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# Finite Element Analysis of Pinned Joints Using Composite Materials

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## 1.ABSTRACT:

In mechanical engineering, there are multiple methods for fastening objects together. A pin joint is a solid cylinder-shaped device, similar to a bolt, which is used to connect objects at the joint area. This type of joint connection allows each object to rotate at the point of joint connection. Most mechanical devices that require bending or opening typically use a pin joint. These joints can be welded solid or allow movement between the two connected objects. The joint area is a region with stress concentrations thus a complicated stress state exists.

In this thesis, different hole cross sections of the pinned joints is analyzed to evaluate the stress concentrations at the joints using composite materials E Glass and S2 Glass epoxy. The cross sections of the hole considered in this work are circular, tapered circular, rectangular and elliptical. Structural analysis is done to determine the stresses and deformations at the joints. Fatigue analysis is done on the joint with less stress concentrations to evaluate the life, damage and safety factor. Structural and fatigue analysis is done in Ansys.

## 2. KEY WORDS:

## 1.1.Introduction to Pro/Engineer:

Pro/ENGINEER is a feature based, parametric solid modeling program. As such, it's use is significantly different from conventional drafting programs. In conventional drafting (either manual or computer assisted), various views of a part are created in an attempt to describe the geometry.

Each view incorporates aspects of various features (surfaces, cuts, radii, holes, protrusions) but the features are not individually defined. In feature based modeling, each feature is individually described then integrated into the part. The other significant aspect of conventional drafting is that the part geometry is defined by the drawing.

If it is desired to change the size, shape, or location of a feature, the physical lines on the drawing must be changed (in each affected view) then associated dimensions are updated. When using parametric modeling, the features are driven by the dimensions (parameters). To modify the diameter of a hole, the hole diameter parameter value is changed. This automatically modifies the feature wherever it occurs - drawing views, assemblies, etc.

Another unique attribute of Pro/ENGINEER is that it is a solid modeling program.The design procedure is to create a model, view it, assemble parts as required, then generate any drawings which are required. It should be noted that for many uses of Pro/E, complete drawings are never created. A typical design cycle for a molded plastic part might consist of the creation of a solid model, export of an SLA file to a rapid prototyping system

(stereo lithography, etc.), use of the SLA part in hands-on verification of fit, form, and function, and then export of an IGES file to the molder or toolmaker. A toolmaker will then use the IGES file to program the NC machines which will directly create the mold for the parts. In many such design cycles, the only print created will be an inspection drawing with critical and envelope dimensions shown.

## 1.2.Different Modules in Pro/Engineer:

•Part Design

•Assembly

•Drawing

•Sheet metal

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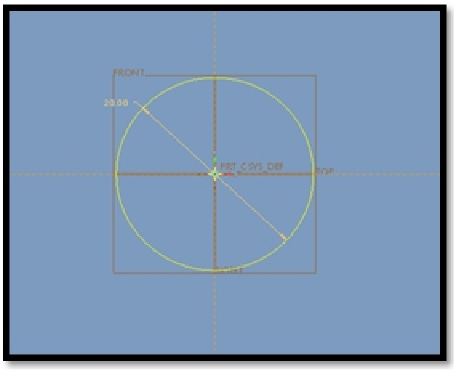
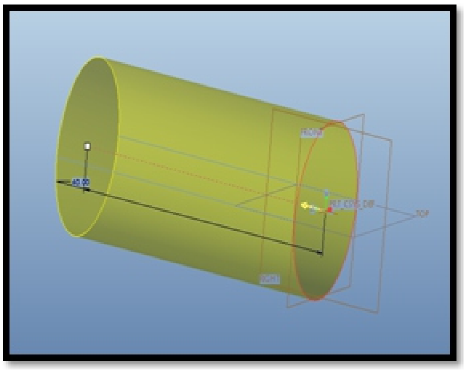
### 1.3.Problems Description:

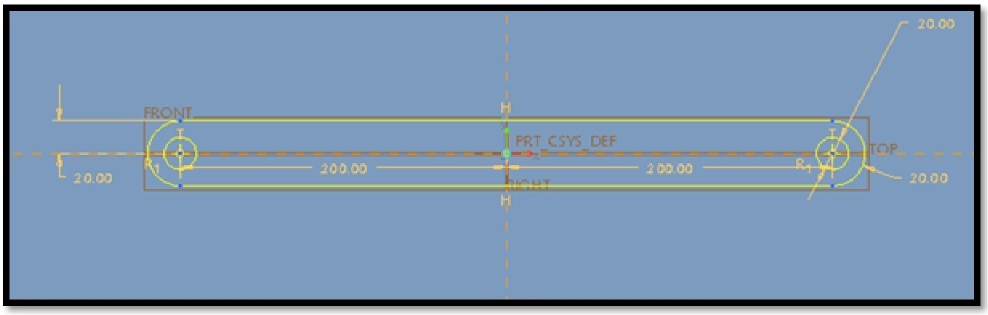
| CASES | MODELS |
|---|---|
| CASE-1 | Circular |
| CASE-2 | Tapered |
| CASE-3 | Square |
| CASE-4 | Elliptical |

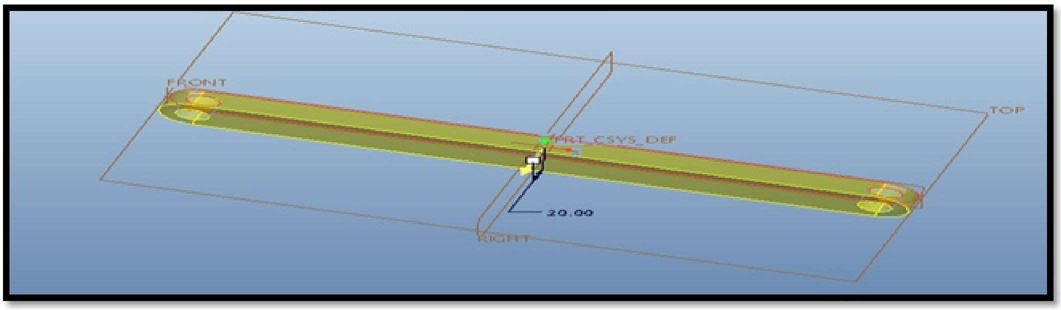
### 1.4.Case-1 cylindrical Pin
### 1.4.1 Sketch





### 1.3.Problems Description:



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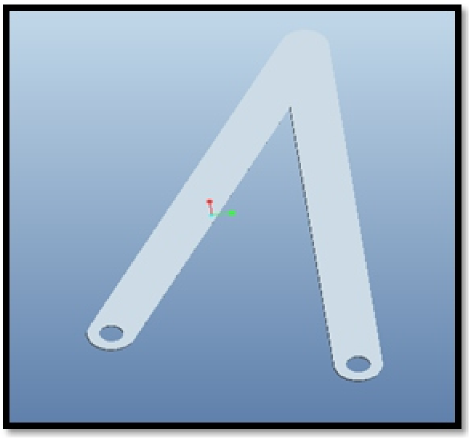
### 1.4.3 Assembly of Cylindrical Pin



### 1.5 Introduction to Ansys:

The ANSYS program is self-contained general purpose finite element program developed and maintained by Swason Analysis Systems Inc. The program contain many routines, all inter related, and all for main purpose of achieving a solution to an engineering problem by finite element method.ANSYS finite element analysis software enables engineers to perform the following tasks:

•Build computer models or transfer CAD models of structures, products, components, or systems.
•Apply operating loads or other design performance conditions
•Study physical responses ,such as stress levels, temperature distributions, or electromagnetic fields
•Optimize a design early in the development process to reduce production costs.
•Do prototype testing in environments where it otherwise would be undesirable or impossible

The ANSYS program has a compressive graphical user interface (GUI) that gives users easy, interactive access to program functions, commands, documentation, and reference material. An intuitive menu system helps users navigate through the ANSYS Program.

Users can input data using a mouse, a keyboard, or a combination of both. A graphical user interface is available throughout the program, to guide new users through the learning process and provide more experienced users with multiple windows, pull-down menus, dialog boxes, tool bar and online documentation.

### 1.6 Structural:

Structural analysis is probably the most common application of the finite element method as it implies bridges and buildings, naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

•Static Analysis - Used to determine displacements, stresses, etc. under static loading conditions. ANSYS can compute both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.
•Transient Dynamic Analysis - Used to determine the response of a structure to arbitrarily time-varying loads. All nonlinearities mentioned under Static Analysis above are allowed.
•Buckling Analysis - Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigenvalue) buckling and nonlinear buckling analyses are possible.

In addition to the above analysis types, several special-purpose features are available such as Fracture mechanics, Composite material analysis, Fatigue, and both p-Method and Beam analyses.

### 1.7. Material Properties:

| | E- GLASS | S2-GLASS |
|---|---|---|
| YOUNGS MODULUS(MPa) | 80000 | 87000 |
| POISSON'S RATIO | 0.27 | 0.22 |
| DENSITY(g/cc) | 1.9 | 2.49 |

### 3.INTRODUCTION:

Pinned Joints are capable of transferring axial forces but cannot transfer moment. For example links of chain in cycle.There are three types of joints:Planar (pinned) Joints:
•Pin Joint
•Pin-in-Slot
•And Sliding joint

## 3.1 Joint Components:

In many models, it is necessary to simulate joints and pinned connections for rotational purposes. Modeling the actual joint components with surface to surface contact will create very long run times. In most cases, the effects on the actual joint components are not important. The easiest way to simulate a joint or pin without a long runtime is to create a Truss element along the axis of the joint and connect it on the ends to the part that will rotate about the axis.

## 3.2 Design of Joints:

It is clear that joints must be considered an integral part of the design process. A structural joint represents a critical element in virtually all hardware designs. In a composite structure, the joint may be made totally or partially of composite materials.The magnitude of the loading, typically expressed as a force per unit joint width, that must be transmitted from one end to the other

•The geometrical constraints within which the load transfer must be accomplished
•The desired reliability of the joint
•Environmental factors in joint operation
•A need for repetitive assembly and disassembly
•Joint efficiency desired (the strength-weight factor)
•Cost of manufacture, assembly, and inspection

## 3.3 Forces in Pin Jointed Structures:

Pin jointed structures are often used because they are simple to design, relatively inexpensive to make, easy to construct, and easy to modify. They can be 'fixed' structures such as frames, or they can be structures that move, more normally referred to as mechanisms.

## 3.4 Applications of Pinned Joints:

Pinned joints are specified below as to the function the pin serves in a joint.

•Pinned joint for fastening
•Pinned joint for driving
•Pinned joint for holding
•Pinned joint for swiveling
•Pinned joint for fitting
•Pinned joint for securing
•Pinned joint for shearing

## 3.5 Robert Hooke's 'Universal Joint':

Robert Hooke is commonly thought of as the inventor of 'Hooke's joint' or the 'universal joint'. However, it is shown that this flexible coupling (based on a four-armed cross pivoted between semicircular yokes attached to two shafts) was in fact known long before Hooke's time but was always assumed to give an output exactly matching that of the input shaft. Hooke carefully measured the relative displacements of the two axes, and found that if one were inclined to the other, uniform rotation of the input produced a varying rate of rotation of the output. He also recognized that this variable rate exactly corresponded to the movement of the shadow of a gnomon across the face of a sundial, as generated by the projection of the uniform motion of the Sun around an inclined polar axis. He therefore proposed that a 'mechanical sundial' might be made by coupling a 24-hour clock movement (with its hour shaft at the appropriate inclination) to a pointer via a universal joint.Robert Hooke (1635–1703) was appointed the first Curator of Experiments for the Royal Society in 1662, and was recognized for his many talents.

## 3.6 Hookes Mechanism :

The quantitative study of technical mechanisms, and ideas for their application and improvement in novel scientific instruments, occupied a significant part of Hooke's early professional life. Horology, astronomy and microscopy were particular favourites,but his name is now most commonly associated with the classic description of elasticity known as 'Hooke's law'. The second item to which his name is familiarly attached is 'Hooke's joint', two of which are used in the transmission of almost every automobile.

•Hooke's and sundials
•Modern analogy

## 3.7 Composite Materials :

A composite material is the material which is made up of two or more materials. The materials used for composite material might have different characteristics. However, when two or more materials are mixed as per the engineering principles of mechanical engineering, the

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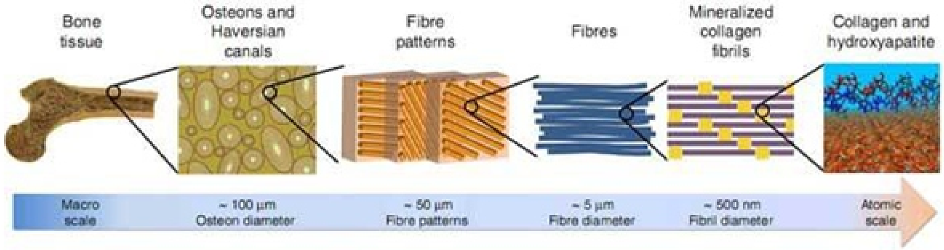
resultant material can have unique characteristics that are very useful. However, identification of materials in composite material is possible as the materials do not dissolve or be converted to other ones.

There are many instances in nature where the combining of multiple materials to form new materials as shown in Fig.

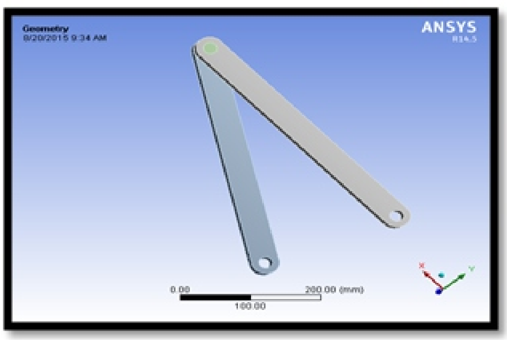


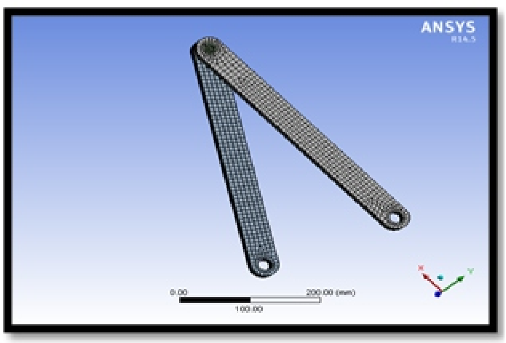

| Laminated Composites | Metals |
|---|---|
| Relatively low toughness | High toughness |
| Sensitive to mild stress concentrations | Insensitive to mild stress concentrations |
| Sensitive to hot/wet conditions | Insensitive to hot/wet conditions |
| Low through the thickness strength/ toughness | High through the thickness strength/toughness |
| Low bearing strength | High bearing strength |
| High damage growth rate | Growth rate fairly slow |
| Immune to corrosion | Prone to corrosion |
| Resistance to fretting | Prone to fretting |
| Low thermal expansion coefficient | High thermal expansion coefficient |

## 4.STRUCTURAL ANALYSIS OF PINNED JOINT

### 4.1 Case 1-Cylinderical Pin (Material - E Glass Epoxy)

#### 4.1.1Imported Model4.1.2 Meshed Model



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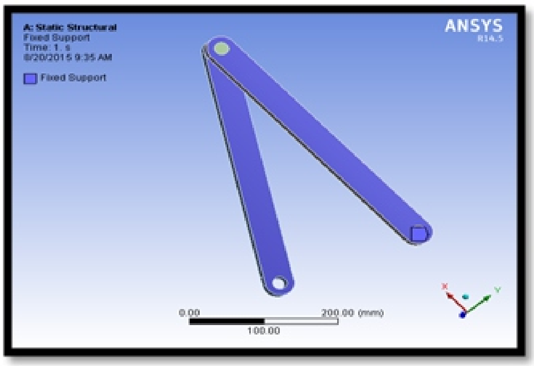
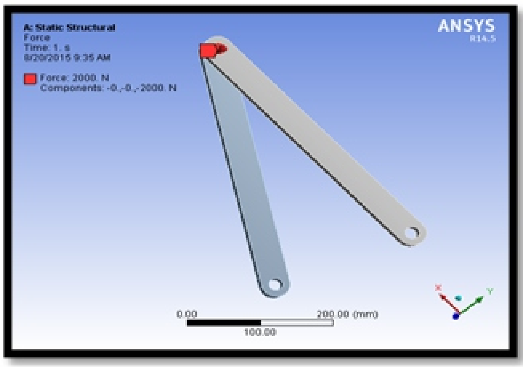
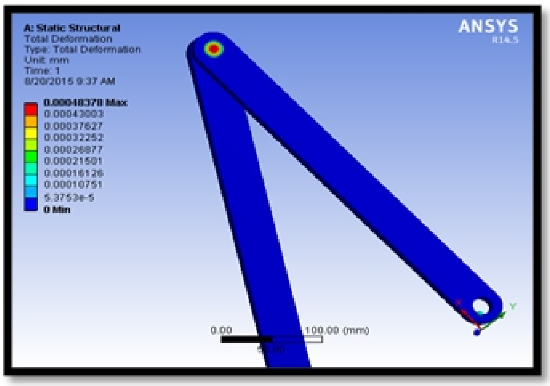
### 4.1.3 Fixed support



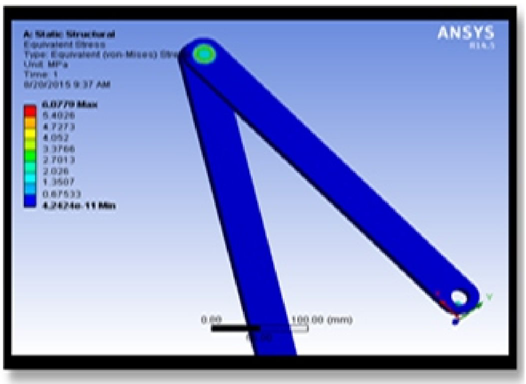

### 4.1.4 Force



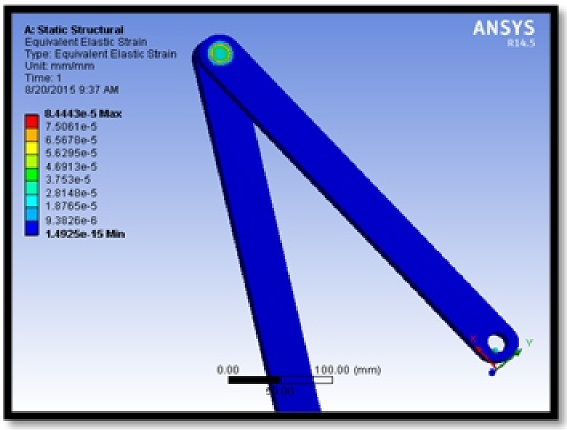

### 4.1.5 Deformation




### 4.1.6 Stress

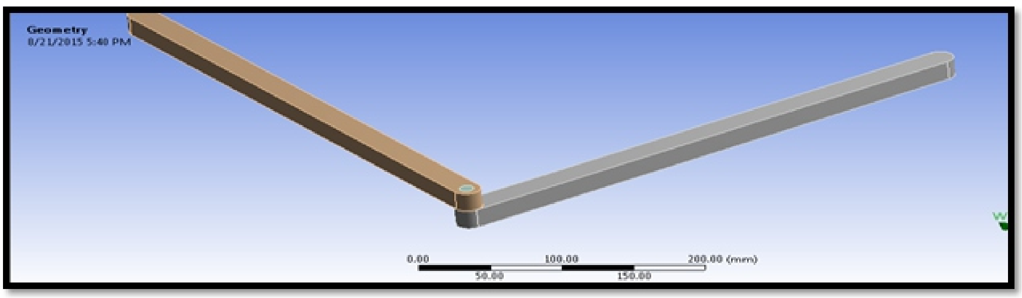



### 4.1.7 Strain




## 4.2 FATIGUE ANALYSIS OF TAPPERED PINNED JOINT

### 4.2.1 Imported Model



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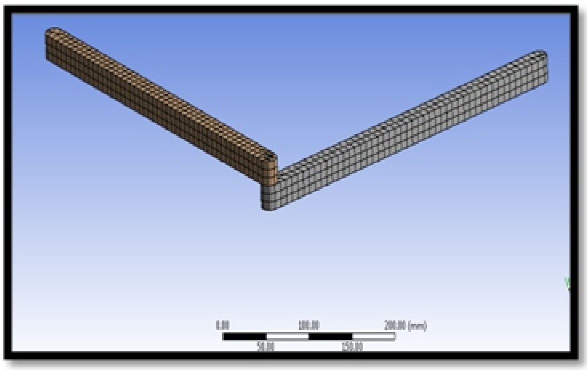
### 4.2.2 Meshed Model:

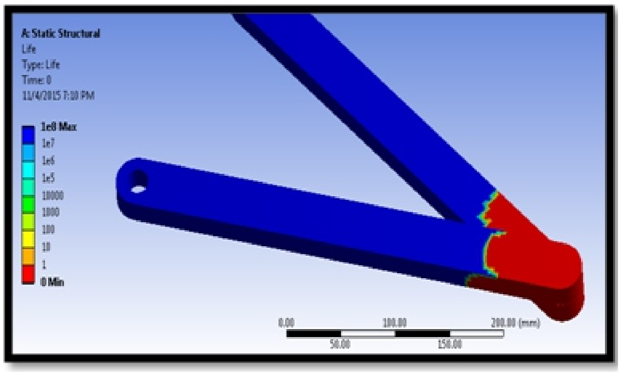
Select mesh on left side part tree → right click → generate mesh → Select –static structural analysis> right click>select fixed support>select fixed area on the component>apply
And select force>select forced area on the component>enter force value(2000N)>apply

Solution>right click>select solve
Select solution> right click>insert>selectfatigue tool >select fully reversed method>and mean stress method is superb Enter no of cycles 10000
Select fatigue tool>right click > insert>select life, damage and safety factor
Go to material properties select alternate stress in life then enter the alternating stress and no of cycles for required material

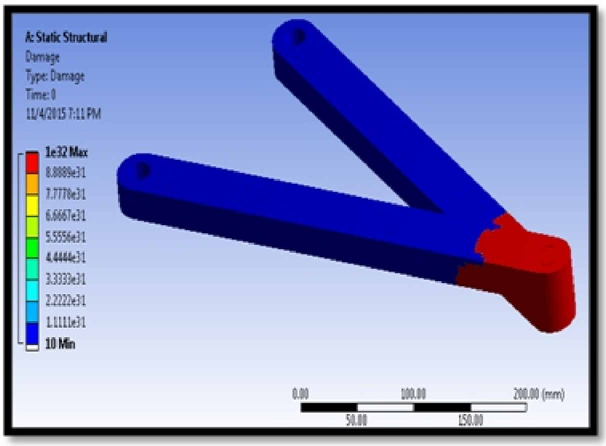
**Meshed model**



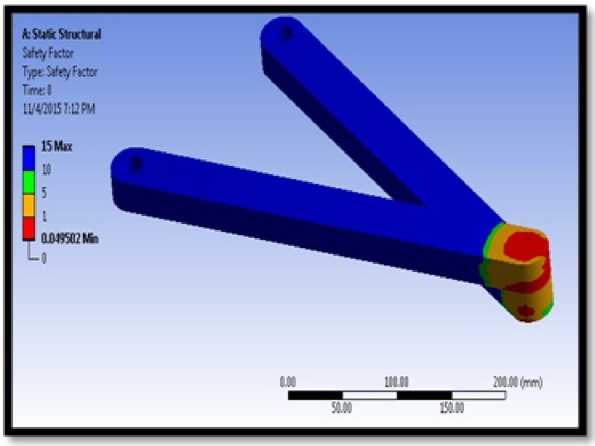
**Life**




**Damage**




**Safety factor**




## 5.RESULTS

### 5.1 Structural Analysis

### 5.1.1 Material-E-Glass Epoxy

| MODEL | RESULTS | | |
|---|---|---|---|
| | DEFORMATION (mm) | STRESS (N/mm$^2$) | STRAIN |
| CIRCLE | 0.00048378 | 6.0779 | 8.443e-5 |
| TAPERED | 0.00052749 | 5.373 | 6.1762e-5 |
| SQUARE | 0.0019166 | 42.754 | 0.00053442 |
| ELLIPTICAL | 0.0020099 | 30.28 | 0.0003862 |

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### 5.1.2 Material-S2-Glass Epoxy

| MODEL | RESULTS | | |
|---|---|---|---|
| | DEFORMATION (mm) | STRESS (N/mm$^2$) | STRAIN |
| CIRCLE | 0.00040184 | 6.1554 | 7.077e-5 |
| TAPERED | 0.00049142 | 5.4301 | 6.2415e-5 |
| SQUARE | 0.0017868 | 43.222 | 0.0004968 |
| ELLIPTICAL | 0.0018891 | 30.94 | 0.00036356 |

### 5.2 Fatigue Analysis of Tapered Pin Joint

| MATERIAL | RESULTS | | | |
|---|---|---|---|---|
| | LIFE | DAMAGE | SAFETY FACTOR | |
| | | | MIN. | MAX. |
| E-GLASS | 1E8 | 1E32 | 0.049502 | 15 |
| S-2 GLASS | 1E8 | 1E32 | 0.0079655 | 15 |

## 6.CONCLUSION:

The cross sections of the hole considered in this work are circular, tapered circular, square and elliptical. Structural analysis is done to determine the stresses and deformations at the joints. By observing the structural analysis results, the deformation is less for circular than other cross sections. For E Glass material, the deformation is increasing by 0.09% for tapered, 3% for square and 3.15% for Elliptical. For S2 Glass material, the deformation is increasing by 0.22% for tapered, 3.44% for square and 3.77% for Elliptical. The stress values are less for tapered circular than other cross sections. For E Glass material, the stress is increasing by 0.1311% for circular, 6.95% for square and 4.63% for Elliptical. For S2 Glass material, the stress is increasing by 0.133% for circular, 7% for square and 4.69% for Elliptical.By comparing the results between materials, the results are slightly better for E – Glass than S 2 Glass but the strength of S 2 Glass is more than E – Glass. Fatigue analysis is done on the tapered joint since the stresses are less to evaluate the life, damage and safety factor.

The life of tapered joint is about 1e8 cycles, the damage is 1e32, and that is, the joint fails if the present applied load is multiplied by 1e32 times. The safety factor is more for E Glass than S 2 Glass.

## 7.FUTURE SCOPE:

The present work can be enhanced with non-linear assumptions. Adding non-linear material behavior and large deformation theory are two improvements that can be made to a linear finite element model. And also the analysis can be done by considering laminated composites with different stacking sequence.

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