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Simulation of Fatigue Crack Growth for Pearlite Structured Steel Using MATLAB

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Abstract

Characteristics of fatigue crack growth for ferrite pearlite structured steel for four different conditions is studied using MATLAB & to obtain the design curves for all four cases and then making a comparative study. Afterwards, parametric study is done by varying one variable at a time and graphs are generated for each MATLAB program. A comparison of fatigue crack growth of all four cases of ferrite-pearlite steel is done and results are compiled. The design curves obtained are in agreement with the literature.

Keywords- **Fatigue, Design Life, Pearlite Steel, Crack**

I. INTRODUCTION

Fatigue crack growth in a material is typically quantified by the size of the crack "a", the rate at which it propagates da/dN, and the linear elastic fracture mechanics term ΔK, the stress intensity factor range. The relation between crack growth rate and stress intensity was originally shown to be linear over a large range of da/dN on a log- log scale[1].However this relation is non linear near fracture[2,3].

The fatigue crack growth threshold is the theoretical value of ΔK at which da/dN approaches zero [4]. It has been shown that small cracks propagate at a ΔK below the threshold value [5,6] determined with the ASTM constant R load reduction test procedure[4]. The constant R load reduction method reduces the maximum and minimum load applied to a cracked specimen such that the load ratio, R, remains constant. Experimental results suggest that the constant R load reduction test procedure develops remote crack closure [7, 8]. Remote closure is generated because tests are initiated at high loads, and shedding load until threshold is reached. Larger plastic strains are produced along the crack wake at the high loads early in the test than in subsequent lower loads near threshold. This plastic wake, or history, can effect the crack driving mechanisms by prematurely unloading the crack tip due to crack face contact along the wake [9, 10].

The material ferrite-pearlite steel behaves as particulate composites such that the path of least resistance to fatigue crack growth is through the ferrite matrix and the pearlite colonies tend to retard the crack growth. The steel with low hardened ability such as A36, that are subjected to very low cooling rate have ferrite-peralite microstructures. The design of the structure is made on the basis of live load and dead load. The fatigue translation (K_t) is dependent on the yield stress and young modulus. The initial crack growth (a_o) is also been effected by the stress intensity (k) and stress ratio (R). The design load is usually taken to be the maximum stress that the structure has to sustain. The stress intensity factor and stress ratio helps in calculating the number of cycles, which in turn helps in finding the summation of cycles in every increasing crack size. The study of fatigue and corresponding fatigue life has become a keen topic of research in recent times since it has acquired a prominent role for controlling the fatigue failures and its consequences.

II. PROBLEM DEFINITION

To develop a series of "Fatigue Propagation Curves" for ferrite pearlite structural steels that can be heat treated to following conditions:

Condition	Yield Strength(MPa)	K_{IC} ()
A	132	414
B	110	483
C	88	552
D	66	621

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The steel is to be used in a structure that will be subjected to a dead load stress $0.2\sigma_{ys}$ and alive load stress of $0.3\sigma_{ys}$. Assuming that the design curves for each condition are for an infinitely wide plate with an edge crack. Series of four design values are expected showing a relationship between initial crack size and propagation life.

III. Development Of An Algorithm

1. Start
2. Take inputs of yield strength and stress intensity factor for all conditions.
3. Take maximum load = dead load + live load, minimum load = dead load.
4. calculate critical crack length
5. Take crack step of Δa = 2.5mm.
6. Calculate a (average) = [a (initial) +a (final)] / 2.
7. Calculate Δk.
8. Calculate R and then dN.
9. Calculate ΣN by adding the previous values of dN.
10. Repeat steps 2 to 9 for conditions B, C and D.
11. Plot the semilog graph between a (initial) and ΣN with ΣN on the log scale for all conditions.
12. Compare the graphs and note the results and draw conclusions.

IV. Results And Discussions

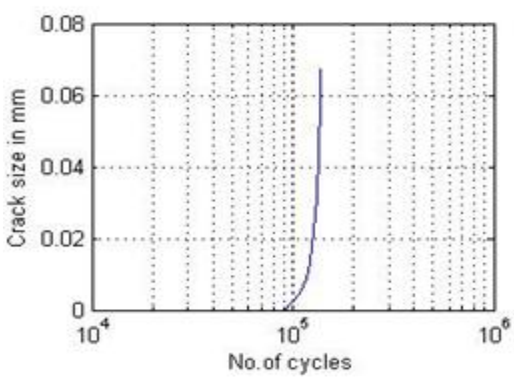

Fig 1(a)

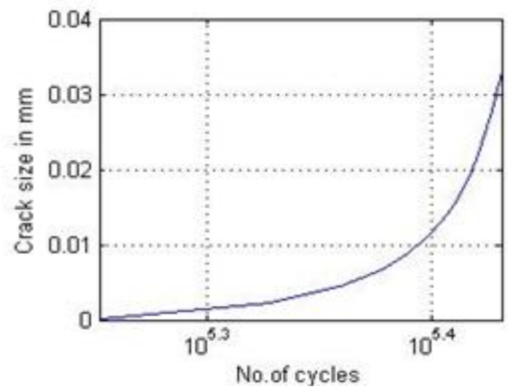

Fig 1(b)

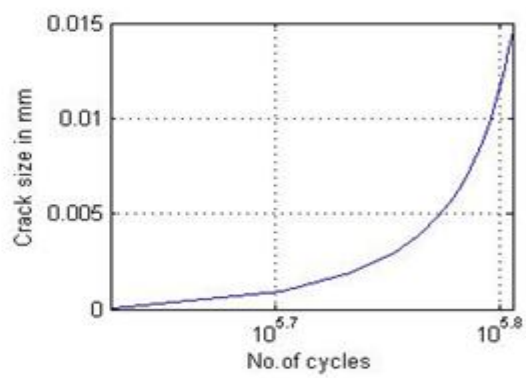

Fig 1(c)

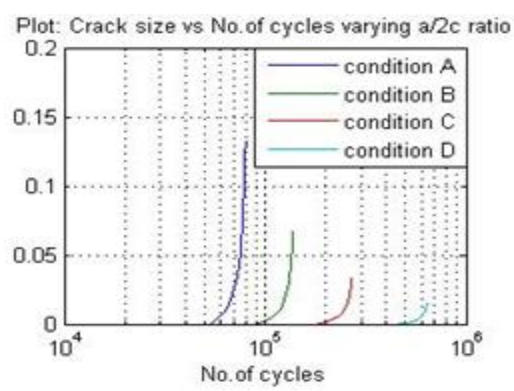

Fig 1(d)

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Fig 1(a,b,c,d)Subplot showing the comparison of crack size and propagation life for different conditions

1. It has been observed from the graph of crack size vs propagation life for condition A that the crack propagates up to 0.13 mm. Moreover the crack grows slowly during initial stage but it propagates at the faster rate later on.
2. Similarly for condition B crack propagates up to 0.07 mm and growth rate at initial stage is less in comparison to the growth rate at later stage.
3. Similarly for condition B crack propagates up to 0.04 mm and growth rate at initial stage is less in comparison to the growth rate at later stage.
4. Comparison of all the four stages is shown ie for condition A, B, C and D. It has been concluded that on increasing the value of yield strength failure takes place much earlier and vice versa.

V. PARAMETRIC STUDIES

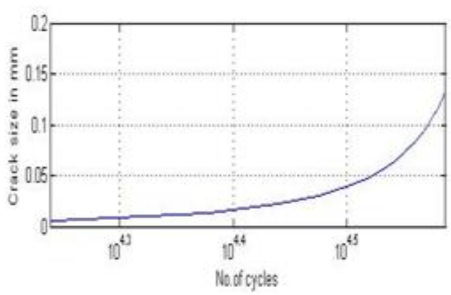


Fig 2(a)

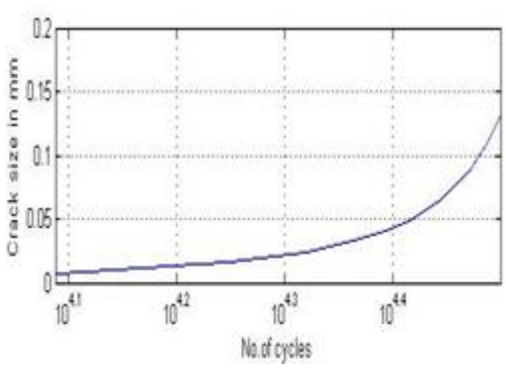
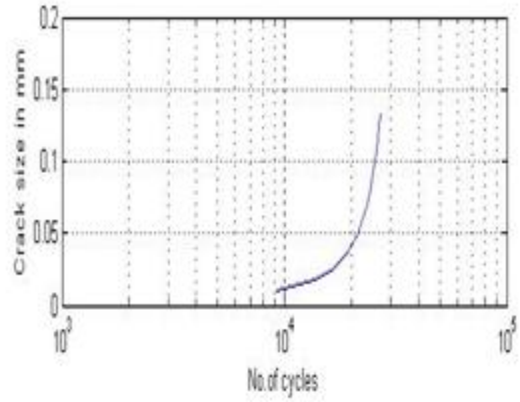


Fig 2(b)



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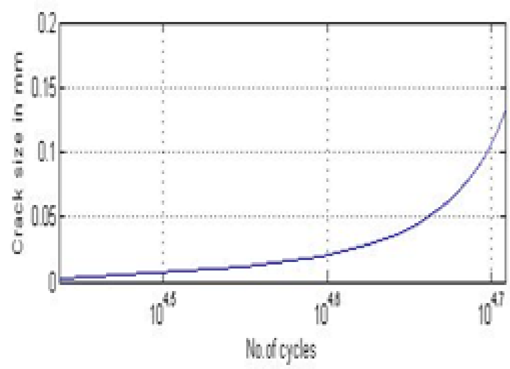

Fig 2(d)

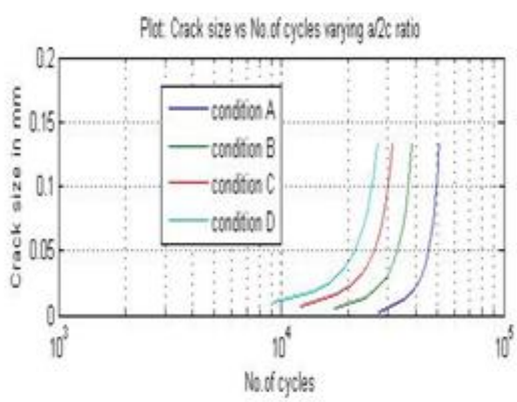

Fig 2(e)

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Fig 2(a,b,c,d,e) Subplot showing the comparison of crack size and propagation life for different condition A by varying the value of a/2c ratio.

VI. Graphs For Condition A By Varying The Value Of KIC

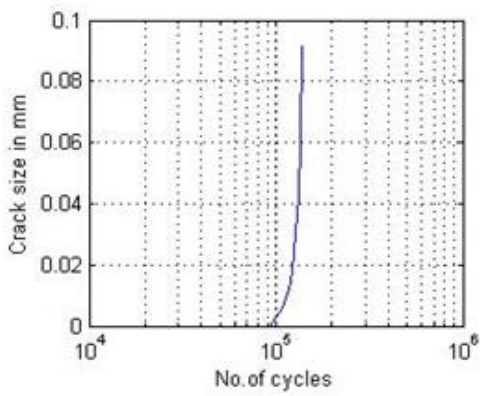

Fig 3(a)

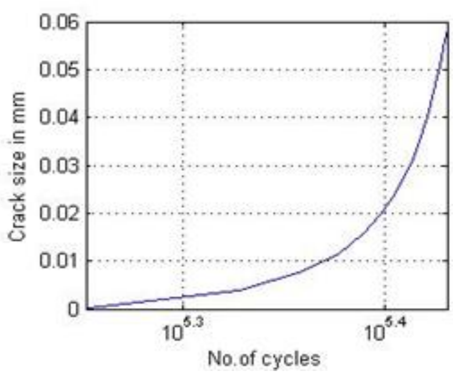

Fig 3(b)

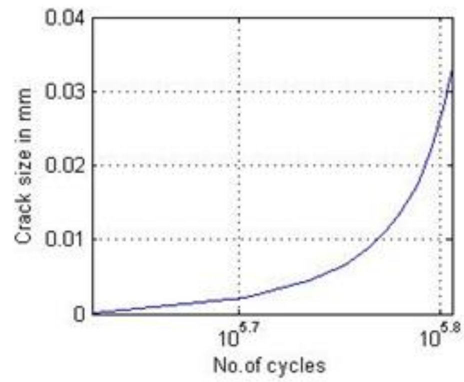

Fig 3(c)

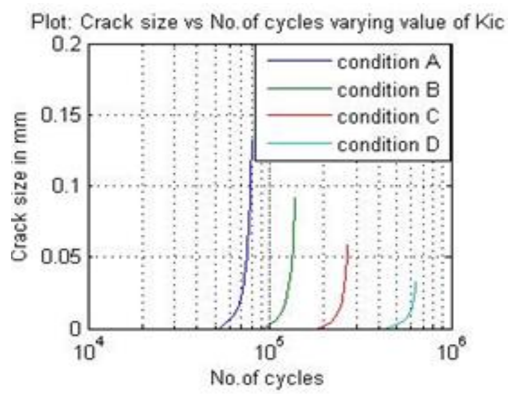

Fig 3(d)

Fig 3(a,b,c,d) Subplot showing the comparison of crack size and propagation life

VII. Conclusion

1. On comparing the three conditions A, B, C and D it has been concluded that the critical crack length for condition A is larger, for condition B it is smaller than A, for condition C it is smaller than B and for D it is least.
2. It has also been concluded that the condition A is the favorable condition among the given conditions from fatigue point of view.

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