EXPERIMENTAL AND NUMERICAL FATIGUE CRACK GROWTH OF AN ALUMINUM PIPE UNDER MIXED MODE FRACTURE CONDITION

***H. Zarrinzadeh*[1]*, M. Z. Kabir*[1]*, A. Deylami*[1]**

[1] *Department of Civil and Environmental Engineering, Amirkabir University of Technology, Tehran, Iran*

1. General

In this study a cylindrical cracked aluminium pipe is studied by extended finite element method, XFEM, by developing a stand-alone XFEM package in MATLAB® programming software. The accuracy of the result is validated by experimental tests. Fatigue crack growth analysis of the pipe is carried out through the enriched finite element numerical simulation assuming 3D degenerated shell elements. The effect of glass/epoxy partial over-wrapped repair is then observed on stress intensity factors.

2. **Numerical formulation**

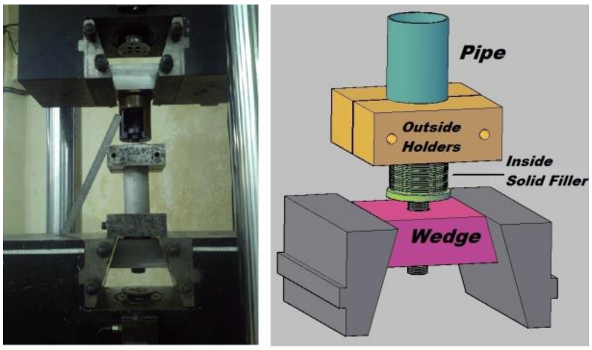
In XFEM formulation, the displacement field is divided into two parts of $\mathbf{u}^{FE}$ and $\mathbf{u}^{ENR}$. $\mathbf{u}^{FE}$ is the conventional finite element displacement. $\mathbf{u}^{ENR}$ is related to the enriched part of approximation. To model weak or strong discontinuities in XFEM framework, one need to incorporate two types of enrichment functions into displacement approximation. The first type of enrichment function which is used to present the discontinuity across the crack, is the Heaviside step function. Dolbow[1] introduced this function to simplify the representation of crack away from the tip. Equation (1) expresses the Heaviside function

(1) $$h(x) = \begin{Bmatrix} 1 & \text{above the crack} \\ -1 & \text{below the crack} \end{Bmatrix}$$

The crack tip enrichment functions are derived from the asymptotic analytical solution. They are used to represent the singularity of stress field near the crack tip [2].

3. Experimental and numerical results and discussions

The specimens are tested with a DARTEC 9600 fatigue testing machine. Maximum tensile stress of 60 MPa with a load ratio $R = 0.1$ is applied to the pipe. As there was no prefabricated fixture to perform a tensile fatigue load, a particular fixture shown in Fig 1 has been designed and built. To apply a uniform tensile stress, inside of the pipe is filled with a solid circular steel filler at both ends. Outside surfaces of both ends are then gripped with two other pieces which hold the pipe edges fixed during the loading procedure. The whole pieces are connected to the machine with two wedges at both ends.



a) b)

Fig 1.a) DARTEC 9600 testing machine with the installed fixture
b) Schematic of the lower part of the designed fixture to apply tensile load on the pipe

3.1. Fatigue crack growth in a pipe with an inclined crack

A cylindrical pipe made of 6063 aluminium alloy with a through-the-thickness crack is considered. The pipe has a length of 400mm with internal and external diameters of 86.5mm and 90.2 mm, respectively.The pipe contains an inclined crack of the angle $\alpha = 45^\circ$ and the initial length of $a_0 = 25.5mm$. The fatigue crack trajectory and also the a-N curves are extracted from the test specimen, while they are also validated with XFEM results. Fig 2 shows the comparison of experimental and XFEM results.

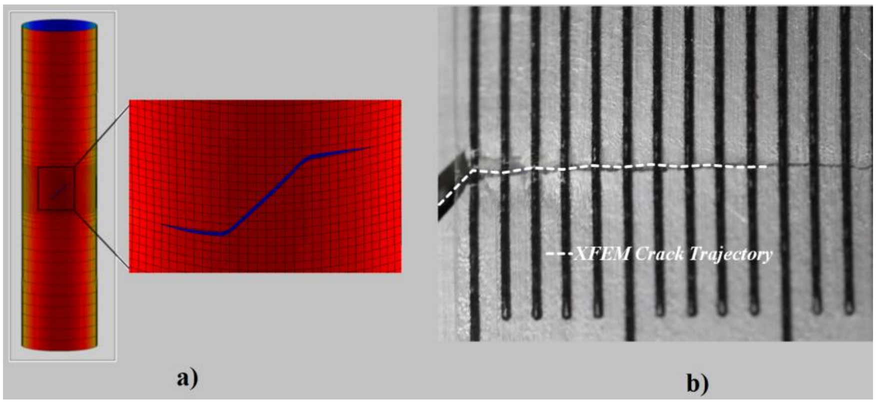


Fig 2. A) Schematic of crack deformation in the pipe with inclined crack
b) Experimental and XFEM crack growth path

3.2. Fatigue crack growth in a patch repaired pipe

The pipe with a circumferential crack is now repaired with glass/epoxy polymer composite. The pipe is wrapped in a length of 100mm with the patch. The transparency of the glass/epoxy patch makes it possible to trace the crack trajectory in the aluminium pipe

Fig 3 compares the values of the SIF for the circumferential cracked pipe with and without patch repair.

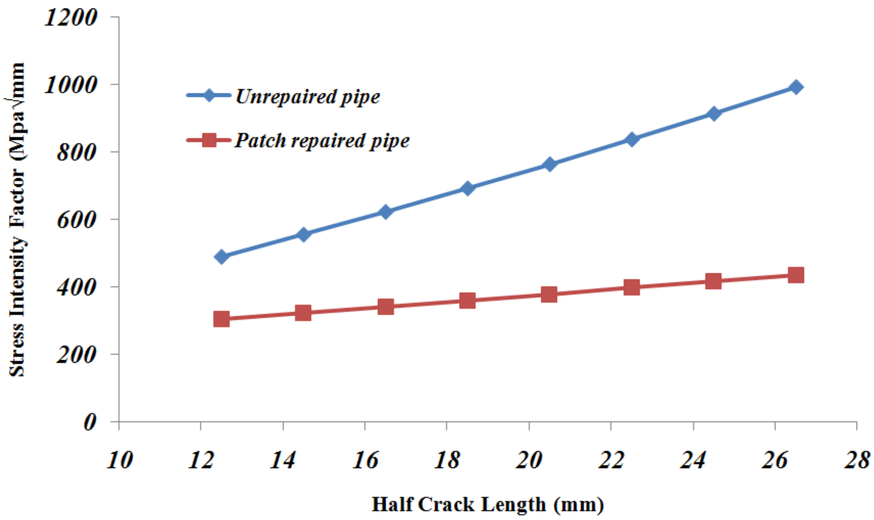


Fig 3. Comparison of stress intensity factors for repairs and unrepaired pipe

6. References

[1] Dolbow, J. and T. Belytschko, A finite element method for crack growth without remeshing. *Int. J. Numer. Meth. Eng*, 1999. **46**(1): p. 131-150.

[2] Bayesteh, H. and S. Mohammadi, XFEM fracture analysis of shells: the effect of crack tip enrichments. *Computational Materials Science*, 2011. **50**(10): p. 2793-2813.