As per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology, 7(09): 41-46, 2021

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0709008
Available online at: http://www.ijmtst.com/vol7issue09.html

Modeling and Fatigue Analysis of Robotic Arm with Lightweight Materials using FEA Technique

K Kaleshwar Singh[1] | Dr. K Vasantha Kumar[2]

[1] M.Tech Student, Dept. of Mechanical Engineering, JNTUH College of Engineering, Kondagattu, Jagtial, Telangana India
[2] Assistant Professor and HOD, Department of Mechanical Engineering, Jawaharlal Nehru Technological University Hyderabad College of Engineering, Jagtial, Telangana state, India

To Cite this Article
K Kaleshwar Singh and Dr. K Vasantha Kumar. Modeling and Fatigue Analysis of Robotic Arm with Lightweight Materials using FEA Technique. *International Journal for Modern Trends in Science and Technology* 2021, *7*, pp. 41-46. https://doi.org/10.46501/IJMTST0709008

Article Info
Received: 15 August 2021; Accepted: 07 September 2021; Published: 10 September 2021

ABSTRACT

A robotic arm is a device that can perform comparable duties to a human arm and is programmable and versatile. It is utilized to execute a variety of mechanical operations with great accuracy and efficiency for extremely repetitive jobs. Because robotic arms are employed for repetitive tasks, fatigue may occur as a result of continuous or continual loading; therefore, fatigue behavior is crucial to investigate with the lightweight materials. In this research, a robotic arm was designed and evaluated utilizing a CAD-tool (solid works) with real-time boundary conditions and five different materials (aluminum alloy 7475, carbon fiber, kevlar29, E-glass fiber, and boron fiber). There was a static analysis, a modal analysis, and a fatigue analysis. Deformations, stress, frequency values, component life, and safety considerations were all detected in these evaluations for all models. It can deduce from all of these data which materials have less deformation and which materials have lower stress levels. It can determine robot with which material to utilize for various situations, such as reduced weight or less stress generating robots with greater fatigue resistance, based on all of these findings. The created structure is compared to the metallic structure's original design. It is observed that the robot arm's stiffness has increased significantly while its mass and inertia have decreased, resulting in a very high specific stiffness, specific strength, and excellent dynamic performance, which will undoubtedly result in good productivity as per our requirements, which is the project's desired goal.

KEYWORDS: Robotic Arm, Lightweight, Fatigue, FEA, SOLIDWORKS.

1.INTRODUCTION

A robotic arm (not robotic hand) is a type of mechanical arm, usually programmable, with similar functions to a human arm; the arm may be the sum total of the mechanism or may be part of a more complex robot. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement. The links of the manipulator can be considered to form a kinematic chain. The terminus of the kinematic chain of the manipulator is called the end effector and it is analogous to the human hand.

A. Types of Robots

Cartesian robot / Gantry robot: Used for pick and place work, application of sealant, assembly operations, handling machine tools and arc welding. It's a robot whose arm has three prismatic joints, whose axes are coincident with a Cartesian coordinator.

Cylindrical robot: Used for assembly operations, handling at machine tools, spot welding, and handling at diecasting machines. It's a robot whose axes form a cylindrical coordinate system.

Spherical robot / Polar robot: Used for handling machine tools, spot welding, diecasting, fettling machines, gas welding and arc welding. It's a robot whose axes form a polar coordinate system.

SCARA robot: Used for pick and place work, application of sealant, assembly operations and handling machine tools. This robot features two parallel rotary joints to provide compliance in a plane.

Articulated robot: 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.

Parallel robot: One use is a mobile platform handling cockpit flight simulators. It's a robot whose arms have concurrent prismatic or rotary joints.

Anthropomorphic robot: It is shaped in a way that resembles a human hand, i.e. with independent fingers and thumbs.

B. Application

Robotic arms are typically used for industrial applications. The application is the type of work robot is designed to do .Different applications will have different requirements. For example, a painting robot will require a small payload but a large movement range. On the other hand, an assembly robot will have a small workspace but will be very precise and fast. Industrial robots are designed for specific applications and based on their function will have their own movement, linkage dimension, control law, software, and accessory packages. Below are some types of applications.

C .Cylindrical Configuration Robot

In the present work, cylindrical configuration robot arm is considered. Cylindrical Coordinate robots are robots whose axes form a cylindrical coordinate system. Used for assembly operations, handling at machine tools. It uses a vertical column and a slide that can be moved up and down along the column. The robot arm is attached to the slide so that it can be moved radially with respect to the column.

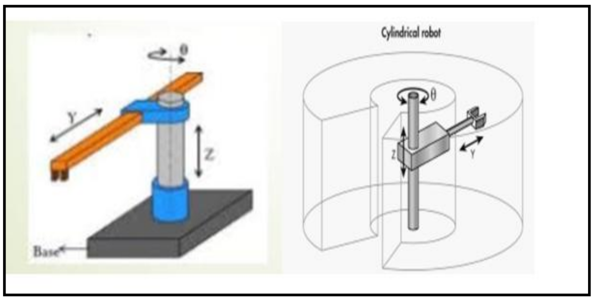


Fig:1 Cylindrical configuration robot

2.LITERATURE REVIEW

Design Analysis of a Remote Controlled “Pick and Place” Robotic Vehicle **[1]** In this paper the design of a Remote Controlled Robotic Vehicle has been completed. A prototype was built and confirmed functional. This system would make it easier for man to unrivalled the risk of handling suspicious objects which could be hazardous in its present environment and workplace.

Design And Analysis Of Circular And Square Arm Robot **[2]**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.

Design and Analysis of Robot’s Arm part for carbon composite material-Mukund Narayan Pandey [3] This paper is presenting to the understanding and importance of digital prototype over prototype in manufacturing engineering. Today, in this modern fast growing industrial age, every company is looking for speed in manufacturing to meet the needs and requirements of its clients. Whereas agricultural field is still an exception.

A development of light weight wearable robot with carbon fiber composite-Lee, Jeayoul **[4]**Structural integrity of the wearable robot by using finite element analysis is evaluated, which is made of CFRP(Carbon Fiber Reinforced Plastic) composite materials to be lightened. On the basis of the ASTM(American Standard Test Method), mechanical tests of the material are carried out in tensile, compressive and shear test for analytical evaluation.

Optimal design of a light weight robotic manipulator using carbon fiber-reinforced composite-Gang Qi [5]This thesis describes the process of analysis and redesign of an anthropomorphic parallel robotic manipulator using graphite/epoxy fiber reinforced composites, which exhibit high stiffness-to-weight ratio and strength-to-weight ratio as well as good damping properties.

3.MODELING AND ANALYSIS

A mechanical robot is a robot framework utilized for assembling. Mechanical robots are mechanized, programmable and equipped for development on at least three tomahawks. Common uses of robots incorporate welding, painting, get together, dismantling, pick and spot for printed circuit sheets, bundling and marking, palletizing, item examination, and testing; all cultivated with high perseverance, speed, and accuracy. They can aid material taking care of.

A. Structural Analysis

ANSYS Autodyn is pc simulation device for simulating the reaction of materials to quick period immoderate loadings from impact, excessive stress or explosions. ANSYS Mechanical is a finite detail evaluation tool for structural assessment, together with linear, nonlinear and dynamic studies.

B. Modal Analysis

In today's world, engineers are focused on designing safe and reliable engineering structures. With the advent of newer materials and better known, structures are becoming lighter and yet they are intended to be safe and reliable. These new requirements have brought even more attention to the dynamics characteristics of the structures, which assume a vital role while designing the structures for safety, reliability and quality.

C. Fatigue analysis

These fatigue analysis example exercises are constructed around the concept of the fatigue "five-box trick." The illustration below depicts this well. For any life analysis whether it be fatigue or fracture there are always three inputs. The first three boxes are the inputs; box four the analysis; and box five the results.

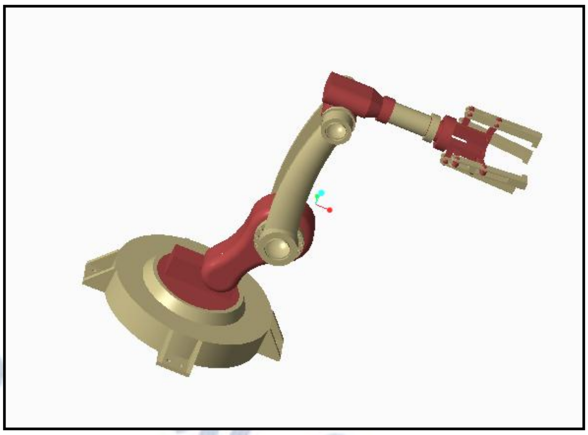


Fig: 2 Assembly Model of Robot Arm

Table: 1 Material properties

Material	Density (kg/m^3)	Young's modulus (Mpa)	Poisson's ratio
Aluminum alloy 7475	2770	70000	0.31
Kevlar	1470	131000	0.35
Carbon Fiber	1800	228000	0.34
E-glass fiber	2560	76000	0.33
Boron fiber	2600	212000	0.28

4.STATIC ANALYSIS OF ROBOTIC ARM

Material-Kevlar

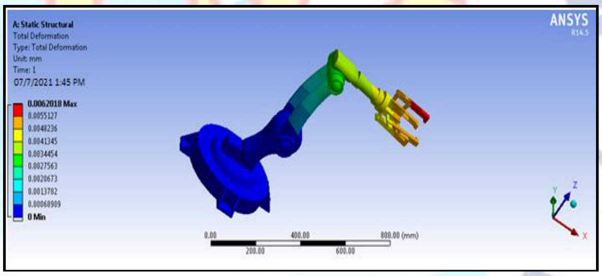


Fig: 3 Total Deformation

According to the above plot, the maximum deformation is at the gripper because of the applied boundary conditions at the base of the robot. The maximum deformation is 0.00604 mm and minimum deformation is 0.0006899mm

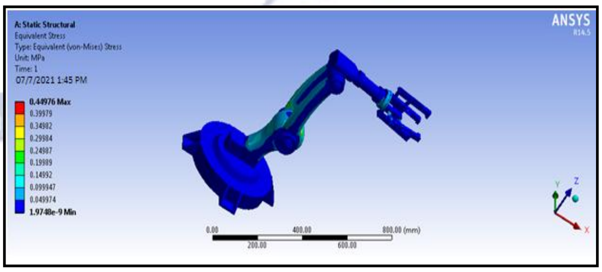


Fig: 4 Von-Mises Stress

According to the counter plot, the maximum stress at base and elbow and minimum stress at the gripper because applied to boundary conditions (force) at elbow of the robot arm. The maximum stress is 0.449N/mm2 and minimum is 0.049 N/mm2

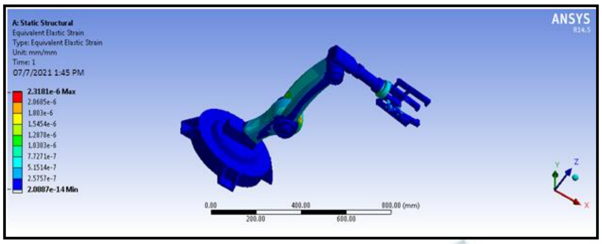


Fig: 5 Von-Mises Strain

According to the counter plot, the maximum strain is at base and elbow and minimum strain at the gripper because applied to boundary conditions (force) at elbow of the robot arm. The maximum strain is 2.3181 e-6 and minimum is 2.0888 e-14.

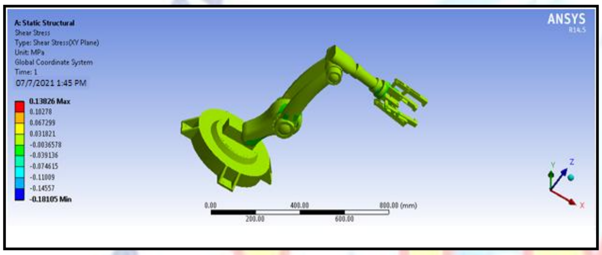


Fig: 6 Shear stress

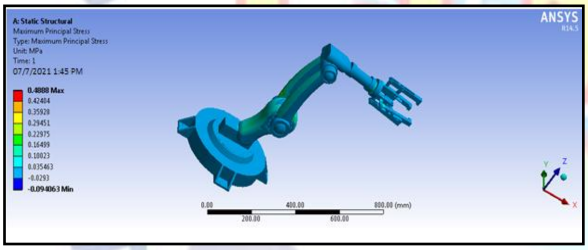


Fig:7 Maximum principle stress

A. Fatigue Analysis

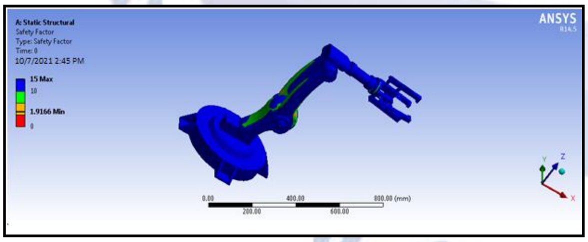


Fig:8 Safety factor

According to the counter plot, the minimum safety factor induced is 1.9166 and 15 is the maximum safety factor value in robot arm.

B. Modal Analysis

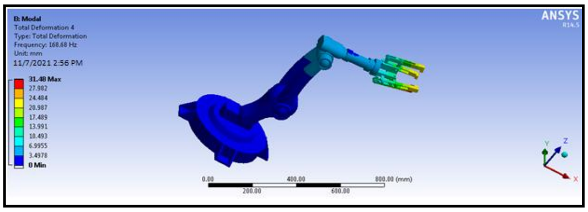


Fig 9: Total Deformation 1

According to the counter plot, the maximum deformation gradually increases from base to grips and minimum at base of the robot arm.

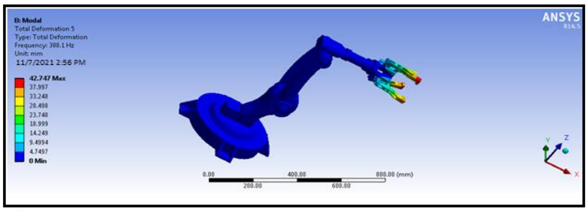


Fig 10: Total Deformation 2

According to the counter plot, the maximum deformation gradually increases from base to grips and minimum at base of the robot arm.

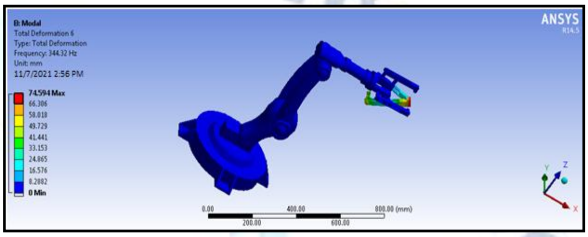


Fig11: Total Deformation 3

According to the counter plot, the maximum deformation at grips and elbow and minimum at base of the robot arm.

5.RESULTS AND DISCUSSION

Table: 1 Static Analysis Results

Material	Total deformation (mm)	Stress (N/mm²)	Strain	Shear stress(N/mm²)	Maximum principle stress
Aluminum alloy 7475	0.01240	0.8953	4.63e-5	0.27651	0.97761
Carbon fiber	0.00950	0.68964	3.544e-6	0.21199	0.7495
Kevlar	0.006208	0.44976	2.31e-6	0.13826	0.4888
E-glass fiber	0.006615	0.47975	2.472e-6	0.147	0.5213
Boron fiber	0.0068219	0.49474	2.549e-6	0.152	0.53768

The above table 1 is the result of static structural analysis performed on robotic arm with the outcomes total deformation, stress, strain, shear stress, maximum principle stress with different materials.

Table: 2 Fatigue Analysis Results

Material	Safety factor
Aluminum alloy 7475	0.958
Carbon fiber	1.2499
Kevlar	1.9166
E-glass fiber	1.7968
Boron fiber	1.7423

The above table 2 is the result of fatigue analysis done on robotic arm with the outcome safety factor with different materials.

Table: 3 Modal Analysis Results

Material	Mode 1	Frequency	Mode 2	Frequency	Mode 3	Frequency
Aluminum alloy 7475	15.711	75.509	15.05	77.654	22.146	141.3
Carbon fiber	15.712	75.503	15.54	77.653	22.143	141.32
Kevlar	31.48	168.68	42.747	300.1	74.594	344.32
E-glass fiber	15.712	75.509	15.05	77.653	22.146	141.31
Boron fiber	15.85	76.109	15.15	77.943	23.046	142.11

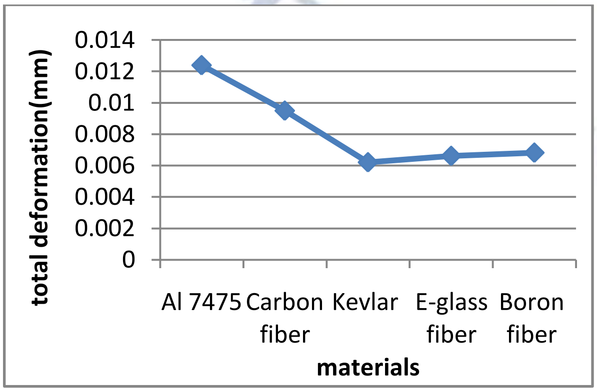
The above table 3 is the result of modal analysis done on robotic arm with the outcomes of different mode deformations and corresponding frequency values with different materials.

Table: 4 Weight estimation

Material	Weight(Kg)
Aluminum alloy 7475	40.3
Carbon fiber	26.18
Kevlar	21.38
E-glass fiber	37.24
Boron fiber	37.82

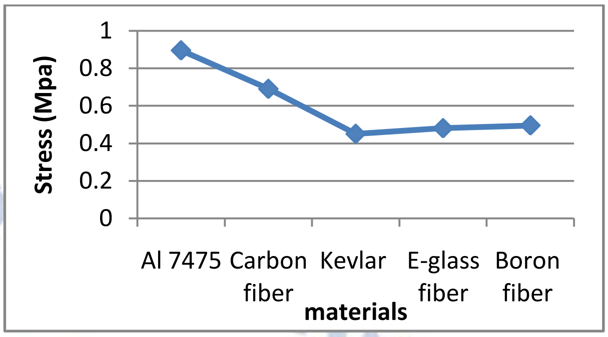
The above table 4 is the result of weight estimation done on robotic arm with different materials.

Graph: 1 material versus deformation



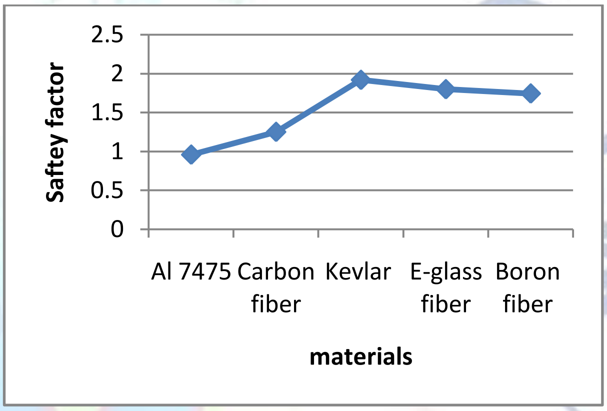
According to the above graph, the total deformation of arm less at Kevlar when compared to the Aluminum alloy 7475, carbon fiber and other materials.

Graph: 2 materials versus stress



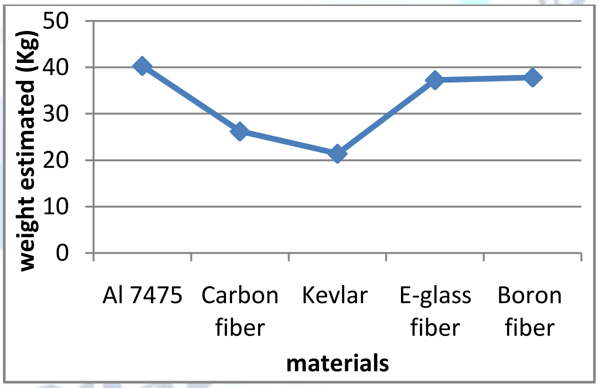
According to the above graph, the stress value less at Kevlar fiber when compared to the Aluminum alloy 7475, carbon fiber and other materials.

Graph: 3 materials versus safety factor



According to the above graph, the safety factor is higher for kevlar material then other materials considered.

Graph: 4 materials versus weight



According to the above graph, the Kevlar poses much less weight compared to Aluminum alloy 7475, carbon fiber and other materials.

6.CONCLUSION

In this research, a robot arm was constructed and evaluated utilizing a CAD-tool (solid works) with real-time boundary conditions using five different materials (Al 7475, carbon fiber, kevlar29,E-glass and boron fiber). The results of deformation and stress, as well as shear stress and strain, frequency values, were displayed and analyzed for all models. We'll determine which material has the least weight and the least number of stress values based on all of these findings. We obtained varied stress and strain values when evaluating models made of various materials. When comparing robotic arm by materials, we can conclude that the kevlar arm robot has decreased total stress by 50% and increased natural frequency by 124 percent when compared to the aluminum alloy 7475 arm robot. In comparison to other materials, Kevlar fiber creates significantly less stress and has a high natural frequency. As a result, we know that composite materials are typically high-strength but also costly materials. When comparing the different materials used in arm robots, we can see that Kevlar arm is 47 percent lighter than Aluminum alloy 7475 and also lighter than other materials. We discovered that Aramide fiber has a longer life and a higher safety factor, indicating that kevlar is the best material for high fatigue strength. As a result, we can infer that the design and material of the robot arm have been adjusted for effective operation using Kevlar composite fiber material.

REFERENCES

[1] B.O.Omijeh, R.Uhunmwangho, M.Ehikhamenle 1,2,3department Of Electrical/Electronic Engineering, University Of Port Harcourt, Port Harcourt. Design Analysis Of A Remote Controlled "Pick And Place"Robotic Vehicle International Journal Of Engineering Research And Development E-Issn: 2278-067x, P-Issn: 2278-800x, Www.Ijerd.Com Volume 10, Issue 5 (May 2014), Pp.57-68.

[2] Design And Analysis Of Circular And Square Arm Robot , Volume 1, Issue 11 (2016, Nov) (Issn-2455-6300) Online Anveshana's International Journal Of Research In Engineering And Applied Sciences.

[3] Mukund Narayan Pandey, Dr. APJ Abdul Kalam Technical University, Lucknow mukundmuskan1973@gmail.com Amit Kr Srivastava Dr. APJ Abdul Kalam Technical University, Lucknow amitme.srivastava@gmail.com Paveen Kumar Maurya. Design & Analysis of Robotic Arm's Part for Carbon Composite Material

[4] Lee, Jeayoul (R&D Division, Korea Institute of Robot and Convergence) ; Jeon, Kwangwoo (Design Technology Center, Defence and Aerospace Division, Hankuk Fiber Co., Ltd.) A Development of the Lightweight Wearable Robot with Carbon Fiber Composite Volume 28 Issue 3 / Pages.81-88 / 2015 / 2288-2103(pISSN) / 2288-2111(eISSN)

[5] Gang Qi Department of Mechanical Engineering McGiII University, Optimal Design of a Lightweight Robotic Manipulator Using Carbon Fiber-reinforced Composites Montreal Your file Votreréférence ISBN: 0-494-12640-X Our file Notre référence ISBN: 0-494-12640