



INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X

Impact factor: 4.295

(Volume3, Issue5)

Available online at www.ijariit.com

Design & Analysis of Robotic Arm's Part for Carbon Composite Material

Mukund Narayan Pandey

*P.G Student'st of Mechanical Engineering,
Dr. APJ Abdul Kalam Technical University,
Lucknow*

mukundmuskan1973@gmail.com

Amit Kr Srivastava

*Assistant Prof. of Mechanical Engineering
Dr. APJ Abdul Kalam Technical University,
Lucknow*

amitme.srivastava@gmail.com

Paveen Kumar Maurya

*Design Engineer
Apsinox Designer Pvt. Ltd.*

ppaveenmaurya@gmail.com

Abstract: *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. Robots are more quickly, cheaply, and accurately than humans have ever been. The materials in contact with the moving arm experience very large elastic deformations and stress and may move at a velocity close to that of the tool. Our project mainly deals with the shearing operation, our challenge is designing and optimizing a light weight material robotics arm's part which is more durable and reliable. After related study we have achieved the design and analysis of a jointed robotic arm's part where the bases are fixed and the remaining joints move in vertical and horizontal directions.*

Keywords: *Digital Prototype, FEA, Ansys 17, Stress & Strength.*

I. INTRODUCTION

Robots designed to share an environment with humans, such as e.g. in domestic or entertainment applications or in cooperative material handling tasks, must fulfill different requirements from those typically met in the industry. To rapidly respond to a given command, industrial robots must have lightweight manipulators. However, light structures tend to be weaker and more susceptible to bending deformations; thus leading to a deterioration in the end effector positional accuracy. It is often the case, for instance, that accuracy requirements are less demanding. On the other hand, a concern of paramount importance is safety and dependability of the robot arm. According to such difference in requirements, it can be expected that usage of conventional industrial arms for anthropic environments will be far from optimal. The inherent danger to humans of conventional arms can be mitigated by drastically increasing their sensitization (using e.g. proximity-sensitive skins such as those proposed by and changing their controllers. However, it is well known in the robotics literature that there are intrinsic limitations to what the controller can do to modify the behavior of the arm if the mechanical bandwidth (basically dictated by mechanism inertia and friction) is not matched to the task. In other words, making a rigid, heavy robot to behave gently and safely is an almost hopeless task, if realistic conditions are taken into account.

One alternative approach to increasing the safety level of robot arms interacting with humans is to introduce compliance right away at the mechanical design level. Accuracy in positioning and stiffness tuning would then be recovered by suitable control policies. This approach is clearly closer in inspiration to biological muscular apparatuses than to classical machine-tool design, which has inspired most robotics design thus far.

Several projects are being pursued in research labs towards the design of passively compliant, biologically inspired arms. Particular attention has been devoted to the development of suitable actuators. Studies on the organization of motor control in humans have been used to inspire control architectures of anthropomorphic robots. We describe our approach to intrinsically safe robot arm's part design using composite materials, and a digital prototype arm's built in our laboratory. The main characteristic of the arm's part is that it introduces relatively high, strength compliance at the mechanical level. The arm's part is designed to achieve position tracking in 3D with a variable effective submission at the joints. Rather than achieving compliance by methods based on controller synthesis, in our design, we have compliant nonlinear actuators that offer intrinsic obedience (hence safety), even in cases where the materials

may fail. On the other hand, modern manufacturing techniques are adopted to recover accuracy in part's design and its strength the arm amenability to accomplish tasks which require those features. A hierarchical manner.

II. OLDHAM COUPLING AND ITS PROPERTIES

Oldham coupling is a robotic arm's part. Couplings are divided into categories: Rigid and Flexible. As compared with flexible couplings, rigid couplings have limited application. Rigid couplings do not have the ability to compensate for shaft misalignments and are therefore used where shafts are already positioned in precise lateral and angular alignment. Any misalignment between shafts will create high stresses and support bearing loads.

Rigid couplings by virtue of their simple rugged design are generally able to transmit more power than flexible couplings of comparable size but this is not an important advantage except in high horsepower applications.

This section will be devoted to the small to medium size flexible type couplings which cover a much larger field of applications. Flexible shafts, which are closely related to flexible couplings will also be discussed. This write-up is divided into the following categories.

A. Oldham Coupling

Oldham couplings consist of three members. A floating member is trapped by 90 displaced grooves between the two outer members which connect to the drive shafts as shown in Figure. Oldham couplings can accommodate lateral shaft misalignments up to 10% of nominal shaft diameters and up to 3 angular misalignments. Lubrication is a problem but can in most applications be overcome by choosing a coupling that uses a wear resistant plastic or an elastomer in place of steel or bronze floating members.

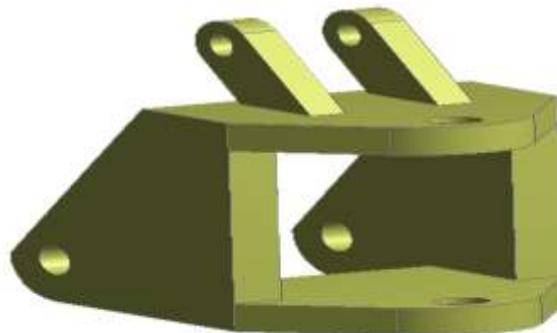


Fig.1 Digital Prototype of Oldham coupling.

Oldham couplings have the following advantages:

- No velocity variation as with universal joints
- High lateral misalignments possible
- High torque capacity
- Ease of dismantling

B. Composite Materials

This part is design using Corban composite material. The idea of combining several components to produce a new material with new properties that are not attainable with individual components is not of recent origin. Humans have been creating composite materials to build stronger and lighter objects for thousands of years. The first use of composite dates back to the 1500 B.C. when early Egyptian and Mesopotamian settlers used a mixture of mud and straw to create strong and durable buildings. Straw continued to provide reinforcement to ancient composite products including pottery and boats. Later, in 1200 A.D. the Mongols invented the first composite bow. Using a combination of wood, bone, and "animal glue," bows were pressed and wrapped with birch bark. These bows were extremely powerful and extremely accurate. Composite Mongolian bows provided Genghis Khan with military dominance, and because of the composite technology, this weapon was the most powerful weapon on earth until the invention of gunpowder. Although composite materials had been known in various forms throughout the history of mankind, the history of modern composites probably began in 1937 when salesmen from the Owens Corning fiberglass company began to sell fiberglass to interested parties around the United States. Fiberglass had been made, almost by accident in 1930, when an engineer became intrigued by a fiber that was formed during the process of applying lettering to a glass milk bottle.

C. Definition

Nano composites are generally defined as composites in which one of the components have at least one dimension (i.e., length, width or thickness) in the size range of 1-100 nm. Nano composites differ from traditional composites in the sense that interesting properties can result from the complex interaction of the nanostructured heterogeneous phases. In addition, nanoscopic particles of a material differ greatly in the analogous properties of a macroscopic sample of the same material. The study of

Nano composite materials is a fast growing area of research. This rapidly expanding field is generating many exciting new high-performance materials with novel properties. The properties of Nano composite materials depend not only on the properties of their individual parents but also on their morphology and interfacial characteristics. There is also the possibility of new properties which are unknown in the parent constituent materials.

D. Types of components used in Nano composites

- Polymer-matrix Nano composites
- Ceramic-matrix Nano composites
- Metal-matrix Nano composites
- Clay as a component of Nano composites

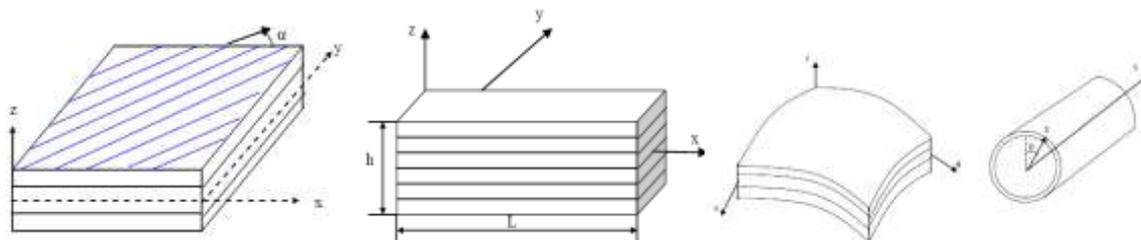


Fig 2. Laminated beams.

Laminated beams in Local coordinate.

Composite Material in curvilinear coordinate system.

As shown in Figure, laminated beams are made-up of many plies of orthotropic materials and the principal material axes of a ply may be oriented at an arbitrary angle with respect to the x-axis. In the right-handed Cartesian coordinate system, the x-axis coincides with the beam axis and its origin is on the midplane of the beam. The length, breadth, and thickness of the beam are represented by L, b and h, respectively.

In practical engineering applications, laminated shells of revolution may have different geometries based mainly on their curvature characteristics such as cylindrical shells, spherical shells and conical shells. The composite shell of revolution is composed of orthotropic layers of uniform thickness as shown in Figure A differential element of a laminated shell shown with an orthogonal curvilinear coordinate system located on the middle surface of the shell. The total thickness of the shell is h.

E. Carbon/Epoxy Composite Carbon fiber - Epoxy Resin Matrix

Carbon fiber reinforced composites have exceptional mechanical properties. These strong, stiff and lightweight materials are an ideal choice for applications where light weight & superior performance are important, such as components for aircraft, automotive, rail and high-quality consumer products. Composite materials are produced by combining a reinforcing fiber with a resin matrix system such as epoxy. This combination of fiber and resin provides characteristics superior to either of the materials alone and are increasingly being used as replacements for relatively heavy metallic materials. In a composite material, the fiber carries the majority of the load and is the major contributor to the composite material properties. The resin helps to transfer load between fibers, prevents them from buckling and binds the materials together. The range offered is based upon composite sheets produced by stacking carbon fiber fabrics one upon another and then infusing the stack with resin under vacuum. This process produces sheets with one smooth glossy resin rich side and the other rougher side showing the fabric weave detail.

Properties for Carbon/Epoxy Composite Material

Properties and its values

Coefficient of thermal expansion - Longitudinal	2.1x10-6 K-1
Coefficient of thermal expansion - Transverse	2.1 x10-6 K-1
Compressive Strength - Longitudinal	570 MPa
Compressive Strength – Transverse	570 MPa
Density	1.6 g cm-3
Shear modulus - in-plane	5 GPa
Shear strength - in-plane	90 MPa
Ultimate Compressive Strain - Longitudinal	0.8 %
Ultimate Compressive Strain - Transverse	0.8 %
Ultimate Shear Strain - in-plane	1.8 %
Ultimate Tensile Strain - Longitudinal	0.85 %
Ultimate Tensile Strain - Transverse	0.85 %
Volume fraction of fibers	50 %
Young's Modulus - Longitudinal	70 GPa
Young's Modulus - Transverse	70 GPa

F. Mechanical properties of composites

The mechanical properties of composite materials usually depend on structure. Thus these properties typically depend on the shape of in homogeneities, the volume fraction occupied by in homogeneities, and the interfaces between the components. The strength of composites depends on such factors as the brittleness or ductility of the inclusions and matrix.

For example, failure mechanisms in fiber-filled composites include fracture of the fibers; shear failure of the matrix along the fibers; fracture of the matrix in tension normal to the fibers or failure of the fiber-matrix interface. The mechanism responsible for failure depends on the angle between the fibers and the specimen's axis.

• Strength of Composite material

Failure of components occurs at low-stress values than the ultimate or yield strength of the material due to the application of a time varying cyclic loadings. This phenomenon is called fatigue. Basically, crack initiation and crack propagation are the main cause of fatigue failure of components. First of all due to cyclic loading components become unstable and crack initiation takes place and after that crack propagation results in sudden failure. Calculation of total fatigue life is done by adding the life of crack initiation and the life of crack propagation. It is not possible to calculate the fatigue life by separating the two phases of crack i.e. by separating initiation of crack and propagation of crack by any method.

• Effect of Ductility/Plasticity

When the ductility of the material plays an important role, EPFM (Elastic Plastic Fracture Mechanics) is a very much precise substitute to LEFM (Linear Elastic Fracture Mechanics) in the evaluation of the active properties of Carbon Composite -2. LEFM correlates crack growth rates resulting from an applied cyclic load (da/dN) to the stress intensity factor ΔK ; this is given by:

$$da/dN=C [(\Delta K)]^m,$$

Where da/dN is the crack growth increment per loading cycle, ΔK is the factor of stress intensity ($K_{max}-K_{min}$), and C and m are functions of the stress ratio, frequency, environment, temperature, material variables etc.

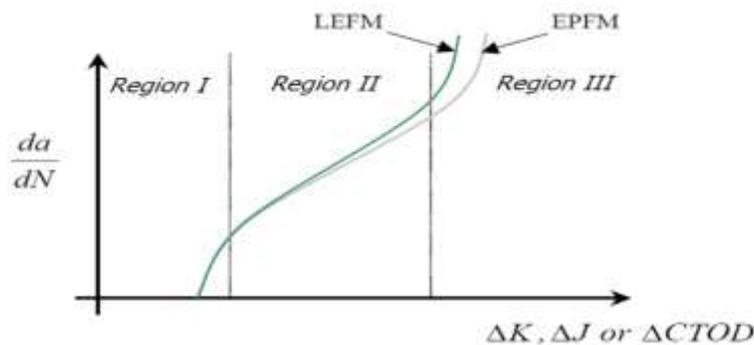


Fig 3. LEFM vs. EPFM in high plasticity conditions.

In graphical form, this relationship is seen in Figure.1.1. Regions I, II, and III correspond to the initiation, propagation, and final failure in crack evolution. It is important to point out that for longer crack length; the plasticity region present in front of the crack becomes more and more significant. Therefore, because of yielding, LEFM becomes less and less accurate at higher ΔK values, and elements of EPFM, such as the J-integral or CTOD (Crack Tip Opening Displacement) need to be considered to obtain realistic representations of the upper Region II, Region III and fracture toughness of the material. KIC values from LEFM evaluations underestimate the behavior of the material. A more accurate approach to both FCGR curves and fracture toughness should consider a cyclic J-analysis using the load-displacement data from the FCGR experiments.

• Fracture Mechanics

Fracture mechanics is a branch of science involving with micro mechanics and strength of materials. Fracture mechanics is applied in order to obtain the fracture parameters of a cracked components or specimens, creating a singular stress field at the tip of the crack. Fracture toughness describes the ability to resist fracture and depends on component dimension, loading and material properties at the operating conditions. In practice, steel components are in many cases too large and too expensive to be tested as such in their operating conditions for their fracture characteristics. Thus, it is more beneficial to divide the fracture toughness determination in two stages: firstly, the determination of the fracture toughness of the material as a function of the test temperature and other operating conditions, and secondly application of a scaling dependent factor to obtain the fracture toughness of the component or its weakest part. Specimens that can be tested in laboratories and are inexpensive enough to be broken in large numbers are used for the first stage of the fracture toughness determination. Currently, there exist numerous standards for the fracture toughness testing of metallic materials. Common to all standards is a requirement of large enough specimen size in order to obtain test results dependent solely on the material properties, not on the dimension or the size of the specimen.

There are two, parallel ways to investigate the geometry effect on fracture toughness: experimental and computational analysis, the latter referring often to Finite Element Method (FEM). This project work includes both types of approaches. Experimental fracture

toughness values have been determined for specimens with varying thickness (B), varying ratio of crack depth to specimen width (a/W) or varying flaw geometry from through the thickness to elliptical surface cracks. Extensive finite element analyses (FEA) have been applied for models with geometries ranging from standardized specimens to plates with surface flaws, having specimen thickness, crack size and material strain hardening exponent as parameters. Also, the effects of side grooving have been studied. For the determination of fracture toughness of metallic materials using the following parameters such as K, J, and CTOD (δ).

- **Effect of Residual Stress**

Carbon Composite is heat treated by quenching solution treatment which is monitored at a temperature approximately 1000°F., As a result, the introduction level of residual stress in the components (or samples) is significant. On the surface of the sample, nature of the residual stresses is compressive, which cools first, while in the center of the sample, nature of the residual stress is tensile, which cools later. Quenching treatment is processed on the whole sample to balance the tensile stress and compressive stress, which results in zero net effective stress in the sample. Subsequently for enhancement of the strength of the sample without having any effect on the residual stresses in the part aging treatment is processed on the sample.

Fatigue crack growth response of Carbon Composite is mainly affected by alloy microstructure and residual stress. Fatigue crack growth behavior is prominently affected by residual stress at low ΔK .

III. METHODOLOGY

Most of the products which are subjected to repeated cyclic loadings will fail eventually. This type of failure is termed as fatigue failure. A major cause of the failure of a product is fatigue failure which can result in substantial injuries and damage sometimes. Varying or repeated loads on repetitive stress for a long time duration changes the microscopic structure of component which resulted in a crack formation that origins the breakdown. Initially, many components work properly but due to fatigue failure, they often fail due to repeated cyclic loadings in their service. Basically, we use to do fatigue simulation for following factors:

- a. Optimization of shape and size.
- b. Optimization of material consumption & Strength.
- c. Desired product life.

Ansys is a tool containing non-destructive simulation process to simulate fatigue life which is governed by the equation of fatigue. Ansys empowers the engineers to calculate the product life with the complete simulation process of fatigue. We can use ansys very efficiently for fatigue life estimation due to its huge material library, convenient way to apply boundary conditions and loads, automatic meshing and much more advantageous information. Ansys is also connected with CAD geometry so that we can import a complicated geometry in ansys. Optimization can also be done by ansys.

Overall material properties using ANSYS

In order to predict elastic modulus in the longitudinal direction, the laminated model is loaded in axial tension by applying a small normal displacement at one side and fully restraining the other side. For example, the $x = 0$ ends is constrained in the axial direction (x direction) and free to move in the lateral directions as shown in Figure. The free edges are constrained to their respective normal directions in order to allow contraction of the model due to tension. An axial displacement, equivalent to the approximate less than 10% of total length of the plate, is applied to all nodes on the end surface ($x = L$), where L is the length of the laminated structure. The displacement and reaction forces are calculated on the data collection surfaces (i.e. constraint area). Then, the values of these displacements and reaction forces are employed to evaluate the effective elastic properties of the composites.

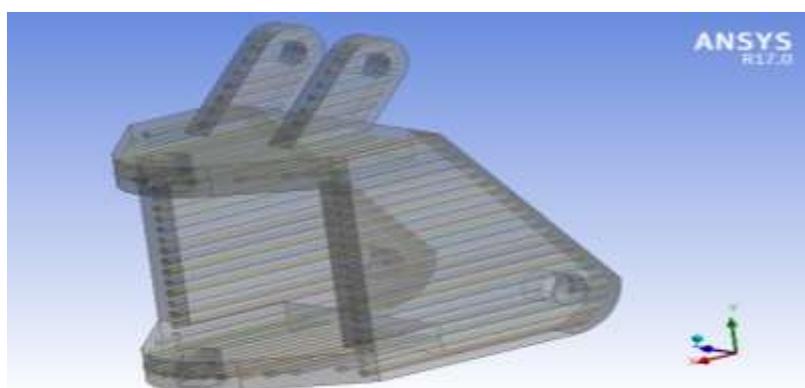


Fig 4. Reinforce composite material part in ansys design modular.

The reaction forces calculated on constraint surface gives average stress on that surface. A far field uni-axial displacement is applied to the finite domain only in the longitudinal direction (the x-direction). The modulus of the laminated composite is estimated using the displacement and average stress result at data collection surfaces normal to the x-axis by the following formula:

$$E_x = \frac{\bar{\sigma}_x}{\epsilon_x} = \frac{L}{(\Delta U)_{avg}} \bar{\sigma}$$

Where U is the displacement applied and the average value of stress on a surface is given by

$$\bar{\sigma} = \frac{1}{A} \int_A \sigma_x ((z = 0), x, y) dx dy$$

Where A is the area of constrained surface at L=0 with the help of FEM results of average stress can be evaluated for the laminated composite. The laminated structure is subjected to a uniform extension within the linear region of the stress -strain curve.

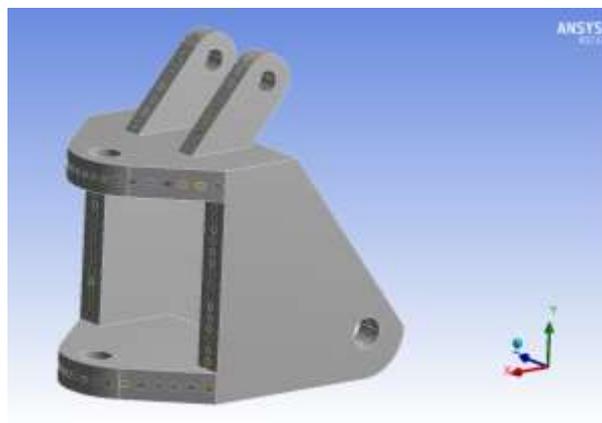
We us $\epsilon_y = \frac{\nu_{xy}}{E_x} \sigma_x$

Fatigue is analyzed by two methods in ANSYS:

A. Stress life. B. Strain life.

Strain life is basically characterized by low cycle fatigue and it can be directly measured. Fewer than 10⁵ (100000) cycles are termed as low cycle fatigue. Required input for strain life is the total strain (Elastic-plastic).

The mechanical property of component for Aluminum Alloy Material:



Volume	0.14829 m ³
Mass	388.93 kg

Fig 5. Geometry & Mesh View for FEA.

Mesh Properties

Sizing	
Size Function	Curvature
Curvature Normal Angle	Default (70.3950 °)
Min Size	Default (8.2347e-004 m)
Max Face Size	Default (8.2347e-002 m)
Defeaturing Tolerance	Default (4.1173e-004 m)
Minimum Edge Length	3.6063e-004 m
Nodes	423848
Elements	233694

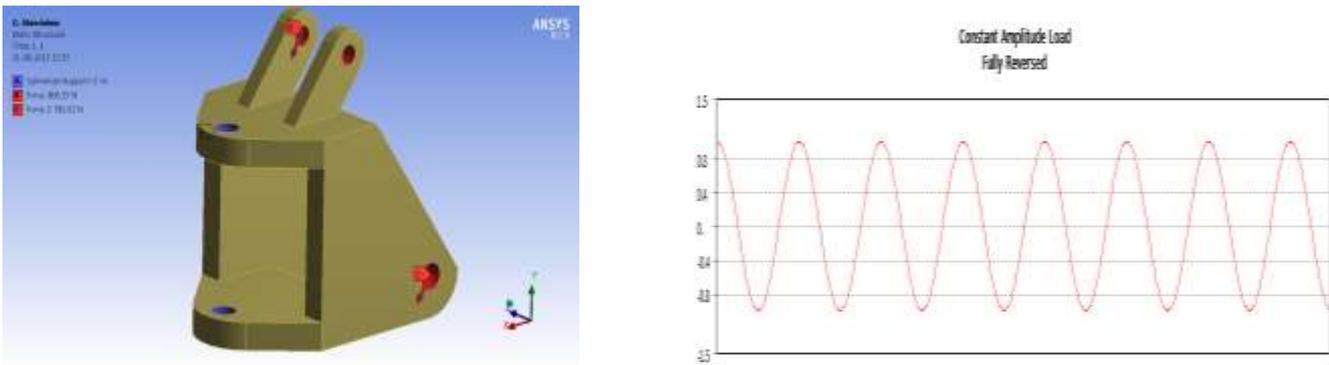


Fig 6. Boundary Condition

The mechanical property of component for Composite Material:

- Young's modulus = 71 Gpa
- Poisson's ratio = 0.33
- Tensile yield strength = 280 Mpa
- Compressive yield strength = 280 Mpa
- Ultimate tensile strength = 310 MPa
- Epoxy Carbon Woven (395 GPa) Prepreg
- Young's modulus = 91.82 Gpa
- Poisson's ratio = 0.3

IV. RESULTS

Equivalent stress

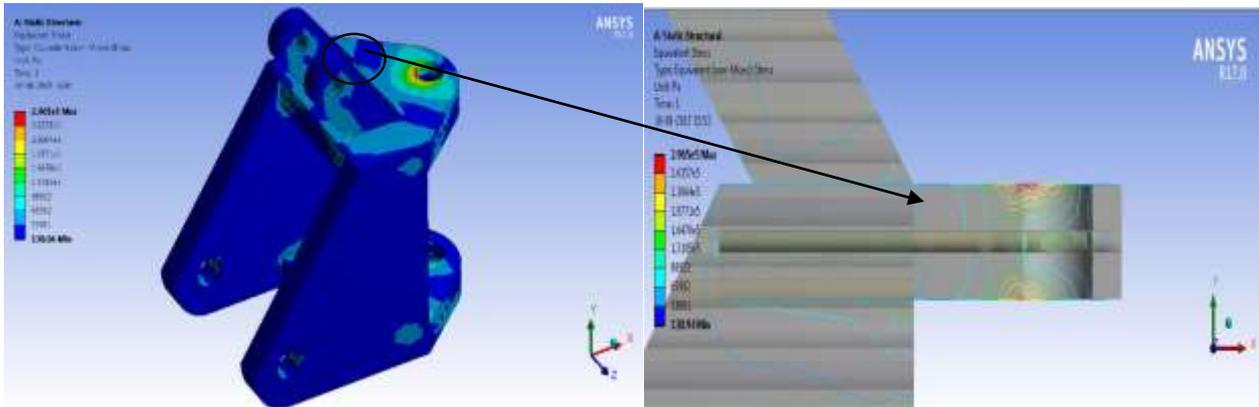


Fig 7. Max. Stress distribution isoline section view Equivalent strain

Equivalent strain

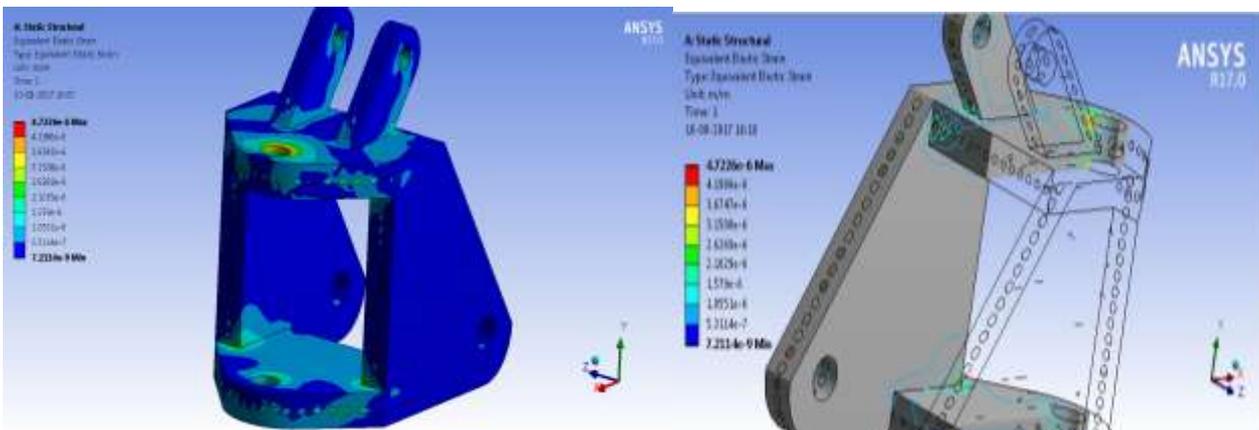


Fig 8. The equivalent strain of Carbon Composite part.

Total Deformation

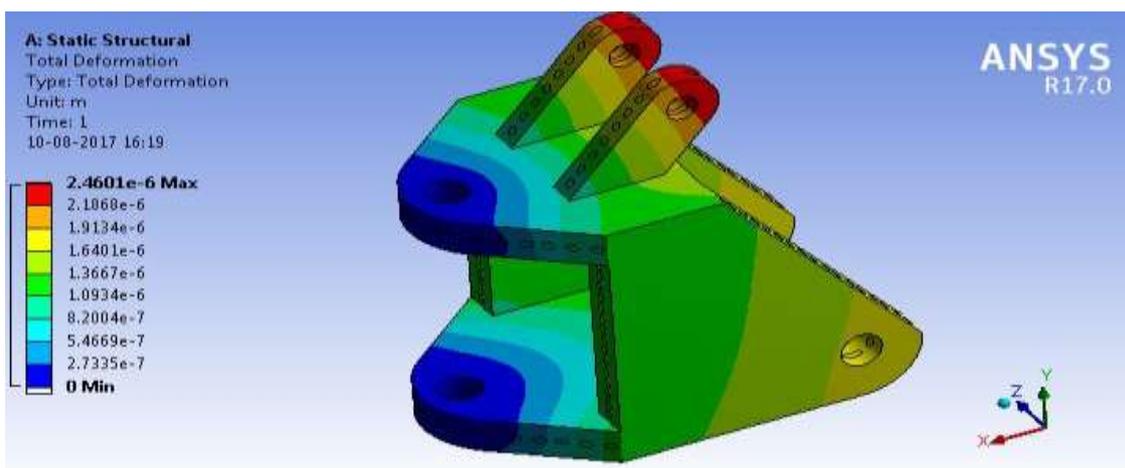


Fig 9. Deformation of Carbon Composite part.

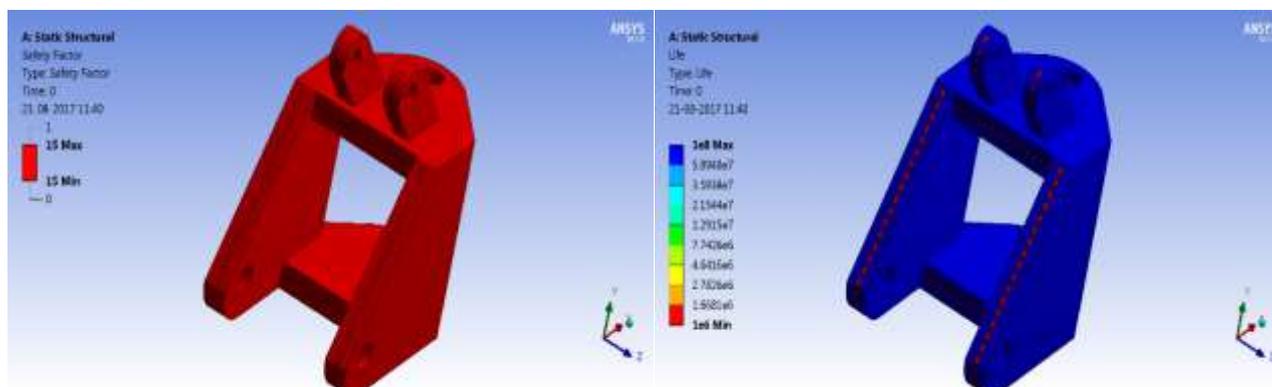
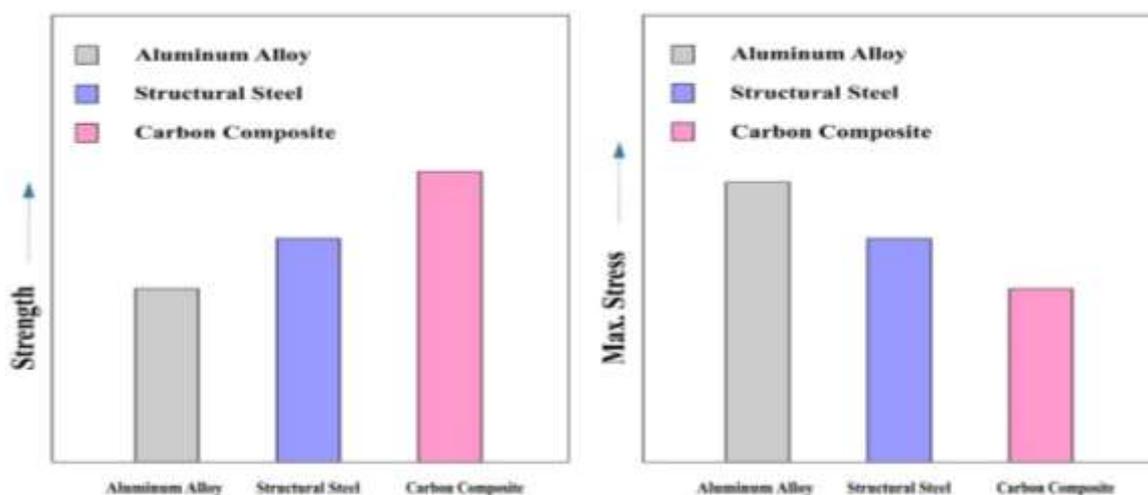
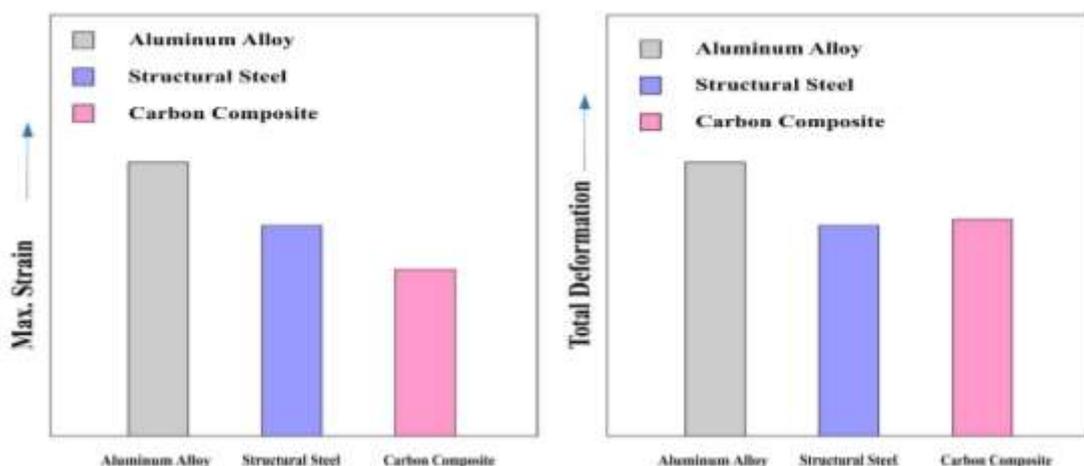


Fig 10. Safety Factor and Life of Carbon Composite part due to cycle load

Comparison with current material





CONCLUSION

In the present work, general classical lamination theory has been employed to predict the stiffness matrices connecting the forces and strains as well as moments and curvatures.

The use of the carbon fiber composite resulted in a wide range of variability in the engineered robotic parts predicted by the FEA. It does, however, possess a high specific modulus not available in any isotropic material. This allows the material to be lightweight but still, have a high strength. The methodology was generalized by using a graphic user interface (GUI). These values were validated using finite element modeling in ANSYS software.

The concept of equivalent modulus beam theory introduced the early 1990s for Euler-Bernoulli beams has been employed to obtain the fundamental natural frequencies for two end conditions. This method involves calculating the eigenvalues of the isotropic Bernoulli beam, using the longitudinal modulus of the composite material computed with the classical back bone theory. This theory is applicable for symmetrically balanced back bone. Due to the low mass required for the robotics parts, composites seemed to be the only viable solution due to the inertial loading caused by the flapping of the robotics parts. However, this means that the Epoxy Carbon Woven (395 GPa) Prepare composite currently used is the best solution. Quasi-isotropic materials are unidirectional composite materials where the laminate arranged such that the material properties in x, y, and z direction are the same. If a material and orientation could be found or developed that would provide the same axial stiffness (the ability of a beam to resist bending) in both the x and y directions of the composite, then a composite material could be viable.

FUTURE SCOPE

The objective of this study is to investigate new techniques for light weight and high strength evaluation of components with a given load condition. The fundamental idea is that finite element analysis of a statics structure analysis will provide better characterization of the components than current empirical techniques. Some following work would be done:

A more recent approach based on stress distribution mechanics will also be evaluated in terms of predicting the equivalent stress limit of the work piece.

Evaluation of strain parameters for propagating load condition must be done for component failure analysis.

Deformation analysis should be done experimentally to validate the computational results.

REFERENCES

1. Roos, E., Eisele, U., and Silcher, H., "Effect of Stress State on the Ductile Fracture Behavior of Large-Scale Specimens, Constraint Effects in Fracture. ASTM STP 1171, E.M. Hackett, K.-H. Schwalbe, and R. H. Dodds, Eds., American Society for Testing and Materials, Philadelphia, (1993) 41-63
2. Starke E.A., Jr. and Staley J.T., "Application of modern Carbon Composite to aircraft and progress in Aerospace Sciences", 1996.
3. Qdom, E. M., and Adams, D.F., "Specimen size effect during tensile testing of an unreinforced polymer", *Journal of materials science* 27 (1992) 1767-1771.
4. Yan .C and Mai, Y.W., "Effect of crack depth and specimen width on fracture toughness of a carbon steel in the ductile - brittle transition region", *International Journal of Pressure Vessels and Piping*, 77 (2000) 313-319.
5. Hu, X.Z., "An asymptotic approach to size effect on fracture toughness and fracture energy of composites", *Engineering Fracture Mechanics* 69 (2002) 555-564.
6. Structural Analysis of Tram Car Using Steel and Aluminum Honeycomb by Benyam Adane, 2014
7. Petti, J.P., Dodds R. H., "Constraint comparisons for common fracture specimens: C (T) s and SE (B) s", *Engineering Fracture Mechanics* 71 (2004) 2677-2683.

8. S.K. Chandole, M.D. Shende, M.K. Bhavsar“ Structural Analysis Of Steering Yoke Of An Automobile For Withstanding Torsion/ Shear Loads”, IJRET: International Journal of Research in Engineering and Technology Volume: 03 Issue: 03 | Mar-2014
9. Zhang B., Poirier D.R., and Chen W., “Effect of Strontium Modification and Hydrogen Content on the fatigue Behavior of A356.2 Aluminium Alloy”.
10. S. Kinme, T. Kamikawa, A. Nishino, K. Ikeda and S. Inoue, “Development of Stamped Yoke for High Rigidity Intermediate Shaft” Koyo Engineering Journal English Edition 165E (2004)
11. Ceccarelli, M.; Carobone, G. and Ottaviano, E. “Multi Criteria Optimum Design of Manipulators”, Bulletin technical sciences (2005).
12. Abdel-Malek, K. and Paul, B. “Criteria for the Design of Manipulator Arms for a High Stiffness to Weight Ratio”, SME Journal of Manufacturing Systems, (1998).
13. S.K. Chandole, M.K. Bhavsar, S.S. Sarode, G.R. Jadhav “Design Evaluation And Optimization Of Steering Yoke Of An Automobile” International Journal of Research in Engineering and Technology Nov-2014,
14. P.G. Tathe, Prof. D.S. Bajaj and Swapnil S. Kulkarni, “Failure Analysis And Optimization In Yoke Assembly Subjected By Torsion And Shear”, International Journal of Advanced Engineering Research and Studies E. July-Sept, 2014