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Experimental Analysis of Propagation of Crack in Aluminium Cantilever Beam using FEM Package

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Abstract

The values of variables V, B, F and D were recorded using accelerometer for frequencies 60 Hz, 80 Hz, 100 Hz and 120 Hz for aluminum cantilever beam of size 500 mm x 50 mm x12 mm under vibration. Considering an additional variable crack growth rate, G, a mathematical model was developed using dimensional analysis. The values of G were calculated and plotted to observe crack growth rate along the vibrating cantilever beam. Vibration analysis was reconsidered under similar condition using FEM Package(ANSYS) for cantilever beam system. Plots developed from mathematical model as well as from simulation were compared and analysed to confirm pattern of crack growth rate associated with vibrating cantilever beam.

Keywords: Cantilever Beam, Crack growth rate, FEM Package, Vibration, Frequency

Introduction

Mechanical vibration is one of the means through which the energy dissipates or generates, for a finite period of time; therefore we can say that vibration is an important phenomenon to be observed. Crack is one of the most common faults that if develops, may cause catastrophic damages in structures. Therefore, it must be detected in the early stage when it is small. Crack-like defects in mechanical and civil engineering structures are a problem that received considerable attention by researchers. There is remarkable effect of Vibration of different frequency on determination of crack growth rate along a vibrating cantilever beam. Therefore, it is very important to introduce a controlled vibration to a cantilever beam. The input vibration at different frequency has effect on crack growth at different position from free end towards fixed end.

Many researchers have reported the behaviour of beam. Dunn et al.[1] have introduced closed form expressions for stress intensity for cracked I-beams subjected to a bending moment. Gao and Herman[2] have estimated the stress intensity factor for cracked beams and pipes. Most structural components are often subjected to cyclic loading and fatigue fracture is the most common form of failure. Stephens et al.[3] reported that fatigue crack growth curve for constant amplitude loading consisting of the crack growth rate (da/dN) versus the stress intensity factor range(ΔK) in the log-log scale typically includes three regions. The application of wavelet Transform to detect crack -like damage in structures are demonstrated [4,5]. Several methodologies have been developed for the understanding of crack propagation under mixed loading. For example crack extension stability was studies by Cotterell[6,7] applying Eigen-function series expansion.

Methodology

In the present work, the characteristics of uniform cantilever beam were investigated for specimen system. Mathematical model was developed to predict crack growth rate. Experimental values were used to calculate crack growth rate along the vibrating aluminium cantilever beam. Vibration condition was also simulated on FEM package(ANSYS) to justify characterization of crack growth rate along vibrating cantilever beam.

The variables considered for the analysis were velocity of vibration(V), force per cross-sectional area (W), distance of crack from fixed end (B), frequency of the force per fixing length (F), distance of accelerometer from free end (D), crack growth rate(G). It was assumed that there would be no change in vibration frequency and also amplitude remains constant throughout the experimental work. It was necessary to observe the values of variables with respect to a reference variable and hence variables were correlated using repeating variable method[8]. Here, the total number of variables = 6, number of fundamental units = 3, number of dimensionless group = 3 and a functional relationship was established as ϕ(V, B, W, D ,F, G) = 0. The relationship obtained using Buckingham Pi Theorem as, V/(D^2.F), B/D and G/(D^2.F). Crack growth rate for specimen were calculated at frequency of 60 Hz, 80 Hz, 100 Hz and 120 Hz. Calculated value of `G` were further plotted for useful analysis.

Experimental Work

A setup was fabricated and installed to mount machined and heat-treated specimens. Experiments were conducted to record the observed values of velocity of vibration at different values of B, F, and D. Specimens were considered for the present investigation with a dimensional value of 500 mm x 50 mm x 12 mm. Horizontal grinding machine and abrasive cutter was used to shape the material. The experimental setup and block diagram were shown in figure 1 and 2 respectively. Specimen positioned as a cantilever beam over a base made of bricks and cement. A vibration generator was positioned below the beam to generate different frequency. Accelerometer was placed over the beam to observe the experimental values. Graphs were plotted to characterize the behaviour of vibrating aluminium cantilever beam. The chemical Composition of aluminium were shown in table 1.

Table 1: Chemical Composition of Aluminium

%Al	%Si	%Mg	%Fe	%Ti	%Ga	%Zn
98.92	0.37	0.457	0.16	0.014	0.011	0.0027

Figure 1: Experimental Setup

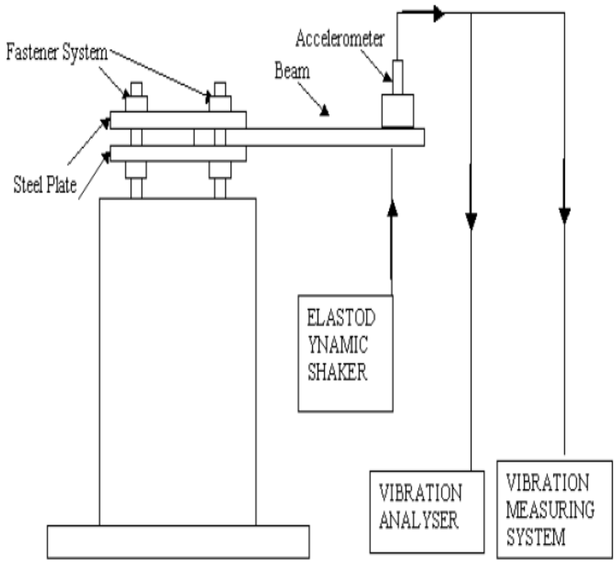

Figure 2: Block diagram of forced vibration experimental setup

Simulation Work

Simulation was performed to know pattern of crack growth rate(G), along the cantilever beam. Stress on vibrating beam increases from free end to fixed end as shown in figure 3. Here analysis done was 3-D analysis. ANSYS was used to simulate vibrating cantilever beam. Element type selected was solid185. Meshing of model was done with smart size of 4. One end of beam was constrained by considering displacement value zero. At other end, a point load was applied as real value of 100 kgf downwards. Poison's ratio value as 0.33, density as 2700 kg/m^3 and Young's modulus of elasticity as 69 GPa to recognize material aluminium. Harmonic Analysis was found suitable to simulate forced vibration. Extraction method used was Block Lanczos and equation solver used was Sparse. At Frequency range from 0 Hz to 60 Hz, nodal solutions were observed.

Contour plot of beam obtained is as shown in figure 3.

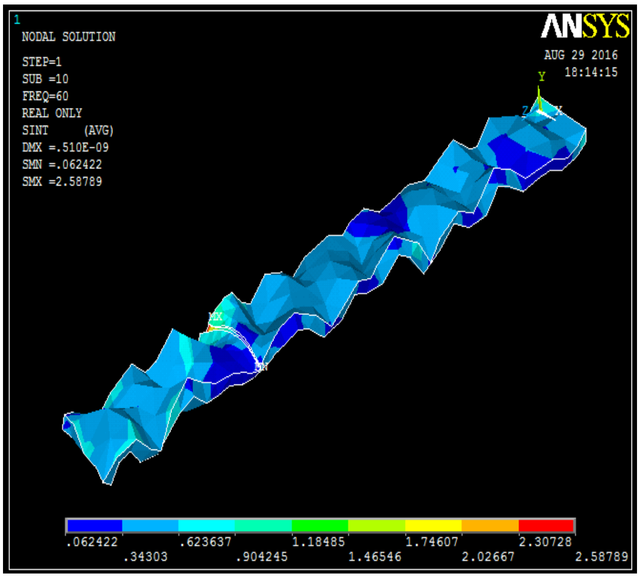

Figure 3: Stress increasing from free end to fixed end

Results and Discussions

Values of crack growth rate of vibrating cantilever beam at frequency of 60 Hz, 80 Hz, 100 Hz and 120 Hz were calculated and plotted to compare the results. In figure 4, variation of crack growth rate and distance of accelerometer from free end were shown at different frequency of 60 Hz, 80 Hz, 100 Hz and 120 Hz. From figure 4 it can be observed that crack growth rate of vibrating beam increases from free end to fixed end. Also stress intensity was observed increasing from free end to fixed end as shown in figure 3.

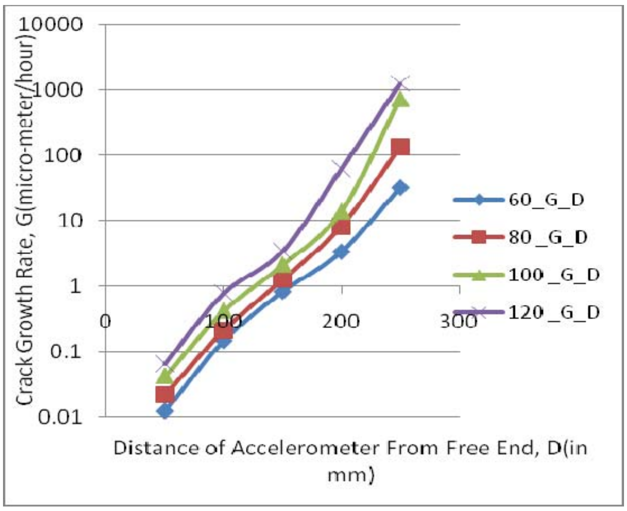

Figure 4: Crack growth rate from free end to fixed end.

Conclusion

Stress intensity and crack growth rate increases from free end to fixed end as observed from nodal plots and graphical plots respectively. Nodal plots for stress intensity obtained from FEM package (ANSYS), indicates that stress increases from free end to fixed end, observation made using mathematical model to characterize crack growth rate along beam.

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