ANNALS of the ORADEA UNIVERSITY.

Fascicle of Management and Technological Engineering, Volume VI (XVI), 2007

THE ESTABLISHEMENT OF THE BONDING MATRIX BETWEEN SPECIFIC DEFORMATIONS AND DISPLACEMENTS (THE MATRIX B) FOR CALCULATION TO CREEP OF THE PIPE-LINE SYSTEMS. PART: II

Niculae GRIGORE
Petroleum and Gas University, Ploieşti,Roumania

Key words :pipe-line, tension, creep

Abstract
The paper draws upon the establishment of the bonding matrix between specific deformations and displacements (matrix B).

.

1. The principal stages for watching calculating the displacements and the tensions at creep

The first stage in calculating pipe-line systems consists in determination of the efforts and displacements in the elastic domain produced by the exterior loads how would be: uniform distributed forces because of self weights, the concentrated forces in industrial valves, the temperature variations .

The algorithm and the program C.S.D.C. [2] are used for this.

After determination the efforts in the elastic domain, is establishs the normal tensions σ_x in the compound chalenge of bend with axial force and those tangentials $\tau_{x\theta}$ in the chalenge of torsion and then on the base of the criterion of the potential deviation energy , the equivalent tensions

$$\sigma_e = \sqrt{\sigma_x^2 + 3\tau_{x\theta}^2} . \tag{1}$$

Adopting the law of creep [1, 2]

$$\varepsilon_e^c = k\sigma_e^n t , \tag{2}$$

the incremental variation of the specific deformations intensity $\left(\Delta\varepsilon_e^c\right)$ for a incremental variation of time (Δt), considering the intensity of the tensions constant in the interval Δt, gives the relation:

$$\Delta\varepsilon_e^c = k\sigma_e^n \Delta t . \tag{3}$$

The variaţion of the components of the specific creep deformations , is determined in the teory of the bar of the pipe lines, when only tensions σ_x, $\tau_{x\theta}$ and the specific deformations ε_x, $\gamma_{x\theta}$ act.

It is define the vector:

$$\Delta\underline{\varepsilon}^c = \begin{bmatrix} \Delta\varepsilon_x^c \\ \Delta\gamma_{x\theta}^c \end{bmatrix} = \begin{bmatrix} \dfrac{\Delta\varepsilon_e^c}{\sigma_e}\sigma \\ 3\dfrac{\Delta\varepsilon_e^c}{\sigma_e}\tau_{x\theta} \end{bmatrix} , \tag{4}$$

which presupposses the valadity of the unanimous accepted theory of the little elastic-plastic deformations.

It is obtained the vector of the creeping forces $\Delta\underline{\overline{F}}_j^{f,(e)}$ in the local system and then, $\Delta\underline{F}^{f,(e)} = \underline{L}^T \Delta\underline{\overline{F}}^{f,(e)}$ the vector of the creeping forces in the general system.

On this base the components are determined:

$$\Delta\underline{F}_j^f = \sum_{ej} \Delta\underline{F}^{f,(e)} = \sum_{ej} \underline{L}^T \Delta\underline{\overline{F}}^{f,(e)}, \tag{5}$$

where e_j all the elements in the knot *j* and then the vector of the knotly forces in the creep for the

$$\Delta\underline{R}^f = \left[\Delta\underline{F}_1^f, \Delta\underline{F}_2^f, ..., \Delta\underline{F}_j^f, ...\right]^T \tag{6}$$

whole structure.

It is obtained the folowing system:

$$\underline{K}\Delta\underline{Z} = \Delta\underline{R}^f, \tag{7}$$

and by it solution result the variations of the knotly displacements $\Delta\underline{Z}$.

Starting with the values $\Delta\underline{Z}$ are determined the components $\Delta\underline{\overline{Z}} = \underline{L}\Delta\underline{Z}$, where $\underline{L}$ is the rotation matrix, and then are determined [1] the values of the total deformations $\Delta\underline{\varepsilon}(x, y, z)$.

From the variation of the total deformations $\Delta\underline{\varepsilon}$ and the variation of the creeping deformations $\left(\Delta\underline{\varepsilon}^c\right)$ [1] i tis obtained the variation of the tensions $\Delta\underline{\sigma}$ because of the creep in the first temporal increment . To the tensions calculated in the loads in the elastic domain are added the tensions $(\Delta\underline{\sigma})$ and is obtained thus the resultant tensions $\underline{\sigma}$ after the first elementary interval of the time. The resultant tensions $\underline{\sigma}$ are considered as initial state for the second temporal increment (Δt) and in the identical way as at the first cycle , are determined the tensions at the end of the cycle 2. The process is repeated untill the tensions in the structure are stabilise, that is in two successive stages the variation of the these becomes negligible.

The verification of the resistance keeping of the creeping phenomenon, consists in the calculation of the safety coefficient with relationship:

$$c = \sigma_d^t \big/ \sigma_{\max}^f, \tag{8}$$

where $\sigma_{\max}^f$ represents the maximum established tension in the most solicitant point of the structure,while σ_d^t represent the technical length resistance. The effective safety coefficient(relationship (7)) must carry out the condition:

$$c \ge c_{d,a}, \tag{9}$$

where $c_{a,d}$ represents the admissible safety coefficient to the technical length resistance.For pipe – line systems in the petrochemical industry $c_{d,a}^{\min} = 1{,}5$.

Remark

The tension $\sigma_{\max}^f$ is calculated in iterative mode with the relationship

$$\underline{\sigma}_{\max,(i+1)} = \underline{\sigma}_{\max,(i)} + \Delta\underline{\sigma}_i, \tag{10}$$

considering that the initial value for $i=0$ is the value $\sigma_{\max,(0)}$ coresponding to action of the external loads in the elastic domain. The values $\Delta\underline{\sigma}_i$ means knowing the matrix $\underline{B}$ whose components are functions of x, y, z.

2. The estabilishment of the bonding matrix between specific deformations and displacements (matrix B)

The finished elements of type bar where they discredit a pipe-line system are of two modes : *elements as straight bar type, elements as circular bent bar*

The rigidity matrix of a spacial bar in the local axis system is presented in [2].

To determine the matrix $\underline{B}$ give successively unitary displacements (respective rotations) after the three axis to the ends i and j of the straight bar, determining the coresponding vector $\underline{\varepsilon}(x,y,z)$.

Considering the vector of the ends displacements $i-j$ in the form

$$\underline{\Delta} = [\ u_i\ v_i\ w_i\ \varphi_i^x\ \varphi_i^y\ \varphi_i^z\ u_j\ v_j\ w_j\ \varphi_j{}^x\ \varphi_j{}^y\ \varphi_j{}^z\ ]^T, \tag{11}$$

the matrix $\underline{\varepsilon}$ can write thus:

$$\begin{bmatrix}\varepsilon_x \\ \gamma_{xz}\end{bmatrix} = \begin{bmatrix} B(1,1), & B(1,2), & B(1,3), & ..., & B(1,11), & B(1,12) \\ B(2,1), & B(2,2), & B(2,3), & ..., & B(2,11), & B(2,12)\end{bmatrix}\underline{\Delta}, \tag{12}$$

where:

$$B(1,1)=\frac{1}{l};\quad B(1,2)=-\left(1-2\frac{\bar{x}}{l}\right)\frac{6}{l^2}\bar{y};\quad B(1,3)=-\left(1-2\frac{\bar{x}}{l}\right)\frac{6}{l^2}\bar{z};$$

$$B(1,4)=0;\quad B(1,5)=\left(1-\frac{3}{2}\frac{\bar{x}}{l}\right)\frac{4}{l}\bar{z};\quad B(1,6)=-\left(1-\frac{3}{2}\frac{\bar{x}}{l}\right)\frac{4}{l}\bar{y};\quad B(1,7)=-\frac{1}{l}=-B(1,1); \tag{13}$$

$$B(1,8)=\left(1-2\frac{\bar{x}}{l}\right)\frac{6}{l^2}\bar{y}=-B(1,2);\quad B(1,9)=\left(1-2\frac{\bar{x}}{l}\right)\frac{6}{l^2}\bar{z}=-B(1,3);\quad B(1,10)=0;$$

$$B(1,11)=\left(1-3\frac{\bar{x}}{l}\right)\frac{2}{l}\bar{z};\quad B(1,12)=-\left(1-3\frac{\bar{x}}{l}\right)\frac{2}{l}\bar{y};\quad B(2,1)=0;\quad B(2,2)=0;$$

$$B(2,3)=0;\quad B(2,4)=\sqrt{\bar{y}^2+\bar{z}^2}\Big/l;\quad B(2,5)=0;\quad B(2,6)=0;\quad B(2,7)=0;\quad B(2,8)=0;$$

$$B(2,9)=0;\quad B(2,10)=-\sqrt{\bar{y}^2+\bar{z}^2}\Big/l=-B(2,4);\quad B(2,11)=0;\quad B(2,12)=0\ .$$

This expresions are obtained by writing the dormations $\varepsilon_x=\sigma_x/E$ and $\gamma_{x\theta}=\tau_{x\theta}/G$ for each unitary component of the displacements ends vector i and j of the double embedded bar. For exemple: in the figure 1.a the displacement $\varphi_j^z=1$, resulting the diagram M^z in figure 1.b.

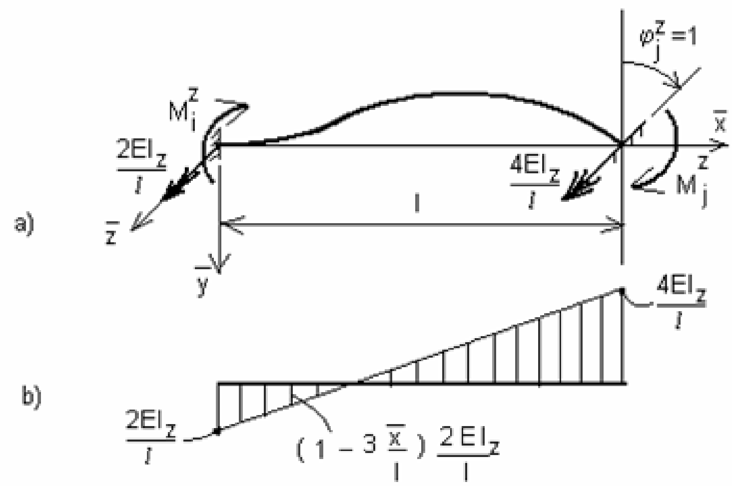

Fig.1. Scheme of calculation

Knowing the bend moment in a curent section and appyling the Navier,s formula is obtained:

$$\varepsilon_{(x)} = B(1,12) = -\frac{M^z}{I_z} y \frac{1}{E} = -\left(1 - 3\frac{\bar{x}}{l}\right)\frac{2}{l}\bar{y}.$$

(The numbers at the elements $B(i,j)$:the first shows the number of the line and the second the number of the column).

Bibliography

1. Grigore, N. – Stabilirea matricei de legătură dintre deformații specifice şi deplasări (matricea B) pentru calculul la fluaj al sistemelor de conducte – partea I-a, Annals of the ORADEA UNIVERSITY, 2006.
2. Grigore, N. – Contribuții privind calculul la fluaj al învelişurilor subțiri cu aplicații la aparate şi conducte specifice industriei petrochimice, Teză de doctorat, Institutul de Petrol şi Gaze,Ploieşti, 1987.
3. Posea, N., Anghel, Al., Grigore, N., Mincu, V. – Statica şi dinamica sistemelor de conducte. Verificări de rezistență, fluaj, durabilitate, Editura Academiei Române, Bucureşti, 1996.