ISSN 2176-5480

22nd International Congress of Mechanical Engineering (COBEM 2013)
November 3-7, 2013, Ribeirão Preto, SP, Brazil

ON THE RATIO DEPENDENCE OF ΔK_{TH} FOR FATIGUE CRACK GROWTH IN ASTM A743 CA6NM

Marcus Vinícius Costa Sá
Universidade de Brasília
marcuscsa@gmail.com

Jorge Luiz de Almeida Ferreira
Universidade de Brasília
jorge@unb.br

José Alexander de Araújo
Universidade de Brasília
alex07@unb.br

Braitner Lobato da Silva
Universidade de Brasília
lobatodecristo@yahoo.com.br

Abstract. *According to linear elastic fracture mechanics, the fatigue crack growth rate (FCG) da/dN can be related to the stress intensity factor range ΔK. Analyzing the region I of the curve da/dN versus ΔK, as ΔK decreases, the value of crack growth rate is reduced significantly until reaches the* ΔK_{th}*, defined as the stress intensity factor range at which the crack growth rate approaches to* 10^{-10}*m/cycle. This region of the curve is strongly affected by microestructure, environment, R ratio and crack tip constraints, such as overloads, cold work etc. In the present work, the influence of R ratio in the range 0.05- 0.66 on the ambient temperature fatigue crack growth behavior of a martensitic stainless steel, ASTM A743 CA6NM, has been studied. The tests were conducted in a servohidraulic machine at a frequency of 25 Hz, using Compact Tension (CT) specimens in the following levels of R ratio: 0.05, 0.1, 0.33, 0.5 and 0.66. Using a clip gage, the length of the crack was measured by the method of compliance. The experiment was replicated for which level of R. Results showed that the cyclic threshold intensity factor* ΔK_{th} *increased with decreasing R ratio.*

Keywords: *fatigue crack growth, threshold, ASTM A 743 CA6NM, R ratio*

1. INTRODUCTION

Usually, structures and mechanical components are designed to have infinity life against fatigue which is a progressive and permanent damage that occur in the material in presence of cyclic loads. However, in many practical situations the presence of crack is observed in many materials applied in engineering. In this context, the Theory of Fracture Mechanics provides tools to deal with components that have defects such as cracks and voids. The Fig.1 shows a crack that appeared in the blade of hydraulic power generator, after 10.000 hours of use.

Figure 1. Crack in the blade of a hydraulic power generator.

This way, the main purpose of this work is to evaluate the influence of the load ratio on the ΔK_{th}, the value of range of stress intensity factor that causes no crack propagation.

ISSN 2176-5480

2. MATERIALS AND METHODOLOGY

The material analyzed was the martensitic alloy steel ASTM A743 CA6NM. The presence of the elements Chromium and Molybdenum gives good properties while operating in severe conditions of corrosion. The Tab.1 presents the composition of the alloy steel. The Tab.2 shows the mechanical properties of the alloy.

Table 1. Chemical composition of ASTM A743 CA6NM (ASTM, 2003).

Chemical Element	%wt	Chemical Element	%wt
Iron, Fe	82,9~88,1	Manganese, Mn	≤ 1,0
Carbon, C	≤ 0,06	Phosphorus, P	≤ 0,04
C**hromium**, Cr	11,5~14,0	Silicon. Si	≤ 1,0
Ni**ck**el, Ni	3,5~4,5	Sulfur, S	≤ 0,03
Mol**ybdenum**, Mo	0,4~1,0		

Table 2. Mechanical properties of ASTM A743 CA6NM (ASTM, 2003).

MECHANICAL PROPERTIES	
Modulus of Elasticity	201 GPa
Yield Tensile Strength, min	550 MPa
Ultimate Tensile Strength, min	755 MPa
Brinell Hardness, max	285 HB
Poisson **Ratio**	0,30

The tests were performed using Compact Tension Specimen (CT), showed in Fig.2. The main dimensions are listed in Tab.3.

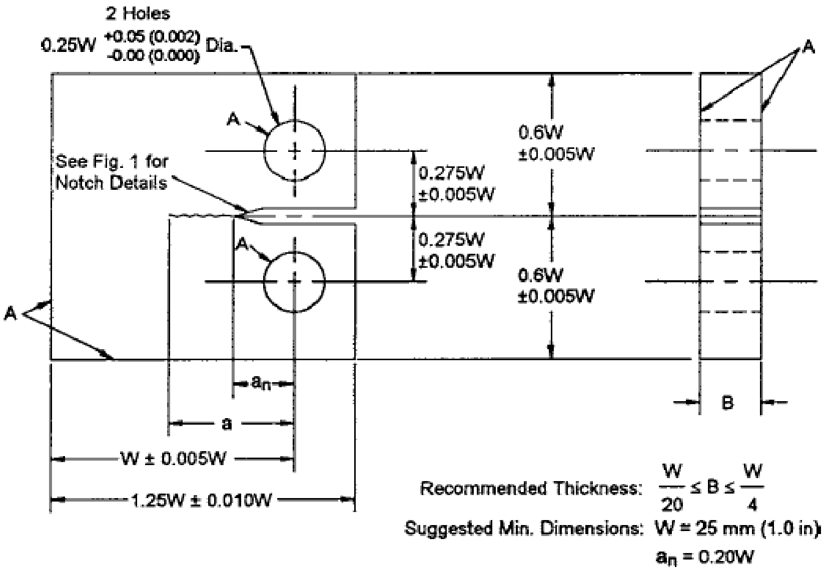

Figure 2. Scheme of compact tension specimen (ASTM, 2011).

Table 3. Main dimensions of the CT specimen.

Component	Dimension (mm)
W	50,0
b	12,5
a_n	10,0
D	12,4

ISSN 2176-5480

The fatigue crack propagation tests were performed in a MTS 810 servohidraulic machine, according to the ASTM E647 standard, at 25 Hz of frequency, controlling the decrease of ΔK. The crack length was measured by the compliance method using the bellow equation:

$$a = \frac{1}{W}\left(C_0 - C_1 \cdot u_x + C_2 \cdot u_x^2 - C_3 \cdot u_x^3 + C_4 \cdot u_x^4 - C_5 \cdot u_x^5\right)$$

where a is the crack length, W is a characteristic length of the specimen and the constants C_0, C_1, C_2, C_3, C_4, and C_5 where calculated by Saxena (1977). The value of u_x is obtained by the equation showed below:

$$u_x = \left[\left(\frac{Evb}{P}\right)^{\frac{1}{2}} + 1\right]^{-1}$$

where E is the modulus of elasticity of the material, P is the applied load and v is the crack opening displacement, given by a clip gage, showed in Fig 3, putt in a position inside the crack mouth.

Figure 3. Clip gage.

For each load ratio, the fatigue crack growth tests were replicated. The Tab.4 shows the load ratios applied in each specimen tested.

Table 4. Specimen and respectively load ratio during test.

Specimen	Load Ratio, *R*	Specimen	Load Ratio, *R*
CP 01	0,10	CP 07	0,05
CP 02	0,33	CP 08	0,05
CP 03	0,50	CP 09	0,33
CP 04	0,66	CP 10	0,50
CP 06	0,10	CP 11	0,66

3. RESULTS

The Fig. 4 shows the relationship between fatigue crack growth rate, *da/dN*, and the range of stress intensity factor, ΔK, at different load ratios.

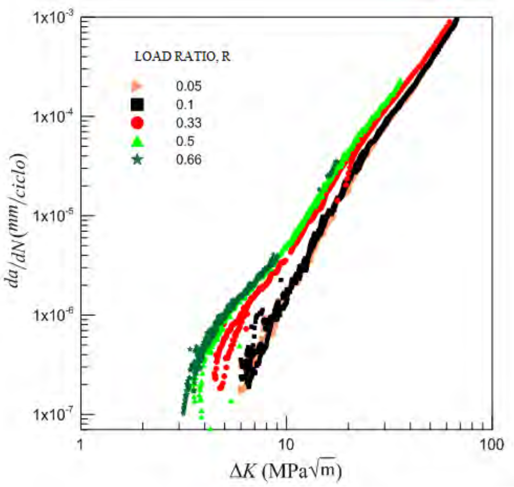

Figure 4. Graphic *da/dN versus* ΔK.

It can be observed that *da/dN* changes almost linearly with ΔK at all load ratios when *da/dN* is above 10^{-5}mm/cycle. In the loading –shedding process, the value of da/dN accordingly. However, for *da/dN* below 10^{-5}mm/cycle, *da/dN* varies nonlinearly with with ΔK, and ΔK reduces slowly. The larger the load ratio, the higher *da/dN*. The range of stress intensity factor at which the crack growth rate reached the value 10^{-7} mm/cycle was defined as the ΔK_{th}. The Tab 5 shows the values ΔK_{th} for the 5 different load ratios studied.

Table 5. Values of ΔK_{th} .

R	CP	ΔK_{th}		
		Avarege	Min limit	Max limit
0,05	7	5,67	4,63	6,94
0,05	8	5,39	4,76	6,12
0,10	1	5,57	5,27	5,88
0,10	6	5,39	4,54	6,39
0,33	2	3,43	2,76	4,28
0,33	9	4,73	2,49	8,99
0,50	3	2,85	2,24	3,63
0,50	10	3,98	2,78	5,72
0,67	4	2,87	2,58	3,19
0,67	11	2,79	2,60	3,00

4. CONCLUSIONS

Ten valid crack propagation tests were performed in order to evaluate the influence of the load ratio on the value of ΔK_{th} for the martensitic alloy steel ASTM A 743 CA6NM. The values of ΔK_{th} have been found for the following load ratios: 0.05; 0.1; 0.33; 0.5 and 0.66.It has been quantified that ΔK_{th} decreases while the load ratio is increased in interval of ratios analyzed.

5. REFERENCES

ASTM, 2003. "*Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application*"**.**In: ASTM A 743/ A743M -2003.

ASTM, 2011. "*Standard Test Method for Measurement of Fatigue Crack Growth Rates1*"**.**In: ASTM E 647-2011.

Saxena, A.; Hudak JR., S. J, 1977."*Review and extension of compliance information for common crack growth specimens*"**.** *International Journal of Fracture.* Vol. 14. No. 5.

6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.