FRACTURE ANALYSIS OF COMPRESSOR BLADE WITH DIFFERENT CRACK DEPTH BY USING FINITE ELEMENT METHOD

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Abstract — in our analysis, ANSYS was used and the model was developed on CREO 5.0. In order to verify the present ANSYS model, the crack depth effect with their variable depth by using structural steel materials are compared with the available experimental results present in the literature. And the design of Turbo expander compressor blade with different crack depth of 0.15, 0.13, 0.5, 0.1. In this study, the simulations of different profile crack depth Structural Steel material is used, was analyzed for Stress intensity factor and the configurations of blade design are proposed.

The results show that increasing crack depth of turbo expander compressor blade decreases the stress intensity factor of K1, K2, and K3 with increase in a number of rotations simultaneously. The natural frequency of the turbo expander compressor blade is compared with reference study

Keywords— Crack Depth, Finite Element Method, Fracture, Compressor Blade, Turbo Expander.

I. INTRODUCTION

Rotor is that the rotating a part of a machine. Rotors consistent with their application are often classified as, rotary engine rotor, electrical rotor, heavier-than-air craft rotor, turbo expander rotor etc. Turbo expander is additionally called enlargement rotary engine. As a district of exploring the globe as youngsters, everyone seems to be conversant in the thought that banging on a structure can create it pick up and vibrate. Some things vibrate additional simply than others (a metal rod versus a wood stick, for example). We tend to even have intuition that it's easier to urge things to vibrate or pull away and forth at sure frequencies. to Illustrate, we tend to tend to find out that a swing with long ropes moves back and forth additional slowly than a swing with short ropes. 'Pumping' the swing at a rate that matches the speed at that it needs to naturally pull away and forth can get you swinging abundant on top of rates that area unit quicker or slower than the swing's natural frequency. Several people have additionally had some expertise with stringed instruments. From this expertise, we tend to develop some concept that significant objects (thick strings) tend to vibrate at a lower frequency than light-weight objects (thin strings). we have a tendency to learn that increasing stiffness (tightening the string) raises the frequency of its vibration. Finally, we tend to additionally learn that decreasing a serious dimension (shorter string) leads to higher frequency vibration. These fans flow into cooling gas, air or chemical element, throughout the machine to take care of the electrical windings at safe operative temperatures. Cooling air is circulated in an exceedingly closed cycle, in a very approach that when passage of air through rotor, it's heated and exhausted from prime of the generator, that then passes through a cooler, which might change state down exploitation water flow. Cool air once more flows towards rotor and by use of fans, that square measure put in on retentive ring at the generator sides is blown round the rotor. Every fan is comprised of many blades that are separated by victimization spacers. In Fig. 1, overall set up of generator and air cycle is shown (Moussavi et al., 2009). Failure of a rotating fan within a generator can cause in depth injury. The hold on movement energy in an exceedingly fan that lets loose can generally destroy the mechanical device winding, generally harm the mechanical device core and cause harm to different rotor elements reminiscent of retentive rings, the rotor winding and presumably even the rotor shaping (Moore, 2002). Fan blades area unit frequently inspected throughout overhauls by visual and dye penetrate inspections and square measure needed to get replaced because of defects caused by crack, corrosion and impact. Initial investigation found out that 3 blades were broken and a number of other others were cracked on the subject of eleven hours once resuming operation following the last major overhaul, inflicting in depth harm to the generator unit specially the mechanical device windings. The failure of the blades was investigated exploitation fractographic and small structural characterization techniques furthermore as mechanical evaluations to spot the basis reason behind the failure. 2 similar failures at this sort of fan that caused in depth harm to generator units are rumoured from Asian nation.

II. MECHANICAL PROPERTIES MEASUREMENTS

- **Strength:**

Strength is a mechanical property they should be able to relate to, but you might not know exactly what we mean by the word "strong" when are talking about polymers. First, there is more than one type of strength. There is tensile strength. A polymer has tensile strength if it is strong when one pulls on it. Tensile strength is more important for a material that is going to be stretched or under tension. Materials need good tensile strength.

- **Elongation:**

There is more to understanding a polymer's mechanical properties than merely knowing how strong it is. All strength tells us is how much stress is needed to break something. It does not tell us anything about what happens to our sample while we're trying to break it. That's where it pays to studies the elongation behavior of a polymer. Elongation is a kind of deformation. Deformation is simply a change in shape that anything undergoes under stress. When we're talking about tensile stress, the sample deforms by stretching, becoming longer. We called that elongation, of course. Usually we talk about paper elongation, which is just the length the polymer sample is after it is stretched, divided by the original length of the sample, and then multiplied by 100.

Materials characterization

Composite is any material fabricated from quite one component. There are a unit plenty of mixed product around you. Concrete could be a mixture. It's fabricated from cement, gravel, and sand, and sometimes has steel rods within to strengthen it. These shiny balloons you get within the hospital once you're sick area unit fabricated from a mix that consists of a polyester sheet Associate in Nursing an Al foil sheet, created into a sandwich. The compound mixture made up of polymers, or from polymers beside different form of materials. However specifically the fiber-reinforced mixture

area unit materials within which a fiber fabricated from one material is embedded in another material.

III. LITERATURE REVIEW

Collins and Cannaday, 1958 [6] and 6 smith [7], 1984

The history of turbo expander and its development is bestowed. Third Baron Rayleigh explained the essential functionalities of a refrigerant growth device in 1988. In continuation to the present varied patents were revealed on refrigerant growth. In 1898 a straightforward liquefying machine was created by British Engineer, Edgar C. Thrupp, within which he used growth rotary engine. At the same time, Joseph E. Johnson in USA proprietary a tool to liquefy the gas. His expander was a DE Laval turbine.

Peter Kapitza, 1939 [11]

He incontestable by each analytical and experimental studies, that associate inward radial flow rotary engine would be preferred to associate axial impulse sort machine. He showed that in associate axial flow machine, the disruption of the regular flow by expansive air from the rotor would create it troublesome to take care of radial equilibrium. He recommended that refrigerant turbines may follow the overall style principles of radial flow hydraulic machines, since each prohibited serious fluids moving at relatively low speeds.

Land [17]

During the planet War II hydraulic machine idea was applied. The choice of turbines were supported the vane parameters like specific speed (ns) and flow constant (φ) etc. The centrifugal flow pure mathematics therefore became the standard configuration for tiny and medium sized refrigerant turbines.

Beasley, S. A. and Halford, P., 1965 [18]

By the tip Nineteen Fifties, European country primarily based company "Lucas company" had developed an oversized range of gas greased inward flow turbines for PDC (Petrocarbon Development Corporation).

2.2 - Recent Developments

Ino et al., 1992 [14] and Kato el al., 1994 [13]

By the Eighties, Europe and USA engineered 2 models of little turbines, one for inert gas liquefiers and another for little air separation units. Naka Fusion analysis Centre related to to the Japan energy Institute modelled an awfully massive size inert gas turbo-expander. An argonon turbo-expander for a seventy MW superconducting generator.

Kun et al., (1985) [10]

The work of Kapitza, paved the approach for the Russian rotary engine industries to use each oil and gas bearings to support turbo-expander. This has continuing through the 90s. By considering demanding safety and dependableness conditions, growth rotary engine of screenwriter was utilized in an exceedingly plant that was activity blanket gas to a metallic element Hexafluoride (UF6) method. Later taking gas-bearing primarily based rotary engine, scientists pair Sulzer Brothers developed a spread of tiny element liquefiers (the LINIT series). Currently European nation companies Linde conductors manufactures this capability and vary of laboratory liquefiers.

Polishchuk et al. 1991 [15]

Mikrokryogenmash Company in Russia developed tiny turboexpanders for microcryogenic systems. Gas bearing technology, was applied to applications in tiny air separation plants. the trendy development includes the small turbines and application of bearings.

Sixsmith, 1988 [16]

He developed a small version of the of the rotary engine for cryo-cooler was engineered by unitedly with Robert Hutchings Goddard house Flight Centre of National Aeronautics and Space Administration. They engineered the rotary engine with diameter one.5 metric linear unit and tested it with a speed of around one thousand thousand revolutions per minute. whereas gas bearings of each the aerostatic or mechanics varieties earned smart quantity of dependableness, they still have method gas consumption, contact in starts and stops, sensitivity to dirt and shocks, and instabilities.

Witek, 2009 [20]

He analyzed through an experiment the behavior of the cracked blade of mechanical device through analysis. He performed FEM and compared it with experimental analysis.

Poursaeidi, Esmaeil, and Hosein Bakhtiar, 2014 [21]

He studied the failure of the mechanical device blade of a GE-F6 turbine because of vibration. He analyzed the fatigue life for 2 cracks on the rotary engine.

Witek, Lucjan, 2015 [22].

He used original hybrid methodology for crack dynamics estimation associate degreed studied crack growth analysis of an aero-engine mechanical device blade subjected to resonant vibration.

Generally varied sorts of turbo machines square measure used for varied sorts of application. typically shaft, growth rotary engine and brake mechanical device square measure taken for analysis of stress and deformation, because the whole assembly is unbroken in housing, there's a chance that thanks to high speed rotation of the Turbo expander, the varied parts of it's going to grow radially decreasing the clearance between the housing and turbo expander. This could cause harmful injury to the housing and {also the} turbo expander and also to the bearings. There square measure sharp edges gift in shaft; brake mechanical device, rotary engine wheel, and people square measure major areas of stress concentration. As turbo expanders square measure terribly delicate and dear, it's imperative to investigate every and each half rigorously before putt it into application.

IV. FINITE ELEMENT ANALYSIS

The finite element method (FEM) (its practical application often known as finite element analysis (FEA)) is a numerical technique for finding approximate solution of partial differential equation (PDE) as well as integral equation. The solution approach is based either on eliminating the differential equation completely (steady state problem), or rendering the PDE into an approximation system of ordinary differential equation, which are then numerically integrated using standard technique such as Euler's method , Runge-kutta, etc.

In solving partial differential equations, the primary challenge is to create an equation that approximates the equation to be studied , but is numerically stable , meaning that error in the input and intermediate calculation do not accumulate and cause the resulting output to be meaningless. There are many ways of doing this, all with advantages and disadvantage. The finite element method is a good choice for solving partial differential equation over complicated domain (like cars and oil pipelines), when domain changes (as during a solid state reaction with a moving boundary), when the desired precision varies over the entire domain, when the solution lacks smoothness[21].

A. Finite Element Analysis

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may

make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

B. Finite Element Analysis Work

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress.

V. RESULT & DISCUSSION

It is evident that there is a increase in the stress intensity factor with increase in Crack Depth and thus decrease in vonmises stress, stress intensity this analysis is performed on turbo expander blade tip to analyze SIFS to predict the effect of gravity and rotational speed on crack, Overall turbo expander total deformation was also analyzed in this analysis

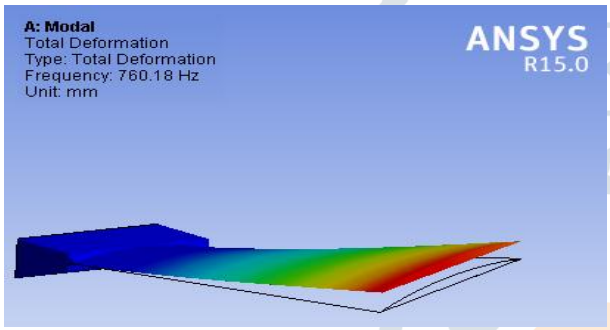

Figure - Deformation of blade

Crack Depth (mm)	K1 (Mpa√mm)	K2 (Mpa√mm)	K3 (Mpa√mm)
0.1	3.92	2.74	0.96
0.15	4.51	2.73	1.08
0.2	5.23	2.32	1.24
0.25	5.9	2.34	1.32
0.3	6.49	2.52	1.42

Table – Variation of stress intensity Factors w.r.t Crack Depth

Crack Depth (mm)	Von Misses stress (MPa)
0.1	9.41
0.15	8.19
0.2	7.87
0.25	7.16
0.3	6.82

Table – Variation of Von Misses stress w.r.t Crack Depth.

Crack Depth (mm)	Stress Intensity (MPa)
0.1	9.42
0.15	8.22
0.2	7.88
0.25	7.17
0.3	6.83

Table – Variation of stress intensity w.r.t Crack Depth

Figure below shows the stress intensity and Von- Misses stress Variation with respect to Crack Depth respectively.

➢ **Crack depth – 0.1 mm**

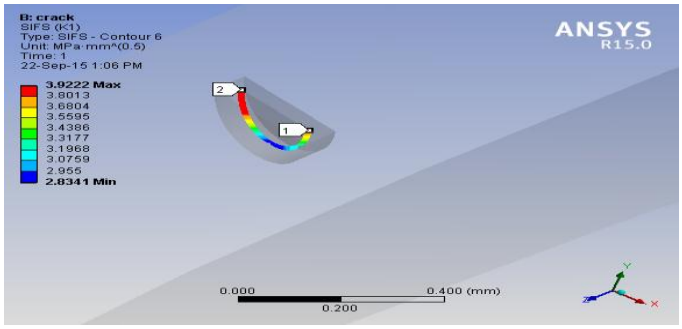

Figure – K1 variation

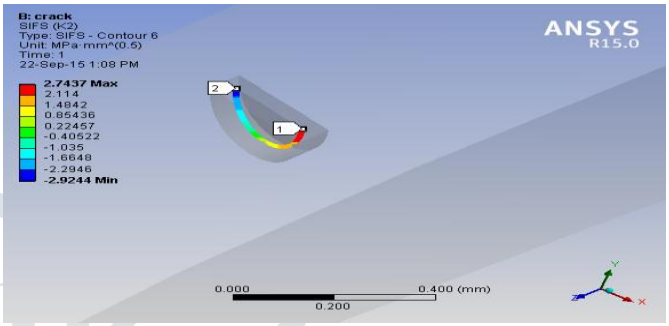

Figure – K2 variation

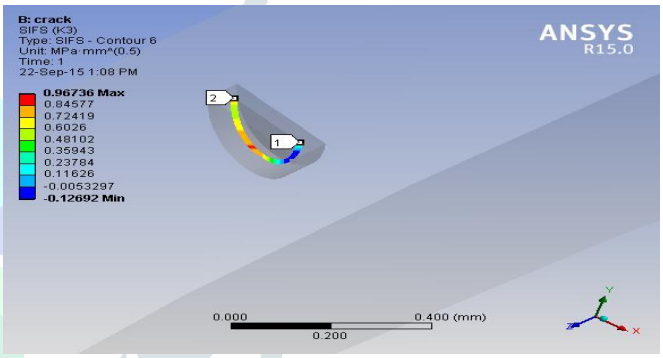

Figure – K3 variation

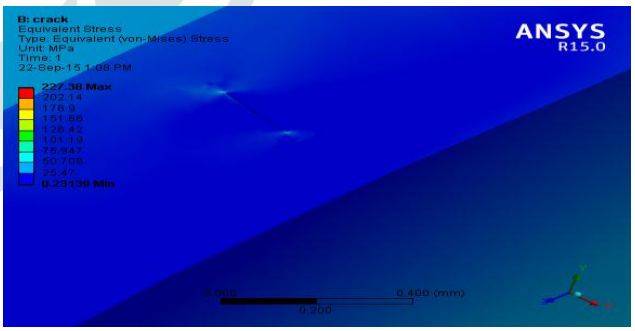

Figure – Von Misses stress variation

➢ **Crack 0.15 mm**

Figure below shows the stress intensity and Von- Misses stress variation with respect to Crack Depth respectively.

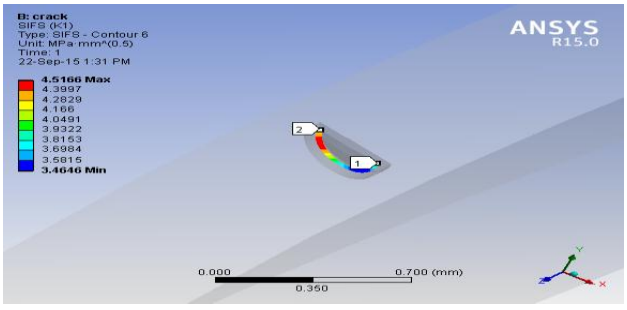

Figure – K1 variation

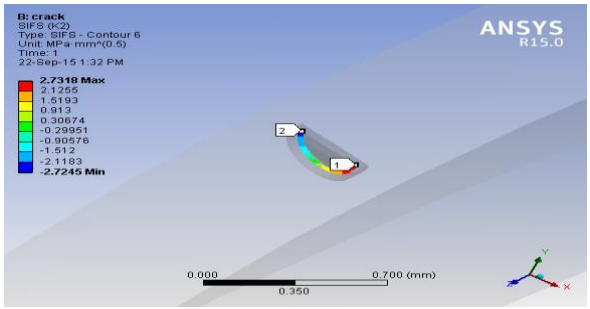

Figure – K2 variation

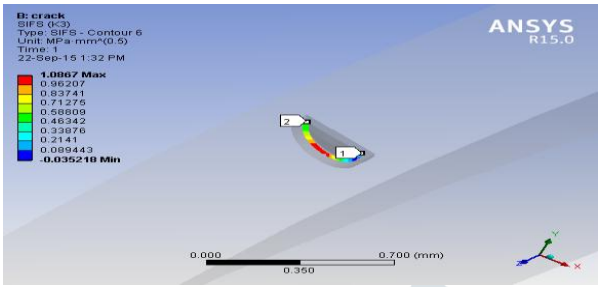

Figure – K1 variation

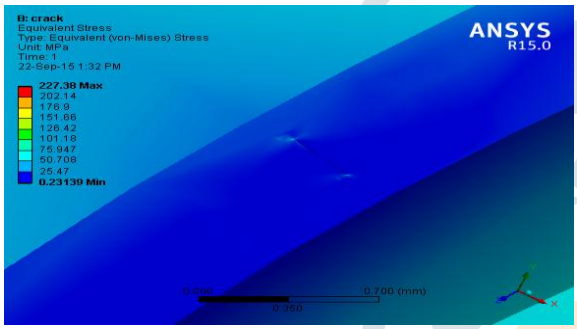

Figure – Von Misses stress variation

➢ **Crack 0. 2 mm**

Figure below shows the stress intensity and Von- Misses stress variation with respect to Crack Depth respectively.

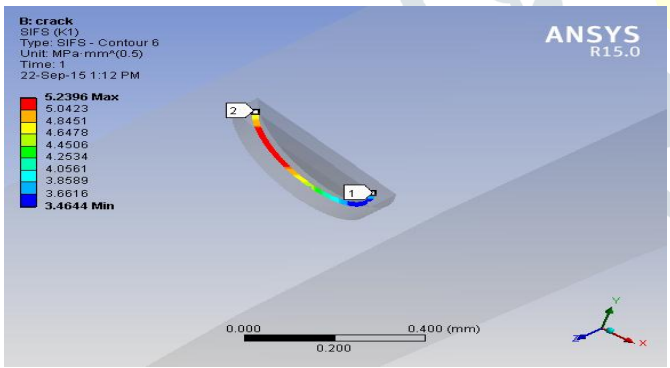

Figure – K1 variation

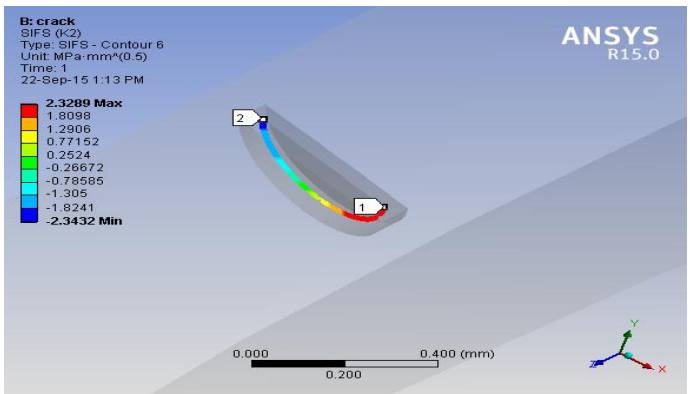

Figure – K2 variation

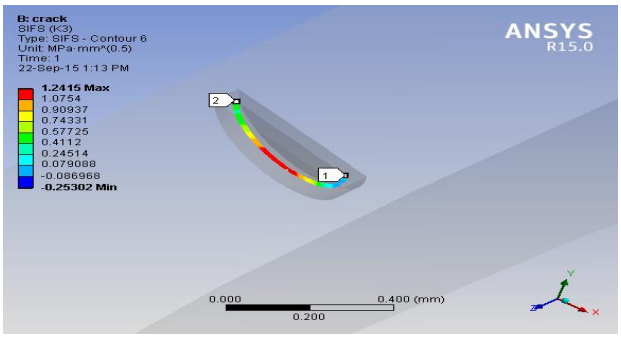

Figure – K3 variation

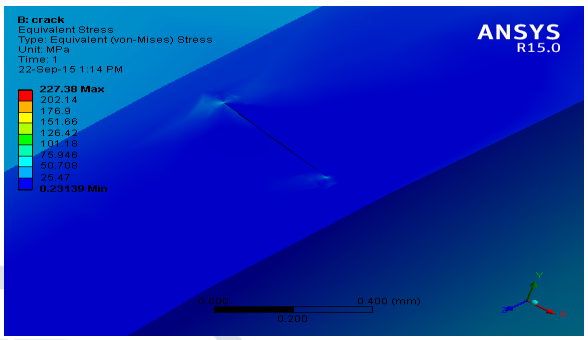

Figure – Von Misses stress variation

➢ **Crack 0.25 mm**

Figure below shows the stress intensity and Von- Misses stress variation with respect to Crack Depth respectively.

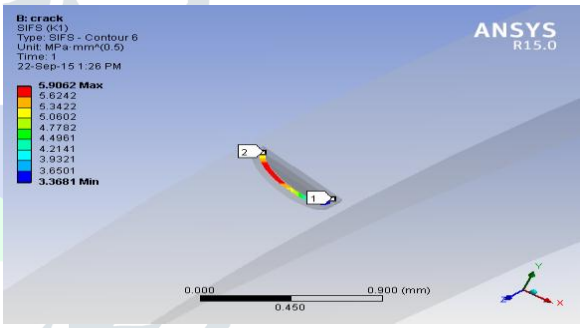

Figure – K1 variation

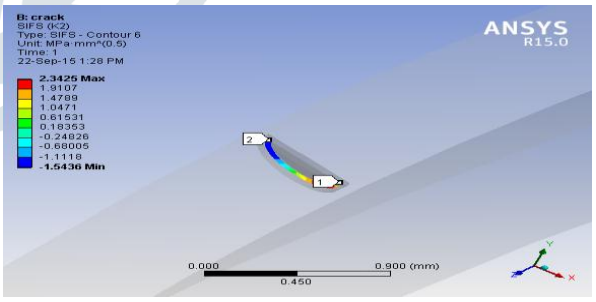

Figure – K2 variation

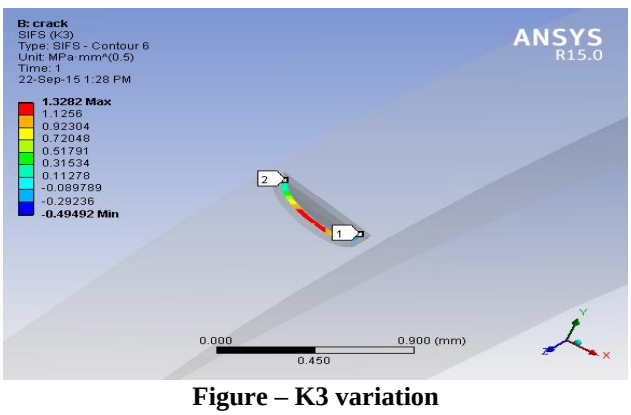

Figure – K3 variation

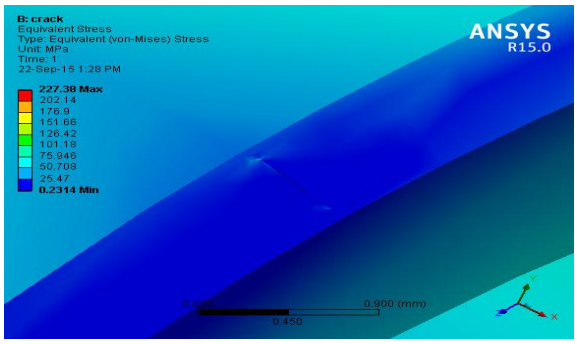

Figure – Von Misses stress variation

➢ **Crack 0.3 mm**

Figure below shows the stress intensity and Von- Misses stress variation with respect to Crack Depth respectively.

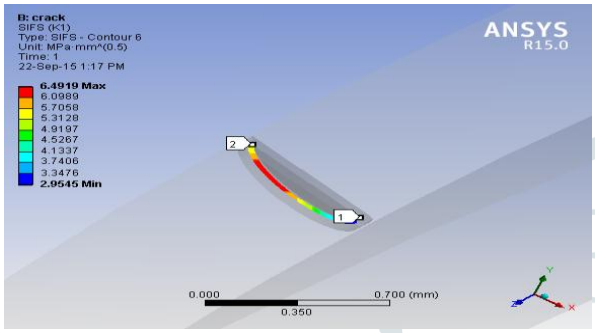

Figure – K1 variation

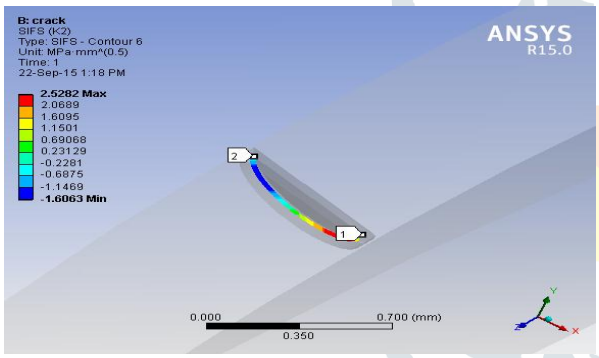

Figure – K2 variation

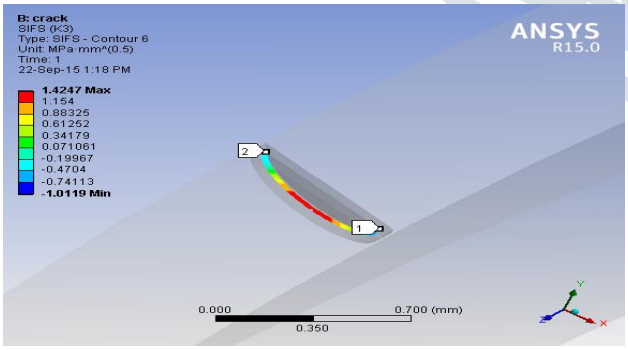

Figure – K2 variation

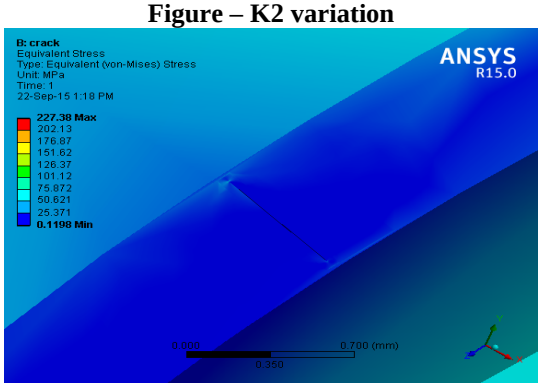

Figure – Von Misses stress variation

Table above shows the variation of stress intensity factors, Von Misses stress and stress intensity with respect to Crack Depth. The same is can be seen in the graph respectively.

VI. CONCLUSION

In the current investigation fracture analysis for compressor of turbo expander is done.

Below are the lists of observation from current analysis.

- First Natural Frequency for blade is found out to be 760.18 Hz which when validated with "L. Witek / Engineering Failure Analysis 16 (2009) 2163–2170" Table No.1 gives acceptable Error of 1.8 %.
- The maximum deflection for compressor is 0.059 mm at outer circumference.
- The maximum Von Misses stress is found out to be 227.38 Mpa near the hub of compressor.

Fracture Analysis

- K1 increases as Crack Depth increases.
- K2 and K3 has negligible effect with Crack Depth.
- Von Misses stress decreases in the crack vicinity as Crack Depth increases.
- Stress Intensity decreases in the crack vicinity as the Crack Depth increases

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