Evaluation of Fatigue crack rate for thin plate using IF- then rule

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Abstract- In the present paper, fatigue crack rates (FCR) of very thin ASTM A240 grade 301L stainless steel sheet under the variable loading histories were predicted by IF-then rule. The FCR has been expected based on using existing experimental equations. The advantage of this proposed method is to estimate the growth rate of the crack initiation with the cycle relationship for each case study. A novel linguistic IF-then application also called rule based system are capable modeling for non-linear and thin plate to predict fatigue life. An automatic prediction application has been assumed to estimate the variable loading. Soft-computing methods show great potential for predicting the fatigue crack growth rate, especially with really data. The expected results were observed in complete agreement with experimental results from previous research when tested on the ASTM A240 alloy.

Keywords: Fatigue crack rate, thin plate ASTM A240, IF- then rule, variable loading

1. Introduction

Two kinds of crack behavior, i.e. crack initiation and propagation, are dependent upon several factors such as materials, geometry and load levels [1]. The crack growth in constructions depends on the amplitude, frequency of the load and stress ratio [2]. These interactions, which are highly dependent upon the loading sequence, make the prediction of fatigue life under VAL more complicate than under CAL [3]. Different models have been developed to predict the fatigue life of components which are subjected to VAL [4]. Fuzzy if-then rules are frequently employed to capture the imprecise modes of reasoning that play an essential role in the human ability to take decisions in an environment of uncertainty and imprecision [5]. These types of fuzzy rules have been used extensively in both modelling and control. Through the use of linguistic labels and membership functions, a fuzzy if-then rule can essentially capture the spirit of a "rule of thumb" used by humans. From another perspective, due to the qualifiers on the premise parts, each fuzzy if-then rule can be viewed as a local description of the system under consideration [6]. A fuzzy conditional statement is an expression of the form if A then B, where A and B are labels of fuzzy sets proposed by Zadeh as reported by [7] characterized by appropriate membership functions. The purpose is to set into motion the rules that function by different factors [8]. The common methods are the centroid, maximum, mean of maximum, height and modified height defuzzifier among others Mamdani and Assilian as reported in [9].

2. Rule-Based System

The rule based system model structure represented the three-layer network. ($a_1, a_2, a_3, b_1, b_2, 3_3$ *and* $c_1, 2_2, 3_3$) as a fuzzy set in layer 1, and it can be defined by three MF's. Each node in this layer is the membership rate. Layer 2 receives the product of all output pairs from the first layer. Layer 3 has two elements (upper element and lower element). The upper element uses the MF's to each of the inputs, while the lower element is a representation of the modular training network that calculates. the layer outputs for the two elements and to increase the rule based system final output with range between 0 to1 and -1 to1 and between -1 to1 under VAL. the fuzzy structure TS type of fuzzy model best fit's
multi-input $a, N, Kmax, \Delta Kmax$ and R and single-output *da/dN* system.

3. Structure Of Rule Based System

The shape of RBS structure used in the present paper, which is Takagi–Sugeno a first-order type. The system for given network analyses output data set through fuzzy 'IF-THEN 'rules. The optimal model input has been determined by hybrid-learning algorithms. The rule based system is a fuzzy Sugeno model put in the framework of adaptive systems to facilitate learning and adaptation [10]. Framework makes the RBS modeling more systematic and less reliant on human expert knowledge. To present the RBS structure, three fuzzy 'IF-THEN 'rules based on a first order Sugeno model are considered:

ISSN 1943-023X
Received: 5 Mar 2018/Accepted: 10 Apr 2018

Rule 1: If (x is a1), (y is 11) and (z is c1) then (f1 =1+ j1x + k1y + m1z + r1+1) (1)
Rule 2: If (x is a2), (y is 22) and (z is c2) then (f2 =1+ j2x + k2y + m2z + r2+1) (2)
Rule 3: If (x is a3), (y is 33) and (z is c3) then (f3 = 1+j3x + k3y + m3z + r3+1) (3)
For:
$j = 1 \ldots\ldots, S1, S2, S3 \ldots\ldots\ldots$
$k = 1 \ldots\ldots, S_{2,S3,S4} \ldots\ldots\ldots$
$m = 1 \ldots\ldots, S_{3,S4,S5} \ldots\ldots\ldots$
$i = 1, \ldots\ldots, S_1 \times S_2 \times S_{3 \times S4}$

Where x , y and z are the inputs, input x has S_1 membership function (mmf) denoted A_j, $j = 1 \ldots S_1$, input y has S_2 membership function (mmf) denoted as B_k , $k = 1 \ldots S_2$ and input z have S_3 membership function (mmf) denoted as C_m , $m = 1 \ldots S_3$, f_i , $i = 1 \ldots S_1 \times S_2 \times S_3$ are the sugeno FIS rules within the fuzzy region. Figure 1 shows the simple structure for the fuzzy system structure has been used to obtained the FCGR.

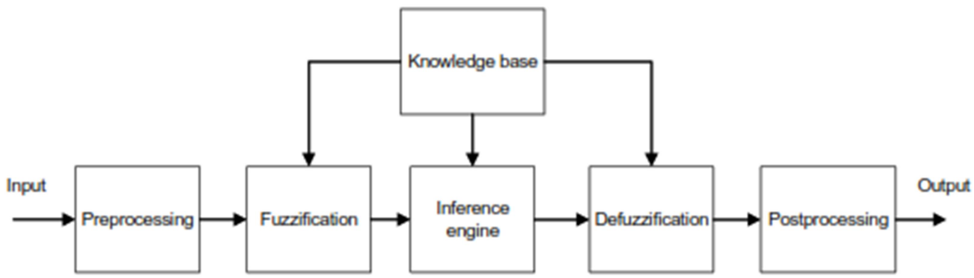

Figure1. Fuzzy processing system

4. Result And Discussion

Rule based system model is implemented by using the MATLAB environment (Fuzzy Logic Toolbox).A MATLAB code has been developed to create a static customized rule based system model. Three input have been choosing to the system (crack length, stress intensity factor range (*ΔK*) and is the stress ratio *(R)*. The mechanical and cyclic material properties, i.e. crack growth constant, the Paris exponent, the fracture toughness and the threshold stress intensity range that's almost got it from the experiment which was used in FCG prediction models after applying the loading are listed in Table 1.1. and obtained by least-squares fitting. After the tensile test to analyse the sample failure process. Figure 3 may also clearly notice small tensile dimples as well as splits and voids on the fracture surface of the sample. Figure 4. The samples used is heat treated, and through the tensile process have been observed more roughness on the surface as well as rupture in some of the dimples.

Specimen thickness	R	C	m	ΔK_{th}	K_C
0.1mm	0.5	1×10^{-9}	1.8	9	140
0.1mm	0.2	1×10^{-9}	1.8	20	113

Table 1 Parameters of the fatigue crack growth models

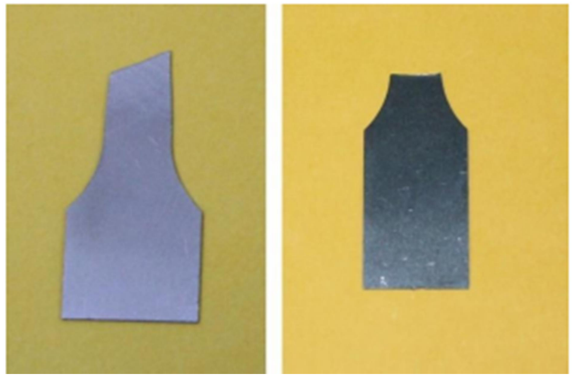

Figure2. Thin plate fracture shape after (a) tensile (b) fatigue.

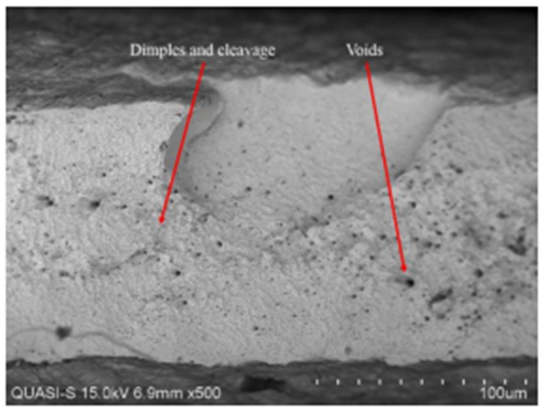

Figure3. SEM fracture tensile for A240 stainless steel sheet (500X magnification).

For the purpose to study the alloy structure behavior for tensile and fatigue test has been used SEM technique as we explained in the previous section. The second section discusses the results after using the experimental cyclic and cyclic material properties in the rule based system. Based on the simulation results. Therefore, it can be concluded that the results obtained after using the IF-then rule represent the better results when compared with the results obtained and depends on the experimental fatigue test for the same material and the difference lies in the operating conditions, manufacturing as shown in Fig.5 and 6., servicing process as well as the material structure. The differences are related to the results presented in the a-N curves for stress ratio 0.5 and 0.2 respectively, easy to observe the life when using 0.5 stress ratio in such a alloy thickness.

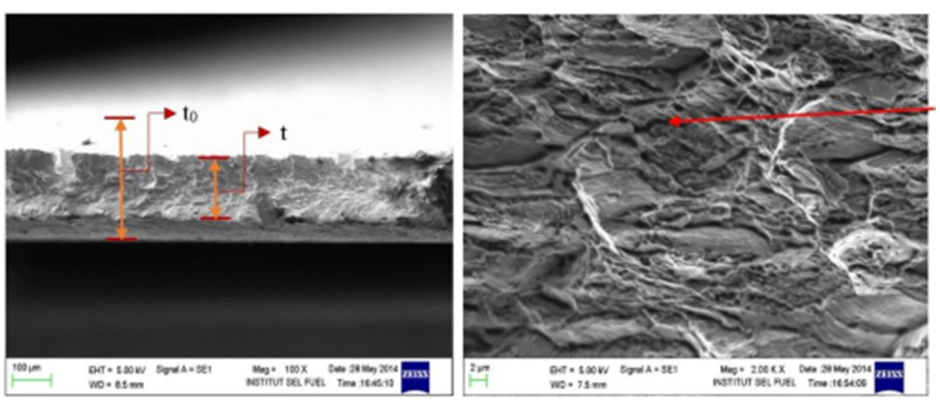

Figure4. SEM fracture surface of heat treated of A240 stainless steel
((a) 100 X magnification and (b) 2000Xmagnification.0

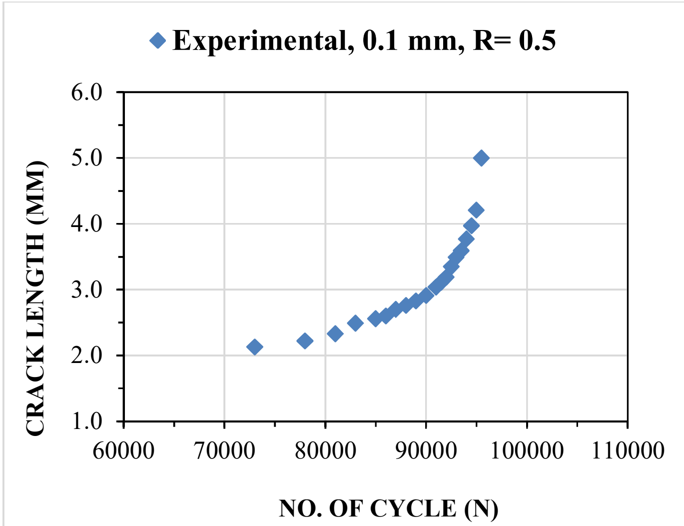

Figure.5. FCG for experimental 0.1mm, R=0.5

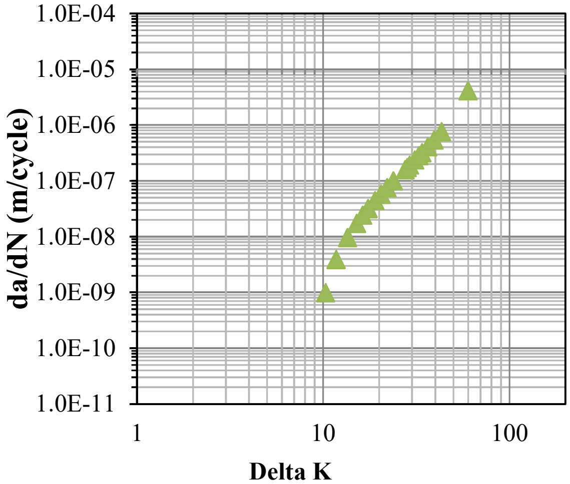

Figure.6. FCG rate for experimental 0.1 mm , R=0.5

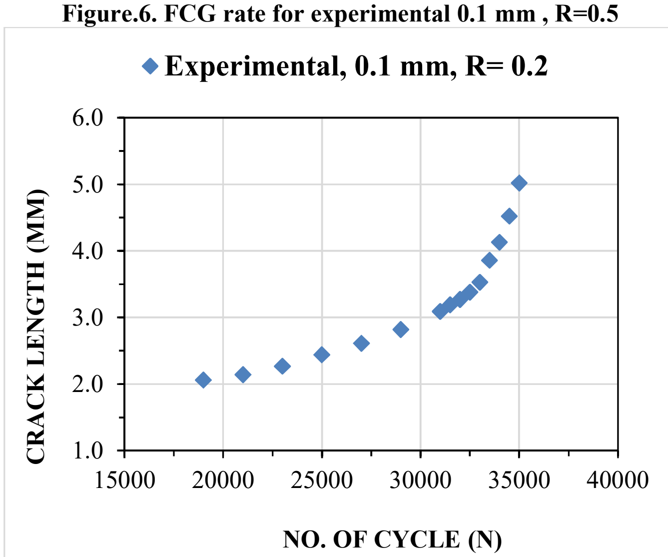

Figure7. FCG for experimental 0.1mm, R=0.2

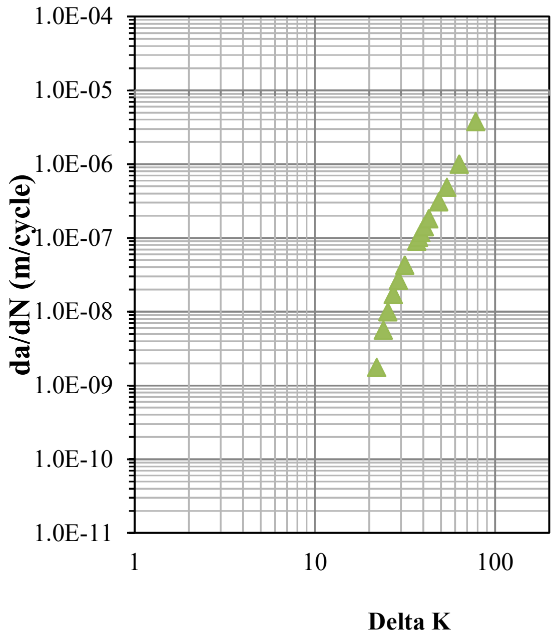

Figure8. FCG rate for experimental 0.1 mm , R=0.2

5. Conclusion

The main objective in the present work is to finding and develop the a appropriate and new method to estimate the crack growth as well as predict the growth rate of the cracks and their behavior. Rule based system(RBS) can provide precise representations of the CGR, Δ K ranges and stress ratio (R) from laboratory test data measurements with reasonable learning speed and high accuracy in comparison to other prediction methods as well as the fatigue models under different loading. It is important to note that the RBS method closely emulate the FCG rate experimental data over the entire data domain. This reveals that the IF-then rule method give a much better performance than fatigue models in terms of percentage within engineering error. The RBS method by initial learning conditions optimized can learn crack growth rate *daldN*. Data pre-processing method which assurances the mutual individuality of input datasets recovers learning speed and simplifying capacity of rule based system much more than fatigue models.

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