Research Article　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　**Open Access**

Software for Optimizing Stop Hole Shape

Awad M*

Department of Production Engineering and Mechanical Design, Mansoura University, Egypt

Abstract

The stop-hole method is investigated previously with creating a non-circular hole. That hole defines as an optimum stop hole shape that gives maximum initial fatigue life. Optimum stop hole shape decreases stress concentration without increasing the nominal stress, by using optimization technique. The effect of this optimum hole shape on crack reinitiating life for different model geometries is studied. The aim of this work is to introduce a software program to make it easy for everybody to determine optimum shape of stop hole suitable for user's geometry. This program is called OHS (Optimum Hole Shape). The input of that program will be only the specimen width, length, and crack length in addition to applied load. Then OHS outputs global optimum hole shape parameters. The optimum hole shape for different models are saved as database for OHS program. OHS can be linked directly with EDM machines to create optimum hole with one click.

Keywords: Optimization; Optimum stop hole shape; MATLAB GUI

Introduction

Design optimization using finite element analysis procedures is not a new idea [1-7]. The development of a numerical technique to compute initial fatigue life taking into account the material mechanical properties and true local stresses and strains by using the analysis results from a created nonlinear model was been studied by Fanni [8]. This work aims to introduce a complete software to give the user the ability to design the optimum stop hole shape considering his case without doing any complex optimization programs. The user needs only to apply geometrical configuration of his specimen and the mechanical properties of specimen material to OHS in order to get the optimum hole shape that gives maximum crack reinitiation life.

Modeling and Methodology

Finite element analysis and optimization programs

In order to get the required database for OHS software, forty two different models are studied. These models are sorted according to the (crack length/specimen width) ratio into eight groups. These groups are 0.1, 0.15, 0.2, 0.225, 0.3, and 0.344 for edge crack and two group for center crack with (crack length/specimen width) ratios 0.1 and 0.2. Each group consists of six different geometries with different (lengths/width) ratios 1, 1.2, 1.4, 1.6, 1.8, 2, and 3. For each specimen an elastoplastic finite element analysis is performed to determine maximum local stress/strain at circular stop hole boundary. The circular stop hole is the initial shape of stop hole that will be changed during optimization process. To save simulation time half model is studied. The stop hole is modeled by a spline connecting seven points distributed at hole boundary at constant angular distance equal to 30 degree. Every point of that spline is defined by angular coordinate (θ) which is held constant during optimization program, and radial coordinate (R) which will be changed during optimization program. Then an optimization program is performed to obtain the optimum hole shape to reduce these maximum stress/strain values without increasing stop hole size. The shapes of these models are saved as a database of OHS software. The optimum hole shape is saved in the OHS as a contour connecting seven points with polar coordinates (R, θ). For example the first group is illustrated in Figures 1 and 2.

OHS software

MATLAB GUI is used to design OHS. The program is performed through two stages. The first stage calculates the circular stop hole needed to arrest that cracks according to formulas of Dexter [9] equation (1):

$$R = \left(\frac{\Delta K}{10\sqrt{\sigma_y}} \right)^2 \qquad (1)$$

$$\Delta K = \Delta \sigma \sqrt{\pi a} \qquad (2)$$

Where: $\Delta\sigma$ is the range of applied stress σ_y is material yield stress (MPa), a is crack length, and R is circular stop hole radius.

The OHS asked user to input crack length, applied stress range and material yield stress. The OHS outputs the hole diameter D which is calculated internally by OHS using equations (1,2). The second stage of OHS selects the appropriate optimum hole shape
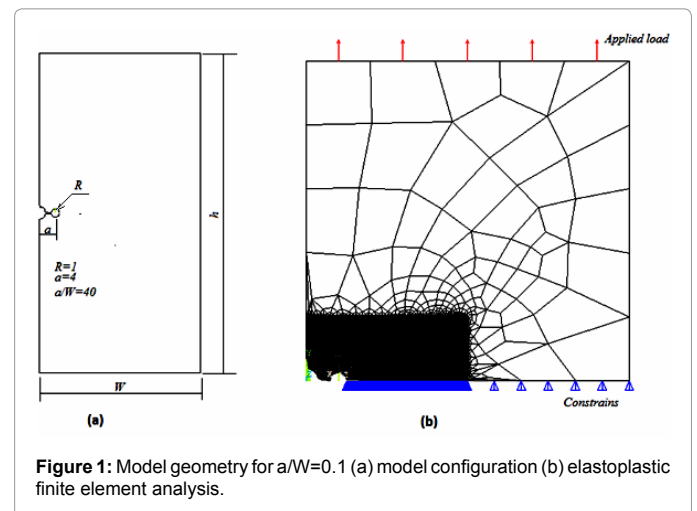
Figure 1: Model geometry for a/W=0.1 (a) model configuration (b) elastoplastic finite element analysis.

*Corresponding author: Awad M, PhD in Production Engineering and Mechanical Design, Mansoura University, Egypt, Tel: +20 50 2244426; E-mail: dr.mona711@gmail.com
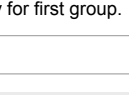
h/W	Optimum shape parameters for a/W=0.1							Optimum shape figure
	θ	0	30	60	90	120	150	175	
1	R	0.9193	1.0142	1.1491	0.9876	0.9936	1.0019	0.9977	
1.2	R	0.9199	0.9907	1.1241	0.9810	0.9706	0.9759	1.0081	
1.4	R	0.87412	0.95718	1.0993	0.99091	1.0187	0.99758	1.0252	
1.6	R	0.90122	0.9622	1.0997	0.9976	1.0009	1.0010	0.9973	
1.8	R	0.9012	0.9621	1.0998	0.9975	1.0009	1.0008	0.9974	
2	R	0.9012	0.9621	1.0998	0.9976	1.0009	1.0009	0.9972	
3	R	0.90743	0.98576	1.1419	1.0003	1.0154	0.99594	1.0080	

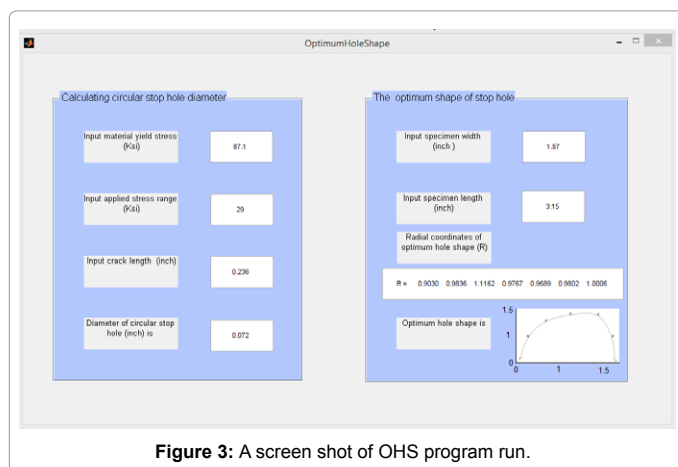**Figure 2:** Optimum hole shape for each h/W geometry for first group.

Figure 3: A screen shot of OHS program run.

for the user from the saved data. In this stage OHS asks user to input specimen configuration (width and length). According to specimen configuration OHS selects hole shape from saved data then mapping it with calculated diameter of circular hole. A screen shot of OHS program run is illustrated in Figure 3.

Conclusion

OHS simplifies the complex optimization programming and give the user the opportunity to get optimum hole shape within several seconds instead of performing optimization programs which take 8 hours at least. OHS is a collection of forty two complete optimization program for different models which could be sufficient to cover most kind of specimen and that save a lot of many and times consumed in optimization programs. OHS could be easily connected to CNC or EDM machines to create optimum hole shape just in time.

References

1. Das R, Optimal shape design with fatigue life as design constraint using a 3d biological method.

2. Chen QR, Guo HD, Cui HT (2013) Structural optimization of monosymmetrical non-circular hole on engine turbine disk based on EAGA with modified immigrant strategy,10th World Congress on Structural and Multidisciplinary Optimization Orlando.

3. Heller M, Burchill M, Wescott R, Waldman W, Kaye R (2009) Airframe life extension by optimized shape reworking. Overview of DSTO Developments, 25th ICAF Symposiums–Rotterdam. Australian Government Department of Defense, Defense Science and Technology Organization.

4. Das R, Jones R (2012) Extending the fatigue life of a fuel flow vent hole in an aircraft component using shape optimization. 3rd International Conference on Engineering Optimization Rio de Janeiro, Brazil.

5. Choi KK, Ogarevic V, Tang J, Park YH. CAD-based design process for fatigue analysis, reliability analysis, and design optimization. Automotive Research Center, Center for Computer-Aided Design College of Engineering, The University of Iowa.

6. Jones R, Pitt S, Peng D (2004) Structural Optimization For Lightweight Durable Structures. SIF.

7. Guagliano M, Bernasconi A, Ghelichi R. Notch optimization under multiaxial loading.

8. Fanni M, Fouda N, Shabara MAN, Awad M (2015) New crack stop hole shape using structural optimizing technique. Ain Shams Engineering Journal.

9. Dexter RJ (2004) Sign, signal, and light support structures and manual for repair of fatigue cracks. Third Annual Bridge Workshop Fatigue and Fracture.