COMPUTER CODE FOR CALCULATING THE FACTOR OF SAFETY AGAINST FRACTURE AND THE FATIGUE CRACK PROPAGATION

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In steam pipes from the Romanian thermoelectrical power station part through cracks are detected frequently, with a certain nondestructive techniques. Thus, it's important to establish the safety of pipe in exploitation and the fatigue crack propagation of a longitudinal internal part through crack, from a pipe subjected to internal pressure.

Finally, we present a concrete example for a pipe.

INTRODUCTION

In steam pipes from the Romanian thermoelectrical power station part through cracks are detected frequently, with a certain nondestructive techniques. Because to replace the damage part of a pipe or the whole pipe is expensive, it is necessary to establish the safety in use of pipe and the evaluation in time of fatigue crack propagation. It is useful to obtain quick and good results using Computer CODE's.

We present a Computer CODE which permits to determine the safety factor against fracture and the fatigue crack propagation for a longitudinal part through crack from a pipe subjected to internal pressure (Fig.1).

The safety of pipe in exploitation is given by safety factor C_K:

$$C_K = K_{IC}/K_{I\max} \qquad (1)$$

The maximum and minimum stress intensity factor for a longitudinal part through crack is given in reference (1):

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$$K_{I\max,\min} = 1.12\sqrt{\pi}\,\sigma_{\max,\min}M_K(a/Q_{\max,\min})^{0.5} \qquad (2)$$

where:

$$Q_{\max,\min} = \Phi^2 - 0.212(\sigma_{\max,\min}/R_{p0,2})^2 \qquad (3)$$

$$\Phi = \int_0^{\pi/2} \sqrt{1 - [1 - 4(a/2c)^2 \sin^2\theta}\, d\theta \qquad (4)$$

The Computer CODE makes the calculus of stress σ_{max} ,σ_{min} function of ratio Ri/h:

- for pipes with thin wall (Ri/h < 10):

$$\sigma_{\max,\min} = (Ri/h)p_{\max,\min} \qquad (5)$$

- for pipes with thick wall (Ri/h > 10):

$$\sigma_{\max,\min} = [(Ri^2 + Re^2)/(Re^2 - Ri^2)]p_{\max,\min} \qquad (6)$$

Determination of fatigue crack propagation keeps in view to calculate number of cycles until the maximum stress intensity factor K_{Imax} reaches the fracture toughness value K_{IC}, or until the crack pierces the whole pipe wall.

If it is known the number of cycles of stress from a day (or year), the CODE is able to determine the number of years until the maximum stress intensity factor K_{Imax} reaches the fracture toughness value K_{IC} or until the crack pierces the whole pipe wall.

For determination the crack growth rate we accepted the law

$$da/dN = C(\Delta K_I)^m/(1 - Rs)^{0.5} \qquad (7)$$

The number of cycles growth ΔN when crack growth with Δa is:

$$\Delta N = \Delta a(1 - Rs)^{0.5}/C(\Delta K_I)^m \qquad (8)$$

and the total number of cycles is:

$$N = \Sigma \, \Delta N \quad (9)$$

Number of years who corresponds to N cycles of loading is:

$$A = N / n_C \quad (10)$$

THE COMPUTER CODE

The Computer CODE made by authors is written in QBASIC. The input data is: geometry of pipe (internal radius Ri, external radius Re, thickness h), crack length a_0, material constants (yield stress $R_{p0,2}$, critical stress intensity factor K_{Ic}, and fatigue constants C and m), work conditions (p_{max} and p_{min}).

The CODE allows:

- determination of the safety factor against fracture
- determination of the number of cycles until the maximum stress intensity factor K_{Imax} reaches the fracture toughness value K_{IC}, or until the crack pierces the whole pipe wall.
- determination of the number of years until the maximum stress intensity factor K_{Imax} reaches the fracture toughness value K_{IC}, or until the crack pierces the whole pipe wall.

The results of the CODE are graphically presented $C_K = f(a)$, $K_{Imax} = f(a)$, $N = f(a)$ and $A = f(a)$.

For calculating the elliptical integral we are using a numerical alghoritm based by Gauss quadrature.

A concrete example . In Fig.2, 3, 4, are shown the results obtained for a steam pipe, from a Romanian thermoelectrical power station, with a longitudinal part through crack.. The input data is Ri=120 mm, Re=158 mm, h=38 mm, a_0 =5 mm, $R_{p0,2}$=245 MPa, K_{IC}= 3000 N/mm$^{3/2}$, m=2.25, C=0.66 10^{-8}, p_{max}=12 MPa, p_{min}=8 MPa.

CONCLUSIONS

From the diagrams presented in Fig.2.3,4 for the studied example results the following:

- even when the crack had pierced the pipe's wall, the safety factor has high values;
- to get to pierce the pipe's wall, it is necessary a big number of years;

- the steel from which is made the studied pipe presents a very good fracture toughness.

SYMBOLS USED

a = crack length (mm)

a_0 = initial crack length (mm)

Δa = crack growth (mm)

A = number of years (years)

C_K = the safety factors

C = empirical material constant

da/dN = crack growth rate (mm/cycle)

Φ = the elliptic integral of the second kind

h = the wall pipe thickness (mm)

K_{IC} = fracture toughness ($N/mm^{3/2}$)

K_{Imax}, K_{Imin} = maximum, minimum stress intensity factor ($N/mm^{3/2}$)

ΔK_I = the stress intensity factor range ($N/mm^{3/2}$)

m = empirical material constant

M_K = the magnification factor

n_C = number of cycles of load from one year

ΔN = number of cycles growth (cycles)

$p_{max,min}$ = maximum, minimum pressure (MPa)

Q_{max}, Q_{min} = maximum, minimum crack shape parameter

Ri = the internal radius of the pipe (mm)

Re = the external radius of the pipe (mm)

Rs = the stress intensity factor ratio

$\sigma_{max, min}$ = maximum, minimum stress from pipe (N/mm^2)

da/dN = crack growth rate (mm/cycle)

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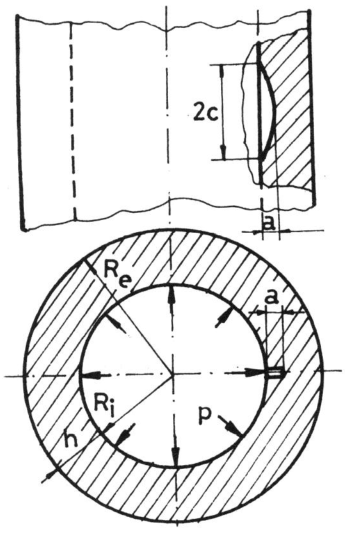

Figure 1 Geometry of pipe with longitudinal crack

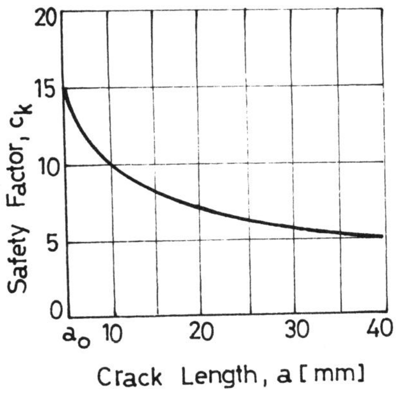

Figure 2 Variation of safety factor with crack length

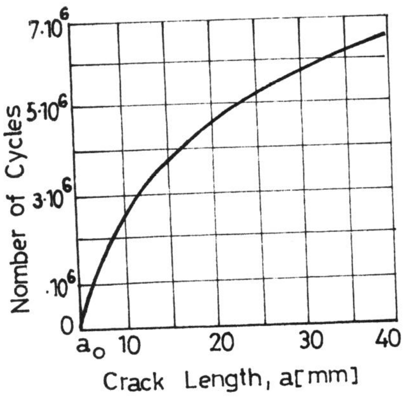

Figure 3 Variation of total number of cycles with crack length

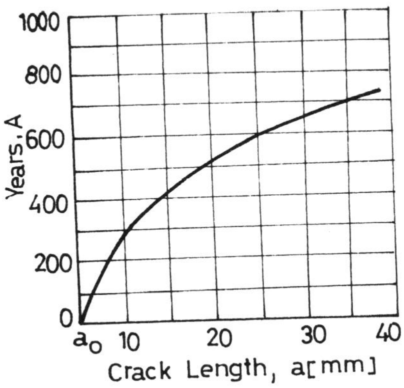

Figure 4 Variation of number of years with crack length