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FATIGUE CRACK PROPAGATION IN A FLAT STEEL PLATE WITH CUT-OUTS UNDER SHEAR

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ABSTRACT

This paper adopts a fracture mechanics based approach to determine the crack propagation characteristics and the crack length versus number of cycles using Paris' law. FRANC2D has been adopted here for the computational simulation of crack growth. The approach gives significant information regarding the fatigue life and crack propagation characteristics. Analysis of steel plate has been carried out under shear load. For fatigue analysis edge crack has been introduced at edge of one hole. Distance between rectangular holes has been increased to the anime at an appropriate distance based on fatigue life. Relation between increased hole distance and fatigue life of steel plate has been studied using Finite Element Analysis Franc 2D.

Keywords: Fatigue, Crack propagation, steel plates, Paris law, Fracture mechanics, franc 2D

I. INTRODUCTION

Steel plates have many requirements in industrial application. Industrial application impose various types of loads on steel plate. Cracks may develop due to static or fatigue loads during service life of the steel plate. It becomes imperative to determine the remaining fatigue life of the steel plates in order to determine the safe life of the structures [1].

When a cracked plate is loaded, the material near a crack tip undergoes plastic deformation. For a small through crack in an infinite plate, if the plate thickness does not affect the stresses and strains, the crack length, 2a, is the only characteristic length of the plate. When a very large plate with a through crack is cyclically loaded, the material ahead of a crack tip undergoes repeated plastic deformation. When a material element is very close to a crack tip, the cyclic plastic strain range experienced by the material element is high and the cyclic deformation causes damage opposite to that, if material is far from a crack tip the cyclic plastic strain range and cyclic deformation is low. Cyclic stresses and strains are dependent on distance from crack tip [2].

Paris' law (also known as the **Paris-Erdogan law**) relates the stress intensity factor range to sub-critical crack growth under a fatigue stress regime. As such, it is the most popular fatigue crack growth model used in materials science and fracture mechanics. The basic formula reads

$$\frac{da}{dN} = C\,\Delta K^{m},$$

Where C and m are material constants, a is crack length, N is no. of cycles and K is stress intensity factor.

Paris' law is used to quantify the residual life (in terms of load cycles) of a specimen given a particular crack size[3].

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In this paper a candidate has been chosen as a steel plate. Steel plate has two rectangular holes, which are some distance apart, with circular arc at re-entrant corners. Steel plate is fixed at one edge and shear is applied at another edge. A crack is introduced at the corner of one hole and distance between two holes is increased and fatigue analysis has been done. Relation between distance between two holes and fatigue life of crack propagation has been established. For fatigue analysis Paris' model has been adopted for analysis of steel plate. For fatigue analysis of fatigue Franc 2D has been adopted.

Dimension of chosen steel plate are 2000mm x 1500mm. Two rectangular holes has dimensions of 150mm x 150mm and 200mm x 200mm with reentrant corner with corner radius of 10mm. For fatigue analysis an edge crack have been introduced at edge of one hole. Distance between rectangular holes has been increased respectively. Relations of increased distance between Rectangular holes and fatigue life of Steel plate has been studied using Finite Element Solution (Franc 2D) [4].

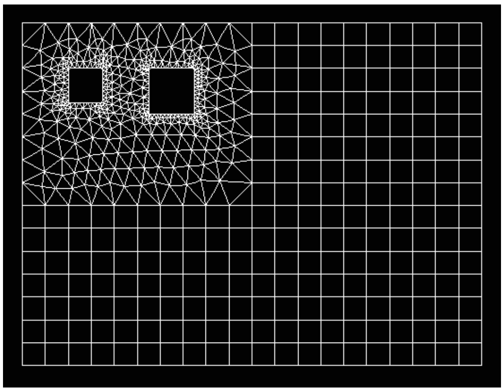

Figure 1. Finite Element Mesh of Steel Plate

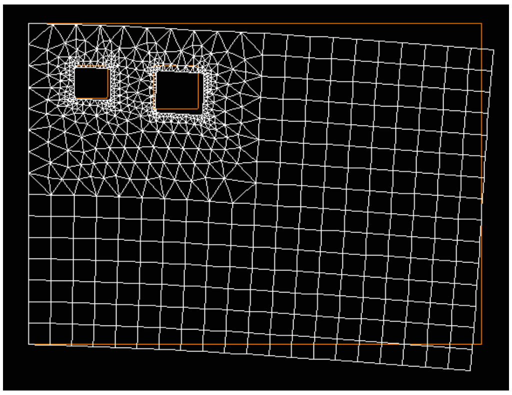

Figure 2. Finite Element Mesh of Deformed Shape of Steel Plate

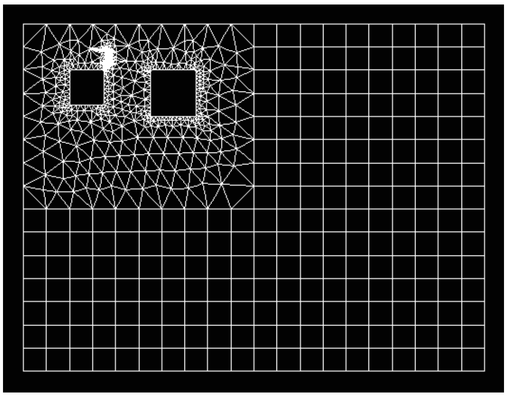

Figure 3. Finite Element Mesh of Crack at Corner of Cut-Out

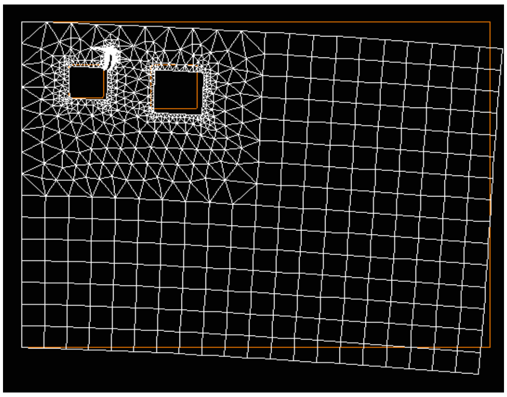

Figure 4. Finite Element Mesh of Deformed Shape after Crack Propagation

The finite element mesh of the plate with Rectangular Cut-Outs along with the deformed shape and the plate with a crack and its deformed shape are shown in fig. 1, 2, 3 and 4 respectively.

II. RESULTS

Fatigue life for various crack length corresponding to different distance between cut-outs have been reported in fig. 5, 6, 7 and 8 respectively.

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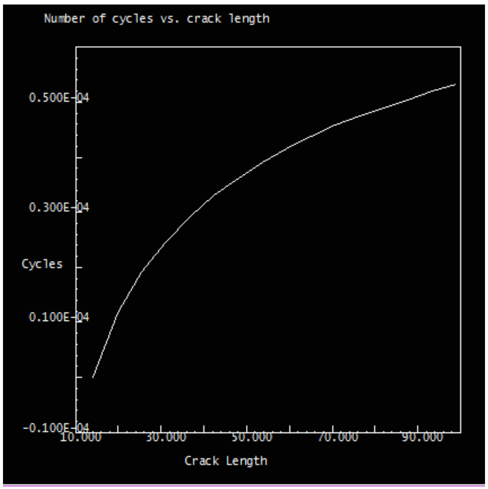

Figure 5. Crack length Vs No. of Cycles plot of Steel Plate with Rectangular Cut-Outs 200 mm apart

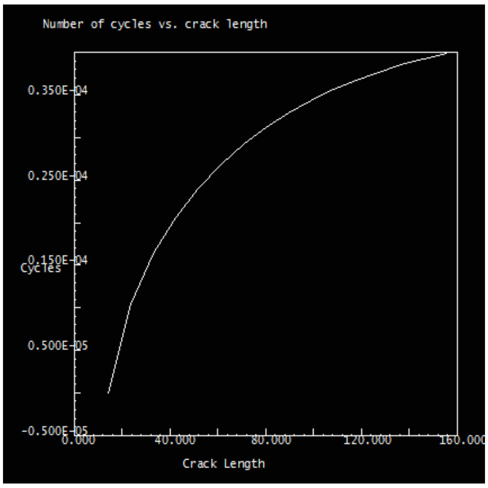

Figure 6. Crack length Vs No. of Cycles plot of Steel Plate with Rectangular Cut-Outs 300 mm apart

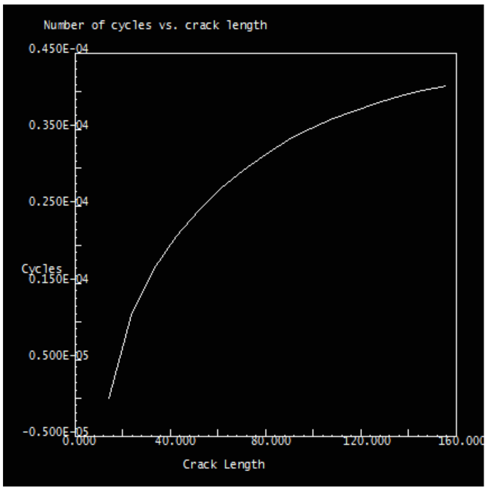

Figure 7. Crack length Vs No. of Cycles plot of Steel Plate with Rectangular Cut-Outs 400 mm apart

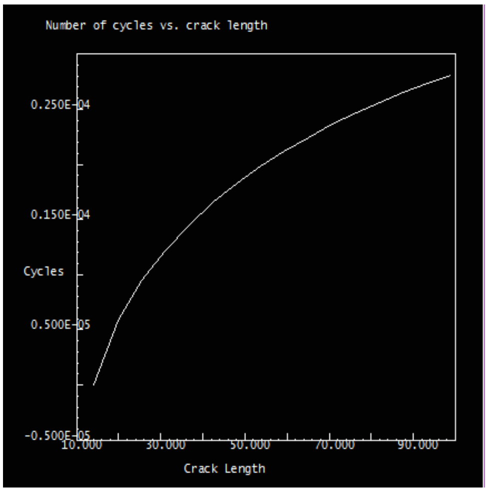

Figure 8. Crack length Vs No. of Cycles plot of Steel Plate with Rectangular Cut-Outs 500 mm apart

Von-Mises Stresses in the plate for various Cut-Out distance have been depicted in fig. 9, 10, 11 and 12.

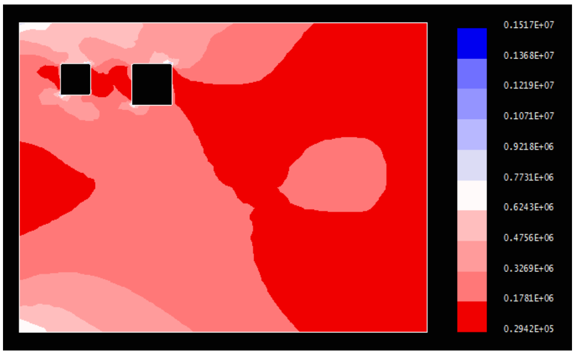

Figure 9. Von Mises Stress Plot of Steel Plate with Rectangular Cut-Outs 200 mm apart

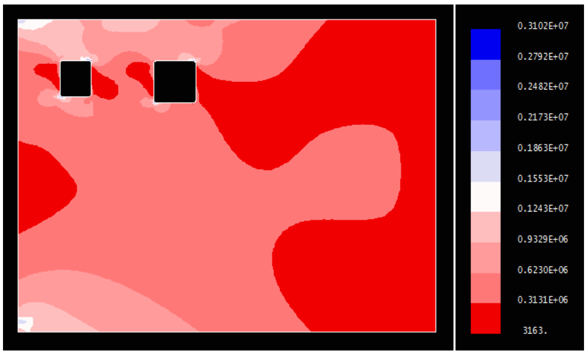

Figure 10. Von Mises Stress Plot of Steel Plate with Rectangular Cut-Outs 300 mm apart

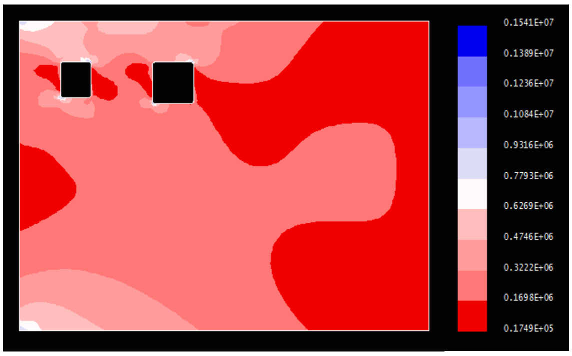

Figure 11. Von Mises Stress Plot of Steel Plate with Rectangular Cut-Outs 400 mm apart

Figure 12. Von Mises Stress Plot of Steel Plate with Rectangular Cut-Outs 500 mm apart

III. CONCLUSION

Fatigue life versus various crack length for different cut-out separation have been studied in a fracture mechanics based Finite Element Simulation. The separation that provided for the maximum fatigue life while provide minimum crack lengths shall be selected as the appropriate configuration. Separation between the cut-outs was observed to be significant due to interaction of the crack tip stress fields with raised stresses at other cut-out.

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