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Critical Study of Crack Propagation in Compact Tension Specimen

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Abstract:*The main purpose of the present research is to demonstrate the threshold stress intensity factor at initiation and at propagation stage. Constant amplitude loading helps to study the crack growth rate. In this paper, ANSYS software analysis has been carried out for stress ratio R=0.1 and 0.8 for fatigue loading. Through the analysis, S-N curve and crack growth rate curve [3] has been plotted for notch to depth ratio 0.45 and 0.55. Results have been evaluated and compared, which agreed well.*

Keywords: *compact tension; fatigue crack growth; fatigue life fracture toughness; SN curve;stress intensity factor*

I. INTRODUCTION

Fatigue damage of components subjected to normally elastic stress fluctuations occurs at regions of stress (strain) raisers, where the localized stress exceeds the yield stress of the material. After a certain number of load fluctuations, the accumulated damage causes the initiation and subsequent propagation of a crack, or cracks, in the plastically damaged regions. Analytical research of fatigue behaviour of CT specimen has been the subject of matter for this present research.
Basically a structural life is classified into two parts where former part is crack initiation and latter part will be crack propagation after that catastrophic failure occurs. Fatigue life determination is important for defects tolerant design of structural component for safety which is associated with serviceable period.Total fatigue life of any component is the sum of number of cycles required to initiate and propagate a fatigue crack [5].

$$N_t = N_i + N_p \dots \quad \text{(i)}$$

If a structural component contains flaws or any pre-existing notch, this will reduce fatigue crack initiation life and hence decrease total fatigue life of that component.
Stress intensity factor (K) is the Linear Elastic Facture Mechanics (LEFM) parameter with which we characterize effect of loading at the crack tip reason. For higher k values crack growth rate is undesirably higher. So stress ratio should be selected between -1 and 0.1. But for negative stress ratio fatigue pre-crack is faster so to avoid this situation 0.1 lower stress ratio and 0.8 higher stress ratio is selected[5].

$$\text{Stress Ratio } R = \frac{\sigma_{min}}{\sigma_{max}} = \frac{K_{min}}{K_{max}} \dots \quad \text{(ii)}$$

Where σ_{min} and σ_{max} are minimum and maximum values of stress respectively, hence similarly for K_{min} and K_{max} as minimum and maximum stress intensity factor respectively. Crack propagation life is estimated using paris law, as follow:

$$da/dN = C(\Delta K)^m \dots \quad \text{(iii)}$$

Where da/dN is crack growth rate, C, m are Paris constants and ΔK is the range of stress intensity factor, with an increment of ΔK da/dN increases which shows growth in the crack.
Material for specimen are selected asmild steel and its chemical composition are mentioned below.

Table 1. Composition of mild steel

Component	Fe	C	Si	Mn	S	K
Percentage	98.44	0.18	0.4	0.9	0.04	0.04

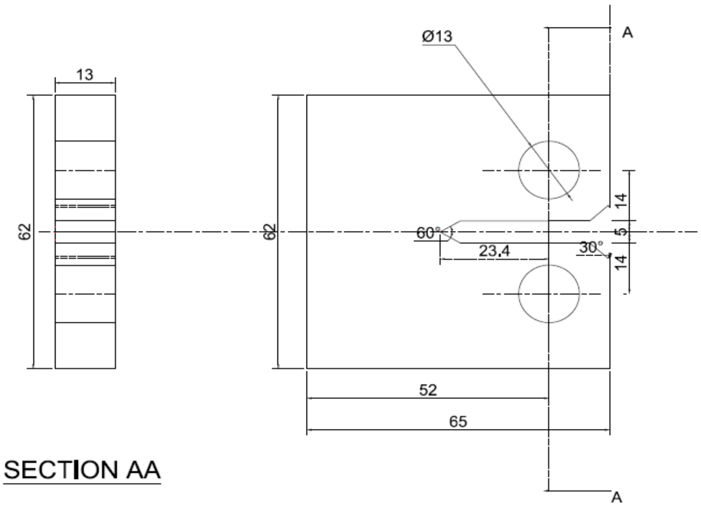

Fig1. Typical Layout of CT specimen

II. RESULTS AND DISCUSSION

TABLE 2.max and min K & N value for a/W=0.45

R	Nmax	Nmin	Kmax (MPa√m)	Kmin MPa√m
0.1	62405	1946	52	43
0.8	72595	96	52	43

TABLE 3. max and min K & N value for a/W=0.55

R	Nmax	Nmin	Kmax (MPa√m)	Kmin MPa√m
0.1	72851	2757	79	66
0.8	50286	1198	79	66

TABLE 4. Comparison of threshold value for region I and region II

R	a/W	Region I (K_{th})	Region II(K_{Ic})
0.1	0.45	2.9	6.9
0.8		2.9	6.9
0.1	0.55	2.98	8.96
0.8		2.98	8.96

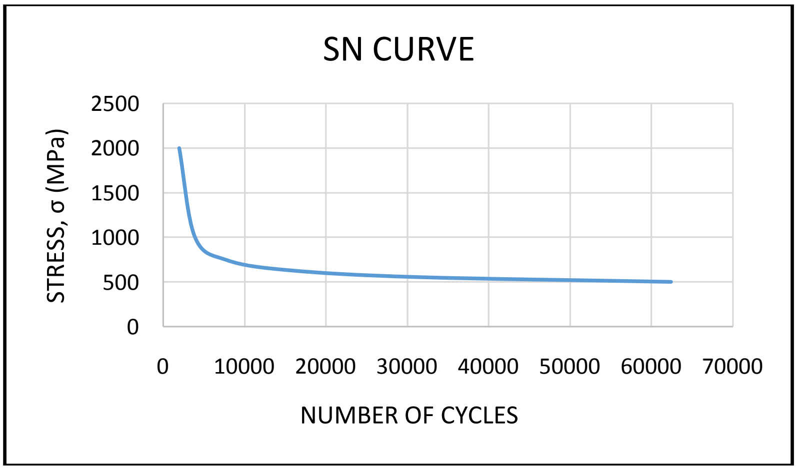

Fig2 (a). a/W=0.45 R=0.1

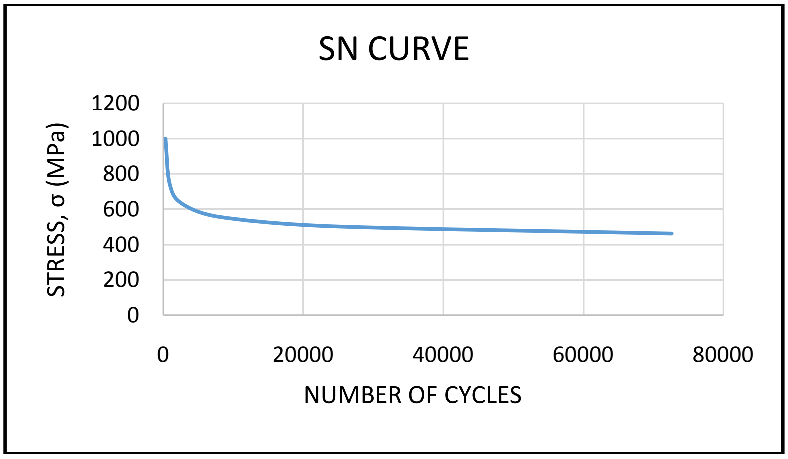

Fig2 (b). a/W=0.45 R=0.8

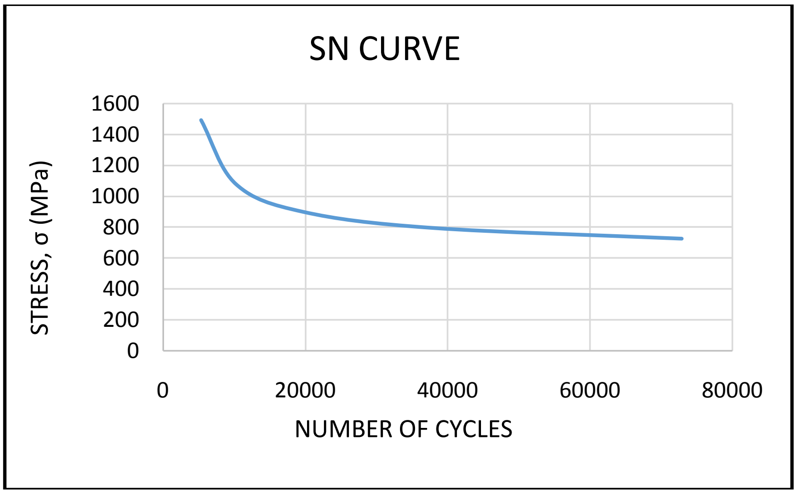

Fig2 (c). a/W=0.55 R=0.1

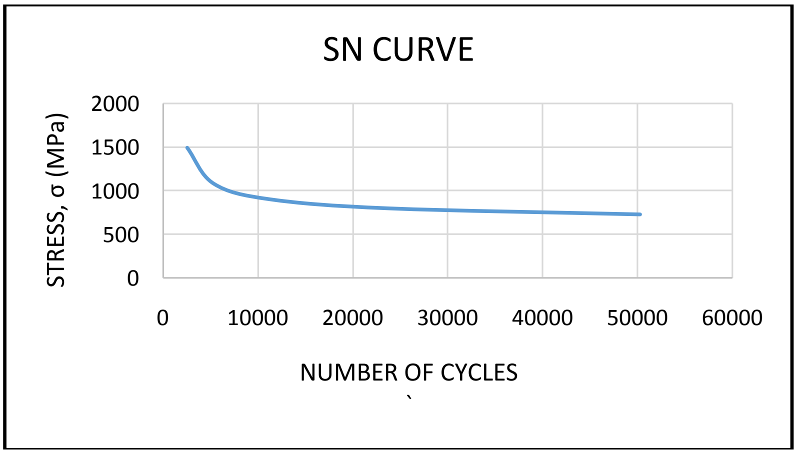

Fig2 (d). a/W=0.55 R=0.8

Fatigue test was performed on CT specimen under R=0.1 and 0.8 for a/W = 0.45& 0.55 for mild steel. It was found that stress required to initiate crack is 2000 MPaand 1000MPa for a/W =0.45under R=0.1 & 0.8 respectively whereas for a/W =0.55 stress required for initiation is 1500 MPafor both R=0.1 & 0.8.Fatigue life of mild steel under R=0.1is 62400 and 72800 for a/W =0.45 & 0.55 respectivelywhereas for R=0.8 fatigue life is 72500 and 50200 for a/W = 0.45 & 0.55 respectively.

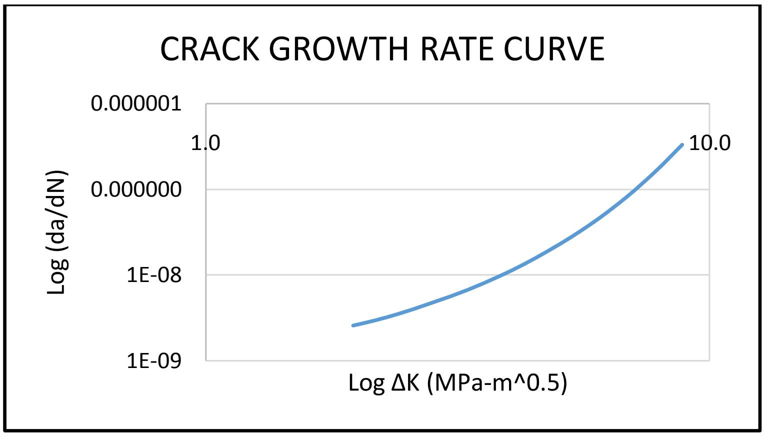

Fig3 (a). a/W=0.45 R=0.1

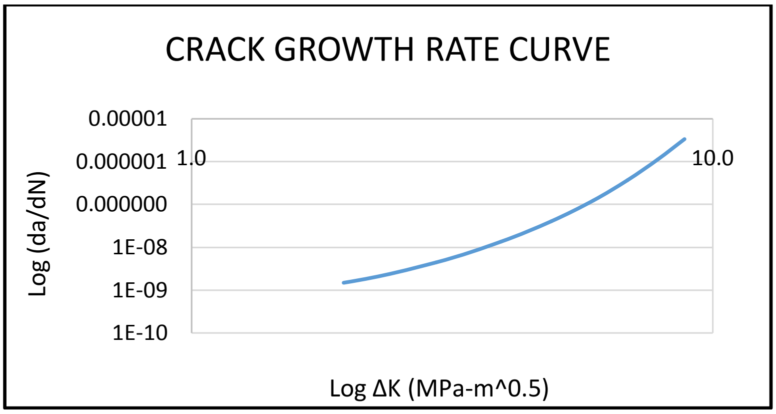

Fig3 (b). a/W=0.45 R=0.8

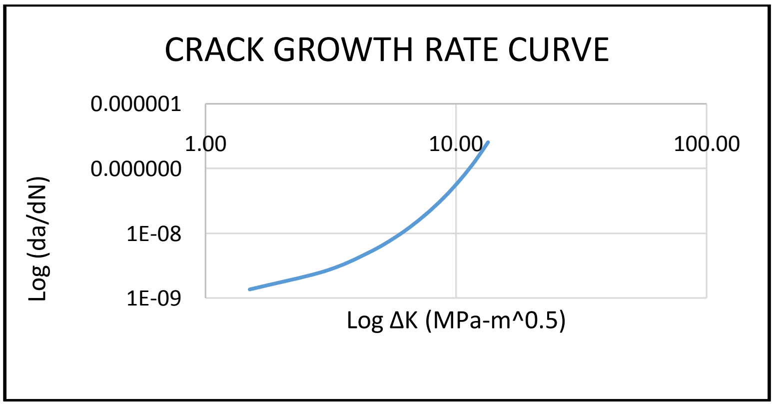

Fig3 (c). a/W=0.55 R=0.1

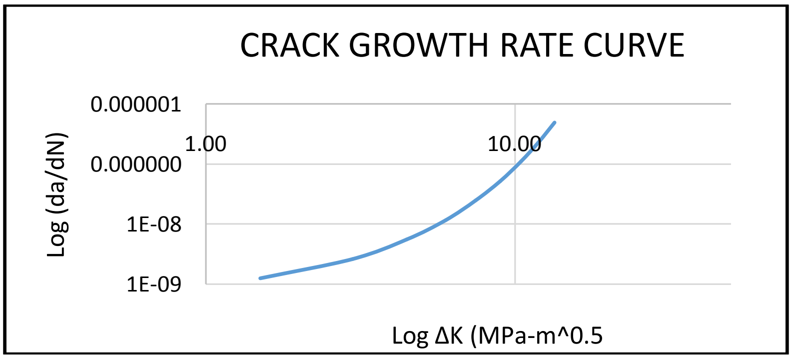

Fig3 (d). a/W=0.55 R=0.8

The Crack growth rate curve is divided into three regions. In region I, below ΔK_{th} there is no initiation of crack which is known as threshold. Region II shows that when ΔK exceeds ΔK_{th} crack propagates and region III shows threshold value after which fracture occurs which is known as ΔK_{Ic}. ΔK_{th} and ΔK_{Ic} are material properties. Figure3 (a), (b), (c) and (d) shows crack growth rate curve for mild steel. [3]

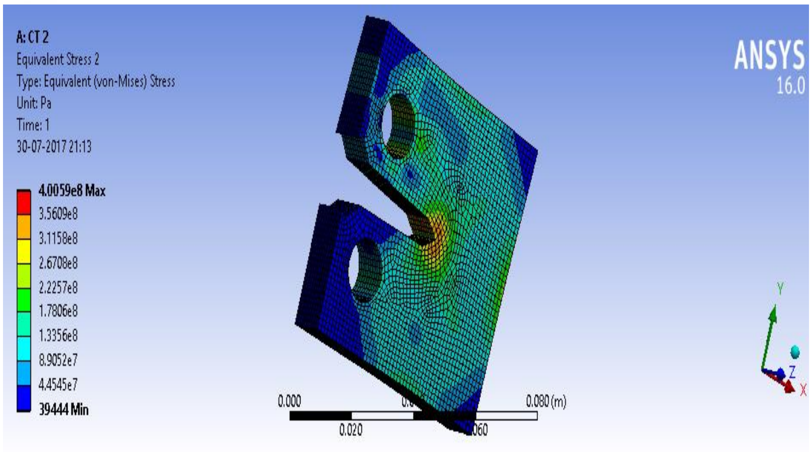

Fig4 .Stress Values

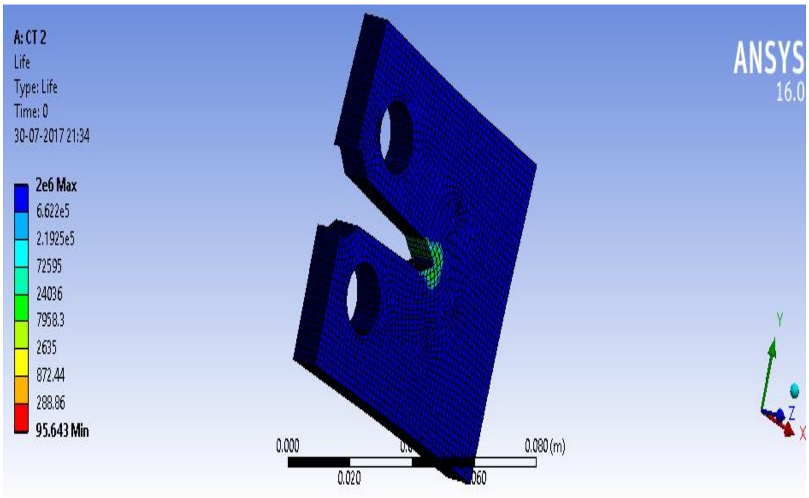

Fig5. Fatigue Life

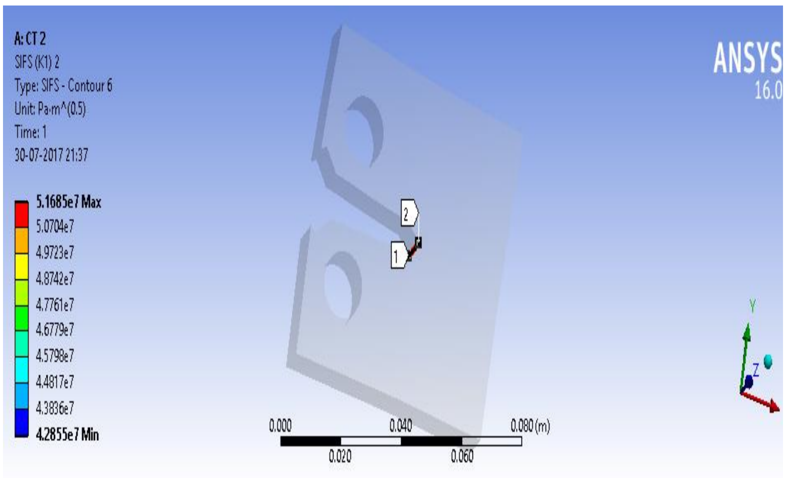

Fig6. Stress Intensity Factor

Figure 4, 5 and 6 shows stress, fatigue life and stress intensity factor results obtained from ANSYS software based solution respectively.

III. CONCLUSION

- From SN curve, we can conclude that as number of cycles continues to increase the stress value gradually decreases.
- While performing ANSYS based solution, it can be observed that for a/W = 0.45 & a/W = 0.55 for stress ratio R=0.1 & 0.8, the threshold stress intensity factor (K_{th})for region I (initiation level) remains same while for Region II (propagation level) K_{th} value of a/W=0.55 is increased to 23% as compared to a/W=0.45 respectively.
- Crack growth rate of short crack for lower and higher stress ratios for a/W = 0.45 & a/W = 0.55 is same, while crack growth rate of long crack for a/W=0.45 is smaller than a/W=0.55 for both lower and higher stress ratios. If necessary to use long crack fatigue data, then data for lower stress ratios are more reliable.
- Measured threshold ΔK_{th} values at stress ratios (R = 0.1 & 0.8) for physically short (0.01 - 2 mm) cracks were found to be 57.9% smaller than the corresponding ΔK_{th} values for long (about 25 mm) cracks. Hence short crack fatigue data are more relevant for defect tolerant design of component containing flaws.
- The fracture toughness continuously increases as notch to depth ratio increases of specimen. It can be observed that for R=0.1 & 0.8 fracture toughness value for a/W =0.55 is 27% higher than a/W=0.45. Hence it is concluded that fracture toughness depends on notch to depth ratio and not on stress ratio. [2]
- Both fracture toughness parameters and stress intensity factor are equally important to study the overall concept of fracture mechanics.
- To study the concept of fatigue failure threshold stress intensity factor and number of cycles are important, which depends upon notch to depth ratio and stress ratio.

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