Fracture Analysis of Crack Propagation Using Different Materials on Three Crack Modes of Failure

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ABSTRACT

In this thesis, the fracture mechanics of crack propagation using different materials Titanium, Nickel Alloy 718, Glass Fiber Reinforced Polymer, and Carbon Fiber Reinforced Polymer is investigated for three modes of failure in a rectangular block. Fracture, Static & Modal analysis is done on all the three modes of failure to determine displacements, stresses, stress intensity factors, and vibrations.

3D modeling is done in Creo 2.0 and analysis is done in Ansys.

INTRODUCTION

In current materials science, fracture mechanics is a precarious device used to improve the execution of mechanical parts. It applies the physical science of anxiety behavior of materials, explicitly the hypotheses of flexibility besides versatility, to the minuscule crystallographic absconds found in genuine materials keeping in mind the end goal to foresee the plainly visible mechanical conduct of those bodies. Fractography is usually applied with fracture mechanics to comprehend the reasons for disappointments and furthermore check the hypothetical disappointment expectations with genuine disappointments. The forecast of split expansion is at the core of the harm resistance mechanical strategy discipline.

LITERATURE SURVEY

M. D. Nikam[1], intended to satisfy this hole and produce more data along these lines expanded comprehension on fracture conduct in 3D Segments. The limited component investigation has been performed to help the outcomes on fracture parameters like Area and Size of Cracks and results has been contrasted and accessible hypothetical arrangements. It is presumed that the size of the basic Stress Intensity Factor can be utilized as a fracture rule for thin Plates. The same system has been adjusted for Investigation of interfacing pole to discover Stress Intensity Factor at different lengths of crack.

M.Shohel[2], Three dimensional (3D) opening mode stress intensity factors (SIFs) for auxiliary steel welded 'T' points of interest were explored by the limited component strategy. A 3D shape dependent revision factor is proposed for semi elliptical surface cracks. The viewpoint proportion (a/c) of a semi elliptical crack assumes a key job in the guess of 3D-SIF qualities, and in the present investigation, it was evaluated for a 3D crack examination. The evaluated 3D-SIF was resolved through a relationship between's the a/c proportion and the two dimensional SIF for semi elliptical cracks in the thickness course adjoining the web flange intersection of a welded 'T'. The subsequent condition can be utilized to appraise the 3D SIF qualities from the two dimensional SIF absent much vagueness.

STATIC AND FRACTURE ANALYSIS OF DELAMINATED BEAMS

Composite beam with delamination

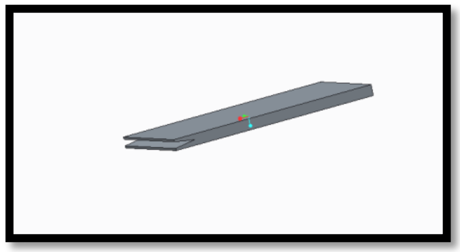

Fig – 3D model of Crack Mode I

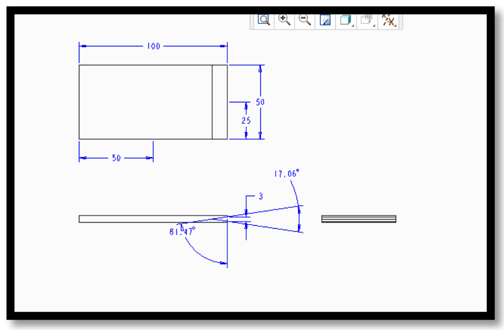

Fig – Drafting of Crack Mode I

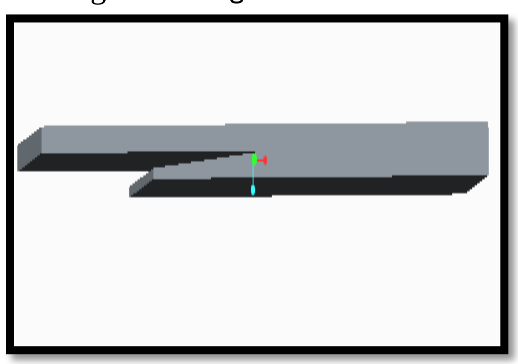

Fig:- 3D model of Crack Mode II

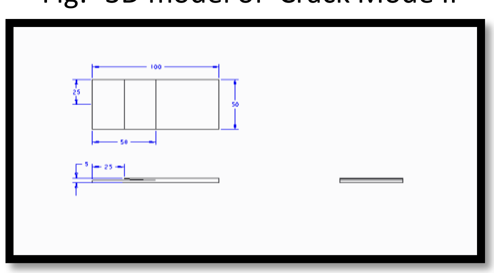

Fig:-Drafting of Crack Mode II

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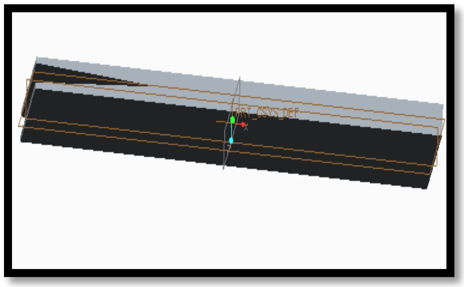

Fig:- Fig:- 3D model of Crack Mode III

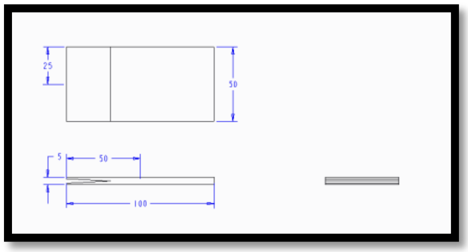

Fig:-Drafting of Crack Mode III

ANALYSIS ON DIFFERENT CRACK MODES

CRACK MODE I

TITANIUM

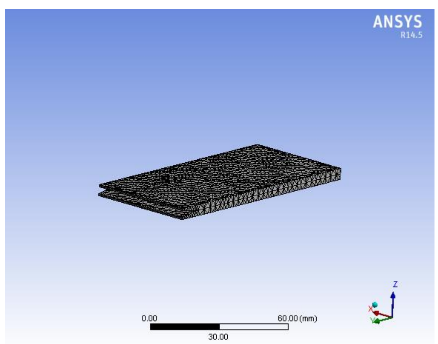

Fig:-meshed model of beam with crack mode I

Select model →select fracture tool

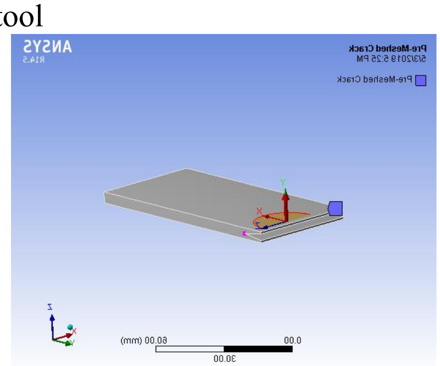

Fig:-Pre-meshed crack

Named Selection→ Crack→ Crack front

Select geometry – Select first plate

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Select Crack Shape – Semi Elliptical
Enter major radius → 5 mm
Enter minor radius →2 mm
Enter Fracture affected zone Height – 13.55mm
Enter largest contour radius – 5 mm

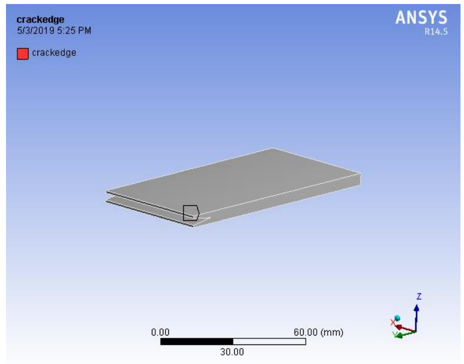

Fig: - Crack on edge

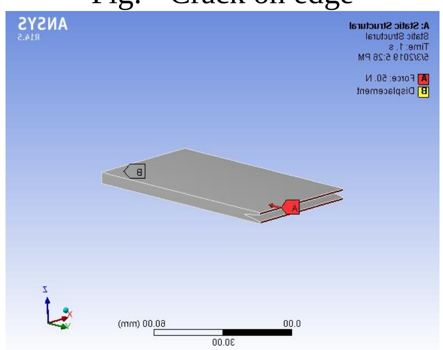

Fig: Load of 50N applied at tip of crack and Displacement is applied on another side of the beam

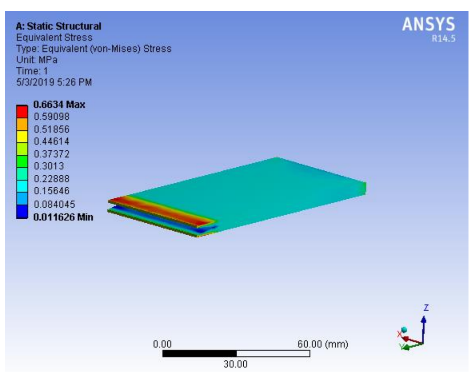

Fig:- Stress of crack mode I by using Titanium

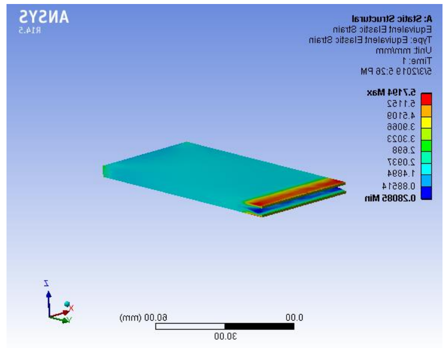

Fig:- Strain of crack mode I by using Titanium

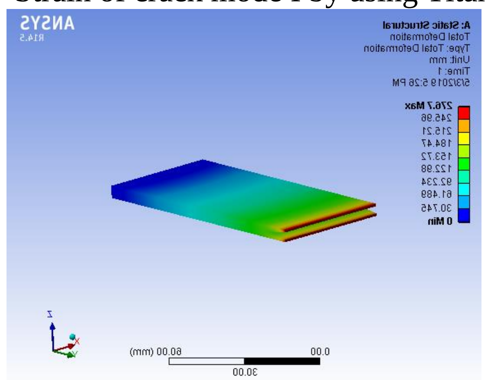

Fig:- Deformation of crack mode I by using Titanium

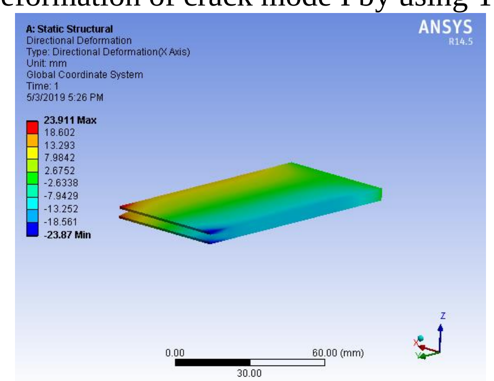

Fig:- Directional deformation of crack mode I by using Titanium

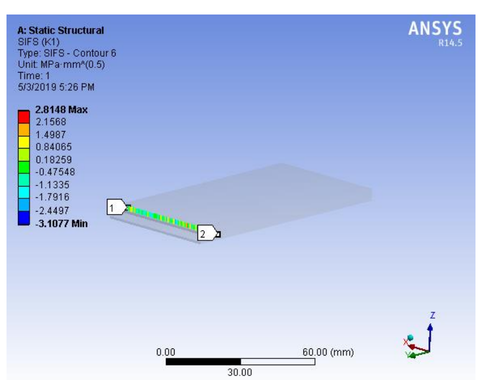

Fig:- Stress intensity factor of crack mode I by using Titanium

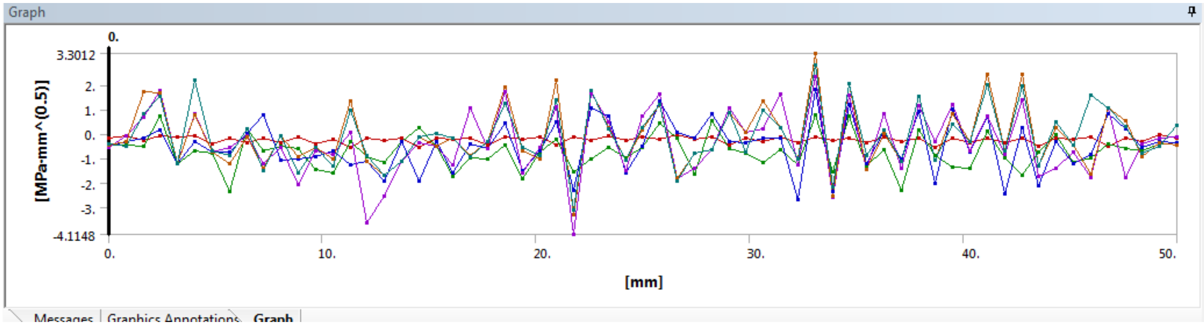

Fig:- Graph of Stress intensity factor of crack mode I by using Titanium

Stress intensity factor obtained is 2.8148Mpa at crack for crack mode I by using Titanium.

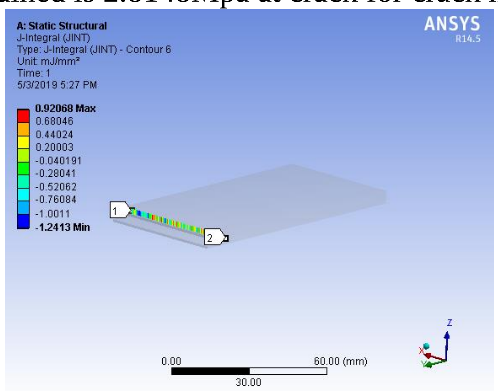

Fig:- J-integral of crack mode I by using Titanium

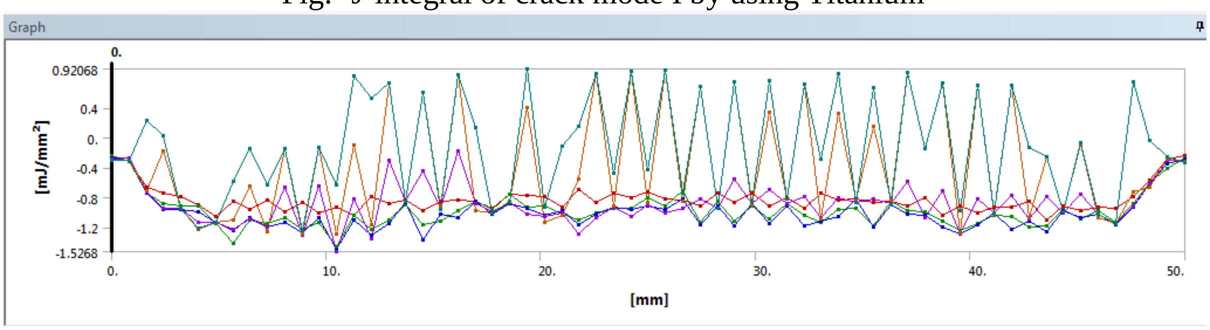

Fig:- Graph of J-integral of crack mode I by using Titanium

CRACK MODE 2

NICKEL ALLOY 718

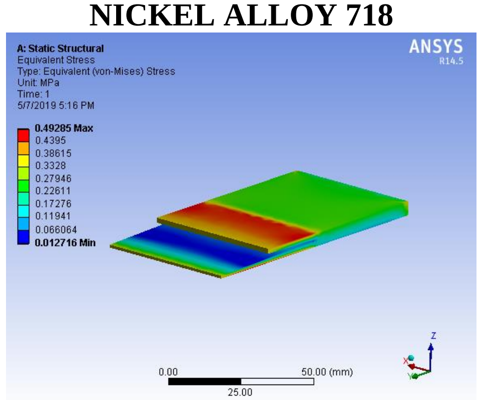

Fig:- Stress of crack mode I by using Nickel alloy 718

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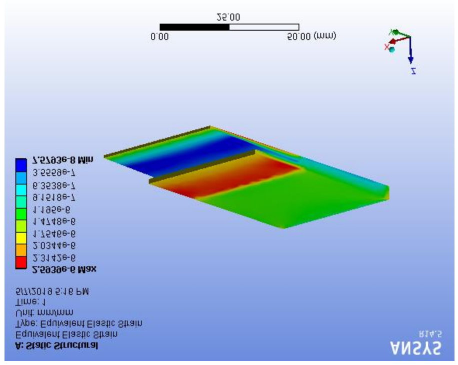

Fig:- Strain of crack mode I by using Nickel alloy 718

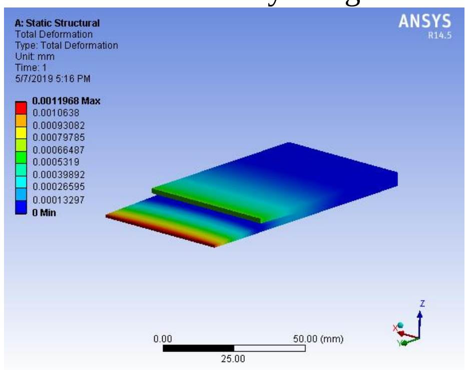

Fig:- Deformation of crack mode I by using Nickel alloy 718

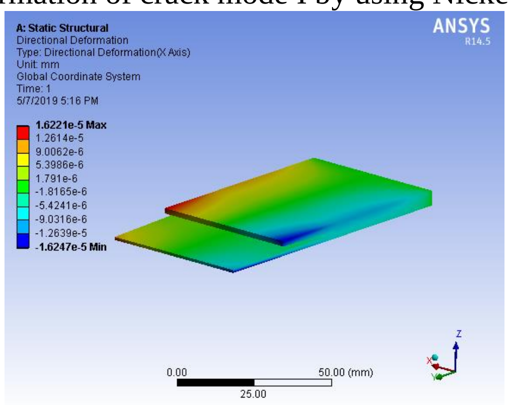

Fig:- Directional deformation of crack mode I by using Nickel alloy 718

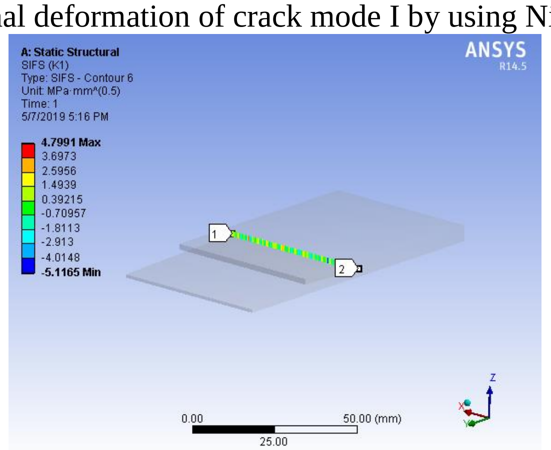

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Fig:- Stress intensity factor of crack mode I by using Nickel alloy 718

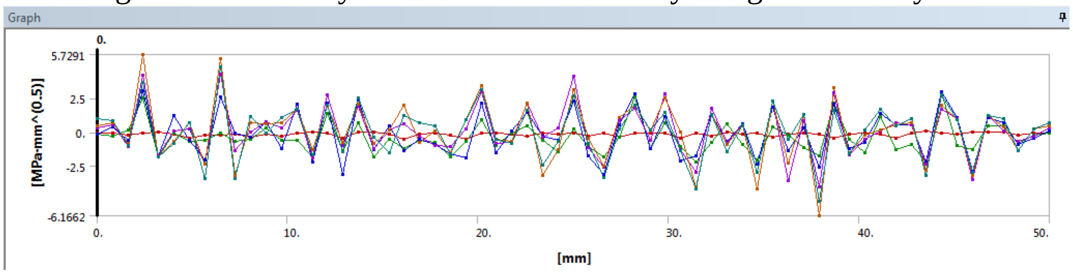


Fig:- Graph of Stress intensity factor of crack mode I by using Nickel alloy 718

Stress intensity factor obtained is 4.7991Mpa at crack for crack mode I by using Nickel alloy 718

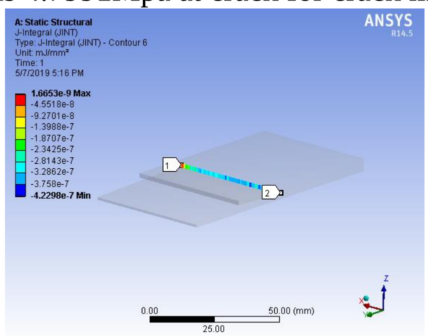


Fig:- J-integral of crack mode I by using Nickel alloy 718

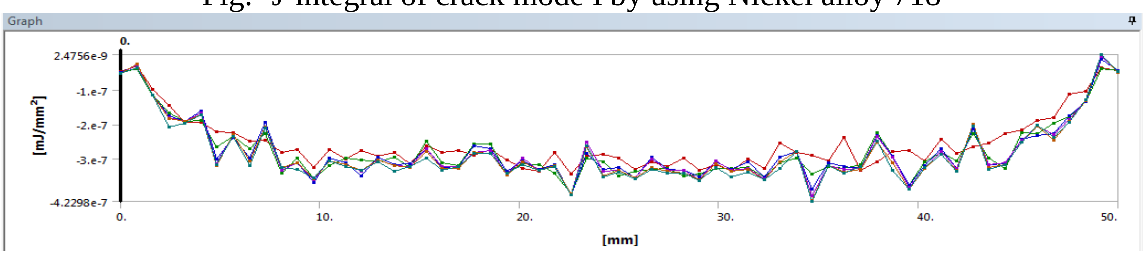


Fig:- Graph of J-integral of crack mode I by using Nickel alloy 718

RESULTS & DISCUSSIONS

FRACTURE ANALYSIS

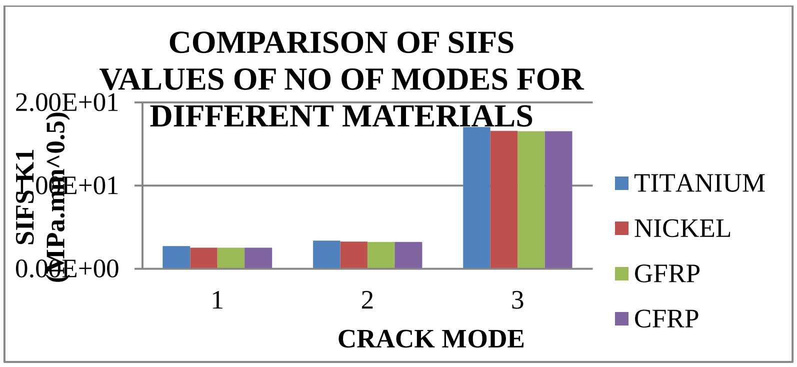
The table below shows the stress intensity factors and J – Integral for 3 crack modes and different materials.

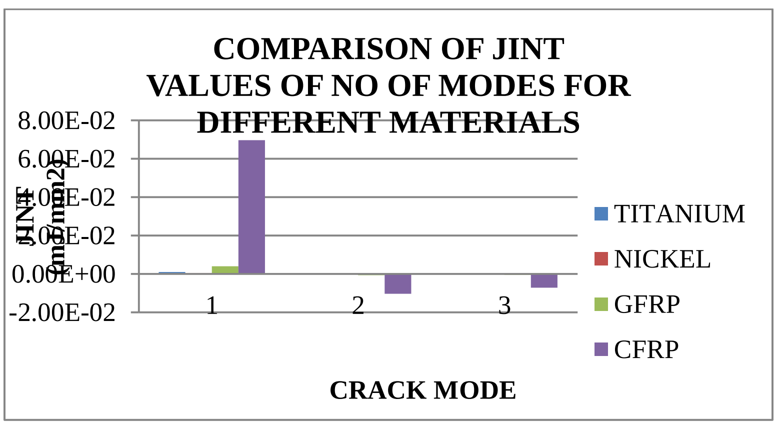
CRACK MODE	MATERIAL	SIFS K1 (MPa.mm^0.5)	JINT (mJ/mm^2)
I	TITANIUM	2.7413	0.001043
	NICKEL 718	2.5502	0.00055147
	GFRP	2.5262	0.0040201
	CFRP	2.5262	0.069681
II	TITANIUM	3.3737	-0.00013731
	NICKEL	3.2485	$-8.0691e^{-5}$
	GFRP	3.2335	-0.00059855
	CFRP	3.2335	-0.010375
III	TITANIUM	17.031	$-4.5185e^{-5}$
	NICKEL 718	16.579	$-5.0582e^{-5}$

	GFRP	16.522	-0.00041159
	CFRP	16.522	-0.0071343

From the above table, the following observations can be made:

- For Titanium material, the stress intensity factor is increasing for Crack Mode II by about 18% when compared with Crack Mode I. The stress intensity factor is increasing for Crack Mode III by about 85% when compared with Crack Mode I.
- For Nickel 718 material, the stress intensity factor is increasing for Crack Mode II by about 21% when compared with Crack Mode I. The stress intensity factor is increasing for Crack Mode III by about 83.7% when compared with Crack Mode I.
- For Glass Fiber Reinforced Polymer, the stress intensity factor is increasing for Crack Mode II by about 21 % when compared with Crack Mode I. The stress intensity factor is increasing for Crack Mode III by about 84% when compared with Crack Mode I.
- For Carbon Fiber Reinforced Polymer, the stress intensity factor is increasing for Crack Mode II by about 22 % when compared with Crack Mode I. The stress intensity factor is increasing for Crack Mode III by about 85% when compared with Crack Mode I.





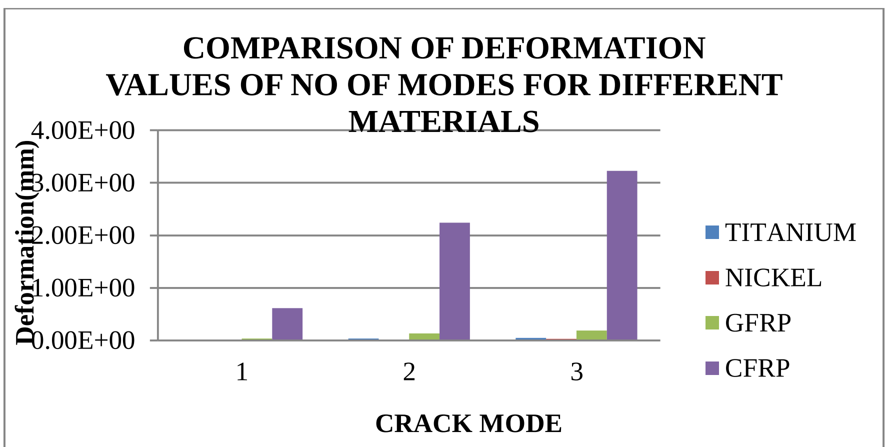
STATIC STRUCTURAL ANALYSIS

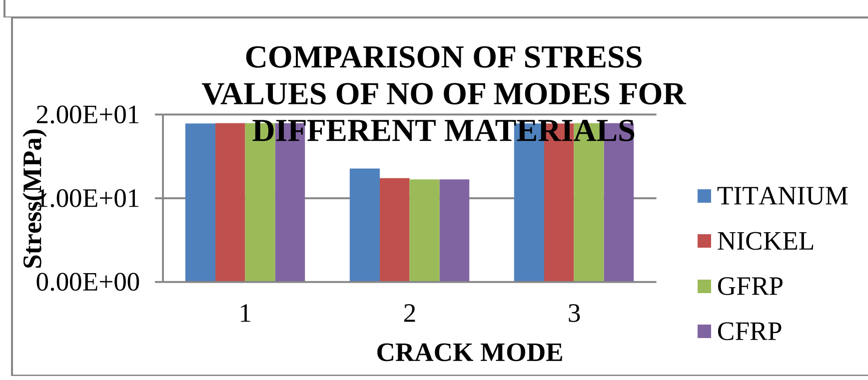
CRACK MODE	MATERIAL	Deformation (mm)	Stress (MPa)	Strain
I	**TITANIUM**	0.008799	18.926	0.00018555
	NICKEL	0.0048136	18.975	$9.987e^{-5}$
	GFRP	0.035259	18.979	0.00072998
	CFRP	0.61116	18.979	0.012653

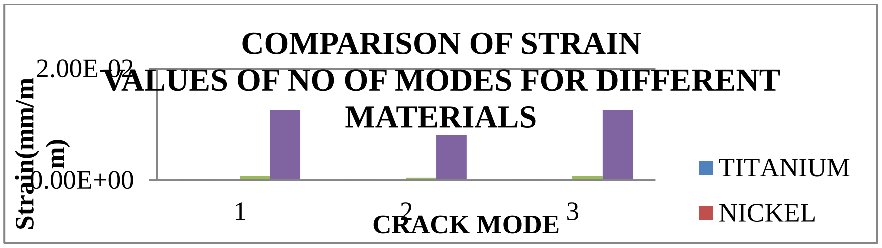
II	TITANIUM	0.032306	13.549	0.00013284
	NICKEL	0.017639	12.42	6.537e^{-5}
	GFRP	0.12917	12.263	0.00047166
	CFRP	2.2389	12.263	0.0081755
III	TITANIUM	0.04581	18.934	0.00018563
	NICKEL	0.025389	18.963	9.9807e^{-5}
	GFRP	0.18624	18.964	0.0007294
	CFRP	3.2282	18.964	0.012643

From the above table, the following observations can be made:

- For Titanium material, the stress is increasing for Crack Mode I by about 28% when compared with Crack Mode II. The stress is increasing for Crack Mode III by about 28.4% when compared with Crack Mode II.
- For Nickel 718 material, the stress is increasing for Crack Mode I by about 34% when compared with Crack Mode II. The stress is increasing for Crack Mode III by about 34.5% when compared with Crack Mode II.
- For Glass Fiber Reinforced Polymer, the stress is increasing for Crack Mode I by about 35.38% when compared with Crack Mode II. The stress is increasing for Crack Mode III by about 35.33% when compared with Crack Mode II.
- For Carbon Fiber Reinforced Polymer, the stress is increasing for Crack Mode I by about 35% when compared with Crack Mode II. The stress is increasing for Crack Mode III by about 35% when compared with Crack Mode II.







MODAL ANALYSIS

From the above table, the following observations can be made:

CRACK MODE	MATERIALS	Mode 1 (mm)	Frequency (Hz)	Mode 2 (mm)	Frequency (Hz)	Mode 3 (mm)	Frequency (Hz)
I	TITANIUM	200.45	420.77	270.84	1644.	225.19	2561.8
	NICKEL	148.02	419.84	199.33	1694.2	165.6	2564.9
	GFRP	316.21	331.38	425.6	1343.3	353.57	2025.3
	CFRP	346.39	87.191	466.22	353.44	387.32	532.9
II	TITANIUM	287.64	449.79	270.9	1377.5	439.05	1413.2
	NICKEL	212.47	448.7	199.07	1369.6	323.86	1456.7
	GFRP	453.92	354.14	424.99	1080.6	691.71	1155.
	CFRP	497.24	93.181	465.55	284.31	757.73	303.9
III	TITANIUM	228.51	461.77	395.52	1605.	385.93	2278.9
	NICKEL	168.6	460.7	291.76	1655.9	285.41	2279.6
	GFRP	360.13	363.62	623.17	1313.1	610.03	1799.8
	CFRP	394.51	95.675	682.65	345.5	668.25	473.55

At Mode 3

- For Titanium material, the frequency is increasing for Crack Mode I by about 45% when compared with Crack Mode II. The stress is increasing for Crack Mode III by about 38% when compared with Crack Mode II.
- For Nickel 718 material, the frequency is increasing for Crack Mode I by about 43% when compared with Crack Mode II. The stress is increasing for Crack Mode III by about 36% when compared with Crack Mode II.
- For Glass Fiber Reinforced Polymer, the frequency is increasing for Crack Mode I by about 43% when compared with Crack Mode II. The stress is increasing for Crack Mode III by about 36% when compared with Crack Mode II.
- For Carbon Fiber Reinforced Polymer, the frequency is increasing for Crack Mode I by about 43% when compared with Crack Mode II. The stress is increasing for Crack Mode III by about 36% when compared with Crack Mode II.

CONCLUSION

By observing analysis results, the deformation and stress values are decreasing by increasing the Fracture, Static & Frequency are done on all the modes of failure to determine displacements, stresses, stress intensity factors, vibrations, directional deformations and shear stresses. Analysis is done by considering materials Titanium, Nickel Alloy 718, Glass Fiber Reinforced Polymer, and Carbon Fiber Reinforced Polymer.

By observing fracture analysis results, the stress intensity factors are less for crack at mode I and when Polymers are used. The stress intensity factors are decreasing for crack at mode I by about 21.8% when compared with that of crack at mode II and by 84.7% when compared with that of crack at mode III when GFRP and CFRP are used.

By observing static structural analysis results, the stresses are less for crack at mode II and when Glass Fiber Reinforced Polymer is used. The stresses are decreasing for crack at mode II by about 54.76% when compared with that of crack at mode I and by 35.33% when compared with that of crack at mode III.

By observing modal analysis results, the frequencies are less for crack at mode II when Carbon Fiber Reinforced Polymer is used. Due to lesser frequencies, vibrations will be less.

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