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Investigation of Fatigue Crack Growth in Aerospace Bracket by Using FEA

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ABSTRACT

The focus of this project is to investigate how a crack propagates and grows in a typical in aerospace bracket. The finite element program ANSYS and the design process was done in CATIA and used to simulate crack growth and to compute the stresses and the stress-intensity factor. A specific bracket design was selected a crack was investigated.

This configuration was used since the engineers often detect this type of crack in brackets. The stress intensity near the crack tip is compared against the yield strength of the material. The Mode I stress-intensity factor is compared against the material's loaded conditions. The results show that the bracket can tolerate small cracks in the structure. The fatigue strength of the structure is recommended to be assessed in the future.

INTRODUCTION:

Fatigue is the formation of a crack due to cyclic elastic loading well within the design stress levels. Most dynamically loaded welded structures are explicitly designed for fatigue by checking the stress range at critical details under some fatigue design loading. The stress range at the critical details is checked by comparison to an S-N curve that relates the life (N) to the stress range (S). Different S-N curves may be used depending on applicable codes or specifications. Until recently, most ships were not explicitly designed for fatigue. Instead, the allowable peak stress was controlled in an attempt to indirectly avoid extensive fatigue cracking.

Consequently, many ships, particularly commercial bulk carriers and tanker ships, exhibit extensive fatigue cracking. Among the details which exhibit cracking on ships are:

- Brackets at the intersections of girders with web frames or bulkheads;
- The intersection of longitudinal stiffeners with transverse web frames or bulkheads;
- Hatch openings
- Butt welds in hull plates, stiffeners, or girders; and
- Drain holes and weld-access holes in stiffeners and girders.

Because of the highly redundant nature of ship structure, these fatigue cracks are typically not a threat to structural integrity. Therefore, the detection and repair of occasional fatigue cracks may be tolerated as a part of routine maintenance. Repairs are often made by arc gouging a V-shaped weld preparation along the length of the crack and welding. Other methods such as modifying the detail by adding soft toes, brackets, insert plates or doubler plates may also be used.

Unfortunately, fatigue cracks are frequently repaired without sufficient consideration of the performance subsequent to the repair. Poorly designed or executed repairs can lead to quick reinitiating of fatigue cracks at the location of the repair. In some cases individual ships have been reported to have thousands of cracks. In these cases, the repair costs may be staggering.

BACKGROUND:

Many aspects of designing ship structures for fatigue and repairing fatigue cracks are essentially the same as

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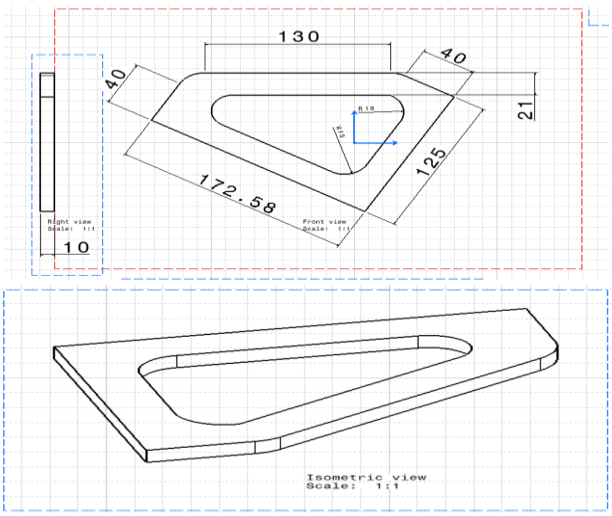
in other types of welded steel structures such as offshore platforms or even bridges. Therefore, this chapter first gives general background on fatigue design procedures. Different fatigue crack repair techniques and research in the literature on testing of repairs are then discussed. Finally, a discussion of typical fatigue-critical structural details in commercial ships is presented.

Fatigue Design and Assessment Procedures
Welded details in any structure can be analyzed using one of several techniques, including:

a. Comparing nominal stress ranges obtained using ordinary strength of materials equations to standard S-N curves.

b. Comparing hot-spot stress ranges obtained using finite-element analyses or predetermined stress concentration factors (SCF) to hot-spot S-N curves

DESIGN AND DRAFT

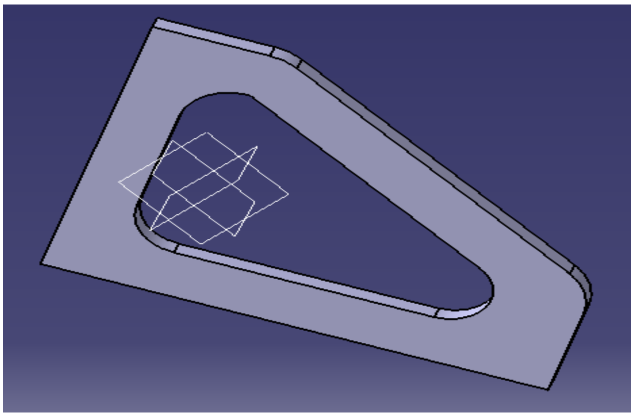


Drafted Model of Bracket in CATIA.

MATERIAL PROPERTIES

MATERIALS	DENSITTY (Kg/m³)	YOUNGS MODULUS (Mpa)	POISSIONS RATIO	ULTIMATE TENSILE STRENGTH (Mpa)
ALUMINIUM ALLOY	2770	71000	0.33	310
GRAY CAST IRON	7200	11000	0.28	240
TITANIUM ALLOY	4620	9600	0.36	1070
GRAPHITE	1630	27600	0.3	2413

Showing Material Properties



Model Developed in CATIA

Materials: Materials used is Isotropic and assumed materials are Homogeneous.

GENERIC STEPS TO SOLVING ANY PROBLEM IN ANSYS:

Like solving any problem analytically, you need to define (1) your solution domain, (2) the physical model, (3) boundary conditions and (4) the physical properties. You then solve the problem and present the results. In numerical methods, the main difference is an extra step called mesh generation. This is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Below describes the processes in terminology slightly more attune to the software.

Build Geometry

Construct a two or three dimensional representation of the object to be modelled and tested using the work plane coordinates system within ANSYS.

Define Material Properties

Now that the part exists, define a library of the necessary materials that compose the object (or project) being modelled. This includes thermal and mechanical properties.

Generate Mesh

At this point ANSYS understands the makeup of the part. Now define how the modelled system should be broken down into finite pieces.

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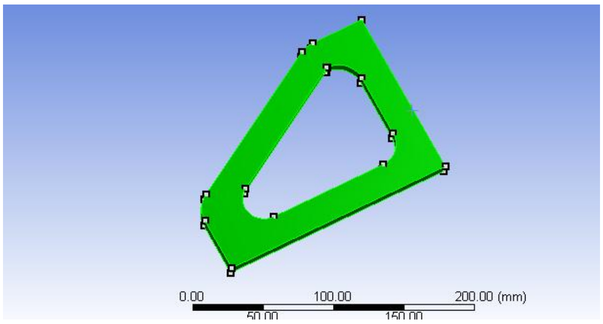
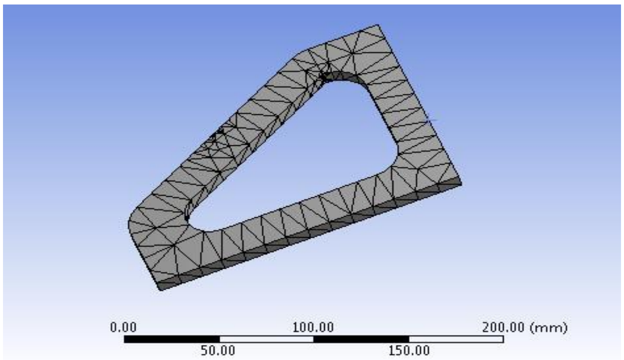
Apply Loads
Once the system is fully designed, the last task is to burden the system with constraints, such as physical loadings or boundary conditions.

Obtain Solution
This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved.

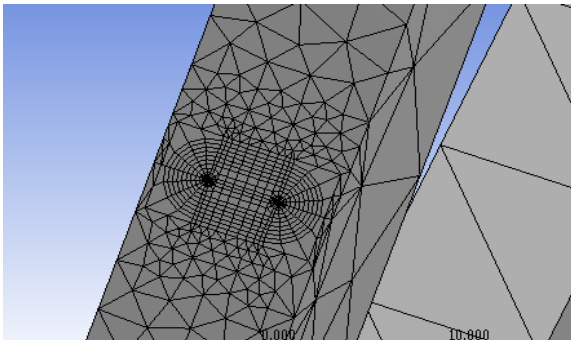
Present the Results
After the solution has been obtained, there are many ways to present ANSYS' results, choose from many options such as tables, graphs, and contour plots.

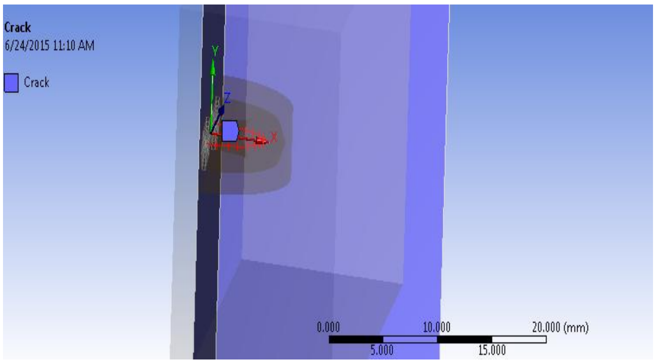


Imported model to ANSYS

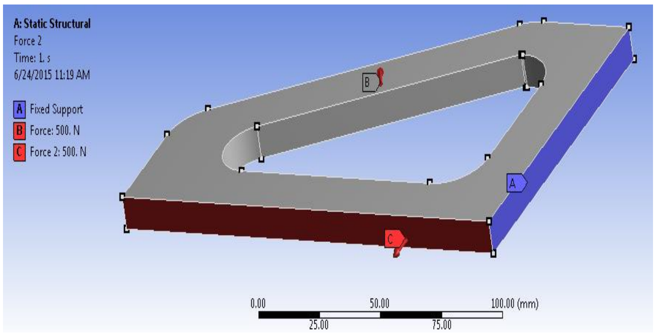


Fine Mesh Developed in ANSYS


.Crack Developing in ANSYS

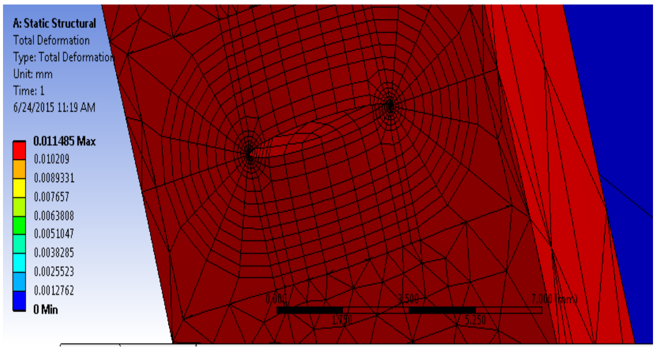


.Development of Crack in ANSYS

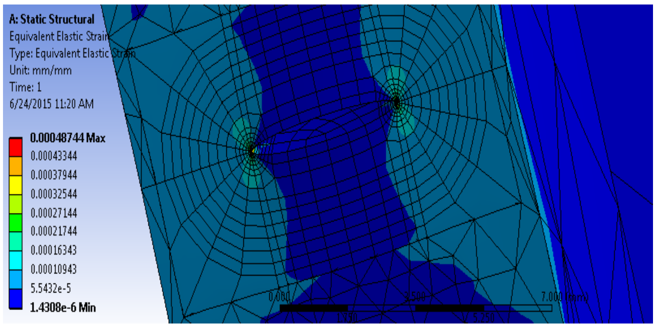


Applying the Forces

TITANIUM MATERIAL



Deformation at 500 N of Load (Titanium)



Strain at 500 N of Load (Titanium)

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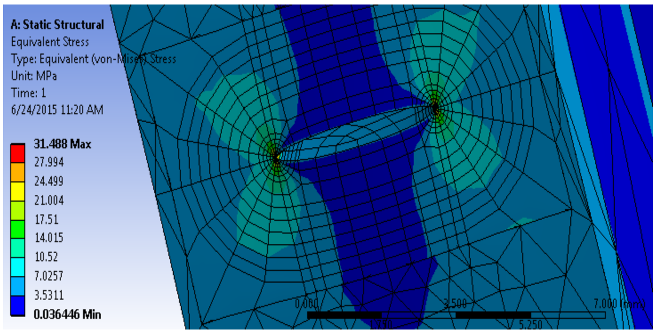
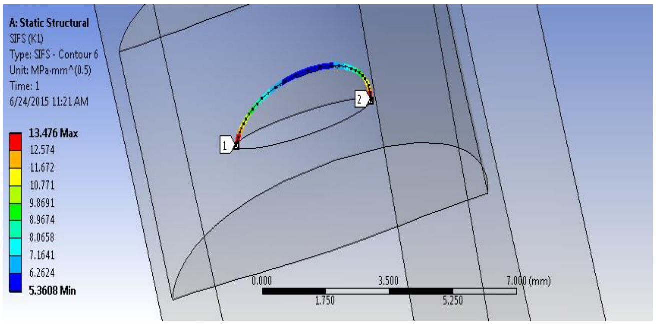


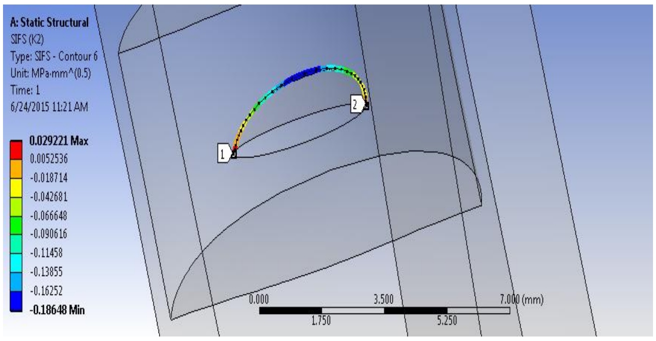
Stress at 500 N of Load (Titanium)

K1 VALUE AT 500 N OF LOAD



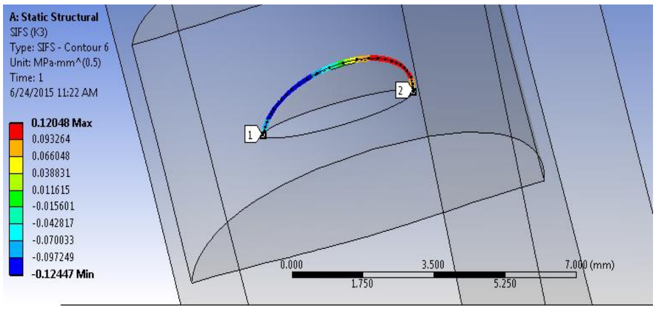
K1 value at 500 N of load (Titanium)

K2 VALUE AT 500 N OF LOAD



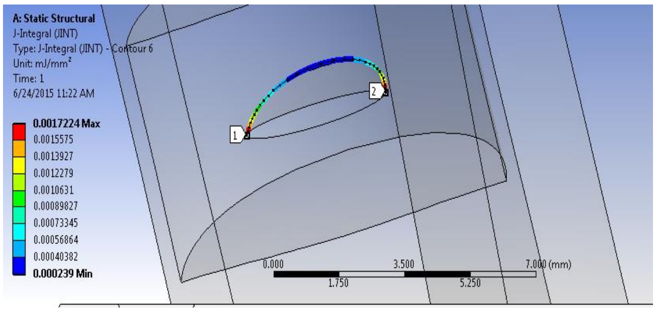
K2 value at 500 N of load (Titanium)

K3 VALUE AT 500 N OF LOAD



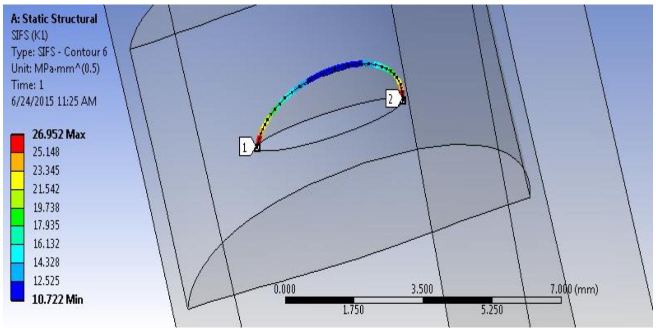
K3 value at 500 N of load (Titanium)

J-Integral VALUE AT 500 N OF LOAD



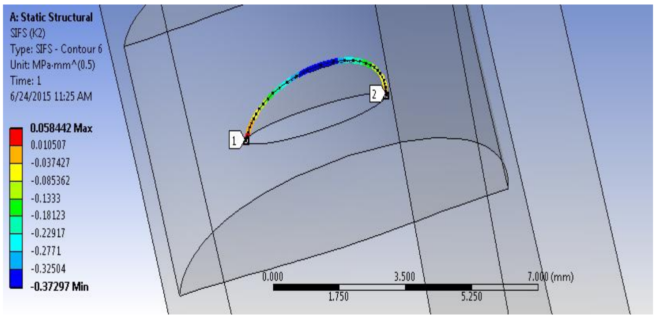
J-Integral value at 500 N of load (Titanium)

K1 VALUE AT 1000 N OF LOAD



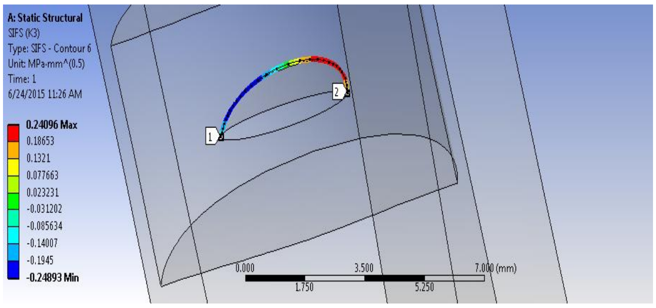
K1 value at 1000 N of load (Titanium)

K2 VALUE AT 1000 N OF LOAD



K2 value at 1000 N of load (Titanium)

K3 VALUE AT 1000 N OF LOAD



K3 value at 1000 N of load (Titanium)

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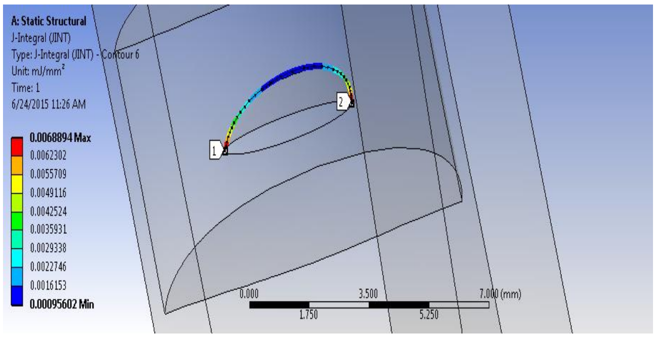
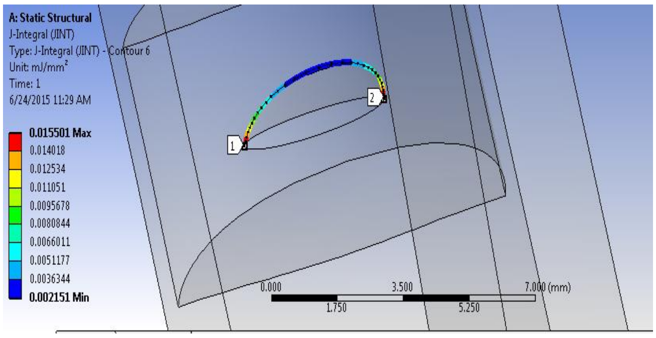
J-INTEGRAL VALUE AT 1000 N OF LOAD



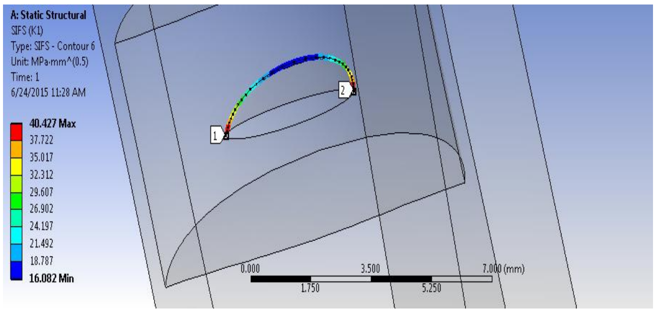
J-Integral value at 1000 N of load (Titanium)

J-INTEGRAL VALUE AT 1500 N OF LOAD



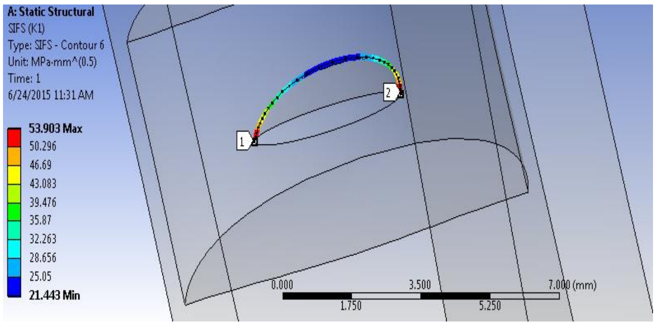
J-Integral value at 1500 N of load (Titanium)

K1 VALUE AT 1500 N OF LOAD



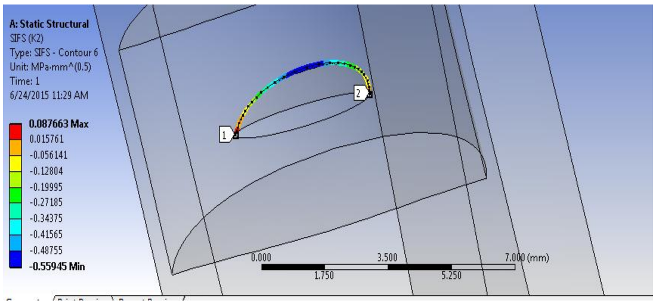
K1 value at 1500 N of load (Titanium)

K1 VALUE AT 2000 N OF LOAD



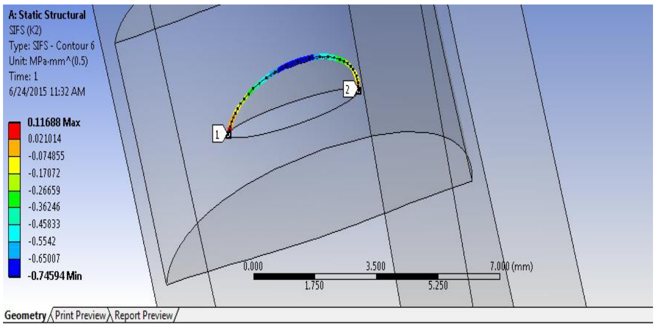
K1 value at 2000 N of load (Titanium)

K2 VALUE AT 1500 N OF LOAD



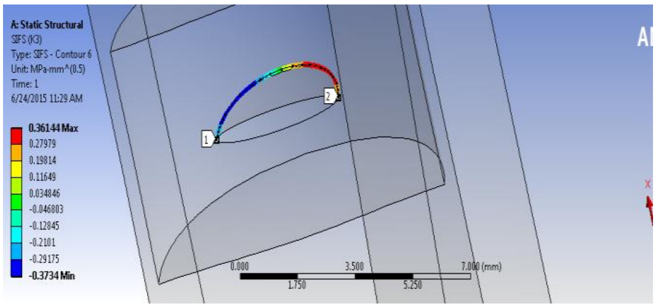
.K2 value at 1500 N of load (Titanium)

K2 VALUE AT 2000 N OF LOAD



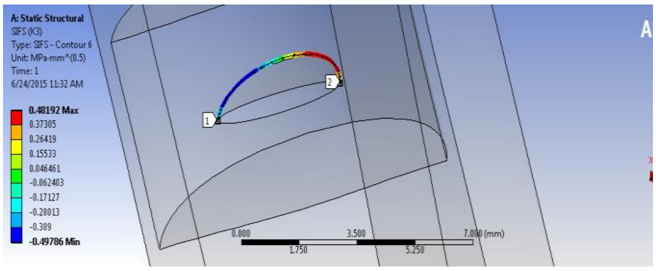
K2 value at 2000 N of load (Titanium)

K3 VALUE AT 1500 N OF LOAD



K3 value at 1500 N of load (Titanium)

K3 VALUE AT 2000 N OF LOAD



K3 value at 2000 N of load (Titanium)

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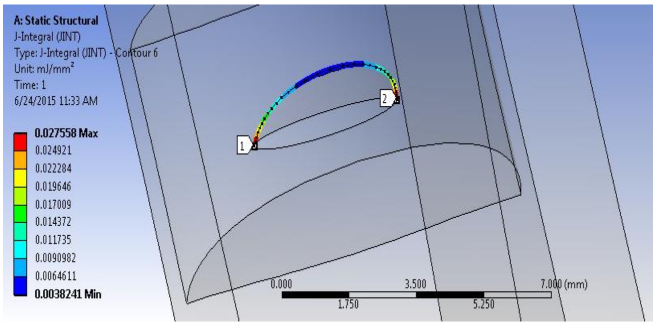
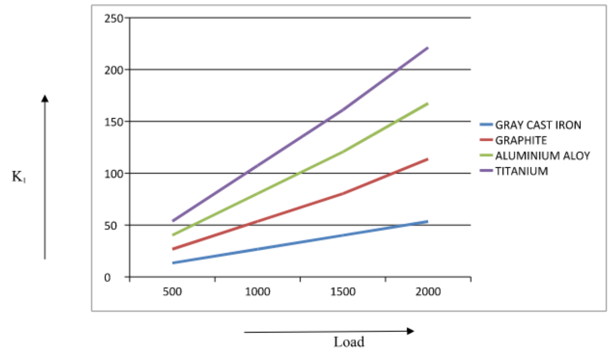
J-INTEGRAL VALUE AT 2000 N OF LOAD



J-Integral value at 2000 N of load (Titanium)

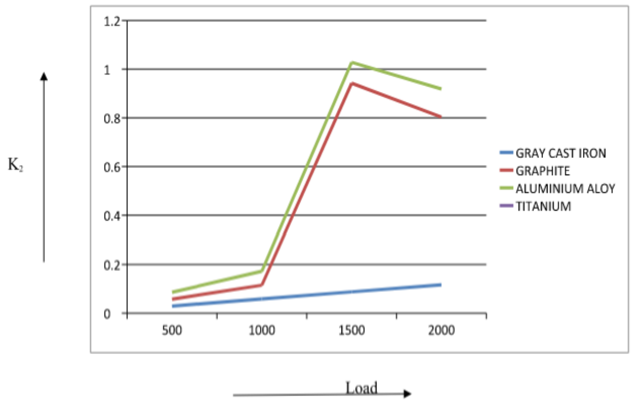
GRAPH REPRASENTING LOAD VS K1



LOAD/MATERIALS	GERY CAST IRON (K_1)	GRAPHITE (K_1)	ALUMINIUM ALLOY (K_1)	TITANIUM ALLOY (K_1)
500	13.364	13.391	13.433	13.476
1000	26.729	26.783	26.866	26.952
1500	40.093	40.174	40.299	40.427
2000	53.457	60.227	53.732	53.903

K1 values at Different Loads of Different Materials

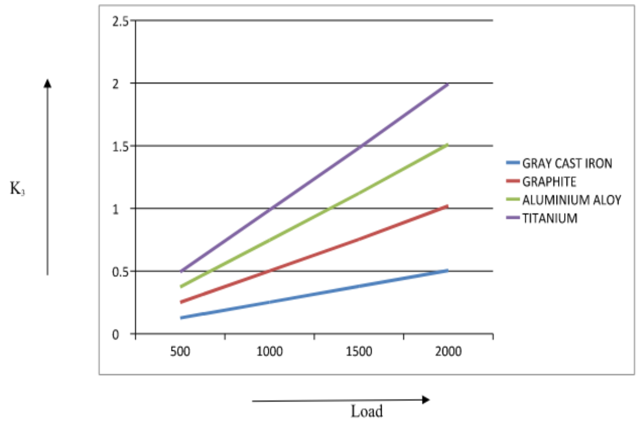
GRAPH REPRASENTING LOAD VS K2



LOAD/MATERIALS	GERY CAST IRON (K_2)	GRAPHITE (K_2)	ALUMINIUM ALLOY (K_2)	TITANIUM ALLOY (K_2)
500	0.02799	0.028256	0.028703	0.029221
1000	0.055979	0.056511	0.057405	0.058442
1500	0.083969	0.854767	0.086108	0.087663
2000	0.11196	0.68667	0.11481	0.11688

K2 values at Different Loads of Different Materials

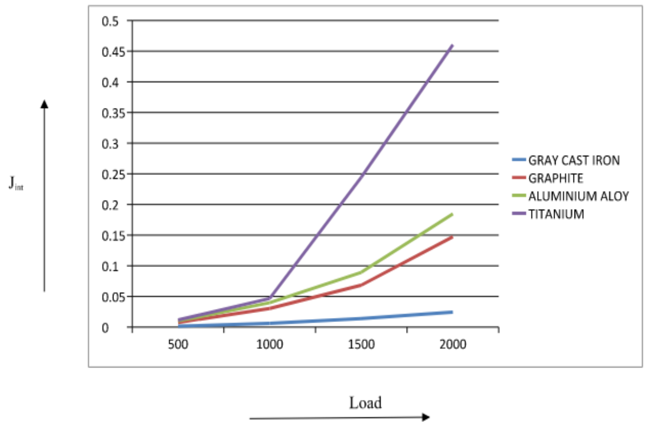
GRAPH REPRASENTING LOAD VS K3



LOAD/MATERIALS	GERY CAST IRON (K_3)	GRAPHITE (K_3)	ALUMINIUM ALLOY (K_3)	TITANIUM ALLOY (K_3)
500	0.12617	0.12481	0.12269	0.12048
1000	0.25234	0.24961	0.24537	0.24096
1500	0.37852	0.37442	0.36806	0.36144
2000	0.50469	0.51579	0.49074	0.48192

K3 values at Different Loads of Different Materials

GRAPH REPRASENTING LOAD VS J-INTIGRAL



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LOAD/MATERIALS	GERY CAST IRON (J_{INT})	GRAPHITE (J_{INT})	ALUMINIUM ALLOY (J_{INT})	TITANIUM ALLOY (J_{INT})
500	0.0015277	0.006064	0.0023397	0.0017224
1000	0.006111	0.024255	0.0093579	0.0068894
1500	0.01375	0.054574	0.021055	0.15501
2000	0.02444	0.12289	0.037432	0.27558

J-Integral values at Different loads of Different Materials

CONCLUSION:

By investigation of the crack analysis done on different materials I can conclude that by considering stress intensity factors and J-integrals that titanium alloy has more withstanding capability where as the other materials also have the capability of withstanding but not as much as titanium alloy.

In this work an attempt has been made to find the process of crack propagation and stress distribution in a typical bracket aerospace bracket by using ANSYS and CATIA.This type of analysis is more economic and time saving phenomenon and can be used to monitor the cracks in various components of aerospace structures and components.

The first step of the analysis consisted of using ANSYS to perform elastic stress analysis on an un-cracked bracket to identify the high stress regions. In step two, the un-cracked model was imported to CATIA and an initial crack of simple geometry was introduced and several ANSYS files were created with crack. Step three of the analysis consists of using ANSYS to perform elastic stress analysis of the previously cracked bracket produced by ANSYS.

For the model of cracks, the results show in the Mode I stress intensity factors for the cracked model are below the materials fracture toughness. Therefore, it appears that the bracket can tolerate small corner cracks in the structure. The analysis procedure thus can be used to continuously monitor the brackets and to take appropriate decision on time of replacement of such brackets.

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[6] C.P.Paris, and G.C Sih, “Stress Analysis of Cracks,” in Fracture Toughness Testing and Its Applications, ASTM STP 381, American Society for Testing and Materials, Philadelphia, 1965. [7] B.J.Carter, P.A. Wawrzynek, and A.R.Ingraffea, Automated 3D Crack Growth Simulation, Cornell Fracture Group, 2003.

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