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Method of real-time assessing of life of HP heater tube-plate in Power Plants

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Abstract

In large power plants, in order to improve safety and stability of HP heaters(High Pressure) in operation, thicker tube-plates are designed and made, which will lead to more thermal stress between tube-plate and end-cover, furthermore, will reduce the thermal fatigue life of HP heaters sharply. so it is necessary to monitor the thermal fatigue its life. However, at presently a large portion of methods carry on calculating or analyzing beforehand or afterwards, which make effect of analyzing life being less greatly. In this paper, according to the theory of calculation of thermal fatigue life, real-time gathering tube-plate's temperatures, and computing the life everyday, provide the basis of operating and maintaining in the power plate.

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1. Introduction

HP heaters is one of important part in feed water system in power plant, and heat feed water to a boiler with the steam extraction from steam turbine, which improve the efficiency of power plant. For long time past, the leak of HP heaters occur now and then, especially, the HP heaters in the large power plants, the case is more serious than others.

2. Theoretical analysis of HP heaters

2.1. The methods of fatigue design

Evolution of life is a important link in projects and management of life-time cycle time of equipments. It is the basis of the interval of time between overhauls and economical operation, what is more, its purpose is to avoid contingent crisis or great expense.

Two aspects can be considered on high temperature equipments of power plants:

- High temperature creep;(to HP heaters, its temperature is low, and its creep can not creep.)
- Low cycle fatigue.

2.2. Low cycle fatigue life

Based on the practices, the method of low cycle design curve is used abroad and the method is used to obtaining the relation curve between material stress or strain and the cycle number of fracture.

The mathematical expression is,

$$\sum_{i=1}^m \frac{n_i}{N_i} \leq 1 \tag{1}$$

where,

m—the type number of cycle in single condition;

n_i —the number of type I of cycle in single condition;

N_i —the number of type I of permitted cycle in single condition.

Thick plate thermal stress formula:

$$\sigma_x = \sigma_z = -\frac{aET}{1-\gamma} + \frac{1}{2c(1-\gamma)} \int_{-c}^c aET(y)dy + \frac{3y}{2c^3(1-\gamma)} \int_{-c}^c aET(y)dy \tag{2}$$

where,

C—a half thickness of plate

2.3. Rainflow method-circuit line method for solution of life

Generally Rainflow method is a counting method of the closest actual condition, because it can record whole and closed cycles. When life calculated with local stress and strain, Rainflow method is almost a most actual method.

2.4. The process of calculation

- Rainflow flow with the first point of experiment record , and along next edge of the curve of experiment record, namely from point 0 and edge 1-2,as shown in Fig.1;
- When Rainflow meet with the peek of the curve, Rainflow drop next bigger peek value or smaller peek value, until meet with the biggest value;
- When meet with the Rainflow form the above one, the Rainflow will stop flowing;
- Find all half cycles of stress fluctuation, and record the amplitudes;
- According to all half cycles and the amplitudes, calculate the life of material.

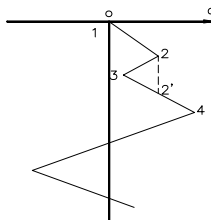


Figure 1. reduced graph of the method Rainflow

Case1:

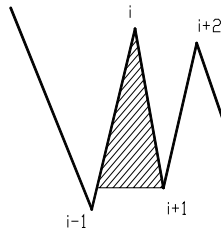


Figure 2. The curve in case1

If $(S_{i-1}-S_{i+1}) (S_{i+2}-S_i) > 0$ and $S_{i-1}-S_{i+1} > 0$, then

$$S_a = \frac{|S_{i+2} - S_{i+1}|}{2} \tag{3}$$

$$S_m = \frac{|S_{i+1} + S_{i+2}|}{2} \tag{4}$$

Remove point S_i and point S_{i+1} , as shown in Figure2

Case 2:

If $(S_{i-1}-S_{i+1}) (S_{i+2}-S_i) > 0$ and $S_{i-1}-S_{i+1} < 0$, then

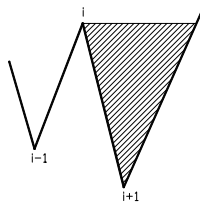


Figure 3. The curve in case2

$$S_a = \frac{|S_{i+1} - S_i|}{2} \tag{5}$$

$$S_m = \frac{|S_{i+1} + S_i|}{2} \tag{6}$$

Remove point S_i and point S_{i+1} , as shown in Figure3

Case 3:

If $(S_{i-1}-S_{i+1}) (S_{i+2}-S_i) < 0$ and $S_{i-1}-S_{i+1} > 0$, then

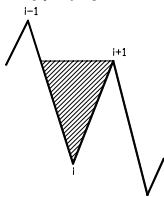


Figure 4. The curve in case3

$$S_a = \frac{|S_{i+1} - S_i|}{2} \tag{7}$$

$$S_m = \frac{|S_{i+1} + S_i|}{2} \tag{8}$$

Remove point S_i and point S_{i+1} :as shown in f.4

Case4:

If $(S_{i-1}-S_{i+1}) (S_{i+2}-S_i) < 0$ and $S_{i-1}-S_{i+1} < 0$, then

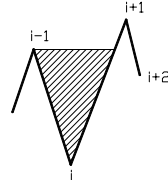


Figure 5. The curve in case4

$$S_a = \frac{|S_{i+1} - S_i|}{2} \tag{9}$$

$$S_m = \frac{|S_{i+1} + S_i|}{2} \tag{10}$$

Remove point S_{i-1} and point S_i :as shown in Figure5

3.Actual calculation of HP heaters

3.1.Life of curve

According to the TableI.

Table I The relation between stress and the number of cycle times

type	time(s)	Stress intensity(MPa)	Stress amplitudes (MPa)	Cycle Number permitted
1	3600	431	216	20000
2	10	789	395	4000
3	30	758	379	4000
4	180	1190	595	800
5	60	1260	630	800

Linear regression,

$$\epsilon N^{0.2169} = 0.012912 \tag{11}$$

When $N = 10^7$, then $\sigma = 76\text{MPa}$, $\epsilon = 0.000391465$, $\Delta T = 62^\circ\text{C}$.

Namely when $\sigma < 76\text{MPa}$, $\epsilon < 0.000391465$, $\Delta T = 62^\circ\text{C}$, tube-plate will not cost its life caused by thermal stress.

3.2. Calculation of Current low cycle fatigue life

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Current life

$$\sum_{i=1}^m \frac{n_i}{N_i} = S \tag{12}$$

m—the type number of cycle in single condition;

n_i —the number of type I of cycle in single condition;

N_i —the number of type I of permitted cycle in single condition.

According to (1), we get,

$$N_i = \frac{1}{0.2169} \ln \frac{0.012912}{0.5\varepsilon} \tag{13}$$

$$\varepsilon = a\Delta T = 12.6 \times 10^{-6} \Delta T \tag{14}$$

Replacing ε in (13) by (14), we get

$$N_i = \frac{1}{0.2169} \ln \frac{0.012912}{6.3 \times 10^{-6} \Delta T_i} = \frac{1}{0.2169} \ln \frac{2048}{\Delta T_i} \tag{15}$$

According to (15), a change of ΔT_i will lead to a life loss. Value of life loss is equal to $\frac{1}{N_i}$.

3.3. Method of treatment of temperature curve

Not all of curves can be calculated conveniently by the method of Rainflow. For example, Actual temperature cure is not too smooth to analyze it, which includes a lot of high frequency small perturbations. In order to use the method of Rainflow, the following method is adopted.

When Get a value of temperature, the value of temperature must meet with the following formula:

$$|T_i - T_{i+1}| > T_{\min} \tag{16}$$

When the value can not meet with the formula (16), the value will be thought about, and then read next value of temperature again.

If T_i always is invariable during tkp ,then $\Delta T = |T_i - T_0|$ can be just calculated once, namely a half life of ΔT is calculated, not one life;

If $T_{i+i} = T_0$, then $\Delta T = |T_i - T_0|$ (T_i is the highest value during the whole process.) life can be just calculated once too;

If $T_i < 62 + T_0$ (T_i is the highest value during the whole process.), then the loss of life is zero, no matter any cases.

3.3. Actual application

Temperature values came from temperature value of inlet water temperature、value of outlet water temperature、 steam temperature in saturated pression.the following Figure6 is side view of HP heaters. In the center of tube-plate in the Figure6, temperature sensor is placed evenly.

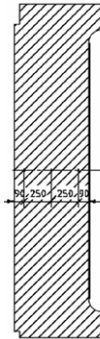


Figure 6. Side view of HP

These Values come into DCS (Distributed Control System) and SIS (Supervisor Information System) obtain data from DCS then relay or save these data. Assessing System for Life of HP heaters obtain related data from SIS at regular intervals, and then it carry on calculating the loss of HP hearters.Every day it can create a value of assessing life for HP heaters.Finally,by the value of assessing life every day, the system draw a curve of life for HP heaters. The results are the following.



Figure 7. Life curve drawn by Assessing System for Life of HP heaters

Figure7 draw life curve during 208.4-2010.10.according to the loss、 the trend and fluctuation of curve during the period, the result correspond to ones which is analyzed and calculated.

4. Conclusions

From the results of analysis to the results of calculation, we can see, it is correct on the whole that the methods carry on calculation of the tube-plate life, although amount of calculation is different from others. However, there are some aspects which should be researched further. For example, value of thermal stress is obtained better and more truly. What is more, according to theoretic calculation on life and actual operation, under the condition of steady rate of temperature change(<3 °C/Min),it is feasible that a large

size of the tube-plate is adopted in HP heaters of large power plants, and it can be working for long time too.

Acknowledgment

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