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ALLDMD Dissipation Energy Analysis by the Method Extended Finite Elements of a 2D Cracked Structure of an Elastic Linear Isotropic Homogeneous Material

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Abstract**: The analysis of the crack parameters of a material is an important effect for characterizing the state of stress. Nowadays, materials occupy a very necessary place in modern industry for the study of the life of such structure. This article deals numerically the evolution of (ALLDMD) dissipation energy for an initial rectilinear crack of α=0°. Furthermore, the second case study is based on a crack inclined by the orientation angle α=15°, 30°, and 45°. The X-FEM extended finite element method was used. In addition, the linear elastic isotropic homogeneous material was applied. Thus, the 4-node quadratic CPS4R elements were used. The crack is then modeled numerically using the ABAQUS finite element calculation code. Characterization parameters such as ALLDMD dissipation energy and von Mises stress were calculated. In addition, the results obtained concerning the numerical simulation were compared and discussed between the different mesh approximate total size TGA=1, 2 and 3mm. A good correspondence was obtained between the different comparison results concerning the evolution of the Von Mises stress in all the modeling cases of our work.

Keywords: Modelization, X-FEM, ALLDMD, Crack, CPS4R.

1. INTRODUCTION

The extended finite element method, XFEM is an evolution of the classical finite element method. Ramesha et al[1] defined Extended Finite Element Method (XFEM) as an innovative approach based on Finite Element Method (FEM). First of all, the X-FEM method was developed by Belytschko and his colleagues in 1999 [2]. Indeed, this method is based on the concept of unit partition, in fracture mechanics, the problems are treated by the classical finite element method, then by the XFEM Belytschko 1999, Moës 1999 [2,3]. In addition, the X-FEM method in recent years has been used by several researchers; Jia et al [4] proposed the

X-FEM method to extract the fracture parameters in the cracking of an isotropic material, via a generalized finite element method/stable expanse. Dekker et al [5] presented a new approach based on the X-FEM method, to deal with arbitrary crack paths. Achchhe et al [6] studied by the extended finite element method, the crack growth and the energy release rate (ERR), of an isotropic edge crack plate under different loadings like traction and stress effect of various discontinuities such as voids. Habib et al [9] presented a complete finite element formulation of complete coupling of the thermomechanical problem of cracked bodies. J.L. Swedlow et al [10] used classical finite elements to analyze the elastoplastic stress and strain of a plate with a crack. On the other hand, Benzley [11]. Gifford and Hilton [12] developed the enriched finite elements, by adding special analytical functions concerning the displacement of the nodes, for the elements located in the zone of the front of crack.

Rahman and Siegfried [13] studied by the (X-FEM) method the effects of particles as reinforcement on the fatigue crack growth behavior of Al 6061/ZrO2 composite material. Bruce et al [14] summarized recent efforts to validate a cohesive zone X-FEM model with a mixed-mode PMMA fracture experiment. Regarding the problem of crack propagation another SFEM method has been proposed by Bentahar et al [15] to study the variation of crack parameters, and further to model the stress intensity factor Bentahar and Benzaama [16].

Background to the X-Fem Method

The extended finite element method (X-FEM) was initially introduced by Belytschko and Black (1999) [2]. They presented a method based on the finite element method for modeling crack propagation. Furthermore, Moëes et al., 1999) [3] described the most important and effective step towards improving this method.

$$H(x) = \begin{cases} +1 & x > 0 \\ -1 & x < 0 \end{cases} \tag{1}$$

$$\left\{F_{i(r,\theta)}\right\}_{i=1,2,3,4} = \left\{\sqrt{r}sin\frac{\theta}{2}, \sqrt{r}cos\frac{\theta}{2}, \sqrt{r}sin\frac{\theta}{2}, \sqrt{r}cos\frac{\theta}{2}sin\theta\right\} \tag{2}$$

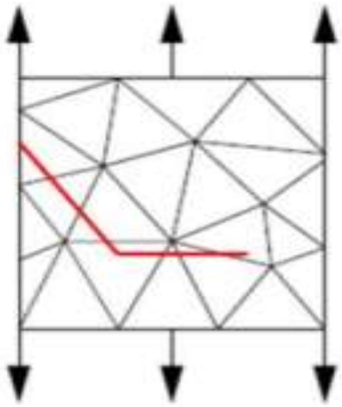

Fig1. Numerical model of the X-FEM method Duflot[17]

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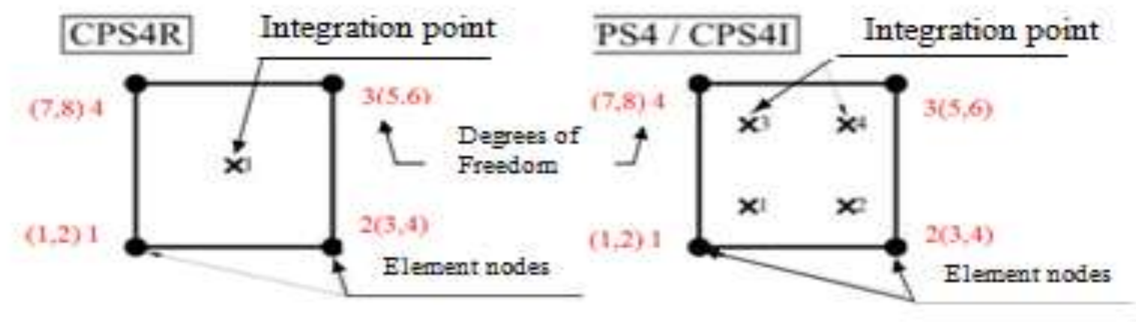

Fig. 2 the (CPS4R) quadrilateral bilinear plane stress elements with 4 nodes Bartosz and Jerzy [18]

Numerical Modelling

The structure considered has a length L=80 mm and a width C=40 mm, with a horizontal crack a=10mm of α=0° and a crack inclined by the angle α=15°, 30°. The plane stress parametric mesh with four nodes of type (CPS4R). The structure in homogeneous isotropic linear elastic material with $E=5.10^3$ Pa and ν=0.3. The number of elements and nodes varies according to the approximate overall size which equals 1, 2 and 3mm. The boundary conditions of the crack propagation simulation are as follows: the fixed support has been applied to the lower surface of the structure (U1 = U2 = U3 = UR1 = UR2 = UR3 = 0), the upper part supports a tensile stress σ=40Pa and U1=UR1=0. See Figure 3(c) below.

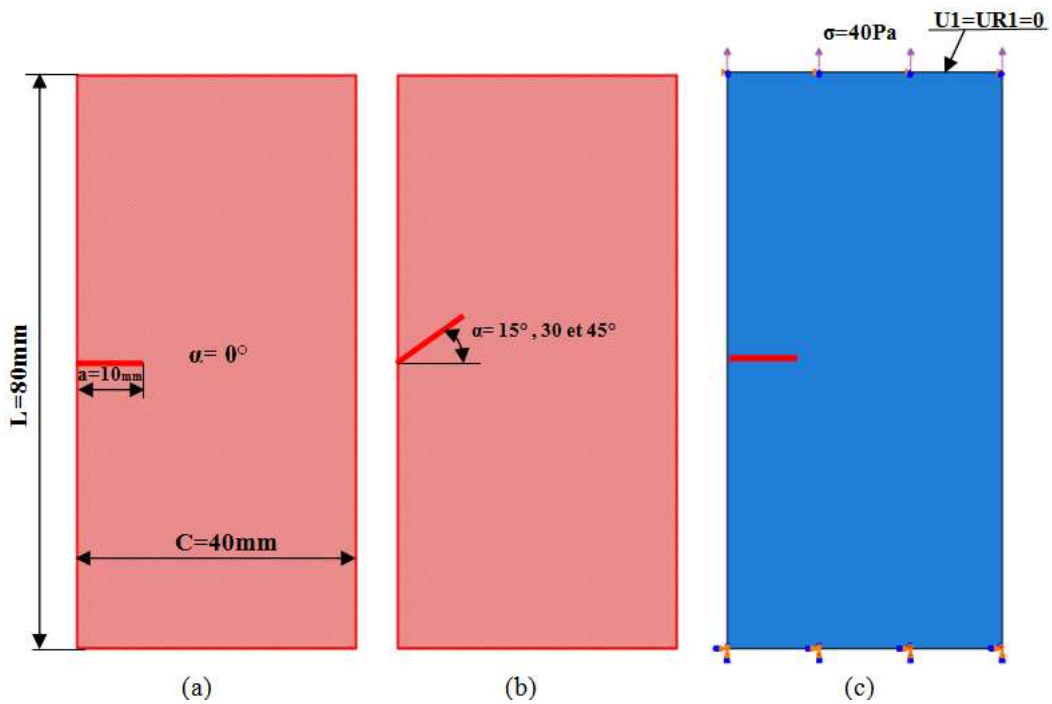

Fig. 3 Model: a) initial crack of α=0°, d) inclined crack of α=15°, 30° and 45°, c) the boundary conditions

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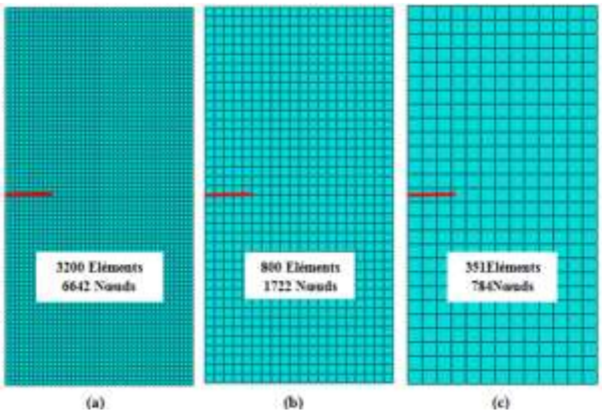

Fig. 4 X-FEM model for the different approximate global sizes: a) TGA=1mm, b) TGA=2mm and c) TGA=3mm

2. RESULTS AND DISCUSSIONS

The figure below presents the modeling model by the X-FEM method concerning the differents stages of the numerical simulation, As well, for the different approximate overall sizes TGA=1, 2 and 3mm. The figure below presents the modeling model by the X-FEM method concerning the different stages of numerical simulation. Thus, for the different approximate overall sizes TGA=1, 2 and 3mm. In addition, the number of elements is 351, 800 and 3200 element and the number of nodes is 784, 1722 and 6642 node. The crack inclination angle is α=0°, 15°, 30° and 45°.

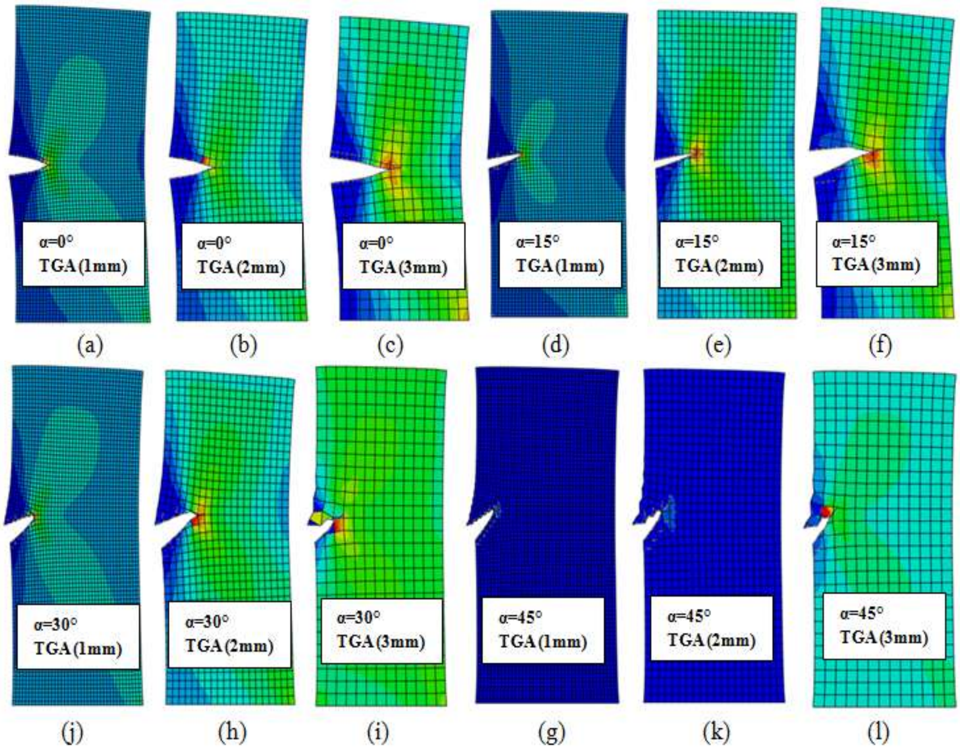

Fig. 5 Crack modeling by the X-FEM method for the evaluation by energy (ALLDMD)

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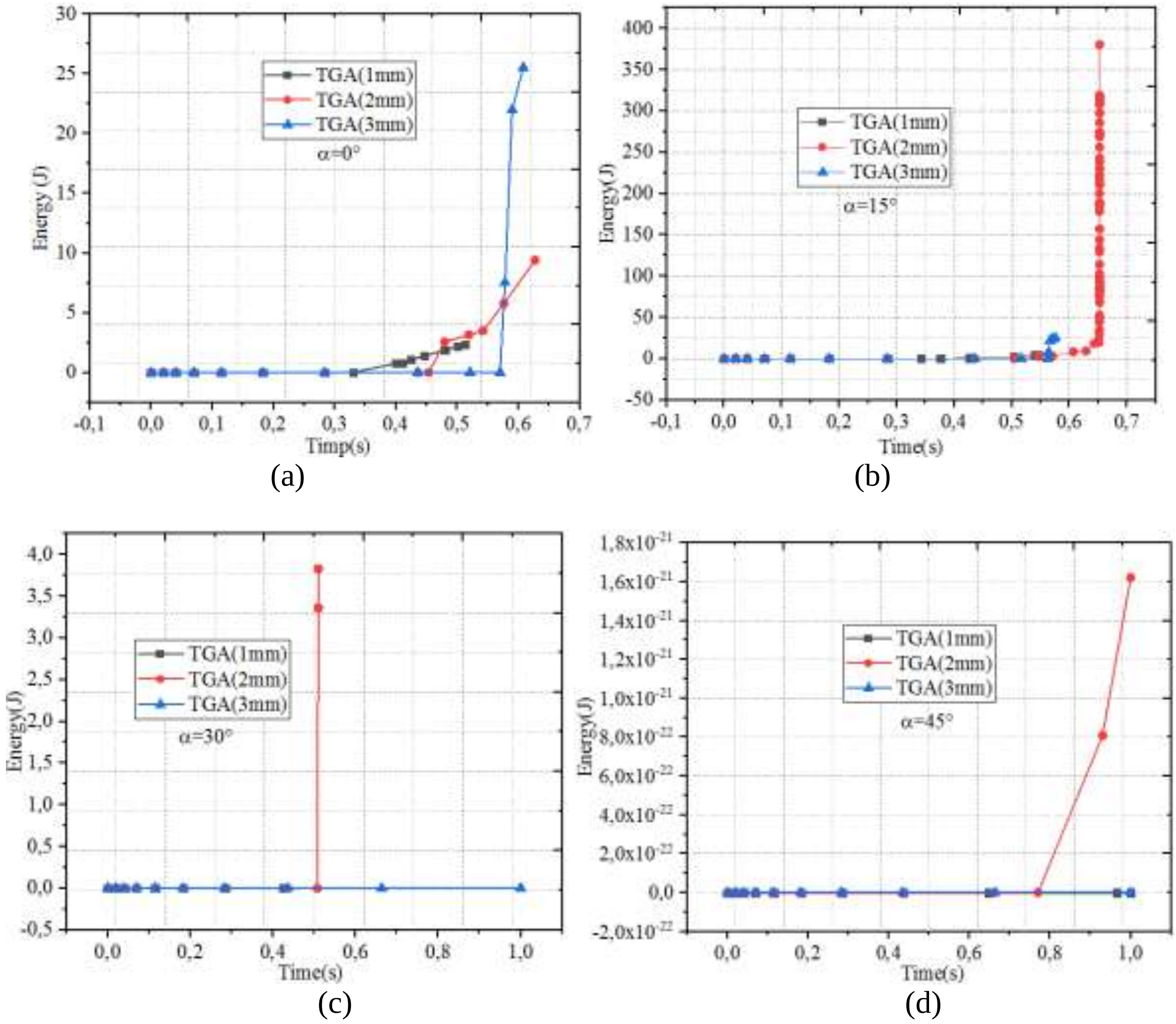

Fig. 5 Evolution of damage dissipation energy: ALLDMD for the entire model for different approximate global sizes (TGA=1, 2 and 3mm) of straight crack of α=0° and inclined of α=15°, 30 ° and 45°.

Figure 5. Shows the comparison of ALLDMD damage dissipation energy as a function of time, for the different values of TGA Fig5(a) of a straight crack, Fig5(b) presents an inclined crack of α= 15°, fig5(c) shows the inclined crack of α=30°, fig5(c) shows the inclined crack of α=45°. We can notice that the dissipation energy is higher in the case of α=0° for TGA=3mm see the fig5(a), moreover TGA increases in the case of α=15° for the value of TGA=2mm . On the other hand, the more the angle α increases, the more the two structures of approximate overall size TGA=1 and 3mm decrease and tend towards the zero, but the structure of TGA=2mm begins to increase. These forms of results were obtained by Bentahar et al [19] for the evaluation of the strain energy ALLSE. Thus, there are similar results were obtained by Xiaodong et al [20]. Moreover, the results obtained are proportional, and the increase in time causes an increase in energy in the case of the angle (α=0°) Fig.(5a).

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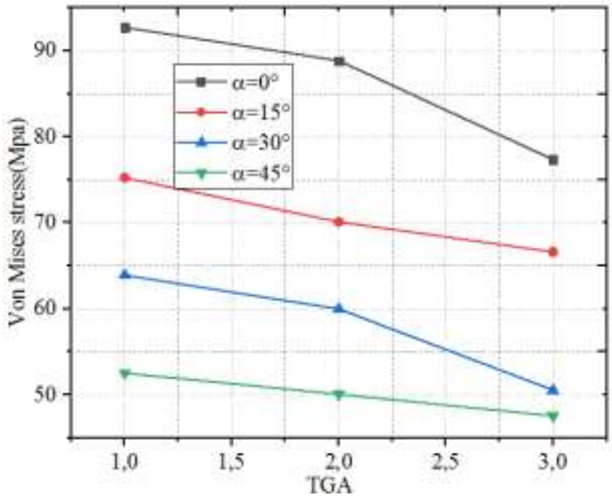

Fig. 6 Comparison of the Von mise stress concerning the different modeling models of α=0°, 15°, 30° and 45°

Figure 9 shows the evolution of the Von Mises stress for the different models for various approximate overall sizes of the mesh TGA=1, 2 and 3mm. It is obtained that according to this comparison the more the crack inclination angle increases the more the Vin Mises stress decreases, the results obtained are proportional to each other. Moreover, the increase in the approximate global size causes a decrease in the Vin Mises stress. The value of the highest Von Mises stress is in the case of TGA=1mm of a rectilinear crack. Indeed, the refined structure is in need of a greater constraint compared to the others.

3. CONCLUSION

In this article, three approximate global sizes are compared to assess the energy dissipation (ALLDMD). The X-FEM extended finite element method was used to model the energy evaluation (ALLDMD) of a problem of crack in 2D rectilinear of α=0° and inclined of by the angle α=15°, 30° and 45°. It is observed that with increasing time the energy increases for TGA=2mm, on the other hand there is a slight increase in both cases of TGA=1mm and TGA=3mm. A good correspondence was obtained between the different comparison results concerning the evolution of the Von Mises stress in the cases of α=0°, 15°, 30° and 45° and even for TGA=1, 2 and 3mm.

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