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# Fracture Analysis of Fuselage and Wing Joint

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## ABSTRACT
The main aim of this thesis is to investigate the fatigue crack and growth by fracture analysis in an aircraft fuselage and wing joint by determining the stress intensity factors, deformation and compared for different metals and composite. Aircraft structure is an example where structural efficiency results in light weight and high operating stresses. Despite all precautions, cracks have arisen in many of the structural elements. These cracks reduce the stiffness and the total load carrying capacity of the structure. The fuselage is the main structure in the aircraft that holds crew, passengers and cargo. A wing is a type of fin that produces lift, while moving through air or some other fluid. As such, wings have streamlined cross-sections that are subject to aerodynamic forces and act as aero foils.

So, in order to avoid the cracks, different materials are used for the analysis and the material which is showing better results will be selected for the design. 3D modelling will be done in CATIA and fracture analysis will be done in ANSYS.

## INTRODUCTION
The fuselage is an aircraft's main body section. It holds crew, passengers, and cargo. In single-engine aircraft it will usually contain an engine, as well, although in some amphibious aircraft the single engine is mounted on a pylon attached to the fuselage, which in turn is used as a floating hull. The fuselage also serves to position control and stabilization surfaces in specific relationships to lifting surfaces, which is required for aircraft stability and manoeuvrability.

### Truss structure
This type of structure is still in use in many lightweight aircraft using welded steel tube trusses. A box truss fuselage structure can also be built out of wood—often covered with plywood. Simple box structures may be rounded by the addition of supported lightweight stringers, allowing the fabric covering to form a more aerodynamic shape, or one more pleasing to the eye.

### Geodesic construction
Geodesic structural elements were used by Barnes Wallis for British Vickers between the wars and into World War II to form the whole of the fuselage, including its aerodynamic shape. In this type of construction multiple flat strip stringers are wound about the formers in opposite spiral directions, forming a basket-like appearance. This proved to be light, strong, and rigid and had the advantage of being made almost entirely of wood. A similar construction using aluminium alloy was used in the Vickers Warwick with less materials than would be required for other structural types. The geodesic structure is also redundant and so can survive localized damage without catastrophic failure.

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A fabric covering over the structure completed the aerodynamic shell (see the Vickers Wellington for an example of a large warplane which uses this process). The logical evolution of this is the creation of fuselages using moulded plywood, in which multiple sheets are laid with the grain in differing directions to give the monologue type below.

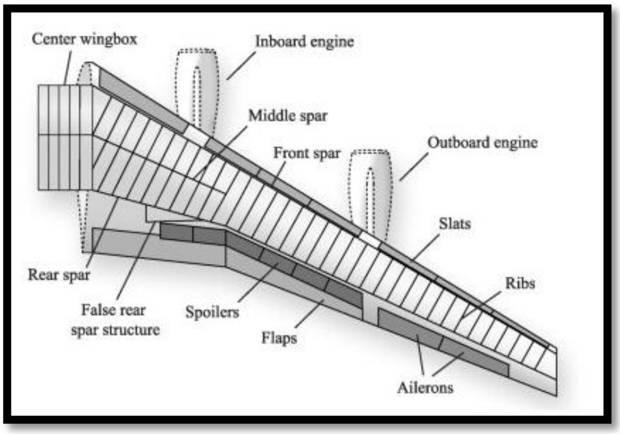
## WING ATTACHMENT TO THE FUSELAGE

Large aircraft wings are generally attached to a “centre wing box”, which is a sturdy construction of ribs (sheet-like parts) and spars (beam-like parts) that looks like a big “box” with reinforced edges. The part of the wing that attaches to the centre wing box is also, interestingly, called a “wing box”. Because the wing boxes are thick (even the wings are fairly thick—that is one reason why they are convenient for fuel tanks), they are stiff and resist very well the (primarily) bending and shear loads generated by flight loads. The wings become aerodynamic when skin and fairing structures (rounded leading and tapered trailing edges) are attached to the wing boxes.

The wing box in the wings is also a box-like structure made of ribs and spars, but it is long and thin, and thus maybe looks a little less “boxlike” and more like a beam. Sometimes such structures are called “box beams”.

The wing box in the wings is also a box-like structure made of ribs and spars, but it is long and thin, and thus maybe looks a little less “boxlike” and more like a beam. Sometimes such structures are called “box beams”.

If one does a search on “centre wing box” and takes a looks at the images resulting from the search, there will be a number of pictures that look something like the one below.




When the wing-wing boxes are attached to this centre wing box, what is formed is essentially a single long, very strong, “box beam” that goes from wingtip to wingtip. The wing “beam” assembly then only needs to be attached firmly to the fuselage so that it doesn't fall off. Engines are attached firmly so they don’t fall off. It turns out this is done with lots and lots of fasteners and (increasingly) adhesives.

Since the wings of a large aircraft are supporting the fuselage, it is more correct to say that the fuselage (body of the aircraft) is supported or mounted to the wings. While the wings are typically seen as two wings, in reality, they are designed and assembled to become one continuous and complete unit before the fuselage is mounted on it.

## LITERATURE REVIEW

**Dinesh kumar K, Sai Gopala Krishna V.V, Syed Shariq Ahmed, Meer Abdul Irfan,** have designed a Wing-Bracket interaction which was not yet designed by any of the industry. And estimated the fatigue life of our Wing-Bracket attachment model. Here compared the fatigue life of our model with three materials such as Maraging Steel, Titanium and Structural A36 steel. Among this three we have proved that Maraging steel gives more fatigue life compared to other two materials. For estimating the fatigue life made some hand calculations. Finally represented the fatigue life with the help of Goodman Curve. The Structural Component is designed and analysed using CATIA and ANSYS Softwares. In analysis the maximum stress at which the component undergoes degradation/damage is calculated for different End Conditions (loadings and stresses),which determines the fatigue life of the component.

**Sriranga B.k1, Kumar .R2,** Civil transport aircraft is used for ferrying passengers from one place to another. Aircraft is a highly complex flying structure. Generally transport aircraft undergoes nominal maneuring flights. During the flight when the maximum lift is generated, the wings of the aircraft will undergo highest bending moment. The bending moment will be maximum at the root of the wing which caused highest stress at this location. Wings are attached to the fuselage structure through wing-fuselage attachment brackets. The bending moment and shear loads from the wing are transferred to the fuselage through the attachment joints. In this project bending load transfer joint is considered for the analysis. First one needs to ensure the static load carrying capability of the wing-fuselage attachment bracket. Stress analysis will be carried out for the given geometry of the wing-fuselage attachment bracket. Finite element method is used for the stress analysis. In the current project, an attempt will be made to predict the fatigue life of wing-fuselage attachment bracket in a transport airframe. In a metallic structure fatigue manifests itself in the form of a crack which propagates. Fatigue cracks will appear at the location of high tensile stress locations. These locations are invariably of high stress concentration. Fatigue life calculation will be carried out for typical service loading condition using constant amplitude S-N data for various stress ratios and local stress history at stress concentration. In this paper for modeling CATIA V5 software is used and for analysis tool MSC/ PATRAN and MSC/ NASTRAN 2010.

**N. Bhaskara Rao, K. Sambasiva Rao,** Brackets are connector type elements widely used as structural supports for pin connections in airframe structure. In this project a detailed Finite element analysis of the fuselage attachment under the worst loading condition was carried out. During the part of project a dynamic and fatigue analysis of bracket was carried out using finite element analysis package. Then the 3-D model of bracket built in NX CAD is imported into ANSYS using the parasolid format. From the analysis results mode shapes and frequencies are documented by using FEA software. Harmonic analysis is also carried out to plot the frequency Vs amplitude graphs.

**A. LANCIOTTI F. NIGRO C. POLESE,** The wing to fuselage connection is one of the most interesting elements from the fatigue point of view. Spars and frames, both integrally machined, are connected by two lug-fork joints; the base material is aluminium alloy 7050-T7451 for both the elements. High interference bushings, ForceMate, produced by FTI (Fatigue Technology Inc., Seattle, WA) were used in the lug/fork connections.
Experimental activity was carried out on two different specimens. The first, a Compact Tension specimen, was tested under constant amplitude loading to verify the fatigue crack growth rate data contained in NASGRO 4, the software used for Damage Tolerance evaluations. Experimental results were fully comparable with the NASGRO 4 material database. Additional variable amplitude loading tests were carried out in order to calibrate crack growth prediction models used in the analyses.

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## MODELING OF WING AND FUSELAGE JOINT

### MODEL OF WING

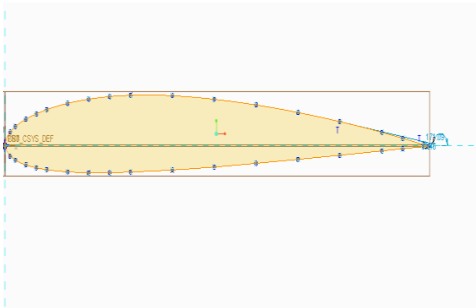


Fig: 2D Sketch of wing

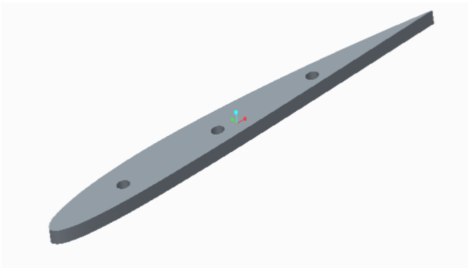
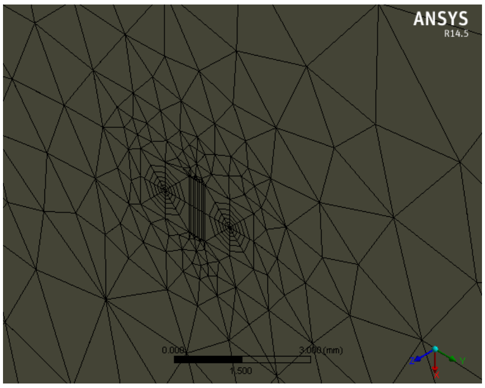


Fig: 3D model of wing

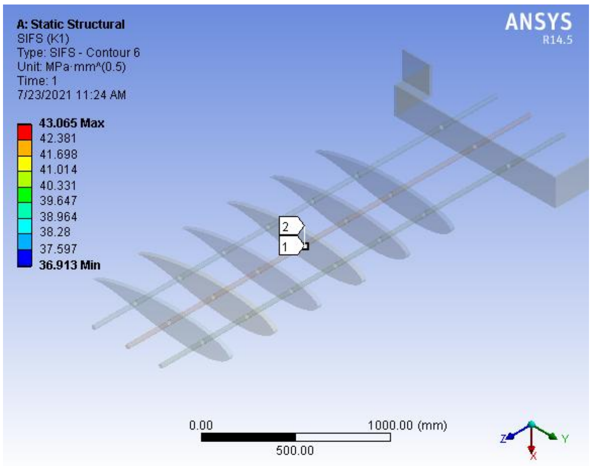
## ANALYSIS OF FUSELAGE AND WING JOINT

### CRACK

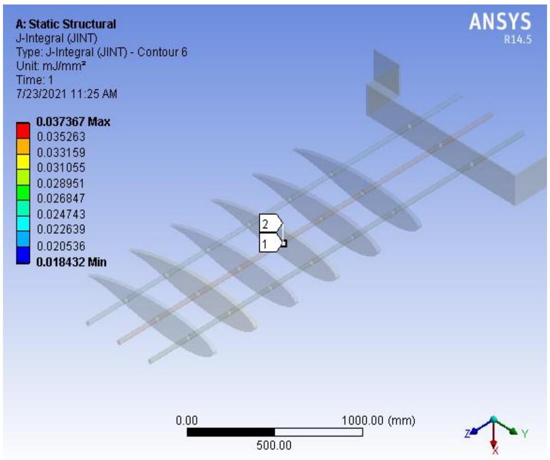



## MATERIAL – ALUMINUM ALLOY 6061

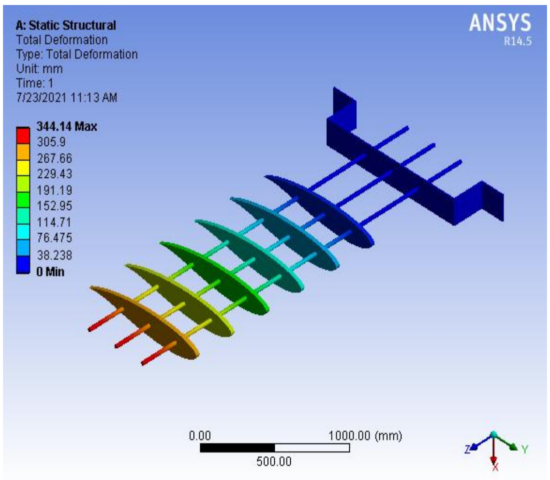
### STRESS INTENSITY FACTOR




### J-INTEGRAL




### TOTAL DEFORMATION



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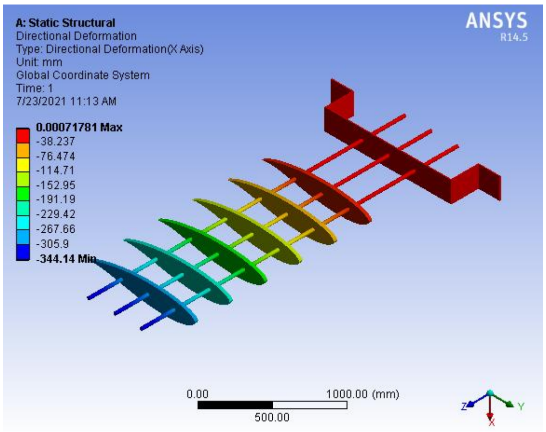
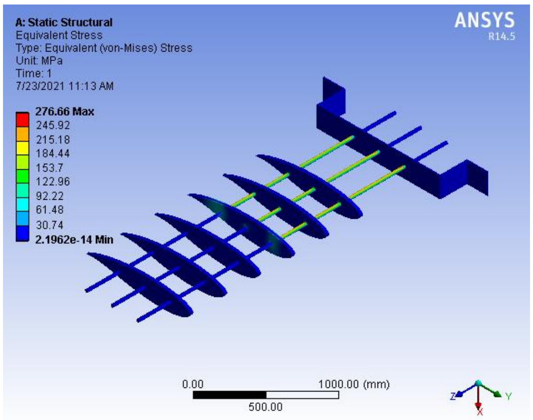
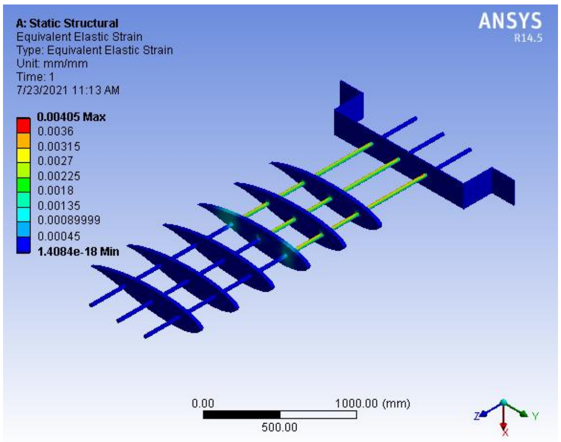
## DIRECTIONAL DEFORMATION



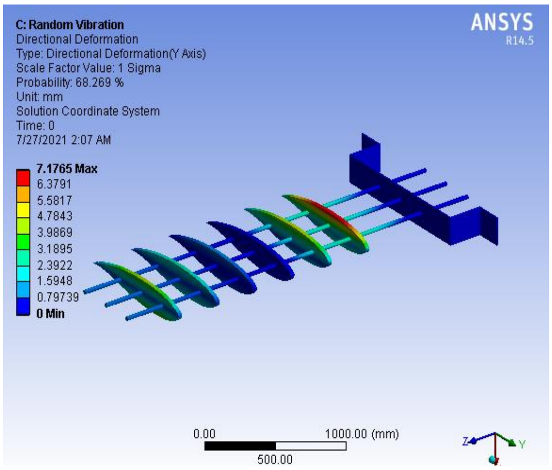

## STRESS

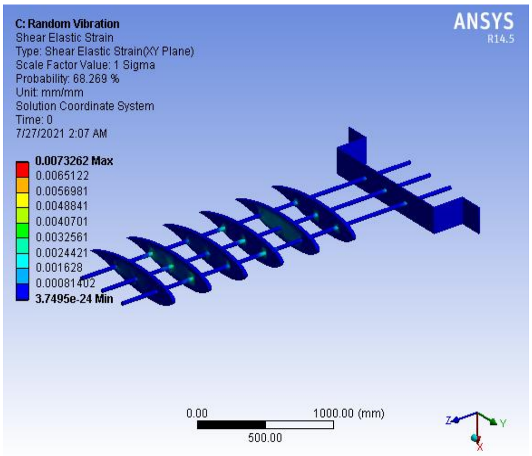


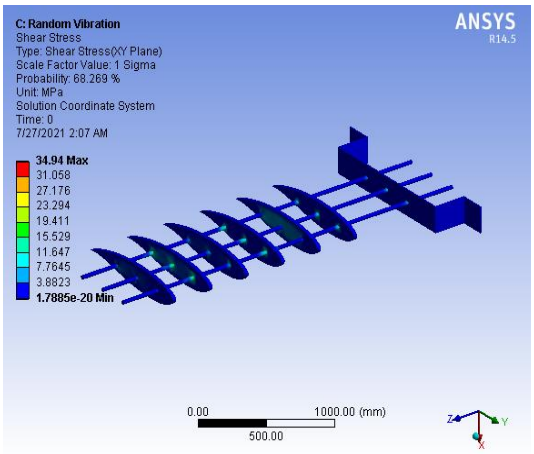

## STRAIN




## RANDOM VIBRATIONAL ANALYSIS OF WING JOINT MATERIAL – CARBON FIBER 30% CARBON



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## TABLE
## STRUCTURAL ANALYSIS

| | Total Deformation (mm) | Directional Deformation (mm) | Stress (MPa) | Strain (mm) | Stress intensity factor (MPa. $mm^{0.5}$) | J – Integral (mJ/mm2) |
|---|---|---|---|---|---|---|
| Al 6061 | 344.14 | 0.00071781 | 276.66 | 0.00405 | 43.065 | 0.037367 |
| Armed Fiber | 2153.9 | 0.0048695 | 276.69 | 0.025369 | 43.351 | 0.23452 |
| Carbon Fiber | 1914.2 | 0.0034962 | 276.56 | 0.022498 | 42.611 | 0.20645 |
| E Glass Epoxy | 328.66 | 0.00035178 | 276.02 | 0.0039688 | 41.219 | 0.03404 |

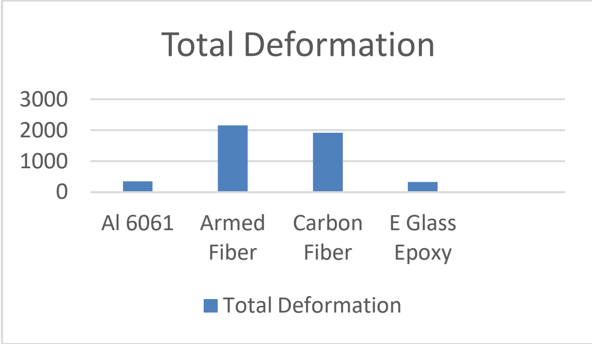
## MODAL ANLAYSIS

| Materials | Total Deformation 1 (mm) | Total Deformation 2 (mm) | Total Deformation 3 (mm) | Total Deformation 4 (mm) | Total Deformation 5 (mm) | Total Deformation 6 (mm) |
|---|---|---|---|---|---|---|
| Al 6061 | 11.361 | 17.559 | 7.5803 | 8.9321 | 15.911 | 19.527 |
| Armed Fiber | 15.835 | 24.487 | 10.56 | 12.463 | 22.176 | 27.31 |
| Carbon Fiber | 16.187 | 24.997 | 10.809 | 12.705 | 22.67 | 27.653 |
| E Glass Epoxy | 11.576 | 17.818 | 7.757 | 9.033 | 16.218 | 19.16 |

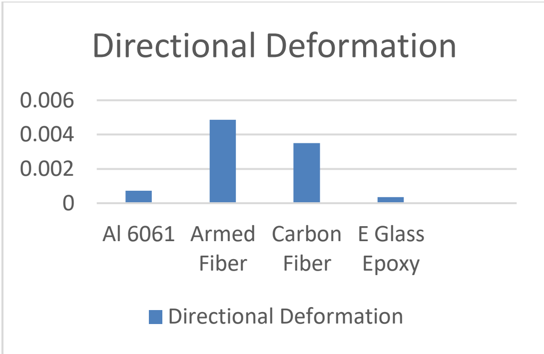
## RANDOM VIBRATIONAL ANLAYSIS

| Materials | Directional Deformation (mm) | Shear Elastic Strain (mm/mm) | Shear Stress (MPa) |
|---|---|---|---|
| Al 6061 | 7.7373 | 0.0089712 | 232.37 |
| Armed Fiber | 6.821 | 0.0085845 | 34.974 |
| Carbon Fiber | 7.1765 | 0.0073262 | 34.94 |
| E Glass Epoxy | 7.9496 | 0.0049737 | 150.04 |

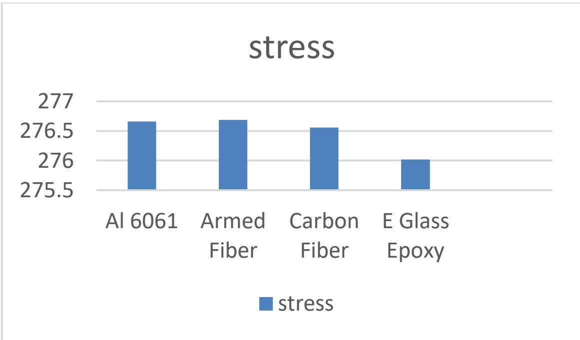
## GRAPHS
## TOTAL DEFORMATION



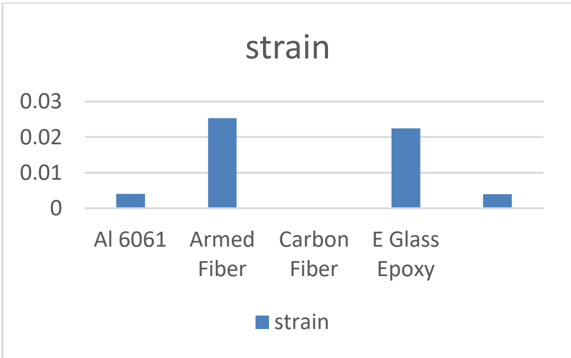

## DIRECTIONAL DEFORMATION




## STRESS




## STRAIN



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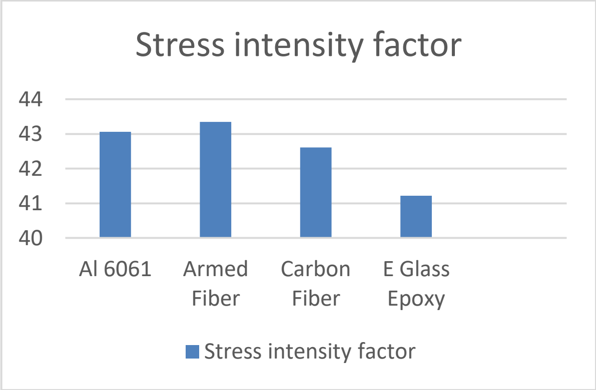
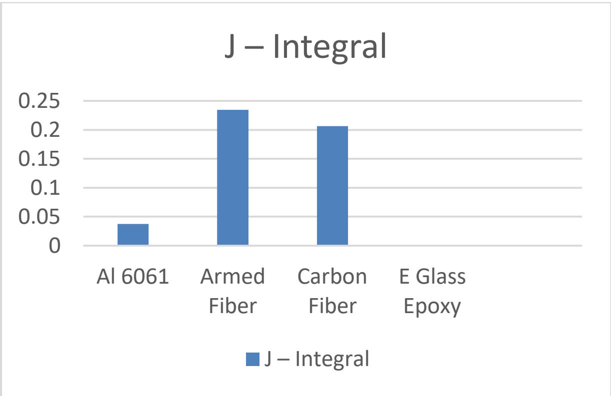
**STRESS INTENSITY FACTOR**




**J – INTEGRAL**




**CONCLUSION**

So, in order to avoid the cracks, different materials are used for the analysis and the material which is showing better results will be selected for the design. Theoretical calculations will also be done to compare the stress intensity factors. 3D modelling will be done in CATIA and fracture analysis will be done in ANSYS.

As if we verify the results obtained here the results in the structural analysis the stress is less for the E glass epoxy and even the other materials are also very minute difference between them. But as if we verify the deformations here the E glass epoxy has obtained the very least deformation when compared with other materials. As if we verify the stress intensity factor here the E glass epoxy has obtained the less intensity when compared with the other materials.

As if we compare the results of the vibrational analysis here the shear stress and the shear strain are considered. As if we verify the results obtained here the least stress is for the carbon fibre material but if we verify the limit, here the E glass epoxy has the limit and can be used for the better parameters.

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