DETERMINATION ON FORCES AND MOMENTS IN PIPE CROSS-SECTIONS: FITTING OF EXPERIMENTAL STRAIN MEASUREMENTS ON A MECHANICAL ANALYTICAL MODEL

A. CAUSSE - J.L. TROLLE

ELECTRICITE DE FRANCE - Direction des Etudes et Recherches - Département R.E.M.E. - 25, Allée Privée - Carrefour Pleyel - 93206 SAINT DENIS

1. INTRODUCTION

The higher unit power of nuclear plants compared with conventional thermal power plants, leads to a considerable increase in steam flow rate. Pipe diameters must be bigger, thus exerting not-well-known forces and moments on the main components of the feedwater heating system particularly on pumps. It is useful to verify that these efforts are in agreement with the designing requirements of the secondary system.

The method described in this paper deals with the determination of forces and moments in pipe cross-section. Two major difficulties occur in performing this method:

- since the values of forces and moments cannot be directly measured, they are inferred from strain measurements taken on the outer wall of the piping; foil strain gauges are used.

- strains are small, and thermal conditions vary according to pump operating conditions. Temperature-induced apparent strain should be accurately estimated, since the measured strains are of the same order of magnitude.

FIGURE 1 - DIAGRAM OF A FEEDWATER PUMP

As an example, some results are shown regarding the efforts on the suction and discharge pipes of a feedwater pump of a 900 MW PWR nuclear power plant.

2. MECHANICAL ANALYSIS
The efforts are given by a theoretical model of strain distribution in a pipe section. The relationship between the efforts and the strains is based upon:
- the Euler-Bernoulli beam theory for the components of forces and moments (tension-bending-torsion),
- the thin shell theory for hydrostatic and thermal loading (linear expansion-through-wall temperature profile).

In a cylindrical coordinate system \((r, \theta, z)\), the theoretical strains \(\varepsilon_{\text{th}}\) are sinusoidal functions of angle \(\theta\) on which the measured strains \(\varepsilon_{\text{mi}}\) of a rosette \(R_j\) (figure 2) are fitted.

![FIGURE 2 - DIRECTION OF THE STRAINS](image)

Seven coefficients \(C_i\) are defined. Each coefficient characterizes a single loading. One obtains the following equations:

\[
\begin{align*}
C_1 &= \frac{E_4}{E_S} \\
C_2 &= \frac{R_e}{E_I} \left[ T_2 \sin(\theta) - T_3 \cos(\theta) \right] \\
C_3 &= (1+\nu) \frac{R_e T_1}{E I_0} \\
C_4 &= -(1+\nu) \frac{R_e^2 + R_e R_i + R_i^2}{3 E I} \left[ E_3 \cos(\theta) + E_2 \sin(\theta) \right] \\
C_5 &= \frac{2 P_i R_i^2}{E (R_e^2 - R_i^2)} \\
C_6 &= \varepsilon_{\text{ap}} \\
C_7 &= \frac{\alpha}{2 (1-\nu)} \left[ T_{\text{int.}} - T_{\text{ext.}} \right]
\end{align*}
\]