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Study and Determination of Crack Development on Aluminium Cantilever Beam by the Help of Pre-Existing Crack Using Buckingham Pie Theorem

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Abstract: **Specimens are prepared for performing experiment. Four Aluminium specimen having dimensions 450 mm x 40 mm x 10 mm is prepared. Then out of four specimens one specimen is kept notch free. On second one specimen a notch on entire width and longitudinal distance of 90 mm from free end is prepared. Similarly third and fourth specimen have notch on 120 mm and 150 mm from free end respectively. We have to observed the impact of crack on cantilever beam of length 390 mm, 340 mm and 290 mm, and We also determined the effect of position of artificially generated notch (90 mm, 120 mm and 150 mm from free end). During the experiment our main motive is to measure the velocity of vibration (V) at different longitudinal distance from free end of the cantilever beam ranging from 50 mm to 250 mm at an interval of 50 mm. Frequency of vibration is kept constant during the process. After one complete reading, process is repeated for different required frequency. Since we have to find the crack Development rate on the observed velocity of vibration that's why we have to develop a relation between velocities of vibration with crack Development rate.Here relation is found out by using Buckingham Pie Theorem. The variables considered for the analysis is, 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) and Crack Development per unit time (G).As mentioned above, total number of variables considered for present investigation is, '6'. Three out of 6 variables are considered as fundamental variables and a functional relationship is established as Φ (V, W, D, F, B, G) = 0. The derived groups are, $V/(D^2.F)$, B/D and $G/(D^2.F)$. The relationship obtained using Buckingham Pi Theorem as, $G/(D^2.F) = f(B/D, V/D^2.F)$.Crack Development rate for cantilever specimen at different length 390 mm, 340 mm, 290 mm are calculated at frequency of 60 Hz, 80 Hz, 100 Hz, 120 Hz. Also at each frequency Crack Development rate is measured at an Accelerometer distance of 50 mm, 100 mm, 150 mm, 200 mm and 250 mm from free end.**

***Keywords*:** **Cantilever Beam, Crack Growth Rate, Crack Location, Fixing Length effect, Frequency of Vibration.**

1. INTRODUCTION

Fixed length beam is always being in use for various industries and civil work purposes so its failure condition are also being check frequently depending upon the material available and the formation of alloy. If one end is fixed and other end to support the load various calculation is made about the length width and thickness of the material and its load carrying capacity is observed for static and fluctuating loads.

Fixing the length of specimen has significant effect on, determining the crack development rate along a vibrating cantilever beam. Vibration is under controlled condition and length of beam in cantilever system at different frequency has effect for velocity and crack development rate at different position from free end towards fixed end. In the recent past it has been observed that both crack location and crack depth has noticeable effect on the modal parameters of the cracked beam.

The transverse crack is also model in a beam as rotational spring having stiffness and negligible mass. For the calculation convenience lumped mass matrix instead of consistent mass matrix is used during the entire experiment. The applications of Wavelet Transform to find crack-like hazard in structures are established. Nonlinear fracture mechanics, which includes, but is not limited to, the critical crack tip opening angle (CTOA) method. Various methods had developed in the understanding of crack development under mixed loading. For example, crack extension stability was studied by applying Eigen-function series expansion on cantilever beam in loading condition.

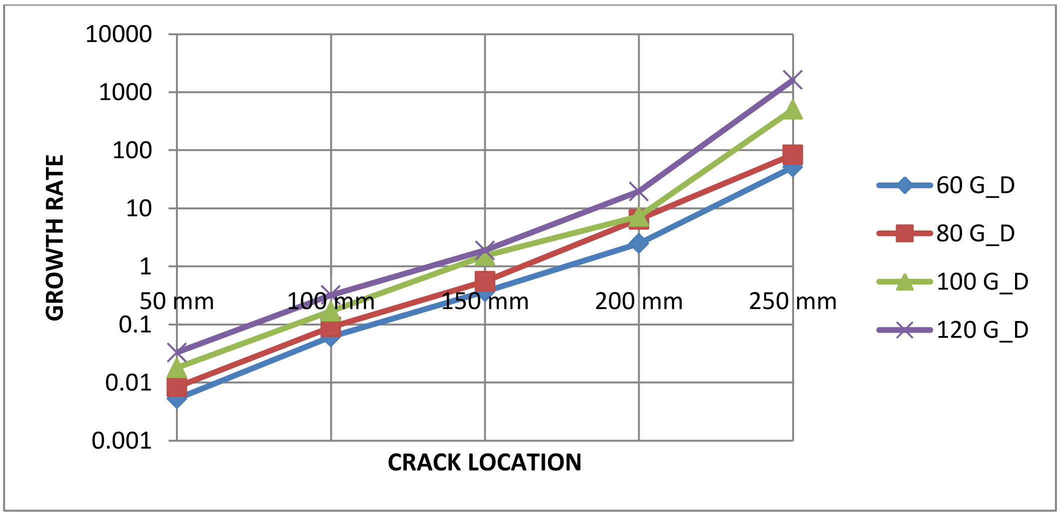
Crack position can be significant parameter to find, in a vibrating cantilever beam because; asperity of crack in a part or component depends on location of crack. There are many critical parts or components that cannot be just spared, therefore, it is very important to know the effect of crack position on the life of a machine component in its working condition. The input vibration at different frequency has effect on, velocity, and crack development rate at different position from free end towards fixed end. In the earlier decades, it has been observed that both crack location and crack depth has significant effect on the modal parameters of the cracked beam. The transverse crack is also modeled in a beam as rotational spring having stiffness and mass is to be negligible. For the computation simplicity lumped mass matrix instead of consistent mass matrix is used during the entire experimental procedure. The applications of Wavelet Transform to detect crack-like damage in structures are presented.

2. EXPERIMENTAL RESULT

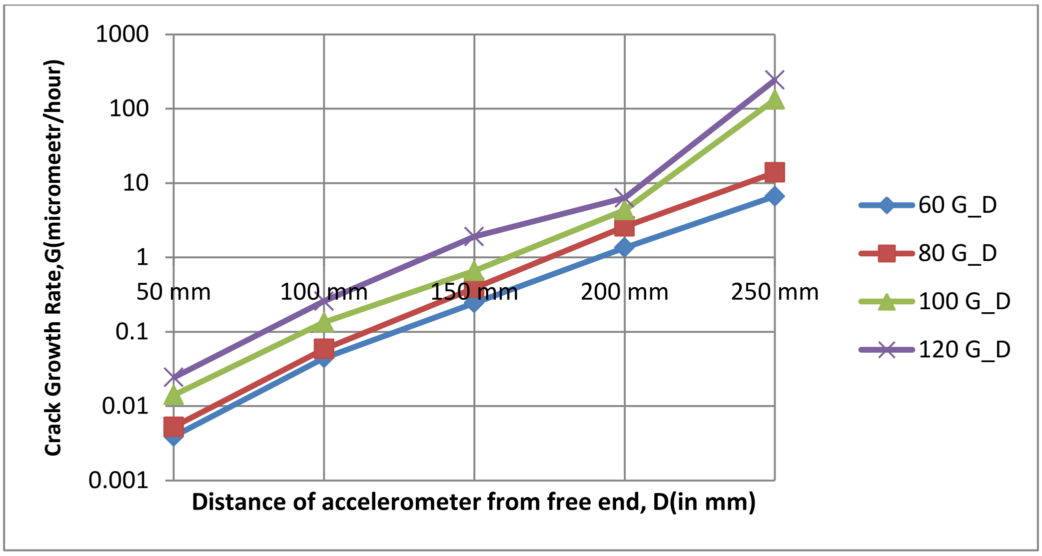
Experiment was carried on to record the observed values of velocity of vibration at different values of Crack location from fixed end (B), Frequency of force per fixed Length (F) and Distance of Accelerometer from free end (D). Fig. represents the observational setup. Specimen held as a cantilever beam on a base made of bricks and cement. A vibration generator was placed below the beam to generate different forced vibrating frequencies. Accelerometer was placed on the beam to observe the observational values. Observations were made for fixed lengths 390 mm, 350 mm, and 290 mm of beam. Graphs were plotted to characterize the behavior of vibrating cantilever beam.

A setup was fabricated and installed, to mount machined and heat-treated specimens. Specimens were further processed through heat treatment process using automatic muffle furnace to ensure material properties to be isentropic. Figure 3.3 represents the observational setup. Heat treated aluminium 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 observational values.

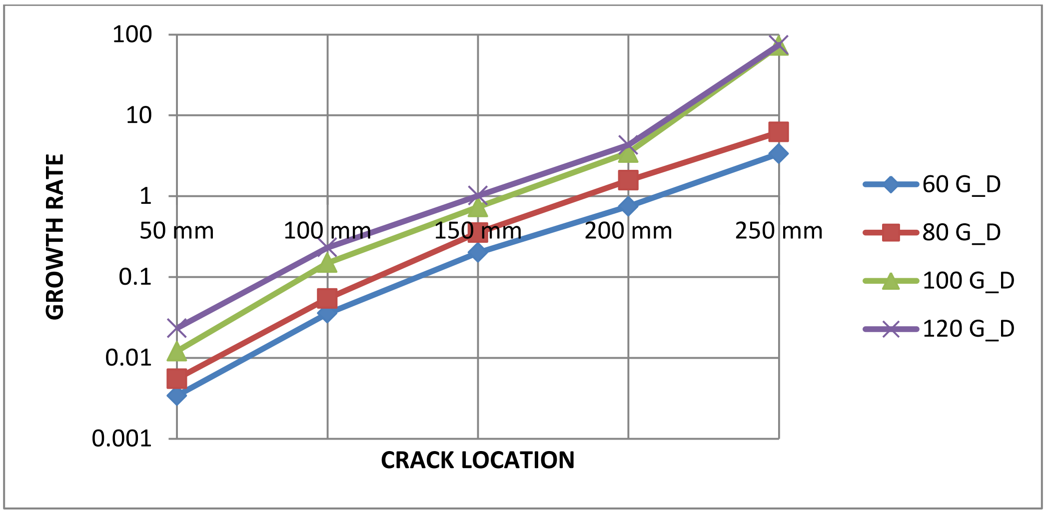
In the present work, the vibration characteristics of uniform cantilever beam were investigated for four specimen systems. The variables considered for the analysis were, velocity of vibration (V), force per cross sectional area (W), distance of crack from fixed end (B), frequency of the force per fixed length (F), distance of accelerometer from free end (D). An Electro-dynamic Shaker was used so that beam could vibrate, for prolonged period of time as per the requirement of the observational work. It was assumed that there would be no chance in the vibration frequency and also, amplitude remains constant throughout experimentation work once set. For any analysis purpose, it was necessary to observe the values of the variables with respect to a reference variable and henceforth, the variables were correlated using repeating variable method. As mentioned above, total number of variables considered for present investigation was, ‘6’. Three out of 6 variables were considered as fundamental variables and a functional relationship was established as Φ (V, W, D, F, B, G) = 0. The derived groups were, $V/(D^2.F)$, B/D and $G/(D^2.F)$. The relationship obtained using Buckingham Pi Theorem as, $G/(D^2.F) = f\,(B/D, V/D^2.F)$. Crack development rate for specimen at fixed length 390 mm, 350 mm, 290 mm were calculated at frequency of 60 Hz, 80 Hz, 100 Hz, 120 Hz. Calculated value of ‘G’ were further plotted for useful analysis.



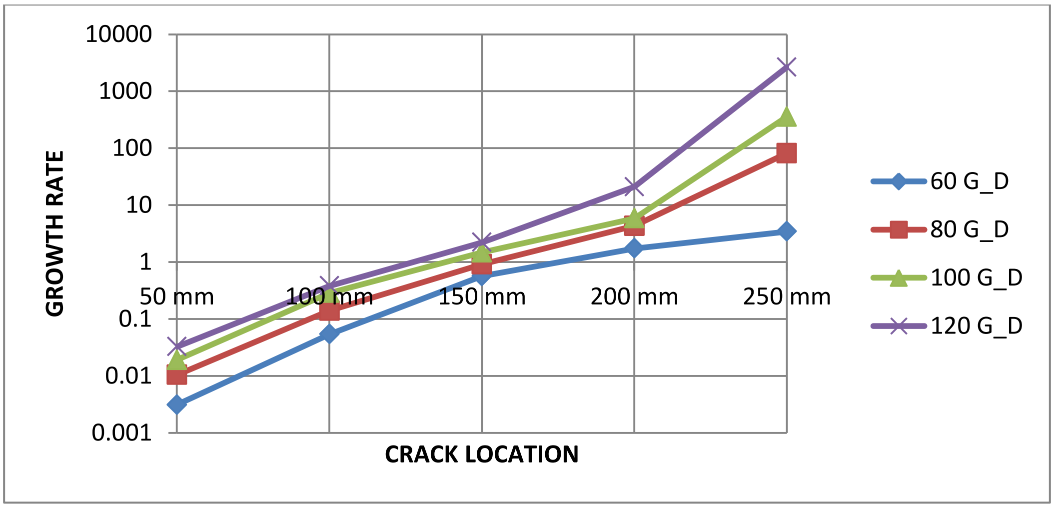
Graph No .1 Finding of crack development rate for accelerometer moving from free end for specimen no.01 with fixed length 390 mm.



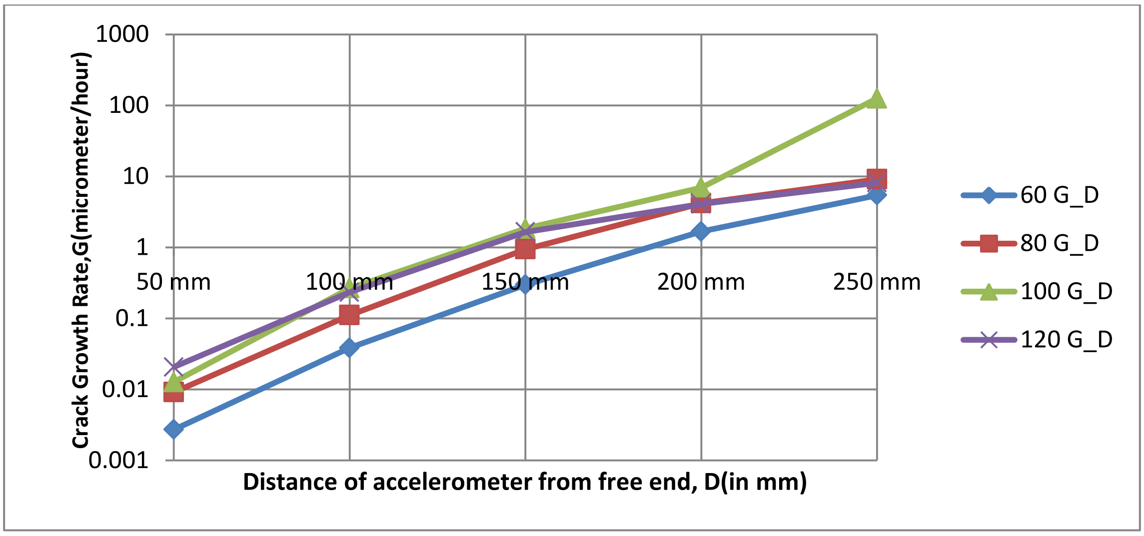
Graph No.2 Finding of crack development rate for accelerometer moving from free end for specimen no.02 with fixed length 390 mm



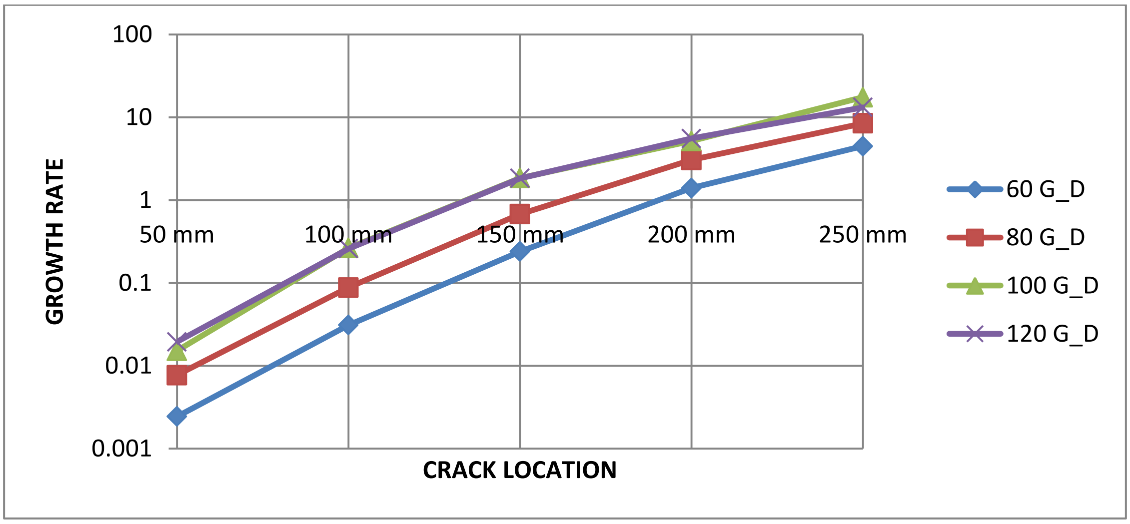
Graph No.3 Finding of crack development rate for accelerometer moving from free end for specimen no. 03 with fixed length 390 mm.



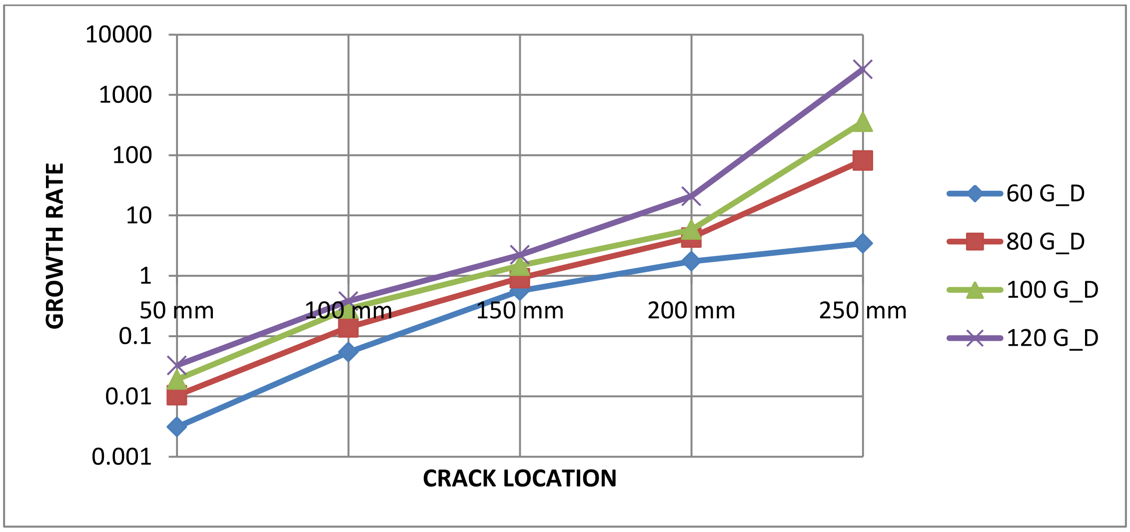
Graph No.4 Finding of crack development rate for accelerometer moving from free end for specimen no.01 with fixed length 340 mm.



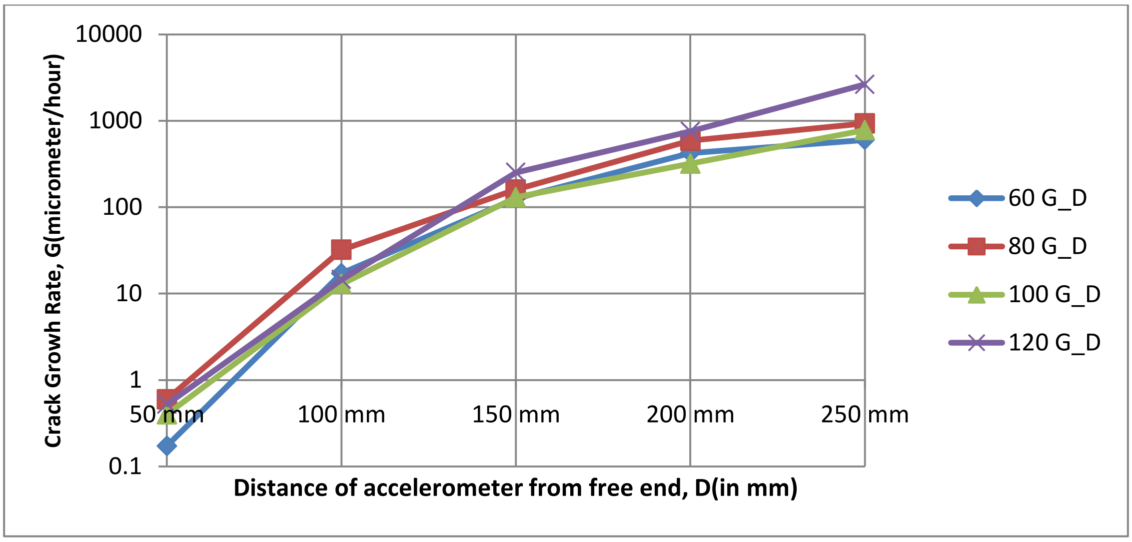
Graph No.5 Finding of crack development rate for accelerometer moving from free end for specimen no.02 with fixed length 340 mm.



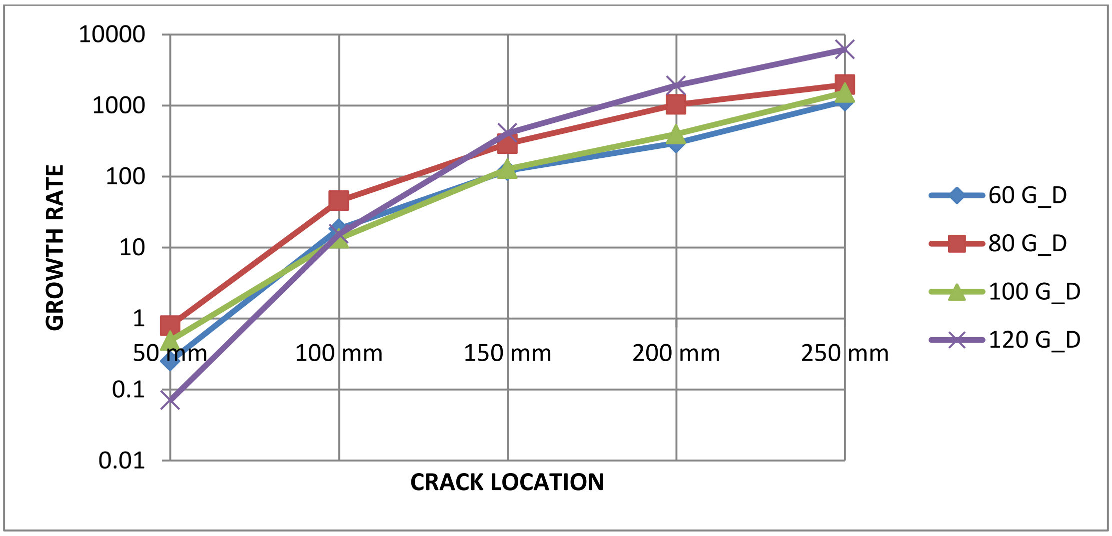
Graph No.6 Finding of crack development rate for accelerometer moving from free end for specimen no.03 with fixed length 340 mm.



Graph No.7 Finding of crack development rate for accelerometer moving from free end for specimen no.01 with fixed length 290 mm.



Graph No.8 Finding of crack development rate for accelerometer moving from free end for specimen no.02 with fixed length 290 mm.



Graph No.9 Finding of crack development rate for accelerometer moving from free end for specimen no.03 with fixed length 290 mm.

3. EFFECT OF FIXED LENGTH OF SPECIMEN ON CRACK DEVELOPMENT RATE OF VIBRATING CANTILEVER BEAM

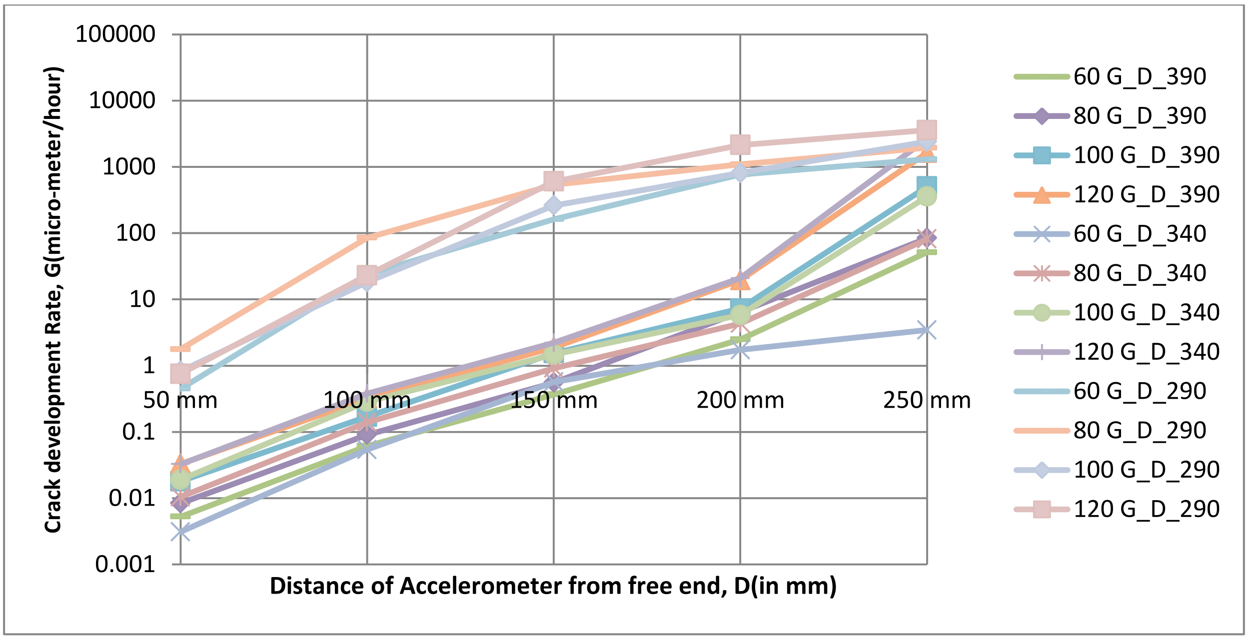
The accelerometer used to calculate the values of variables V, B, F, and D observed for a vibrating cantilever beam. Data was determined for frequencies 60 Hz, 90 Hz, 100 Hz, and 120 Hz at various fixed length 390 mm, 340 mm and 290 mm. Analyzing crack development rate, an additional variable, a mathematical model was developed using dimensional analysis and calculated values of G were plotted to observe crack development rate along the beam for different fixed length. Plots was compare and analysis was made to find out the effect on change of fixed length for every frequency for knowing the crack development rate nature along beam from free end to fixed end.

Fixed length of specimen has significant effect on, finding of crack development rate along a vibrating cantilever beam. Controlled vibration and length of beam in cantilever beam system at different frequency has effect on, velocity, and crack development rate at different position from free end towards fixed end. In the recent past it has been observed that both crack location and crack depth has noticeable effect on the modal parameters of the cracked beam.

The Horizontal grinding machine and abrasive cutter were used to shape material. Specimens were further processed through heat treatment process using automatic muffle furnace. The specimens were put inside the muffle furnace held at 670°C. The temperature of Muffle furnace was subsequently increased to 930°C. After the temperature reached 930°C the start of soaking time was recorded. For this experiment the soaking time was set to half an hour. Experiments were conducted to record the observed values of velocity of vibration at different values of B, F and D. Heat treated aluminium were preferred over other materials because it is possible to control its mechanical properties. Fig.(3.2) represents the observational setup. 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 observational values. Observations were made for fixed lengths 390 mm, 340 mm, and 290 mm of beam. Graphs were plotted to characterize the behavior of vibrating cantilever beam.

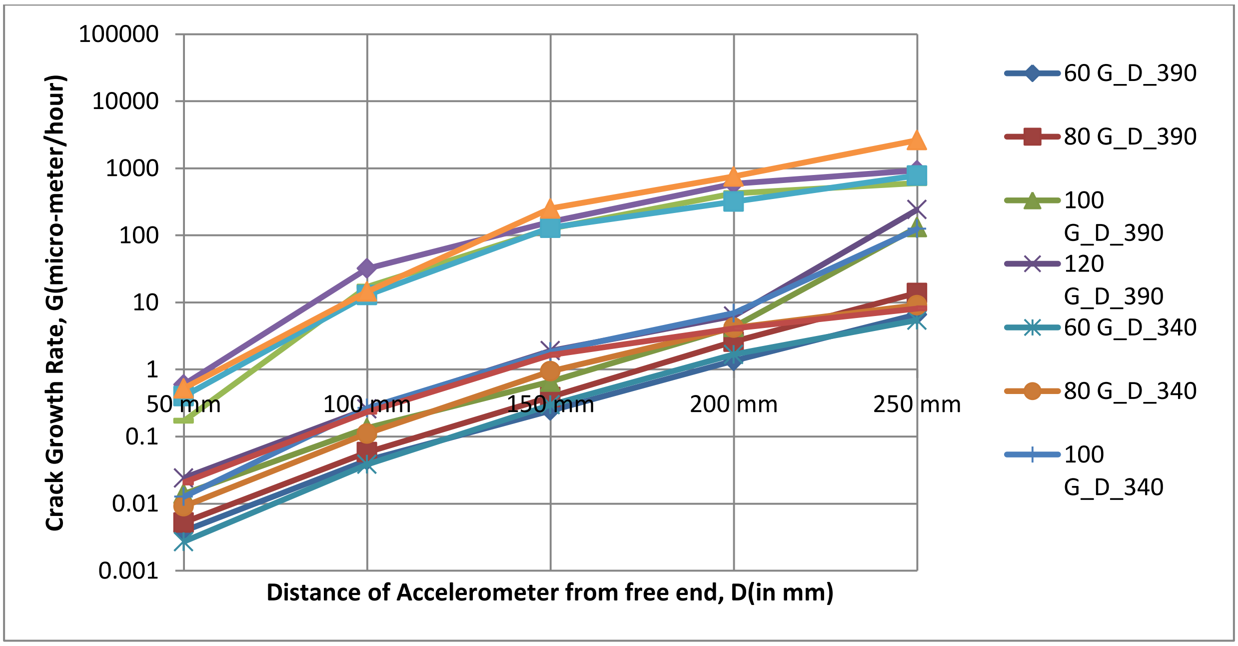
For the four specimens we will observe the following graph as follows.

SPECIMEN NO.1



Graph No.10 Plots between Crack Development Rate and Position of Accelerometer along the Beam for Different Fixed Length and Frequency at Crack Location 150mm.

SPECIMEN NO.2



Graph No.11Plots between Crack Development Rate and Position of Accelerometer along the Beam for Different Fixed Length and Frequency at Crack Location 120mm.

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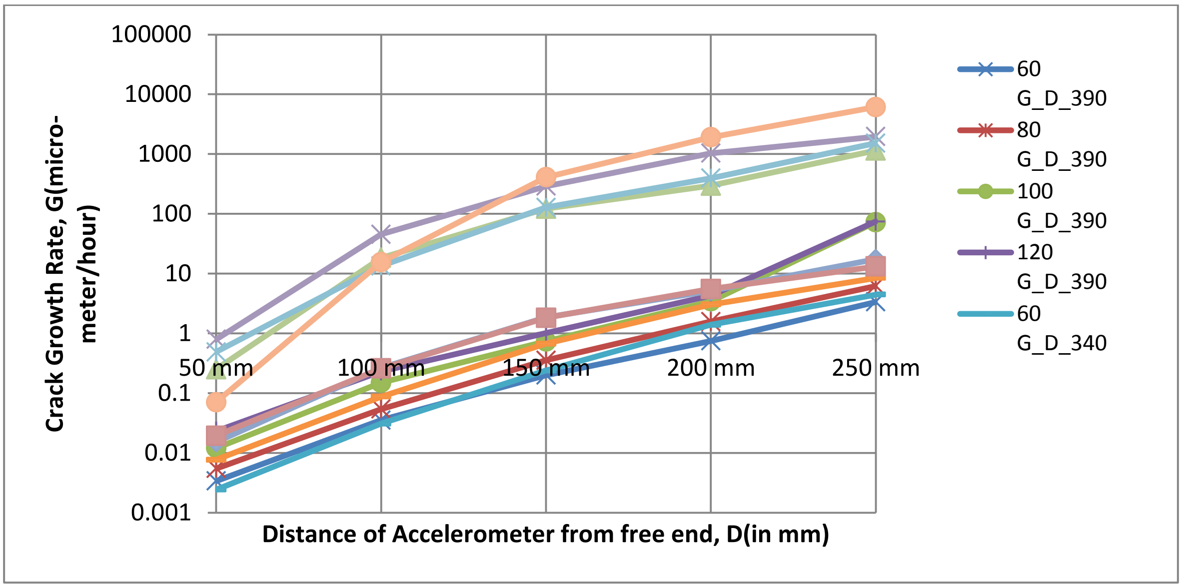
SPECIMEN NO.3



Graph No 12. Plots between Crack Development Rate and Position of Accelerometer along the Beam for Different Fixed Length and Frequency at Crack Location 90mm.

4. RESULTS AND DISCUSSIONS

The Crack Development rate for various frequency range and distinct position accelerometer Distance is plotted in each Crack development Location. The Crack is developeded in specimen 01, 02 and 03 at a distance of 150 mm, 120 mm and 90 mm. The features of Crack Development rate analysed by the graph No.1 to graph No 09 is as followed summed up.

1. In the Graph No 1,2 and 3 it was observed that Crack Development rate is increases with increase in frequency and Accelerometer distance from free end to fixed end.
2. In the Graph No 1. at fixed length 390 mm, frequency of 120Hz and 250 mm from free end along the vibrating cantilever beam, the value obtain for crack development rate for Specimen 01 was 1624.219 micrometer/hr.
3. In the Graph No 2. it can be observe that crack development rate of Specimen 02 at 120Hz was 242 micrometer/hr.
4. In the Graph No 3. it can be observe that the crack development rate of Specimen 03 at 120Hz and 250mm from free end was 74 micrometer/hr.
5. In the Graph No 4. at fixed length 340 mm, frequency of 120Hz and 250 mm from free end along the vibrating cantilever beam, the value of crack development rate for Specimen 01 was 2644 micrometer/hr.
6. In the Graph No 5. it was observe that crack development rate of Specimen 02 at 120Hz was 8.11 micrometer/hr.
7. In theGraph No 6. it was observed that the crack development rate of Specimen 03 at 120Hz and 250mm from free end was 13 micrometer/hr.
8. In the Graph No 7. at fixed length 290 mm, frequency of 120Hz and 250 mm from free end along the vibrating cantilever beam, the value of crack development rate for Specimen 01 was 3577 micrometer/hr.
9. In the Graph No 8. it can be observed that crack development rate of Specimen 02 at 120Hz was 2626 micrometer/hr.

In the Graph No 9. it can be observed that the crack development rate of Specimen 03 at 120Hz and 250mm from free end was 6137 micrometer/hr.

5. CONCLUSION

1. It help in study the pattern of failure due to crack in material. We had taken a standard specimen without any crack generated on it and the various curves of different parameter has been recorded from the equipments. Taking it as standard we had compared other specimen from its graph variation in different loading condition at various position.
2. Significant result obtain from this used to relate a pattern from the unnaturally generated crack specimen at various position from fixed end and used for result analysis to the specimen we have taken in consideration for experimental

analysis of crack development From the study of various pattern on graph obtain during entire experiment. Graph 4.4, 4.5 and 4.6 at 390 mm fixed length it was observed that the crack development rate is firstly increasing at the slow pace till 100 mm accelerometer distance. Shows that at free end the crack travel is with less speed but as It advances to next 100 mm and then there is sharp increase and when accelerometer distance moves further from 200 mm to 240 mm. so we can say that in larger distance from fixed end leads to more time for development of crack along depth. Likewise results were shown in Graphs 4.7, 4.8, 4.9 at 340 mm fixed length.

3. In the Graphs 4.10, 4.11 and 4.10 at 290 mm fixed length it was observe that crack development is sharp as compared to the 340 mm and 390 mm fixed length condition excluding in specimen 01 where Crack development at 290 mm fixed length is almost equal to 390 mm fixed length. It has been observed that crack development rate of vibrating beam at fixed length of 290 mm has higher value along beam from free end to fixed end.
4. Crack development rate for fixed length of 390 mm is in descending order whereas for fixed length of 340 mm crack development rate is ascending. Significant difference in the crack development rate in all three specimens for fixed length of 390 mm and 340 mm was observed only after 150 mm from free end and evidence change in material continuity. At fixed length of 290 mm crack development rate has a higher value along beam and decreasing from free end to fixed end.
5. From Graph No 1. to Graph No 7. it can be observed that crack development rate increases along the vibrating cantilever beam from free end to fixed end. From Graph No 1., 4.5 and 4.6 it can also be observed that after crack location 140mm from free end, crack development takes place with a higher rate. This deflection in crack development rate due to crack breathing can be observed in Graph No 2. and Graph No 3., after crack location of 120mm and 90mm respectively.

6. SYMBOLS USED

V -Velocity of vibration (m/s)
B -Distance of crack from fixed end (m)
D -Distance of the accelerometer from the free end (m)
W -Force per cross sectional area (N/m2)
F -Frequency of the force per fixing length (m-1 .s-1)
G -Crack growth per unit time (m/s)

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