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# Sensibility analyses of X-FEM for crack propagation in residual stresses

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## 1 Introduction

The simulation of crack propagation with eXtended Finite Element Method (X-FEM) is proposed. The quenching process induces residual stresses which have an important effect on the in service behavior of mechanical components. In this study, a thick plate is sawed after quenching but this manufacturing step can initiate the propagation of a crack due to residual stresses as observed experimentally. The material is a high yield stress steel whose toughness is low (40CMD8 steel). So, it is very sensitive to brittle fracture phenomena. The aim of this work is to study the crack trajectory after the simulation of the quenching process. The XFEM results are compared with a remeshing technique based on the classical Finite Element Method in 2D.

## 2 Simulation of quenching

A bi-dimensional simulation is carried out on a quarter section for symmetry reasons (Cf. Fig1). All simulations have been performed using the computer code Sysweld®. A discontinuous quenching is simulated. The plate is initially at the uniform temperature of 900°C in a full austenitic state. It is then quenched in a water bath at temperature T equal to 20°C. Then, the plate is taken away from the water bath after 3000s, the end of the cooling occurring more slowly in air at 20°C. The formation of martensite on the skin of the plate can be observed. In the middle, the austenite transforms essentially into bainite. The residual stresses are plotted in Fig 2. Compressive stresses are obtained on the skin of the plate, while tensile stresses are observed in depth.

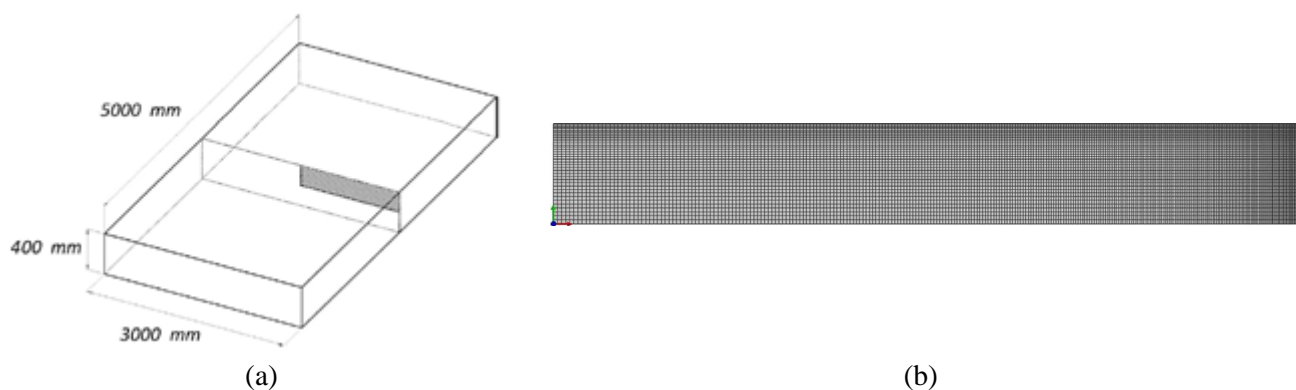


Figure 1: a) geometry of the plate b) 2D mesh of the quarter section made of 12000 linear elements.

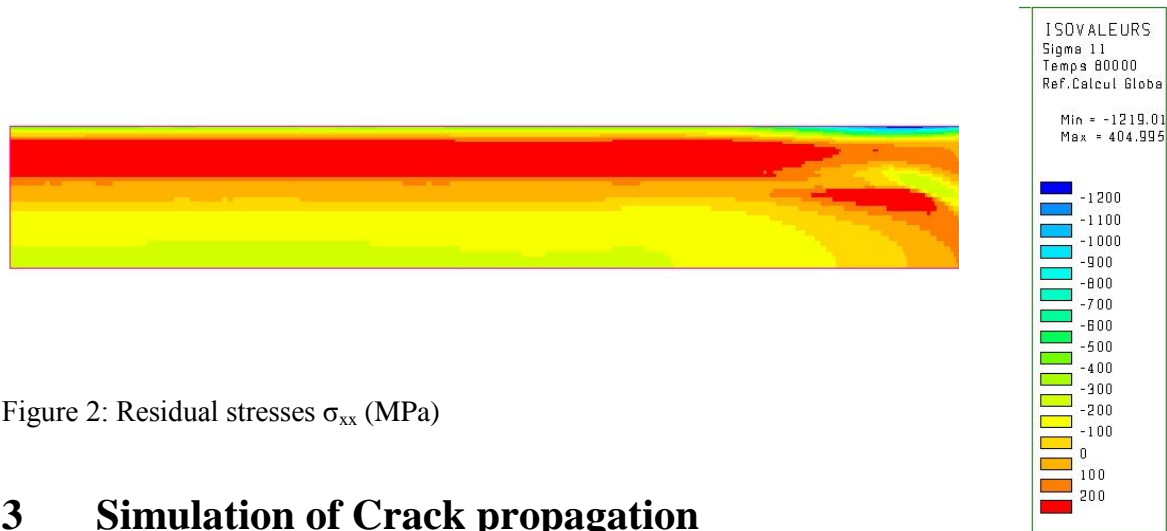


Figure 2: Residual stresses  $\sigma_{xx}$  (MPa)

### 3 Simulation of Crack propagation

The XFEM method is used to carry the simulation of crack propagation [1], [2]. At each step of propagation, the levelset are updated via interaction integral that allows estimate the stress intensity factors (SIF),  $K_I$  and  $K_{II}$ . The effect of residual stresses is taken into account in the first term through the internal stresses of the structure. Then, the plastic strain induced by the quenching process is taken into account in a second term. The orientation  $\Theta_c$  of the crack is obtained from the criterion of maximum normal stress [3] depended of SIFs  $K_I$  and  $K_{II}$ .

$$\theta_c = 2 \arctan \frac{1}{4} \left( \frac{K_I}{K_{II}} \pm \sqrt{\left( \frac{K_I}{K_{II}} \right)^2 + 8} \right) \quad (1)$$

Levelset are updated on the base of the orientation angle  $\Theta_c$  and the feed pitch given by the user. After the sawing process, the crack encounters negative stresses in the middle of the plate. Due to crack propagation, the stress field will be modified and the deviation of the crack propagation is expected. This phenomenon corresponds to what has been observed experimentally. Results are compared with the crack path obtained by [4].

Effects of initial position of the crack and of the given size of the feed pitch have been studied.

Two numerical integration methods have been investigated. A first using an enriched integration scheme of  $16 \times 16$  Gauss integration points and a second using standard Gauss quadrature rule on triangular sub-elements.

## References

- [1] E. Feulvarch, M. Fontaine, J.-M. Bergheau, XFEM investigation of a crack path in residual stresses resulting from quenching, *Finite Elements in Analysis and Design* 75 (2013) 62-70.
- [2] E. Feulvarch, M. Fontaine, M. Geuffrard, J.-M. Bergheau, XFEM investigation of a crack propagation influenced by quenching residual stresses, *International Conference on Extended Finite Element Methods*, Cardiff, United Kingdom, 29<sup>th</sup> June to 1<sup>st</sup> July 2011.
- [3] F. Erdogan, G. C. Sih, On the Crack Extension in Plates Under Plane loading and Transverse Shear, *Journal of Basic Engineering* 85 (1963) 519-525.

- [4] P. Autessere, Simulation numérique de trajet de propagation de fissures en mécanique linéaire bidimensionnelle de la rupture, Ph.D. Thesis, Université Paris VI, 1995.
- [5] P. Autesserre, J.-B. Leblond, Modélisation numérique de trajet de propagation de fissure en mécanique linéaire bidimensionnelle de la rupture, Actes du 1er Colloque National en Calcul de Structure, Giens, France, 1993.
- [6] N. Moes, J. Dolbow, T. Belyschko, A Finite element method for crack growth with remeshing, International Journal for Numerical Methods in Engineering 46 (1999) 131-150.