robotic Arm. IEEE Robotics and Automation Letters, 3(3), 2702–2709.

[13] Kumar, S. P., Varman, K. S., & murugan, R. B. (2016). Design and Implementation of multi handling Pick and Place Robotic Arm. International Journal of Engineering Trends and Technology, 33(3), 164–166.

[14] Wongphati, M., Matsuda, Y., Osawa, H., & Imai, M. (2012). Where do you want to use a robotic arm? and what do you want from the robot? Proceedings - IEEE International Workshop on Robot and Human Interactive Communication, 322–327.

[15] Kadir, W. M. H. W., Samin, R. E., & Ibrahim, B. S. K. (2012). Internet-controlled robotic arm. Procedia Engineering, 41(Iris), 1065–1071.