International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:8, No:5, 2014

Stress Intensity Factor for Dynamic Cracking of Composite Material by X-FEM Method

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***Abstract*—**The work involves develops attended by a numerical execution of the eXtend Finite Element Method premises a measurement by the fracture process cracked so many cracked plates an application will be processed for the calculation of the stress intensity factor SIF. In the first we give in statically part the distribution of stress, displacement field and strain of composite plate in two cases uncrack/edge crack, also in dynamical part the first six modes shape. Secondly, we calculate Stress Intensity Factor SIF for different orientation angle θ of central crack with length (2a=0.4mm) in plan strain condition, KI and KII are obtained for mode I and mode II respectively using X-FEM method. Finally from crack inclined involving mixed modes results, the comparison we chose dangerous inclination and the best crack angle when K is minimal.

***Keywords*—**Stress Intensity Factor (SIF), Crack orientation, Glass/Epoxy, natural Frequencies, X-FEM.

I. Introduction

THE innovative idea to enrich the field edge near the FEA method [1]-[3], the basic principles of the division of the FEA method and the extended finite element method X-FEM unit were developed twenty years later by [4]. In under a decade, X-FEM has become the major thorough search for solving a variety of problems of discontinuity. Components calculated with cracking are now reinterpreted using the method of sharp discontinuities or extended finite element method X-FEM based upon the concept of partition of the unit [5]. Enhance the cinematic of the continuum; such techniques can introduce discontinuities in the field of displacement with the aid of a relatively limited number DOF. The main advantage here is that the grid does not require conforming to the geometry of the crack. Overall, these methods necessitate another meshing of the point of the crack that modifies component of the problem. As well, packaging problems persist. Finally, the X-FEM approach representing properly the singular solution to the crack tip and highly simplifies the product selection meshing and another meshing method of standard finite elements. Consequently based of these advantages is suggested to address this method (X-FEM). The first one actual quality interpreting fatigue and fracture mechanics is presented 1920 by Griffith [6]. Irwin [7] has provided than the stress and displacement near of the crack-tip can be described using one parameter associated with the rate of energy release G. This parameter resulting from the linear fracture mechanics is called the stress intensity factor (SIF). The concept of (SIF) has also been used by Paris [8] to describe the cracks growth by substituting the concept of toughness by the notion of fatigue forecasts of superior quality of the service life of components. The period between 1960 and 1980 saw an intensification of research into the break with two competing schools. On the one hand the supporters of the approach using linear fracture mechanics and those interested primarily in lamination developed at the end of a crack on the other. To account for the effect of stratification on the fields of stresses and displacements of the slot end, several authors as Irwin 1962 [7], later, in 1968 H. Rice et al. [9] developed a novel parameter known as J integral to better describe the distribution of stresses in plastic zones. Reference [10] also offered a method of use them not only to describe the complete tenacity, as well as to connect to the flaw size and in the area of applied constraints, and made the link among J integral and CTOD . In close proximity of the front, are stress singularity at (1 / r) and the peculiarity is characterized by using the stress intensity (K_I, K_{II}) Irwin factors defined by [7]. SIF characterize the strength of the peculiarity of the stress field at the crack tip. About Extended Finite Element Method X-FEM, from the way the crack is unknown a priori mixed-mode, developed by computer simulations will be carried using the extended finite element method X-FEM where the cracks are not disclosed expressly by the mesh. This method is based on a mesh partition [11]. Benefits of this method for computer simulation of the dynamic rupture were subject numerous publications. It was used for sequentially the 2D crack growth [12]. The procedure is here developed for the vibrant crack growth in the work [13]. The first applications of X-FEM for composites have been reported by [14]-[16] thinner stratified composites simulated and found that the isotropic enriching office can not represent the asymptotic solution for a crack in an orthotropic material. The newest work is reported by [17] on the propagation of cracks in general orthotropic composites. They debated the impact of enrichment tip cracks and different types of interaction integral factors in identify intensity stress combination mode. The development of crack-tip enrichment office orthotropic has been reported in a number of documents by [18]-[19]. They have developed three function types of wealth for the different classes of composite.

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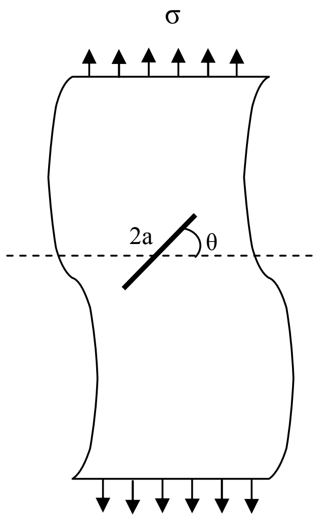

Fig. 1 Inclined Central crack in infinite composite plate

II. Model of Plat

In this part of work we will see the numerical simulation of composite material plate by Abaqus software which can give the distribution of stress, strain and displacement field of composite plate, material properties of this plat gives:

- 2 value of young modulus: E1= 38600MPa E2= 8270MPa
- 3 value of shear modulus: G12= 4140MPa G23= 4140MPa G13=4140MPa
- Poisson ratio: Nu12=0.26
- Density: 2.56Kg/m3

We create composite lamina with 2 ply with deferent's angles of fibers (0°/90°) in the progress of simulation we make deferent's numbers of ply with orientation of fibers.

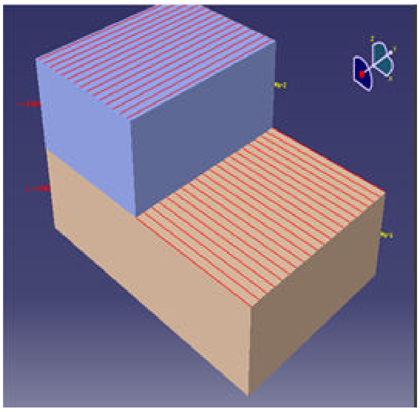

Fig. 2 Modeling of plate and create composite laminate

We make our boundary condition is this case we take into account for the displacement which are U1= U2= U3= UR1= UR2= UR3= 0 and we applied tensile.

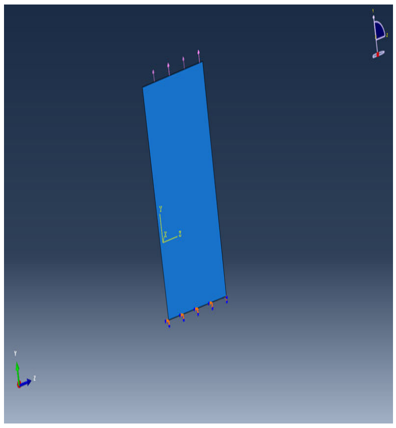

Fig. 3 Load and boundary condition of specimen

A. Stress

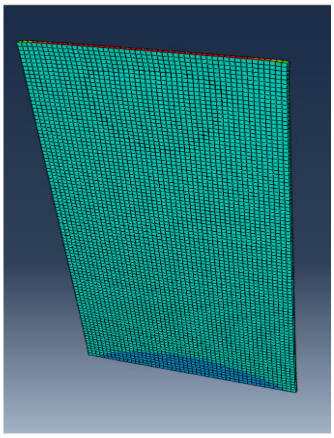

Fig. 4 Maximum stress of Von Misses S_{max}=1.057 e+02Mpa

B. Strain

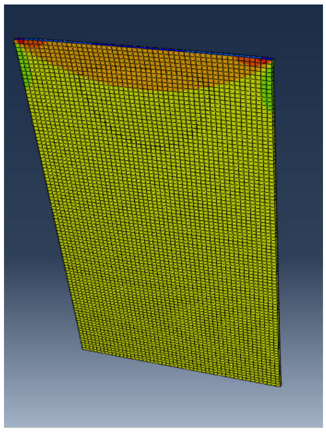

Fig. 5 Maximum strain E_{max}=4.829 e-03

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C. Displacement

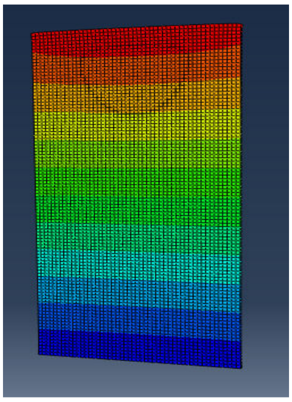

Fig. 6 Maximum displacement U_{max} = 2.186 e-01mm

D. Modes Shapes

The figures below shown the first six natural frequencies with displacements

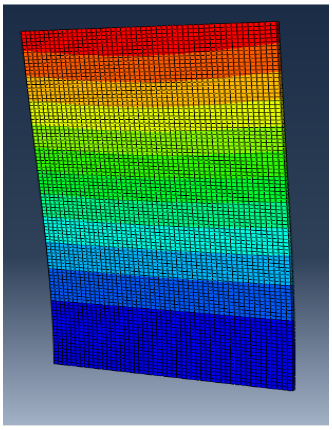

Fig. 7 First Mode shape bending U_{max}=1mm, f_1=0.96156 HZ

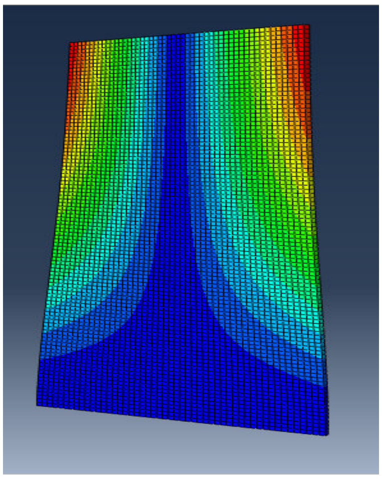

Fig. 8 Second Mode shape torque U_{max}= 1mm, f_2=6.0403HZ

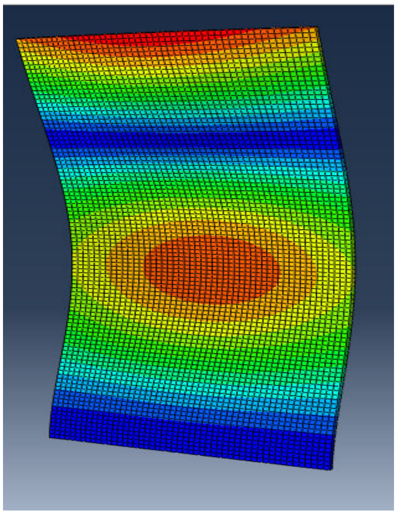

Fig. 9 Third Mode shape U_{max}= 1mm, f_3=8.6226 HZ

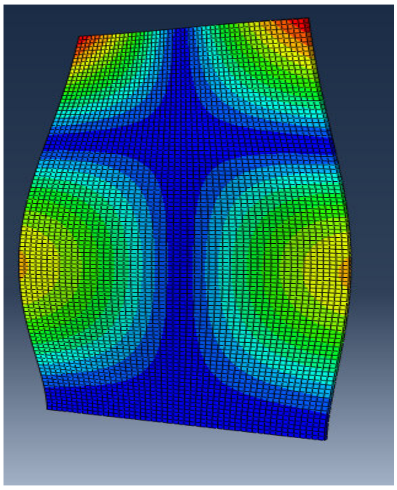

Fig. 10 Fourth Mode shape U_{max}=1mm, f_4=17.002 HZ

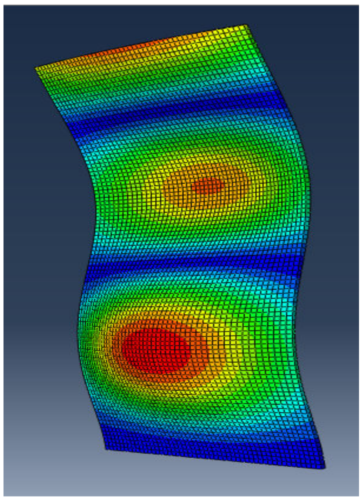

Fig. 11 Fifth Mode shape U_{max}= 1mm f_5= 19.705 HZ

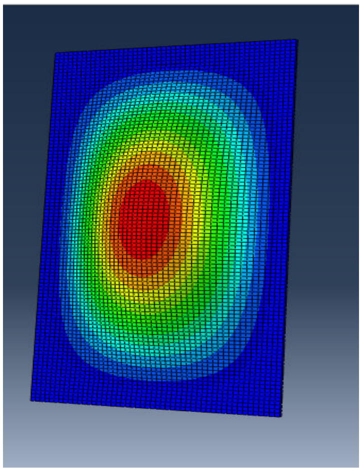

Fig. 12 Sixth Modes shape U_{max}=1mm, f_6=26.501 HZ

TABLE I
SIX FIRST NATURAL FREQUENCIES OF UNCRACK PLATE

F1 (Hz)	F2 (Hz)	F3 (Hz)	F4 (Hz)	F5 (Hz)	F6 (Hz)
0.96	6.04	8.62	17.00	19.70	26.50

III. EDGE CRACK INITIATION

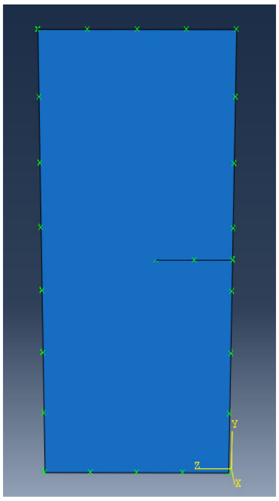

Fig. 13 Crack initiation in plate composite

We will do the same manipulation with the same boundary condition.

Stress:

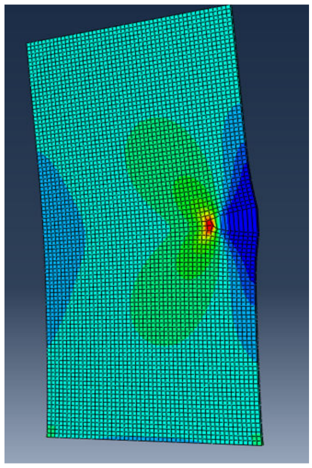

Fig. 14 Von Misses stress for cracked plate S_{max}= 1.180E+02 MPa

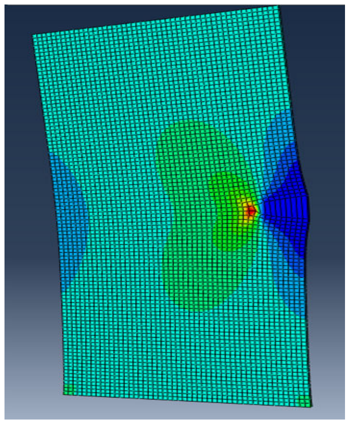

Fig. 15 Maximum Stress in the X direction by XFEM method (max S11=63.23MPa)

We have concentration of stress in the level crack tip.
Displacement:

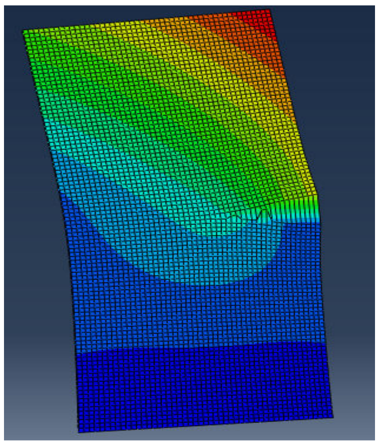

Fig. 16 Maximum displacement by XFEM method U_{max} = 3.088 e-01mm

Finding of the table above that the displacement max augments and the stress takes a very important increase because we have concentration of stress at crack-tip.

TABLE II
COMPARISON OF MAXIMUM DISPLACEMENT AND STRESS WITHOUT AND WITH CRACK

	Stress (MPa)	Max displacement (mm)
Plate without crack	105.7	0.218
Plate with crack	118.0	3.088

IV. CENTRAL CRACK INITIATION

A rectangular plate of dimension 0.5 x 01 under uniform tension= 100 pa over its width has an inclined angle to the perpendicular to the direction of pull of crack length 2a= 0.4mm. From [15], [19]:

$$KI = \sigma \cos^2\theta\sqrt{2\pi a}$$
$$KII= \sigma \cos \theta \sin \theta\sqrt{2\pi a} \quad (1)$$

Physically, these formulas mean that K is a maximum if the crack is perpendicular to it and the bias decreases to be zero when the crack s aligns therewith when the mode II is for a maximum angle of 45 No and no to 0 ° or 90 °.

To calculate K_I and K_{II} of mixed modes known equations are applied following:

$$K_I=\sigma 11\cos^2\theta\sqrt{2\pi r}$$
$$K_{II=} \sigma 11\cos \theta \sin \theta\sqrt{2\pi r} \quad (2)$$

$\sigma 11$: Nodal solution of the stress field was obtained by Abaqus by XFEM.

r: the distance between the crack tip and enrichment singular nodes was obtained by Abaqus.

The procedure for calculating k_I and k_{II} is done by taking the values in Abaqus's and apply the equation.

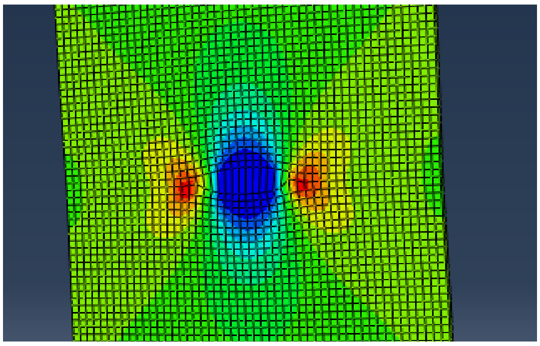

Fig. 17 Crack inclined angle 0^0

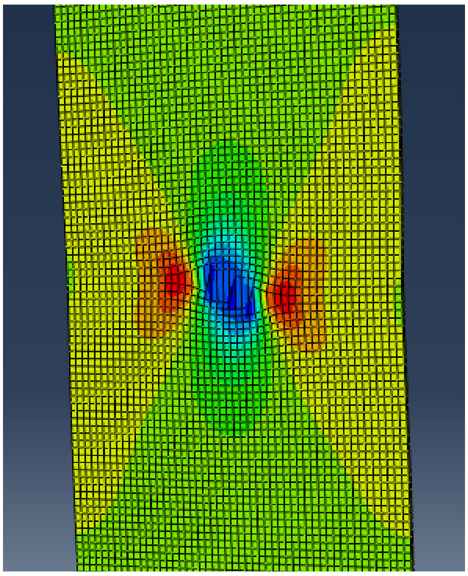

Fig. 18 Crack inclined angle 15^0

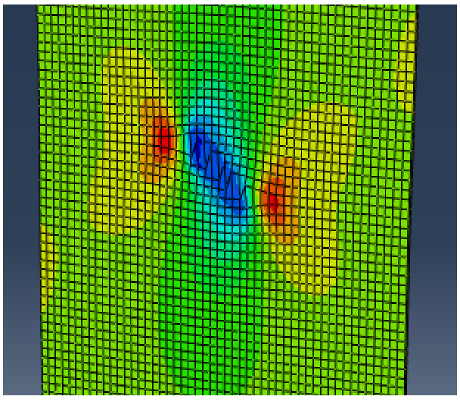

Fig. 19 Crack inclined angle 30^0

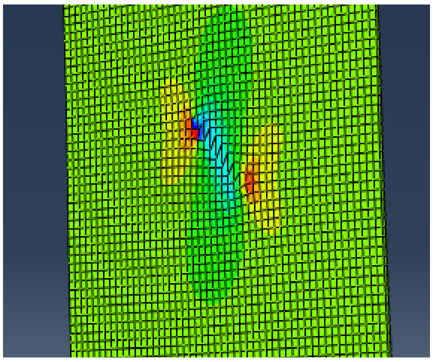

Fig. 20 Crack inclined angle 45^0

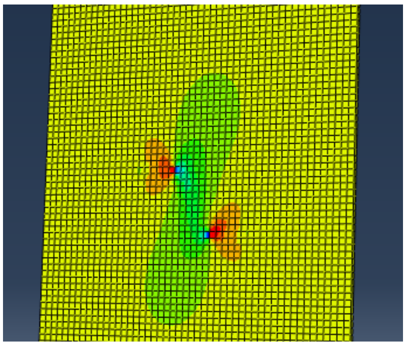

Fig. 21 Crack inclined angle 60^0

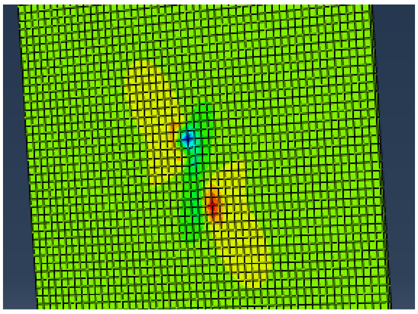

Fig. 22 Crack inclined angle 75^0

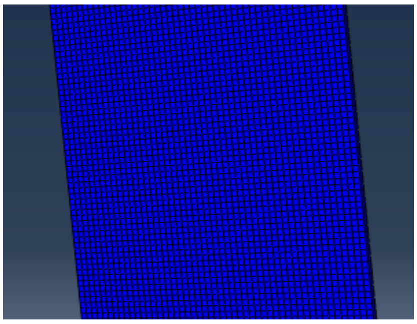

Fig. 23 Crack inclined angle 90^0

TABLE III
KI AND KII AS A FUNCTION OF THE INCLINATION ANGLE

θ	K_I MPa$\sqrt{m}$	K_{II} MPa$\sqrt{m}$
0°	9.34	0
15°	8.32	2.25
30°	7.57	4.37
45°	3.91	3.91
60°	3.23	6.17
75°	0.64	2.32
90°	0	0

The values of KI, KII y are given in:
We notice that KI=KII for {θ=45°and θ=90°}

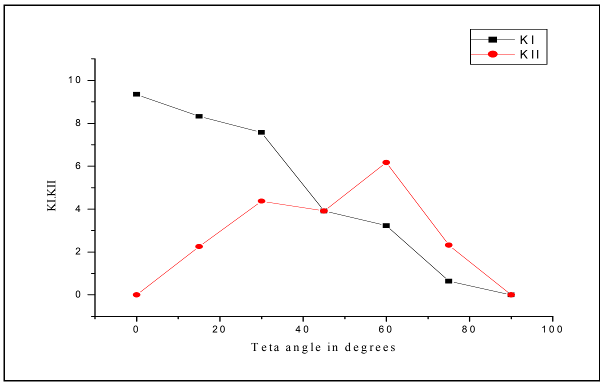

Fig. 24 KI and KII based on the driven plate and an inclined crack centered

KI >KII for 0°<θ<45°, KI>KII for 45°<θ<90° and KI=KII for (θ=45°, θ=90°)

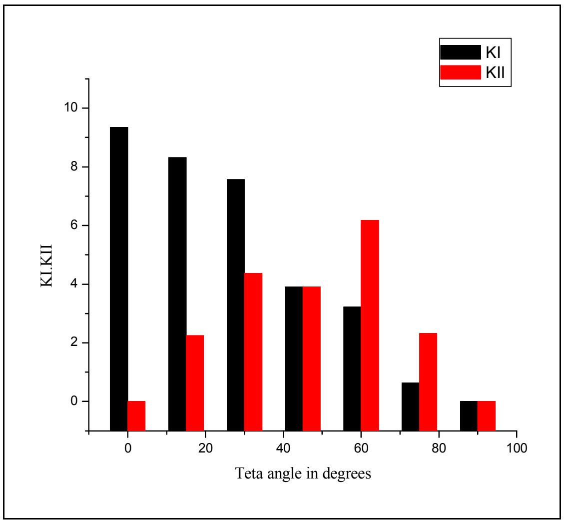

Fig. 25 KI and KII based on the driven plate and an inclined crack central

KI decreases with the increase of the angle θ, the KII increases to 60 ° and then decreases.

Assessing SIF mixed modes by XFEM infinite plate with a crack centered and tilted, we can calculate KI and KII. The results in Table showed the efficiency XFEM. Indeed, the functions of singular and discontinuous enrichment provide a significant advantage in the calculation accuracy of XFEM.

V. CONCLUSION

This study calculates the local and analyzing materials by the XFEM method, particularly composites cracked with deferent angles. Calculation and evaluation of the stress intensity factor SIF in different configurations and mixed modes (I and II) are also studied. The results show that a concentration of stress at the edge crack in the level crack tip. The displacement max augments and the stress takes a very important increase because we have singularity point of stress at crack-tip. K is the minimum angle for θ = 90 ° crack.

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