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Crack initiation and propagation analysis on heavy vehicle propeller shaft

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Abstract- The paper deals with the behavior of structural components with surface cracks. Circular bar with an elliptical surface crack under tension load is focused in this. The main aim of this project is to find the effects of the shape and size of cracks at the structural part on the fracture mechanics parameters. Using finite element method, stress intensity factors (SIF) are considered with a straight round bar under tension, bending and moment loads are analyzed. Using three-dimensional finite element analysis (FEA) models, with singular 20-node elements arranged around the crack tip are calculated with the help of stress intensity factor like elliptical surface cracks in tensile round bar. The graphical representation and the review of stress intensity factors are also examined. For various dimensions of surface cracks the stress intensity factors are calculated. With these results the analytical form of the SIF which is necessary in crack growth analysis are determined. Crack growth analysis is determined using derived analytical formulae for SIF with the help of finite element analysis. This work results are present work results are proved with the help of few reviewed articles. In propeller drive shaft, few extensions are made.
Keywords – Stress intensity factor (SIF), modeling of drive shaft, crack initiation and elliptical crack.

I. INTRODUCTION

In machinery, cylindrical shaped components with a round cross section are used to operate. Bars, reinforcement, pins, shafts, wires, bolts or screws are some examples of cylindrical shaped structure. These structures are used in loading condition which is complex. Usually engineering structures are designed to withstand the loads till the day of maintenance. Among these structures, beams are considered the most utilized structural components within various structural elements in many applications in machinery and it experiences a wide mixed bag of static and element loads. For most of the engineering applications, beams are widely used as main structural components in engineering applications because it provides a fundamental model for various engineering applications. Some examples of structural components are helicopter rotor blades, Aircraft wings, spacecraft antennae, and robot arms etc, which might be modeled with beam like element. Beam like structures are generally used in steel shaped structure and manufacturing of machines.

1.1 Stress Intensity Factor (SIF)

When the crack surfaces are displaced in the opening mode (Mode I), the measurement of the stress field intensity near the tip of an ideal crack in a linear elastic solid is called as stress intensity factor. The stress intensity factors are used to interpret the singular stress or local stress and displacement field in the cracked tip. The SIF depends on the loading, the crack size, the crack shape, and the geometric boundaries of the specimen. The recommended units for K are MPa√m. it is customary to write the general formula in the form $K=Y\sigma\ \pi a$ where σ is the applied stress, a is crack depth, Y is dimensionless shape factor.

II. DETERMINATION OF THE STRESS INTENSITY FACTORS

Various numerical analyses, theoretical studies and experimental investigations have been carried to obtain stress intensity factors (SIFs) for three-dimensional (3D) cracked bodies. Explicit solutions or empirical expressions have been obtained for surface and corner cracks on smooth strips or straight round bars and at circular holes in finite thickness plates.

The main purpose of this paper is to investigate the dependence of SIFs of the surface cracks in round bars upon notch geometry, Fig.1. The surface crack has a semi-elliptical geometry with the semi-major axis c and the semi-minor axis a as shown in Fig.1, where a is also the depth of the surface crack.

The relative depth $\xi=a/D$ of the deepest point A on the defect front and the flaw aspect ratio $\alpha=a/b$ define the crack configuration. The point B is the end of the flaw. The parameter S=ael/a is constant and its value is 1. The geometrical parameter α is made to vary from 0.2 to 1.2. As well as ξ is made to vary from 0.1 to 0.5. The diameter of the shaft is D=50 mm.

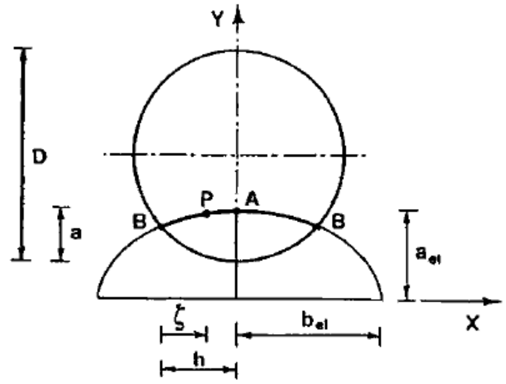


Fig 1, Elliptical-arc surface flaw in a round Shaft: geometrical parameters.

A finite element analysis is done to calculate the stress-intensity factors along the crack front that are subjected to tension or bending loads (Fig.1). to be exact, the round bar being considered is subjected to either a tensile axial force F perpendicular to the crack plane or a bending moment M about an axis parallel to the ellipse semi-axis bel ,The stress-intensity factors are obtained from the stresses near the flaw front, as is shown below.

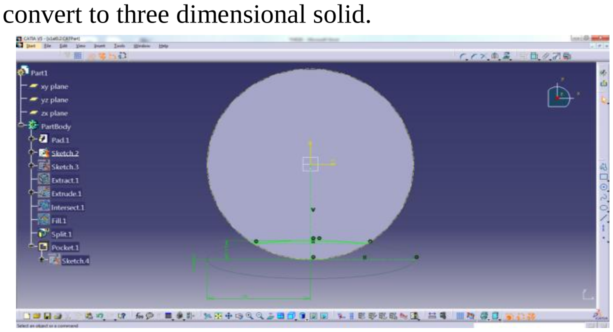
The dimensionless stress-intensity factors and , are calculated as follows:
KF=stress-intensity factor for tension.
KM= stress-intensity factor for bending.
Applied Uniform Tensile Stress,
Maximum Bending Stress,

$$K_F = \frac{K(fem)}{\sigma_F\sqrt{(\pi X a)}}$$

$$K_M = \frac{K(fem)}{\sigma_M\sqrt{(\pi X a)}}$$

III. RESULTS AND DISCUSSIONS

Three dimensional software called CATIA is used in this project. Initially, CATIA name is an abbreviation for Computer Aided Three-dimensional Interactive Application, the French Dassault Systems is the parent company, and CATIA is widely used in industrial sectors, and has been explained in the previous post position of CATIA between 3d modelling software. Before using sketch select the plane of the CATIA display and then go to sketch. So that generating of face can be done in CATIA. Draw the drawing which is having an accurate dimension then convert to three dimensional solid.



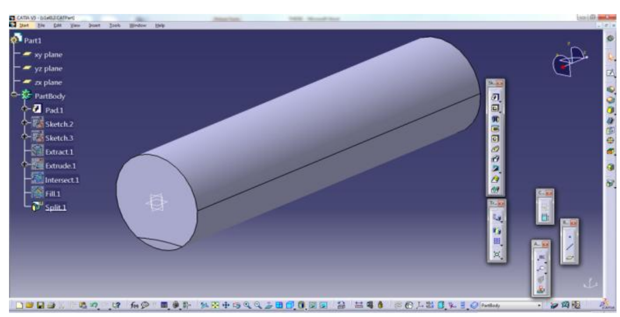


Fig2: Geometric model of elliptical cracked shape. Fig3: Geometric model of circular cross-section cracked shaft.

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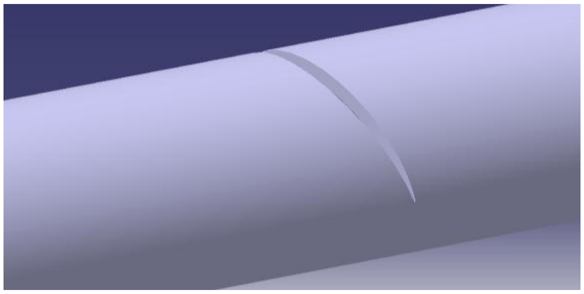

Fig4: 3d view of drive shaft.

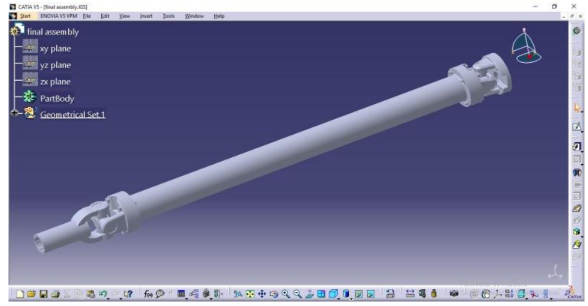

Fig5: crack created on drive shaft.

After creating the total sketch, axis line is created in sketch module. Using this, revolve option is used to apply on the shaft with the angle of 360 degree. From the reviewed article, the crack parameters are taken that are created using surface module. Finally symmetric model is prepared using CATIA software. And the final model is saved in IGES format.

To run the Analysis, 64 bit operating system, 4GB ram And ANSYS 19.0 is very apt configuration to run analysis. The previously created IGS file from CATIA is imported on ANSYS file geometry. Using ANSYS software, the static structure and modal analysis are performed. The tabular column of different parameters and circular cross section of the different materials for different components are used bicycle seat assembly are shown below. Solid mesh 200 elements are used to divide the geometric body in to small strips using finite element method.

The material used in the present work is Mild Steel and its structural properties are given in the table 1.

Parameters	Circular cross-section beam
Young's Modulus	2.1×1011 N/m2
Density	7850 kg/m3
Poisson ratio	0.3
Length of beam	562 mm
Diameter of beam	25.5 mm

Table 1 Material Properties of the Shaft

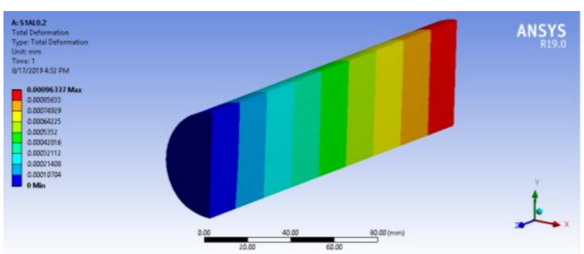

Fig 6: axial load deformation of simple shaft

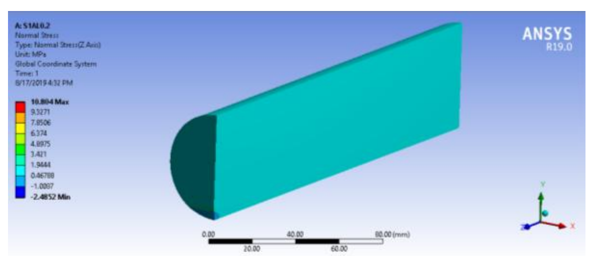

Fig 7: axial load stresses of simple shaft

In figure6 shows the total deformation of simple shaft after 1000 N load applied on end face of shaft. The colour red in the image indicates the maximum deformation and the colour blue indicates minimum deformation. Maximum deformation had occurred at the tip of blade because there is no support at the tip, so there is a high chance of the shaft to get bent. Minimum deformation appears at the fixed portion and we can clearly able to see in the above image. All together maximum value of deformation is 0.00096mm.This deformation is much of considerable deformation.

In figure7 shows the stresses of simple shaft after 1000 N load applied on end face of shaft. The colour red indicates the maximum stresses and colour blue indicates minimum stresses. Maximum stresses occur at the crack portion. A minimum stress occurs at the overall portion of shaft and we can clearly able to see in the above image. All together, the maximum stress value is 10.804 Mpa. This deformation is much of considerable stress.

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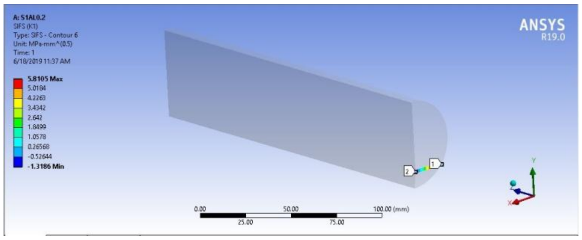

Fig8: stress intensity factor for tension (S1,α0.2, ξ 0.3)

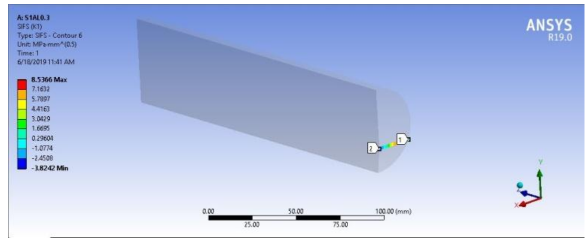

Fig9: stress intensity factor for tension (S1,α0.6, ξ 0.3)

In the figure8 the stress intensity factor for tension with S1,α0.6, ξ 0.3 crack parameters. Maximum stress intensity is occurring at the crack portion and value is 5.81M Pa-m^0.5.Iin the image the colour red indicate the maximum stresses and colour blue indicates minimum stresses. Maximum stresses occur at the crack portion.
In the figure9 shows the stress intensity factor for tension with S1,α0.6, ξ 0.3 crack parameters. Maximum stress intensity is acting at the crack portion and value is 8.53 M Pa-m^0.5. Here the red indicate the maximum stresses and blue indicates minimum stresses. Maximum stresses occur at the crack portion.

S=1;α=0.2; ξ=0.1 to 0.5;			
ξ	α	SIF	[1]
0.1	0.2	0.96	1
0.2	0.2	1.24	1.22
0.3	0.2	1.51	1.48
0.4	0.2	1.86	1.89
0.5	0.2	2.68	2.65

Table 2: Dimensionless SIF for S=1;α=0.2;

S=1;α=0.4; ξ=0.1 to 0.5;			
ξ	α	SIF	[1]
0.1	0.4	0.89	0.95
0.2	0.4	1.21	1.15
0.3	0.4	1.42	1.39
0.4	0.4	1.68	1.77
0.5	0.4	2.53	2.46

Table 3:Dimensionless SIF for S=1;α=0.4;

S=1;α=0.6; ξ=0.1 to 0.5;			
ξ	α	SIF	[1]
0.1	0.6	0.84	0.87
0.2	0.6	1.12	1.04
0.3	0.6	1.21	1.25
0.4	0.6	1.49	1.56
0.5	0.6	2.37	2.14

Table 4: Dimensionless SIF for S=1;α=0.6;

S=1;α=0.8; ξ=0.1 to 0.5;			
ξ	α	SIF	[1]
0.1	0.8	0.68	0.79
0.2	0.8	0.89	0.93
0.3	0.8	1.00	1.09
0.4	0.8	1.42	1.32
0.5	0.8	1.77	1.73

Table 5: Dimensionless SIF for S=1;α=0.8;

S=1;α=1.0; ξ=0.1 to 0.5;			
ξ	α	SIF	[1]
0.1	1.0	0.75	0.71
0.2	1.0	0.91	0.82
0.3	1.0	0.89	0.93
0.4	1.0	1.12	1.08
0.5	1.0	1.30	1.35

Table 6: Dimensionless SIF for S=1;α=1.0;

S=1;α=1.2; ξ=0.1 to 0.5;			
ξ	α	SIF	[1]
0.1	1.2	0.58	0.64
0.2	1.2	0.65	0.72
0.3	1.2	0.87	0.8
0.4	1.2	0.96	0.9
0.5	1.2	1.00	1.02

Table 7: Dimensionless SIF for S=1;α=1.2;

By observing the above tables,if increasing the relative depth of crack dimensionless stress intensity factor increases.Both software and fem results are having good agreement.

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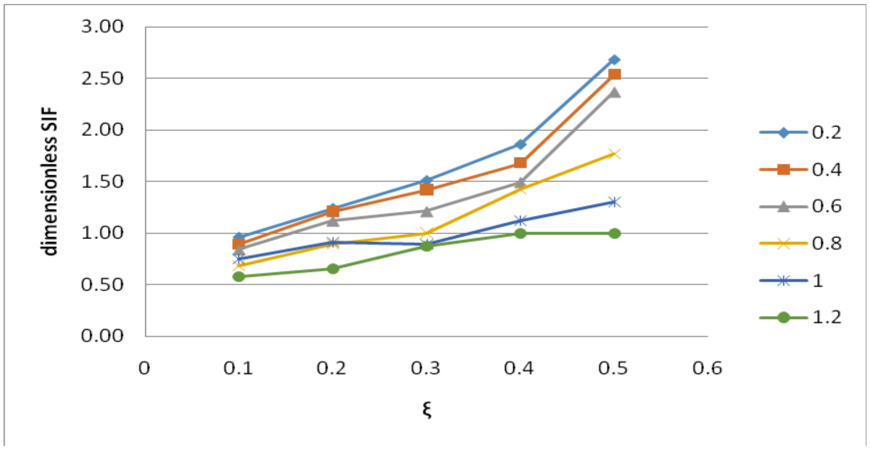
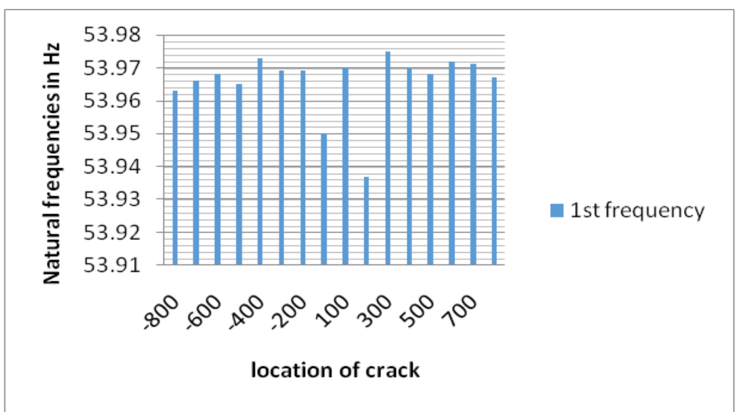


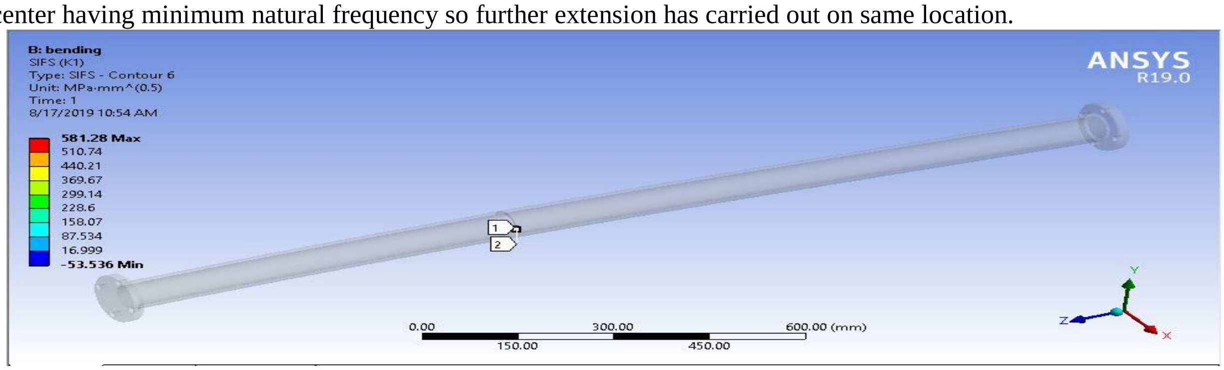
Graph 1: SIF readings for different crack parameters.

Crack Initiation of the Drive Shaft: This work addresses the inverse method of fault detection in shaft part. One of the failures might be due to the crack initiation and propagation in any of the shaft part. Being susceptible to minute changes, the natural frequency is monitored to access crack location and crack size in shaft. The study is based on observation of changes in natural frequency.The model of beam is generated using Finite Element Method of analysis. In Finite Element Analysis, the natural frequency of shaft is calculated by Modal Analysis using the software ANSYS.



Graph 2: natural frequency reading of drive shaft

The above graph shows the natural frequency reading of with and without crack shaft. Here to find out the crack initiation initially geometrical creak provided on shaft at different locations on drive shaft and at 200 mm from the center having minimum natural frequency so further extension has carried out on same location.



Stress intensity factor of propeller shaft in bending. (c/b=0.8)

The stress intensity factor for bending with c/b=0.8 crack parameters .maximum stress intensity is acting at the crack portion and value is 581.2 MPa-mm^0.5. Here the red indicate the maximum stresses and blue indicates minimum stresses. Maximum stresses occur at the crack portion.

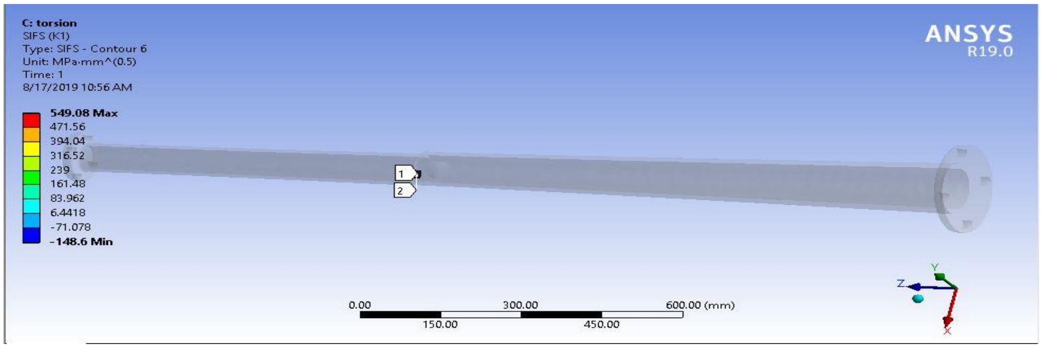


Figure **Error! No text of specified style in document.**.1 Stress intensity factor of propeller shaft in torsion loading. (c/b=0.8)

The stress intensity factor for bending with c/b=0.8 crack parameters .maximum stress intensity is acting at the crack portion and value is 540 MPa-mm^0.5. Here the red indicate the maximum stresses and blue indicates minimum stresses. Maximum stresses occur at the crack portion.

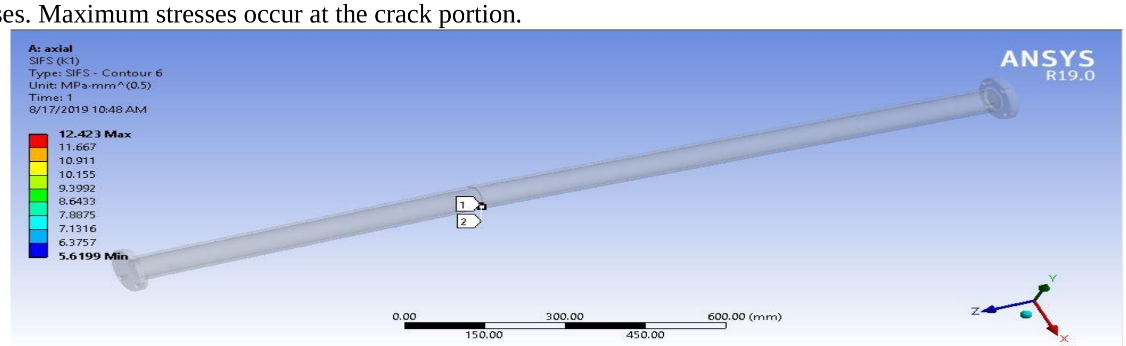


Figure **Error! No text of specified style in document.**.2 Stress intensity factor of propeller shaft in axial loading. (c/b=0.8)

The stress intensity factor for tension with c/b=0.8 crack parameters .maximum stress intensity is acting at the crack portion and value is 12.43MPa-mm^0.5. Here the red indicate the maximum stresses and blue indicates minimum stresses. Maximum stress occurs at crack portion

c/b	SIF	ANSYS
0.1	0.068458	0.0642
0.2	0.159586	0.149659
0.3	0.214263	0.200935
0.4	0.260811	0.244588
0.5	0.302063	0.283274
0.6	0.339171	0.318074
0.7	0.372426	0.349261
0.8	0.4019	0.376901
0.9	0.427913	0.401296

Table8:Bending stress intensity readings

c/b	SIF	ANSYS
0.1	0.030941	0.0335
0.2	0.074927	0.081124
0.3	0.103388	0.111938
0.4	0.128096	0.13869
0.5	0.149871	0.162266
0.6	0.169129	0.183117
0.7	0.186087	0.201476
0.8	0.200931	0.217548
0.9	0.213956	0.23165

Table9:Torsion loading stress intensity readings

c/b	SIF	ANSYS
0.1	1.053907	1.0517
0.2	1.877442	1.865
0.3	2.545064	2.532
0.4	3.107718	3.104
0.5	3.597535	3.57
0.6	4.032526	4.025
0.7	4.421278	4.412
0.8	4.76765	4.751
0.9	5.075469	5.02

Table10:Axial loading stress intensity readings

The above tables shows Dimension less stress intensity factor for relative crack depth ratio(c/b). if increasing the relative depth of crack, dimensionless bending, axial loading, torsion loading stress intensity factor increases. Both software and fem results are having good agreement.

IV.CONCLUSIONS

The stress intensity factors for elliptical surface cracks in round bars, propeller drive shaft and residual life estimation are considered in this project. A circular bar with an elliptical surface crack under tension load is mainly focused. By the 3D FE method with 20-node singular elements arranged around the crack border, SIFs of surface cracks in round bars are studied systemically.

For a given value of the relative crack depth ξ= a/D, the stress intensity factor variation along the crack front is remarkably dependent on the crack aspect ratio α. All the diagrams obtained for different values of the ellipse shifting parameter s show a transition phenomenon, that is to stay the stress intensity factor reaches the maximum either at the middle point on the crack front or near the free surface, depending on the condition of whether the aspect ratio is lower of higher than a transition value respectively.

The work results are validated by using reviewed article. The natural frequency reading of with and without crack shaft. Here to find out the crack initiation initially geometrical creak provided on shaft at different locations such as center, left and right side of wheel arrangement. Here five types of crack depth are considered on shaft.

Natural frequency reduces when creaks place right side of wheel. It is considered creak initiated point. Further analysis is carried using this location

By singular finite elements for various crack depths stress intensity factors is determined. The work results are validated by using reviewed article. Another extension has been made on propeller drive shaft. 1000 N, 1000 N-mm load is considered on the axial, bending and torsion. Deformation and stresses are increases if we increase the crack Depth ratio and stresses intensity factor also increases.

V. REFERENCE

[1] [1] Andrea Carpinteri ,"Fatigue Propagation Of Surface Flaws In Round Bars:A Three-Parameter Theoretical Model" fatigue fract, engng master, struct. Vol 19,No12pp1471-1480,1996

[2] [2] Aniket S. Kamble, D. S. Chavan, "Identification of crack parameters in a cantilever beam using experimental and wavelet analysis", International Journal on Mechanical Engineering and Robotics (IJMER), pp.23-27, 2014.

[3] [3] Marco A. Perez, Lluis Gil, Sergio Oller, "Impact damage identification in composite laminates using vibration testing", Composite Structures 108,pp.267–276,2014.

[4] [4] P. K. Jena, D. N. Thatoi, J. Nanda, D. R. K. Parhi, "Effect of damage parameters on vibration signatures of a cantilever beam", International Conference on Modelling, Optimisation and Computing (ICMOC 2012),pp.3318-3330,2012.

[5] [5] Kaushar H. Barad, D. S. Sharma, Vishal Vyas,"Crack detection in cantilever beam by frequency based method", Nirma University International Conference on Engineering (NUiCONE), pp.770-775, 2013

[6] [6] Amit Banerjee, G Pohit, "Crack Investigation of Rotating Cantilever Beam by Fractal Dimension Analysis", International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME, pp.88-195, 2014.