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NUMERICAL MODELING OF THE CRACK PROPAGATION FOR THE EVOLUTION OF THE STRAIN ENERGY ALLSE BY THE X-FEM METHOD

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RESUME

In this article, the 2D extended finite element method (XFEM) in mode I, was used to model the crack propagation. this use based on modeling by the ABAQUS computer code. The quadratic elements with 4 CPS4R nodes were used to make this modelization. Two examples of meshs with different approximate overall sizes of the mesh one of 0.2 and the other of 0.5 were studied. In addition, the XFEM method was used to know the maximum value of the final crack load of the mesh. The evolution of the strain energy (ALLSE) was studied between the two cases.

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1. Introduction

The extended finite element method, XFEM, is an evolution of the classical finite element method. This method was first developed by Belytschko and his colleagues in 1999 [1]. indeed, This method is based on the concept of unity partition. In fracture mechanics, the problems are treated by the classical finite element method, then by the XFEM introduced in Belytschko 1999, Moës 1999 [1,2]. on the other hand, J.L. Swedlow et al [3] used conventional finite elements to analyze the stress and elastoplastic deformation of a plate comprising a crack. On the other hand, Benzley [4]. Gifford and Hilton [5] developed the enriched finite elements, adding special analytical functions concerning the displacement of the nodes for the elements located in the area of the crack front. The advantage of these enriched finite elements is that the FIC can be directly calculated such as part of the results. Another method based on the classical FEM called the Extended Finite Element Method (XFEM), or the Generalized Finite Element Method, this method is an extension of the FEM, it has been applied to the problems of fracture mechanics since 1999. The crack propagation is simulated by replacing the elements newly crossed by a crack by a special element.

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Moës et al [2] present the 2D method which is based on the concept of unit partition (PUM), proposed by Melenk and Babuška [6], consists in enriching the approximation of the finite element method using of functions making it possible to better describe the field of displacement of a problem considered.
To model the dynamic rupture by numerical simulation, numerous publications have been carried out; (Duarte et al. [7]; Moës et al. [8]; Gravouil et al. [9], for the propagation of 2D cracks, (Dolbow et al. [10]) for contact problems, (Moës et al. Belytschko [11]) for cohesive areas, (Belytschko et al. [12] , Réthoré et al. [13], Song and Belytschko, [14]) for the use of different crack propagation criteria in the prediction of the growth path of crack by X-FEM.
Other works known in the literature which have developed the X-FEM method for the dynamic propagation of cracks, such as the work of Réthoré et al. [13,15,16,17], thus Grégoire et al. [19] Moës et al. [19] present the two-dimensional method. For quasi-static cases, this method was developed by Belytschko and Black [1]; Moës et al. [2]. The main idea of XFEM is to model the discontinuity the moving through the mesh, of the model with the help of enrichment of standard finite element shape functions. Dekker et al [20] presented a new approach based on the X-FEM method to deal with arbitrary crack paths. Rahman and Siegfried [21] studied the effects of particles as a reinforcement on the fatigue crack growth behavior of the Al 6061 / ZrO2 composite material by the (X-FEM) method. Others by, Guangwu et al [22] have used the X-FEM method to examine the effect of interphase thickness on the propagation of a predefined matrix crack. Bruce et al [23] summarized recent efforts to validate a cohesive zone X-FEM model with a mixed-mode PMMA fracture experiment.

2. X-FEM theory background

The extended finite element method (X-FEM) was initially introduced by Belytschko and Black (1999) [1]. They presented a method based on the finite element method for modeling of the crack propagation. This method does not need the re-engagement process.
In this process, discontinuous enriched functions are added to the approximation by finite elements for the crack demonstration and the crack develops arbitrarily in the finite element mesh. The most important and effective step towards improving the extended finite element method has been described by (Moëes et al., 1999) [2].
The existence of a crack in the extended finite element method, leads to two different enrichments in the interior problem of crack and enrichment of the crack tip.
The interior of the crack is enriched by a modified discontinuous Heaviside function (Eq. (2.1)), and the crack tip is enriched by using the functions presented in the equation (2.2) Belytschko and Black (1999) [1].

$$H(x) = \begin{cases} +1 & x > 0 \\ -1 & x < 0 \end{cases} \tag{2.1}$$

$$\left\{F_{i(r,\theta)}\right\}_{i=1,2,3,4} = \left\{\sqrt{r}\,sin\frac{\theta}{2}, \sqrt{r}\,cos\frac{\theta}{2}, \sqrt{r}\,sin\frac{\theta}{2}, \sqrt{r}\,cos\frac{\theta}{2}sin\theta\right\} \tag{2.2}$$

The function ($\sqrt{r}$ sin (θ/2)) is discontinuous, among these functions, which indicates the discontinuity of the function along two faces of the crack.
Where r and θ are the coordinates of x in the polar reference frame centred at the crack tip.

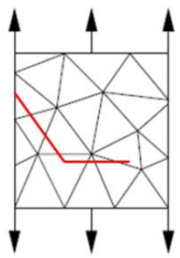

Figure 1- Schematic illustration of the numerical XFEM method for the analysis of a cracked body Duflot [24]

3. Elements modeling

In our model, the elements (CPE4R) with 4 bilinear nodes, reduced integration with hourglass control, was used to make the modeling of the evaluation of energy (ALLSE) of the propagation of the crack in 2D.

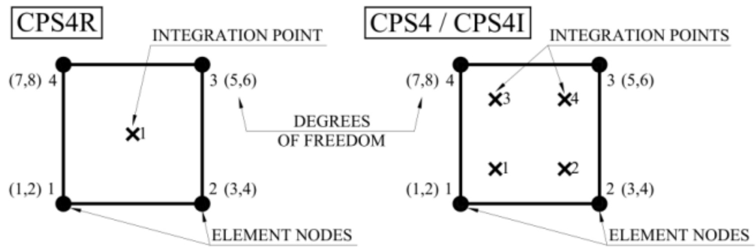

Figure 2- Plane stress elements of linear geometric order (first order) (author study based on Abaqus user manual)

The phenomenon is described more precisely in Cook et al [25] and in the Abaqus user manual.

4. Numerical model

The structure considered has a length L = 16 mm and a width C = 7 mm, with an initial crack (a = 1 mm). The parametric mesh and made up of 448 square elements of plane stress with four nodes of the type (CPS4R) and 495 nodes. The steel structure with $E = 72 \times 10^9$ Pa and $\nu = 0.3$ is subjected to a tensile stress σ. A parametric mesh of approximately 0.2 and 0.5 overall size was used. The mesh admits an initial crack of dimension (a) being able to be modified according to the various values of the applied load. The mesh admits an initial crack of dimension (a) being able to be modified according to the various values of the applied load. The boundary conditions of the simulation of crack propagation are the following ones: the fixed support was applied to the lower surface of the structure (U1 = U2 = U3 = UR1 = UR2 = UR3 = 0), and the upper surface supports a stress load σ, the left border is blocked in the case of rotation. and the boundary condition is shown in Figure 3.

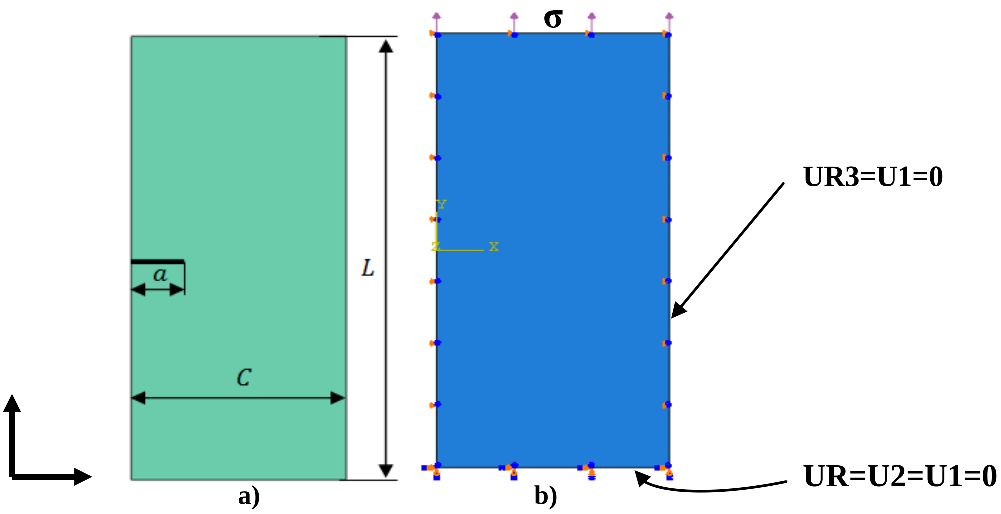

Figure 3- Model a) crack presentation b) Boundary conditions

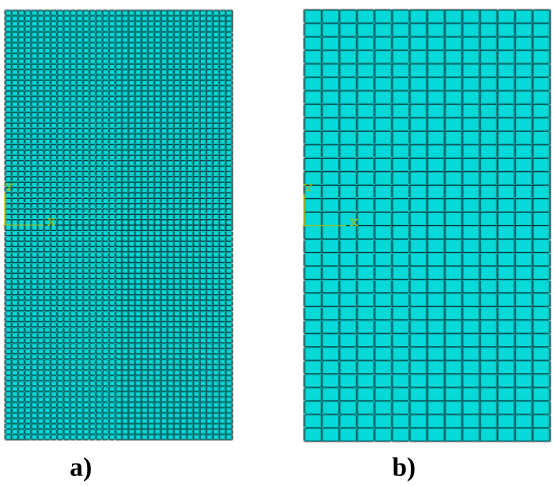

Figure 4- Model X-FEM a) mesh of approximate total size 0.2 b) mesh of approximate total size 0.5

4.1. Mesh for approximate overall size 0,5

The figure below presents the model XFEM concerning the unrefined mesh for an approximate value of 0.5 the study will be made in the various cases of crack propagation, having varying the values of the tensile stress σ which equals 50, 60 , 70, and 75Pa. Until the total crack of the Mesh.

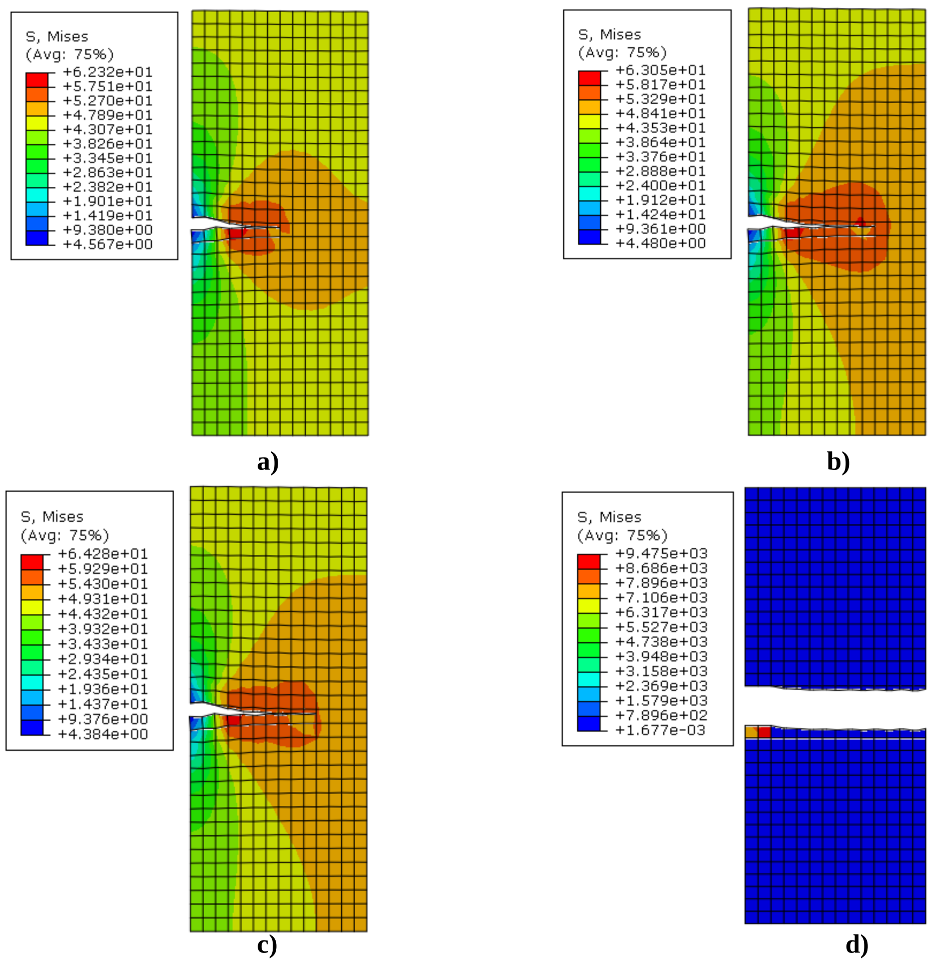

Figure 5- Model X-FEM for a Mesh of approximate total size 0.5 of mesh: a) 50N, b) 60N, c) 70N and d) 75N

4.2. Mesh for approximate overall size 0.2

The figure below presents the model XFEM concerning the mesh refined for an approximate value of 0.2. The study will be made in the various cases of crack propagation, one making varies the values of the tensile stress σ which equals 50, 60, 70, and 75Pa, and until the value of the total crack of the Mesh which equals 305Pa.

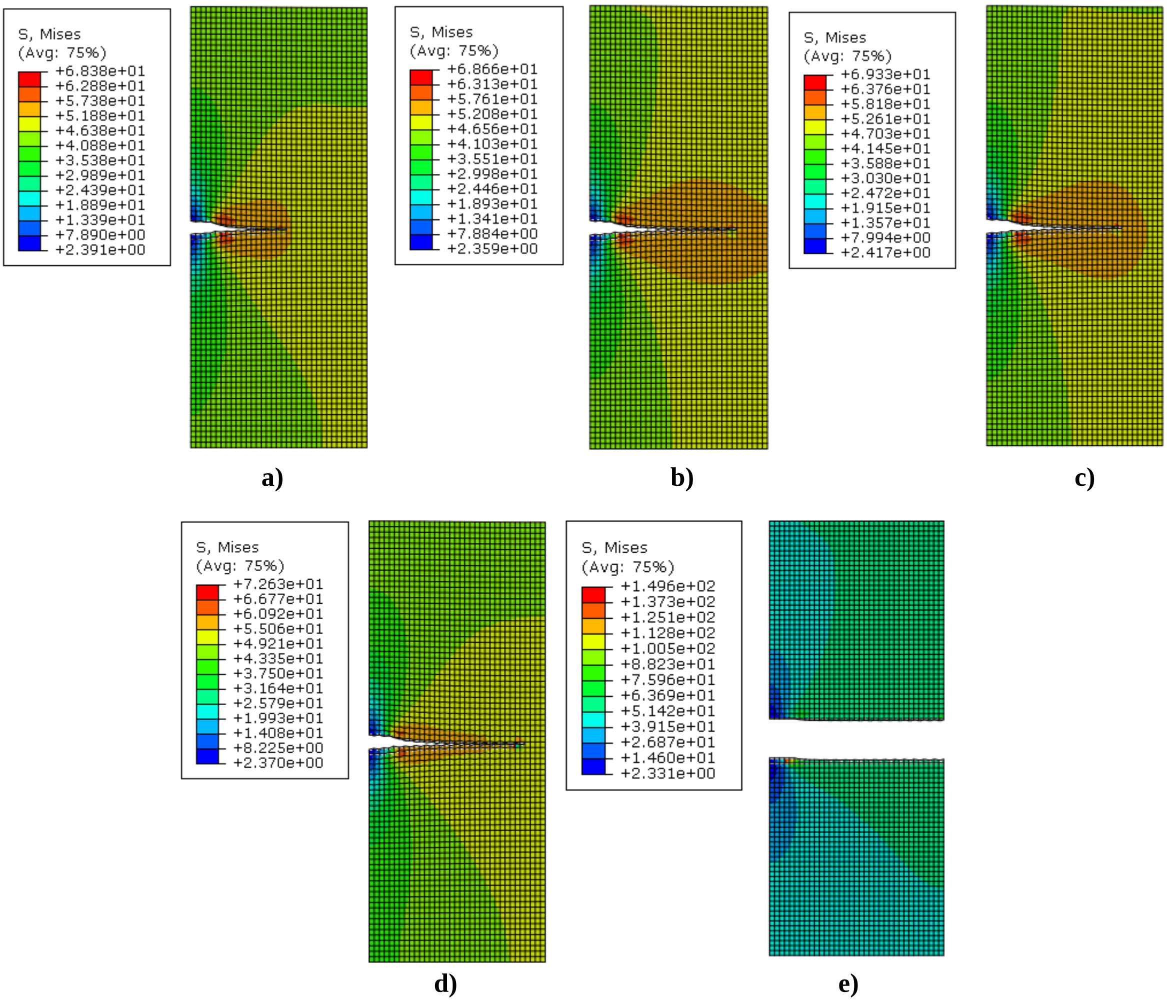

Figure 6- Model X-FEM for a mesh of approximate total size 0.2 of mesh a) 50N, b) 60N, c) 70N d) 75 and e) 305N

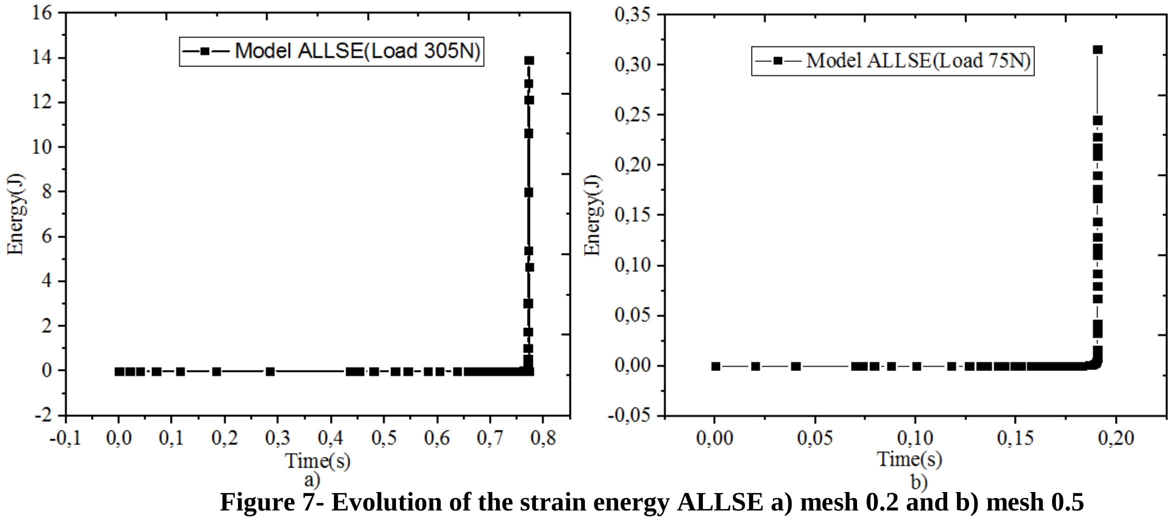

Figure 7- Evolution of the strain energy ALLSE a) mesh 0.2 and b) mesh 0.5

Figure 7 shows the evolution of the strain energy (ALLSE) as a function of time for the applied load of 305N (fig 7 (a)), and for the applied load of 75N (fig 7 (b)), we observe that the energy is linear horizontally and then vertically. However, there are similar results were obtained by Xiaodong et al [26].

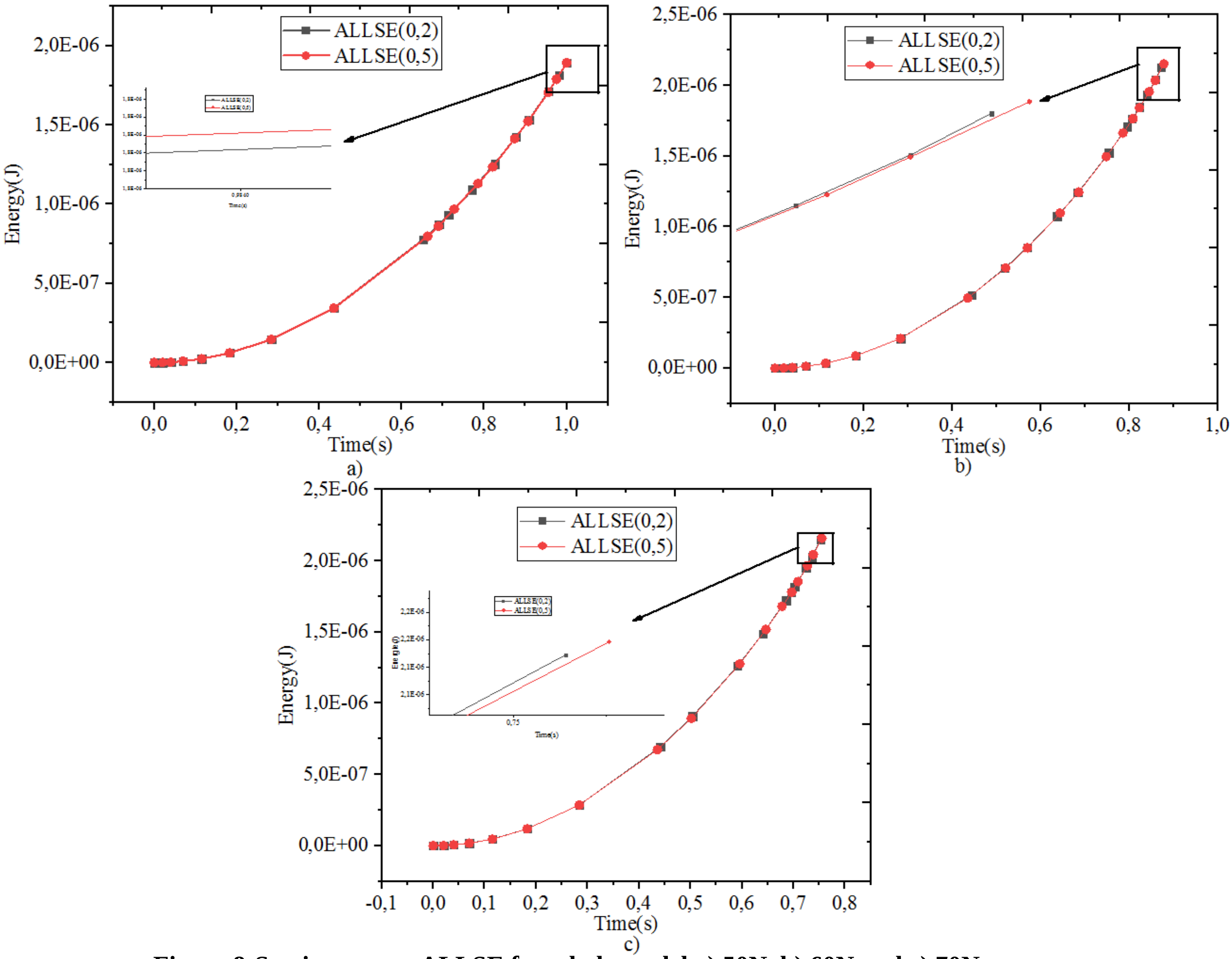

Figure 8-Strain energy: ALLSE for whole model a) 50N, b) 60N and c) 70N

Figure 8 presents the evolution of the strain energy (ALLSE) as a function of time for various approximate overall sizes of the mesh. Note that, a good match was obtained between the two comparison results. In addition, the increase in time causes an increase in energy for both cases.

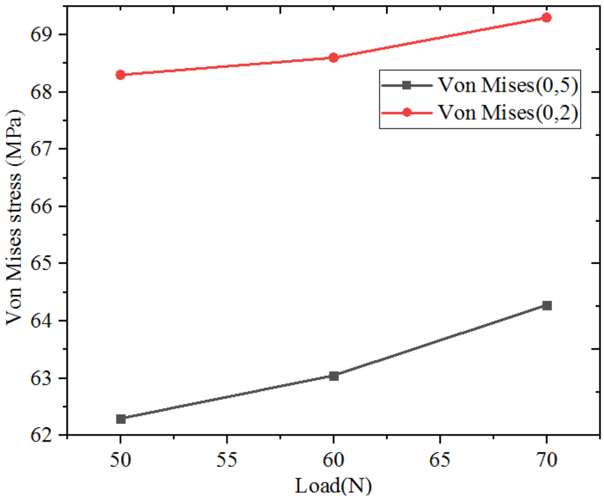

Figure 9- The comparison of the Von Mises stress between the two meshes

Figure 9 shows the evolution of the Von Mises stress for the two meshes one of approximate total size 0.2, and the other mesh of an approximate total size of 0.5. One obtains that the value of Von Mises of the mesh of an approximate overall size 0.2 is greater compared to the mesh of an approximate overalll size 0.5 (0.2> 0.5). Furthermore, the increase in the load causes an increase in the Vin Mises stress.

5. Conclusion

In this article, two meshes at different approximate overall sizes are compared using strain energy (ALLSE).
The extended finite element method X-FEM was used to model the evaluation of energy (ALLSE) of a problem of crack propagation in 2D.
The maximum value of the load for the total cracking of the mesh 0,2 is more superior, of that obtained in the case of a mesh of approximate total size 0,5.
Each load applied at a certain time increment.
a good correspondence was obtained between the two results of comparison concerning the evolution of the stress of Von Mises.

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