A METHOD FOR DETERMINATION OF THE FREE FLUCTUATIONS OF METAL PIPELINE

V. Pozhidaeva[1], Dr. Zhivkovich[2], M. Ranchich[2]

[1] Mining-and-geological University "St.Ivan Rilski", 1700 Sofia, Republic of Bulgaria
[2] Higher Technical School, 23000 Zrenyanin, Serbia

Abstract: The present methods refer to the determination of free fluctuations in technological pipelines from steel alloy and carbonic steel under working pressure of up to 10 MPa and temperature of 70 to 700°C. Various constructions of pipelines are presented, as the methods of approach are illustrated for determining the own frequencies in specific case.

МЕТОДИКА ЗА ОПРЕДЕЛЯНЕ НА СВОБОДНИТЕ КОЛЕБАНИЯ НА МЕТАЛНИ ТРЪБОПРОВОДИ

[1] Минно-геоложки университет „Св. Иван Рилски", 1700, Република България
[2] Висше техническо училище, 23000 Зренянин, Република Сърбия

РЕЗЮМЕ: Настоящата методика се отнася за определянето на свободните колебания в технологични тръбопроводи от легирана и въглеродна стомана с работно налягаге до 10 MPa и температура от 70 до 700°C. Разгледани са различни конструкции тръбопроводи и са илюстрирани подходите за определянето на собствените честоти за конкретните случаи.

INTRODUCTION

The present methods according to the Instructions on calculation on toughness and vibration technological steel pipe line RTM 38-001-94, refer to the determination of the free variations in technological pipelines from steel alloy and carbonic steel under working pressure of up to 10 MPa and temperature of 70 to 700°C. The vibro acoustic stability of the pipeline systems is important characteristics referring to the reliable and flawless exploitation of the pipelines. The resistance of vibro acoustic disturbances of a specific pipeline is determined and set as a parameter back in the process of its designing. One of the main requirements for these calculations is the elimination of the possibility for the appearance of resonance phenomena that are the result of the matching of the frequencies of the hydro-dynamic disturbances and the frequencies of the own variations of the fluid in the pipe section. In connection with the above, one of the most basic tasks of the vibro acoustic calculations is the precise determination of the own ffrequencies and forms of acoustic variations in the pipe line.

METHODS FOR DETERMINATION OF THE FREE FLUCTUATIONS OF PIPELINES

In connection with the determination of the vibration stability, the pipeline is being divided into sections according to constructive characteristics and is being presented as a system of bars. As for the rectilinear sections of the pipeline, the own frequencies of the acoustic variations are determined according to the following formulae:
- for pipes with acoustically opened or closed ends:

$$f_{ip} = \frac{0{,}5ic}{L} \qquad (1)$$

- for pipes with one open acoustic end:

$$f_{ip} = \frac{0{,}25(2i-1)c}{L} \qquad (2)$$

where: i =1, 2, 3 ... ,
c - speed sound, m/s,
$\mathbb{L}$ - pipe length, m.

The evaluation of the vibro-acoustic stability of the pipeline is made for all own frequencies within a range of up to 100 Hz. Their calculation is made according to the scheme of rods by rendering the mass of the working fluid and the insulation. The reinforcement is presented as a concentrated mass. The reports also render the increased pliability of the system in the curvilinear pipeline sections. Upon approximation of the form of the own variations, the number of the sections of account where the mass of the section under consideration is being concentrated, is to be chosen in a way which exactly described the number of forms of the variations. The sections with mass adjusted are being selected in the copper of the vibration loading applied. In cases of complex branched pipeline schemes, approximate methods may be used for analysis of the forms of the own variations. The own frequencies are determined by the numerical determination of the following linear algebra problem:

$$[\Phi] = \left| \varpi_i^2 \right| [\Lambda][M][\Phi] \qquad (3)$$

where: $\varpi_i = 2\pi f_i$ - circular frequency of the i form of own variations,

$[\Phi] = [(\varphi)_1, (\varphi)_2 .....(\varphi)_k]$ - matrix of won form of bending variations,

$[\Lambda] = [K]^{-1}$ - matrix of dynamic pliability,

$[M]$ - diagonal matrix of masses.

Dampening is not being taken into account when calculating the own frequencies.

As for pipelines presented as a rod of two bearings, with a constant cross section, the own frequency f_i, corresponding to the i form of the own variations is being determined according to the following formula:

$$f_i = \frac{10^{-3}}{2\pi} \frac{k_i^2}{L^2} \sqrt{\frac{EI}{m}} \qquad (4)$$
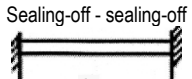
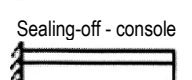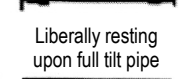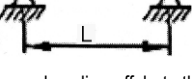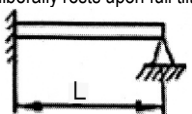where: k_i - the i root of the frequency equation;
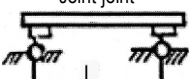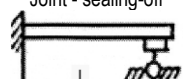
L - length of the pipeline between the supports, m;

$I = \pi(D^4 - D_i^4)/64$, mm^4;

m - linear mass of the pipeline with a report of the insulation and the working fluid, kg/m.

Table 1 presents the main schemes of account for a pipeline of one section and the respective quantities of the frequency coefficients k_i.

Table 1. Frequency coefficients for the calculation of the own frequencies of variations of pipelines of one section.

Type of the project of the pipe line	Formulas calculation	k_i , Hz	
		First	second
Joint-joint	πm Where: m =1, 2, 3, ..	3,14	6,28
Joint - sealing-off	$\pi(4m+1)/4$	3,93	7,07
Sealing-off - sealing-off	$\pi(2m+1)/2$	4,71	7,85
Sealing-off - console	$\pi(2m+1)/2$	1,57	4,71
Liberally resting upon full tilt pipe	πm	3,14	6,28
One end sealing-off, but other liberally rests upon full tilt		3,87	7,07
L-shaped U-shaped Z-shaped		3,14 / 1,93 1,76 / 1,41 1,67 / 1,5	

The tension axis effort increases the own frequency, and decreases it with respect to the pressure. This fact is of significant importance for the determination of the first form of the variations. As for pipes of two knuckle bearings, the importance of the first own frequency with reporting of the axis strength N is being determined according to the following formula:

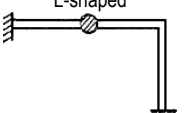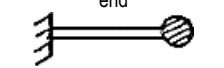$$f_i = 10^{-3} \frac{\pi}{2L^2} \sqrt{\frac{EI(1+N/N_{st})}{m}} \qquad (5)$$
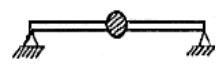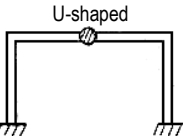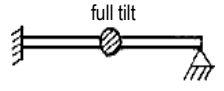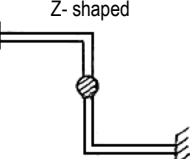
where: $N_{st} = 10^{-\sigma} \pi^2 \frac{EI}{L^2}$ - critical loading of the rod upon pressure, N;

As for pipelines of two bearings of constant cross section but with additional concentrated mass, the own frequency is being calculated according to the following formula:

$$f_i = \frac{10^{-3}}{2\pi} \sqrt{\frac{EI}{m(1+k_q\ Q/mL)}} \qquad (6)$$

where: Q - concentrated mass [kg], k_q - repairing coefficient, the importance of which is presented in Table 2.

Table 2. Repairing coefficient k_q for reporting the concentrated mass from an equation (6)
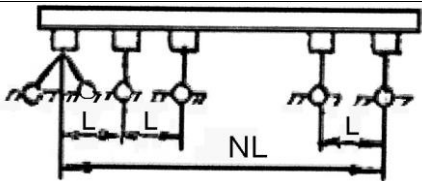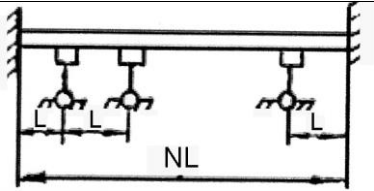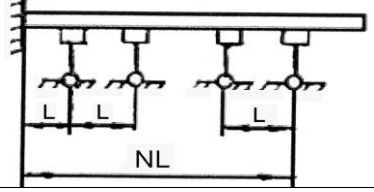
Type of the project of the pipe line	k_q	Type of the project of the pipe line	k_q
Sealing-off - sealing-off	2,7	Tumbling, shoulder equal L-shaped	0,28
Console with load on the end	3,9		
Liberally resting upon full tilt pipe	-	U-shaped	0,6 0,7
One end sealing-off, but other liberally rests upon full tilt	2,3	Z- shaped	0,66 0,68

As for pipelines with a great number of sections of equal lengths, the own frequency is being calculated according to the following formula: ,

$$f_i = \frac{10^{-3}}{2\pi} \frac{k_{in}^2}{L^2} \sqrt{\frac{EI}{m}} \qquad (7)$$

where: k_{in} - the i root of the characteristic equation determined in Table 3.

92

Table 3. Frequency coefficients k_{in} for a pipeline with sections of same lengths

Scheme of the fastening the pipe line	Number stair well	Number of the harmonics				
		1	2	3	4	5
	1	3,14	6,28	9,42	12,57	15,70
	2	3,14	3,93	6,30	7,06	9,42
	3	3,14	3,55	4,30	4,30	6,70
	4	3,14	3,39	3,92	4,46	6,28
	5	3,14	3,30	3,70	4,15	4,55
	10	3,14	3,20	3,30	3,48	3,70
	1	4,73	7,85	10,99	14,14	17,28
	2	3,93	4,74	7,07	7,86	10,21
	3	3,55	4,30	4,74	6,69	7,45
	4	3,39	3,93	4,46	4,74	6,53
	5	3,30	3,71	4,15	4,55	4,74
	10	3,20	3,30	3,49	3,70	3,93
	1	3,93	7,97	10,21	11,35	16,49
	2	3,39	4,46	6,53	7,60	9,68
	3	3,27	3,93	4,59	6,41	7,07
	4	3,20	3,64	4,21	4,65	6,35
	5	3,20	3,49	3,93	4,37	4,68
	10	3,14	3,24	3,46	3,58	3,80

The own low frequencies of a pipeline with many sections of different lengths are calculated along the section of the biggest length. If this section is located in the pipeline, the own frequency of the longest internal sections for a specific pipeline is being additionally calculated, as the lower one of the two quantities obtained is being selected.

CONCLUSIONS

The determination of the free fluctuations is a basic task for the dimensioning of the pipeline systems for avoiding resonance phenomena and determination of the vibration stability of the pipelines. The last mentioned is directly connected to the reliable exploitation and durability of the systems.

REFERENCES

VNIPIneft, RTM 38-001-94, The Instructions on calculation on toughness and vibration technological steel pipe line, Approved by Gosgortechnadzor RF 1994, http://dwg.ru/dnl/2059.

NTP Truboprovod Ltd.,STP 09-04-02 (001-STP/A), Calculation on toughness and vibration steel technological pipe line, 2005.

Goncharov I.B., Matangin K.M., Defectoscopy of the coal-mining equipment, Moscow, Nedra, 1990.