Chapter 3

Vibration Strength of Pipelines

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Additional information is available at the end of the chapter

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Abstract

Damage of offshore oil-and-gas pipelines results in significant pollution of the marine environment. Extent of pipeline damage during an earthquake depends on a number of factors: the seismic force and the seismic waves' propagation direction, the geological and groundwater conditions, the operation and process duties, the pipeline design and the joints, the pipeline material's characteristics, and the extent of pipeline wear. Requirements to the structural reliability of subsea pipelines are much stricter than those set to underground and overhead pipelines. An offshore pipeline is in the combined stressed condition. It is characterized by tension of the pipeline walls caused by pressure pulsations and cyclic bending due to the vibrations. This chapter tackles the vibration analysis issues. The main goal is to present to the industry specialists the principles of vibration assessment as applied to the offshore pipelines in seismic regions and to outline solutions of the vibration problems. The dynamic calculations of the offshore pipelines based on the natural frequency analysis are represented in the industrial construction standards only.

Keywords: marine subsea pipeline, stresses in the pipeline wall, pipeline vibration, the amplitude of offshore pipeline movements, seismic resistance of the offshore pipeline

1. Introduction

During operation of the offshore pipelines, the vibration processes occur as a result of pump plant running, activation of shutoff valves, emergency shutdowns, and external effects. Vibration protection issues are highlighted in the manual (design documentation), but during the design stage of the offshore pipeline system, these factors are not taken into consideration. Sea pipelines are new type of constructions in Russia. Only in VSN R 42-81 [8] are considered dynamic problem definition laying sea pipelines. All private oil-extracting companies are not interested in researches. A research of vibrations of pipelines demands the state researches.

The provisions [2–4] take into account the following stresses acting on the offshore pipeline: pressure of the product being transported, temperature exposures, and weight coating; however, dynamic nature of loading on the pipeline wall is not considered during the operation.

When calculations are made in regard of hazard assessment of the pipeline vibrations, criteria shall be used to determine the vibration behavior of the pipelines. Vibrations of the pipelines caused by external effects such as impact and earthquake can be described by a general integral of the forced vibration equation.

For example, in case of vibrations of the base plate to which a pipeline support is fixed (**Figure 1a** and **b**), the latter has a dynamic impact by which degree is determined by the support yield δ_A, $P = Y_0\delta_A \cos \omega t$.

It is highly important to have an opportunity to determine stressed condition of the pipelines subject to vibrations in the form of elastic curves, which occur during vibrations caused by external excitations.

Stresses in the pipeline wall can be regarded as criteria.

2. Vibration structure

It is used as a reliability factor of the structure under vibrations [1, 3]. Under harmonic vibrations, the vibration velocity can serve as a reliability criterion for the pipeline.

The harmonic vibrations are characterized by two parameters: frequency of vibrations and displacement amplitude:

$$y = Y_0 \sin \omega t \tag{1}$$

Vibration velocity and vibration acceleration are expressed as follows:

$$v_0 = \omega Y_0; \quad g_0 = \omega^2 Y_0 \tag{2}$$

3. Bending vibrations of the pipelines

Under bending vibrations of the pipelines, when distribution of stresses and vibration velocities is significantly different for various fixing conditions, factor c shall be determined individually for each case [3].

$$\frac{d^2y}{dx^2} + \frac{m\omega^2}{T} y = 0 \tag{3}$$

Form of the elastic curve of the pipeline is expressed by a sine wave.

$$y(z) = Y_0 \sin \frac{i\pi z}{L}, y(z) = Y_0 \overline{y}(z) \tag{4}$$

where Y_0 is an amplitude of vibrations.

Bending moment in the random location on the pipeline is equal to:

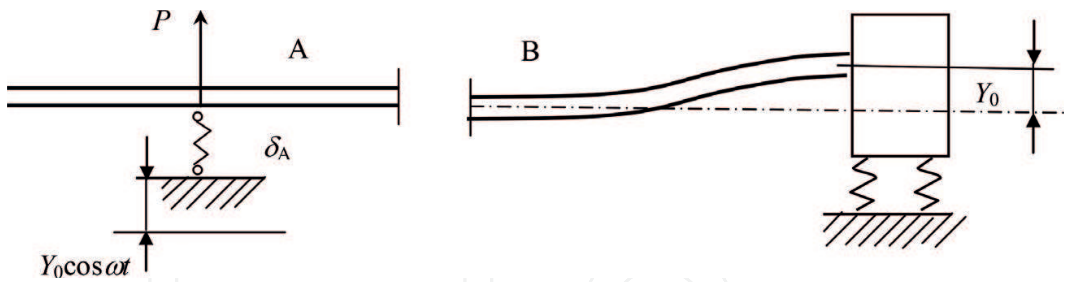

Figure 1. Force excitation of vibrations. (a) Excitation through an elastic support; (b) kinematic excitation of vibrations.

$$M(z) = EIy''(z) = -EI\frac{i^2\pi^2}{L^2}Y_0\sin\frac{i\pi z}{L} \tag{5}$$

where I is a moment of inertia.

Maximum stresses in the pipeline:

$$\sigma_{makc} = EI\frac{i^2\pi^2}{WL^2}Y_0, \tag{6}$$

then W is a moment of resistance in the pipeline.

At initial approximation, certain typical ideal forms of vibrations are used for vibration analysis. Then, the natural vibration frequency of the pipeline is expressed by the following formula:

$$\omega_i = \frac{i^2\pi^2}{L^2}\sqrt{\frac{EIg}{\rho F}} \tag{7}$$

where F is a square section of the pipeline.

According to [3, 5], the maximum vibration velocity is determined from the following equation:

$$\mathrm{V}_{\max} = v_{\text{base}}\mathrm{K}\eta \tag{8}$$

where v_{base} is a vibration velocity of the base plate; η is a dynamic magnification factor; k is a form engagement factor: $k = \int_0^1 \overline{y}d\overline{z}/\int_0^1 \overline{y}^2 d\overline{z}$, $\overline{y}$, $\overline{z}$ are dimensionless forms of pipeline vibrations and current coordinate.

Expansion bends are regarded as vibration damping elements for the pipelines to ensure their vibration resistance. The expansion bends prevent the transfer of vibrations along the pipeline.

4. Analysis of pipeline vibrations

Stresses across the cross sections of the pipeline under natural vibrations can be determined from the following equation:

$$\sigma_k = \frac{ED}{2} C_k(\omega) \frac{\partial^2 y_k(z)}{\partial z^2}. \tag{9}$$

Stresses acting on the pipeline can be expressed as follows:

$$\sigma = Y_0 \frac{EI\overline{y''}}{W(z)},$$

where EI is bending rigidity of pipe, N·m^2.

Allowable amplitude of vibration equals to:

$$[Y_0] = \frac{[\sigma]W(z)}{EI\overline{y''}}, \tag{10}$$

where [σ] is a permissible stress in the pipe metal.

The analysis of pipeline vibrations is performed using root mean square of instantaneous vibration parameters over a period determined by the following formula [8]:

$$\overline{y} = \frac{1}{T}\int_0^T y^2 dt. \tag{11}$$

Measurement results of real pipeline vibrations show that such vibrations are of complex, and in some cases, they are of random nature. For the determination of stresses in the pipeline walls, the process loads P_p due to operating pressure of the product being transported, the effect of hydrostatic water head pressure shall be taken into consideration as well as time-variable loading on the pipeline such as pressure pulsations and seismic forces. It is effective to use spectral method during the analysis of the pipeline random vibrations [1, 3].

The internal pressure of the gas line generates random vibrations.

Elastic stress in the pipe walls can be expressed as follows:

$$\delta = \frac{F}{A} = \frac{\overline{p}_2 D}{2t}, \text{when } \overline{p}_2 = 2Et\frac{\Delta D}{D^2} = \frac{4Et}{D^2}d, \tag{11a}$$

where δ is a dynamic stres, N/m^2. Pressure changes in this manner $p \ \sin \omega t = \overline{\mathrm{p}}_2 + \overline{\mathrm{p}}_3$, in this case the balance between the elastic and internal force in the pipe wall shall be equal to:

$$\overline{\mathrm{p}}_1 = \overline{\mathrm{p}}_2 + \overline{\mathrm{p}}_3 = \frac{4E\mathrm{t}}{D^2}\mathrm{d} + \mathrm{t}\delta a$$

As displacement and acceleration, at a given frequency, are related by $-\omega^2$, the expression can be changed to:

$$\overline{p}_1 = +\left[\delta - \frac{4Et}{D^2\omega^2}\right]\text{ta} \tag{12}$$

Or

$$\overline{p}_1 = \left[\frac{4E}{D^2} - \omega^2\right]td \tag{13}$$

Combined stress in the axial direction due to pressure pulsations and vibration:

$$\sigma_t = \sigma_{\Delta pt} + \sigma_V \tag{14}$$

5. Spectral transforms

Spectral density corresponds to the spectral form of the internal pressure sinusoidal vibrations $u(t) = \sin \omega_0 t$. Periodic function spectrum $S_T(f)$ is determined by a direct Fourier transform of the time function

$$\begin{aligned} S_T(f) &= \int_{-\infty}^{\infty} s_T(t)e^{-j2\pi ft}dt = S(f)\cdot\frac{1}{T}\sum_{m=-\infty}^{\infty}\delta\left(f-\frac{m}{T}\right) \\ &= \frac{1}{T}\cdot\sum_{m=-\infty}^{\infty} S\left(\frac{m}{T}\right)\cdot\delta\left(f-\frac{m}{T}\right) = \sum_{m=-\infty}^{\infty} C[m]\cdot\delta\left(f-\frac{m}{T}\right) \end{aligned} \tag{15}$$

Complex weights of S-functions at frequencies multiple of 1/T. They represent expansion coefficients of the function (15) into a Fourier series as follows:

$$C[m] = \frac{1}{T}\cdot S\left(\frac{m}{T}\right)$$

Time function $s_T(t)$ and spectral function $C[m]$ of the impact are the main characteristics. They are interrelated by a complex Fourier series.

The function containing n vibrations is described by the following equations,

$$F(t) = \sin\omega_0 t \text{ at } 0 < \text{t} < \frac{2\pi n}{\omega_0} \text{ and } F(t) = 0 \text{ at } 0 > \text{t} > \frac{2\pi n}{\omega_0}.$$

Then amplitude spectrum is determined by the following expression:

$$S(\omega) = \left|\frac{2\omega_0 \frac{n\pi\omega}{\omega_0}}{\omega_0^2 - \omega^2}\right| \tag{16}$$

At small values of ω_0: $S(\omega) \approx \frac{1}{\omega}$.

Upon the completion of the vibration analysis according to the scheme of the single-degree-of-freedom system (which includes the reduced weight of the pipeline and its components, and elastic support action), stresses and deformations in the support elements shall be calculated.

Transfer function of the maximum stress relative to acceleration of the pipeline supports can be written as

$$|H_\sigma(\omega, z)| = \frac{C_k(\omega)\frac{ED}{2}y_k''(z)}{\sqrt{\left(\omega_0^2 - \omega^2\right)^2 + \left(2\beta\omega\omega_0\right)^2}}. \tag{17}$$

Spectral density of the pipeline response to random excitations will be equal to

$$\boldsymbol{\Phi_{YY}(\omega)} = \frac{\boldsymbol{\Phi_{QQ}(\omega)}}{\left(\boldsymbol{\omega_0^2 - \omega^2}\right)^2 + \left(\boldsymbol{2\beta\omega\omega_0}\right)^4} \tag{18}$$

Considering the tensile strength and fatigue strength, the allowable amplitudes of stresses in the pipeline wall can be calculated from the following formulas:

$$\sigma_{\Lambda m} = \frac{\sigma_{-1}\beta k}{n_m\left(1 + \frac{\sigma_{-1}}{\sigma_B}\frac{1+q_r}{1-q_r}\right)}, \quad \sigma_{\Delta t} = \frac{\sigma_{-1}\beta k}{n_t\left(1 + \frac{\sigma_{-1}}{\sigma_B}\frac{1+q_t}{1-qr_t}\right)} \tag{19}$$

where $\boldsymbol{\sigma_B}$ is a tensile strength; $\boldsymbol{\sigma_{-1}}$ is a fatigue strength under symmetrical loading cycle; $\boldsymbol{\beta}$ is a coefficient that takes into consideration the effect of the pipeline surface finish on the fatigue strength: for new pipelines $\boldsymbol{\beta = 0.80–0.85}$, for corrosion susceptible pipelines, this coefficient is reduced to $\boldsymbol{\beta = 0.5}$; $\boldsymbol{k}$ is a stress concentration factor [1, 3, 4].

Stress ratio is shown as follows:

$$q_r = \frac{P_p - \Delta P}{P_p + \Delta P}, \quad q_t = \frac{P_p D/(2\delta) - \sigma_t}{P_p D/(2\delta) + \sigma_t},$$

During the installation of the pipeline system, the rated natural load shall be assumed as maximum* at the most probable sea condition for the time period under review, which is determined using (H_3, T_p), and applicable stream and wind conditions. Rated load is assumed as maximum at the most probable parameters of the natural environment (in other words, waves, stream, and wind- L_E), and equals to.

$$R(L_E) = 1 - \frac{1}{N}$$

where $R(L_E)$ is a probability distribution function L_E.

N is a number of loading cycles of minimum 3 h in length at a certain sea condition.

Note that the specific sea condition for the time period under review can be interpreted as a sea condition for an applicable location and period of pipe laying. Ordinary requirement is that the

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duration of the time period shall be long enough to consider all potential delays. Pipe laying period shall not exceed this time interval.

σ_{-1} value can be defined either using reference data or Manson formula [4]:

$$\sigma_{-1} = 1.75\sigma_B/N^{0.12}$$

here N is a number of loading cycles.

6. Pipeline vibration limiting

Pipeline vibration limiting regulations can be divided into the following categories:

- for pipeline soundness and quality
- for pipeline vibration resistance under exposure to external vibrations.

The requirements [design documentation] state that "the maximum allowable amplitude of vibrations of the process pipelines is 0.2 mm at vibration frequency of max 40 Hz" [2].

Offshore pipeline specifications do not provide either limitations for the pressure pulsations or vibration limitations.

Low-frequency vibrations of the pipelines under principal modes, when such vibrations are close to be harmonic, can be easily evaluated on the basis of the amplitude of vibration displacement since in this case they are proportional to the stresses induced in the pipelines and can be regarded as a strength factor of the pipelines.

We get the following expression for k-form of the vibrations using formula [5], for the root mean square value of vibrations:

$$\sqrt{\overline{\sigma_k^2}(z)} = \left[\int_0^\infty C_k(\omega)\frac{\Phi_{QQ}(\omega)d\omega}{\sqrt{\left(\omega_0^2-\omega^2\right)^2+\left(2\beta\omega\omega_0\right)^2}}\right]\frac{ED}{2}$$

In the event of random vibrations, the combined stress in the pipeline is the following:

$$\overline{\sigma^2}(z) = \sum_{k=1}^{N}\overline{\sigma_k^2}(z).$$

However, in the regulatory documents for offshore pipelines, there are not only restrictions on pressure pulsations but also restrictions on vibrations. Low-frequency oscillations of pipelines along lower forms, when these oscillations are close to harmonic, can be conveniently estimated from the amplitude values of the vibrational displacement because in this case they are proportional to the stresses arising in the pipelines and are indicators of the strength of the pipelines.

Vibration velocity can be written as:

$$V_l = \int_0^T a(t)dt = \int_0^T B_0 \sin\ \omega t dt = B_0 n / 2\pi f_K \tag{20}$$

where V_l is vibration velocity (mm/s); a is vibration acceleration (mm/s^2) with amplitude B_0; f_k is frequency of multiplicity factor k.

During the evaluation of the vibration strength, the maximum amplitude of equivalent vibration stresses shall be determined for each representative section of the pipeline. This amplitude is obtained as a result of various modal superpositions. Dimension of the transfer function depends on the type of disturbance and response against which the transfer function is determined.

When exposed to random vibrations, root-mean-square value of the maximum stress in the pipeline can be found using the transfer function for the maximum stress with respect to acceleration of the pipeline supports:

$$|H_\sigma(\omega, z)| = \frac{C_k(\omega)\frac{ED}{2} y_k''(z)}{\sqrt{\left(\omega_0^2 - \omega^2\right)^2 + \left(2\beta\omega\omega_0\right)^2}} \tag{21}$$

where D is outside diameter of pipe.

Pipeline response to broadband random vibrations can be defined as a combined effect of several narrowband random vibrations. The narrowband vibrations of the pipelines occur as a response to the broadband excitation under low damping. The mean frequency of the narrowband vibrations can be calculated from the Rice's formula:

$$\omega_0^2 = \frac{\int_{-\infty}^{\infty} \omega^2 \Phi_{YY}(\omega) d\omega}{\int_{-\infty}^{\infty} \Phi_{YY}(\omega) d\omega} = \frac{R_y''(0)}{R_y(0)} = \frac{\sigma_{\dot{y}}^2}{\sigma_y^2} \tag{22}$$

Root mean square value of the pipeline movement to be subject to vibrations can be calculated from the following formula:

$$\sigma = \left[\int_{f_1}^{f_2} \eta_f^2 \Phi(f) df\right]^{1/2}, \quad \text{here } \sigma = \sqrt{\sum_{i=1}^{N} \eta_{f_i}^2 \Phi(f_i) \Delta f_i}. \tag{23}$$

where η_f is a dynamic response factor-relation between displacement amplitude of the anchor points for the pipeline and relative displacement amplitude of the pipeline sections at specified frequency; $\Phi(f)$ is a spectral density of the disturbed random vibration in the frequency band f_1 and f_2; Δf_i is an interval of the frequency band segmentation f_1, f_2; N is a number of intervals of the frequency band segmentation.

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Development of the standardized vibration limits is complicated due to a wide variety of the requirements to the characteristics of the vibration capacity of various equipments.

However, for determination of the pipeline system reliability exposed to vibrations, it is required to consider the effect of vibrations on failures and malfunctions on the basis of certain assumptions regarding damage accumulation in the structures and failure occurrence. If stresses in the elastic elements of pipelines (supports) are considered failure criteria, the vibration strength of the supports shall be evaluated using calculation models of support structures. The private oil-extracting companies apply burying of pipelines. It is just concealment of a problem. In the seismic phenomena, vibrations arise in the thickness of the Earth.

During the analysis of the first fundamental forms of vibrations which lie within 20 Hz, vibration displacement is frequently used as a test parameter.

The following stages are included into the obligatory vibration tests of the pipeline: study of the operating conditions of the system and analysis of the dynamic loads acting on the pipeline; determination of the potential failure patterns; and selection of failure occurrence criteria due to vibrations.

According to the regulations of the Ministry of Gas Industry, emergency vibration level [2] is measured using vibration velocity V_e = 18 mm/s, and the warning vibration level is estimated by the exceedance V_e = 41 mm/s [9, 10].

During the pipeline vibration analysis, it is necessary to know rigidity characteristics of the system components. The rigidity of pipe of permanent round section is characterized by the following parameters: EI is bending rigidity, $N \cdot m^2$.

Up to the present moment, frequency ranges have not been yet defined for the offshore pipelines where one or another vibration parameter shall be used for vibration limitation purposes.

The allowable amplitude of vibrations is defined as follows:

$$\mathrm{V}_{\mathrm{max}} = v_{\mathrm{base}} k\eta \, \mathrm{V}_{\mathrm{max.}}$$

Amplitude of vibration stresses at different frequencies is determined during calculation of the forced vibrations of the pipeline [8].

The main criterion of the pipeline vibration strength is detuning of natural frequencies f_j from discrete frequencies of the excitatory loads f_{ip}, defined as described in 2.2 [6].

Let us determine safe vibration velocity for the pipeline kinematically excited on the movable base plate. Amplitudes of vibration voltage at different frequencies are determined by the results of calculation of forced oscillations of the pipeline. The way to ensure the vibration resistance of the pipeline is to detune the natural frequencies fj of the structure [7].

Vibrations of marine pipelines with a protective coating to decrease the interaction of the pipeline with the coating result in cracking in the coating of corrosion and damage to the coating.

Example.

Vibration strength of pipelines.

Low-frequency vibrations of the pipelines under principal modes, when such vibrations are close to be harmonic, can be easily evaluated on the basis of the amplitude of vibration displacement because in this case they are proportional to the stresses induced in the pipelines and can be regarded as a strength factor of the pipelines.

σ_{-1} value can be defined either using reference data or Manson formula [4]:

$\sigma_{-1} = 1,75\sigma_B/N^{0.12}$, here $\boldsymbol{N}$ is a number of loading cycles.

Let us consider the following example of calculating the allowable stress amplitudes in the pipeline wall.

Researches were made for vibration speed (response characteristic: root mean square value of V_{max} = 0.0103 cm/s) and pressure pulsation amplitude of ΔP = 0.5 MPa for the landfall section of the offshore pipeline with rated pressure of 17.5 MPa. Outside diameter of the pipeline is D = 406 mm, wall thickness is 17.5 mm. Material grade is X52 ($\sigma_в$ = 455 MPa, σ_{-1} ≈ 916 MPa, E = 0.20457·106MPa, σ_e = 358 MPa). Pipe section modulus is W = 0.00199 m^3.

$$Kt:=1$$

σBB·β·k=806.08

$$\text{nm1}\cdot\left(1+\frac{\sigma\text{BB}}{\sigma\text{B}}\cdot\frac{1+\text{rq}}{1-\text{rq}}\right)=64.214$$

If length *l* of the pipeline section is 30 m, displacement y_0 is determined by the formula (7) and is equal to 0.026 m, considering the formula (9) v_{max} = 0.035 m

If pressure pulsation Δ*P* is 0.5 MPa and work pressure is 15.7 MPa (β = 0.8), stress variation on the pipeline wall is 6.386 MPa. Stress ratio (17) q_r is 0.938. Stress amplitude in the pipeline wall is equal to $\sigma_{\Delta q} = 12.553$ MPa considering steel tensile strength and fatigue strength (refer to **Table 1**).

Temperature fluctuations Δt = 5° result in stress variation of 12.36 MPa in the pipeline wall and are equal to r_t = 0.817 as shown in the formula (19). Allowing for tensile strength and fatigue

Name of the characteristics	**Steel**	
	X52∅406	**X65∅711**
Yield strength, MPa	358	448
Strength limit R_m, MPa	455	530
Permissible stresses in metal pipes σ, MPa	255.6	292.8

Table 1. The main physical characteristics of steel pipe [2].

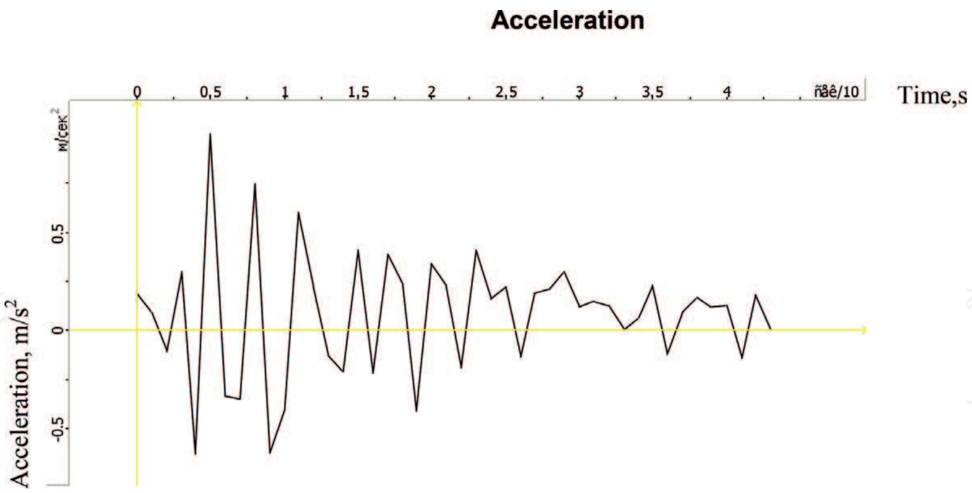

Figure 2. Accelerogram recording used during calculations.

strength of the pipeline steel (see **Table 1**), stress amplitude $\sigma_{\Delta t} = 38.322$ MPa in the pipeline wall. Fatigue strength factor of the pipeline shall be at least $n = 2.0$ [3].

Let us review the seismogram of seismic intensity 6 to MSK-64 scale for the vibration strength analysis of the landfall section of the offshore pipeline. The seismic impact is characterized by the following parameters: maximum acceleration $a_{max} = 0.94485$ cm/s^2 at t = 0.12 s (**Figure 2**).

We get the line spectrum of the signal consisting of the harmonics:

$$\Delta\omega = \frac{2\pi}{T_{min}} = \frac{2\pi}{N \cdot \Delta t} (\mathrm{rad/s})$$

where T_{min} is a minimum period.

Periodogram results can be interpreted as dispersed data at frequencies given in **Table 2** and **Figure 3**.

Ser.no.	Frequency	Period	Periodogram	Density	Spectral density in hamming window
0	0.00000		0.0	1488.55	0.035714
1	0.02174	46.0	2836.21	1828.18	0.241071
2	0.04348	23.0	1695.297	1839.68	0. 446429
3	0.06522	15.3333	1456.8	1528.67	0.241071
4	0.08696	11.5	1341.92	1355.41	0.035714
5	0.1087	9.2	1255.43	1258.18	
6	0.13044	7.66667	1174.63	1174.32	
7	0.15217	6.67143	1092.56	1091.35	
8	0.17391	5.75	1007.15	1005.84	
9	0.19585	5.11111	918.245	917.192	
10	0.21739	4.6	826.556	825. 941	

Ser.no.	Frequency	Period	Periodogram	Density	Spectral density in hamming window
11	0.23913	4.18182	733. 242	733.16	
12	0.26087	3.83333	639.703	640.204	
13	0.28261	3.53846	547.464	548.566	
14	0.30435	3. 28571	458.096	459.796	
15	0.32609	3.06667	373.16	375.439	
16	0.34783	2.875	294.168	296.99	
17	0.36957	2.70588	222.536	225.855	
18	0.3913	2.55556	159.563	163.32	
19	0.41304	2.42105	106.391	110.52	
20	0.43478	2.3	63.992	68.417	
21	0.45652	2.19048	33.139	37.781	
22	0.47826	2.09091	14.398	19.172	

Table 2. Vibration impact periodogram.

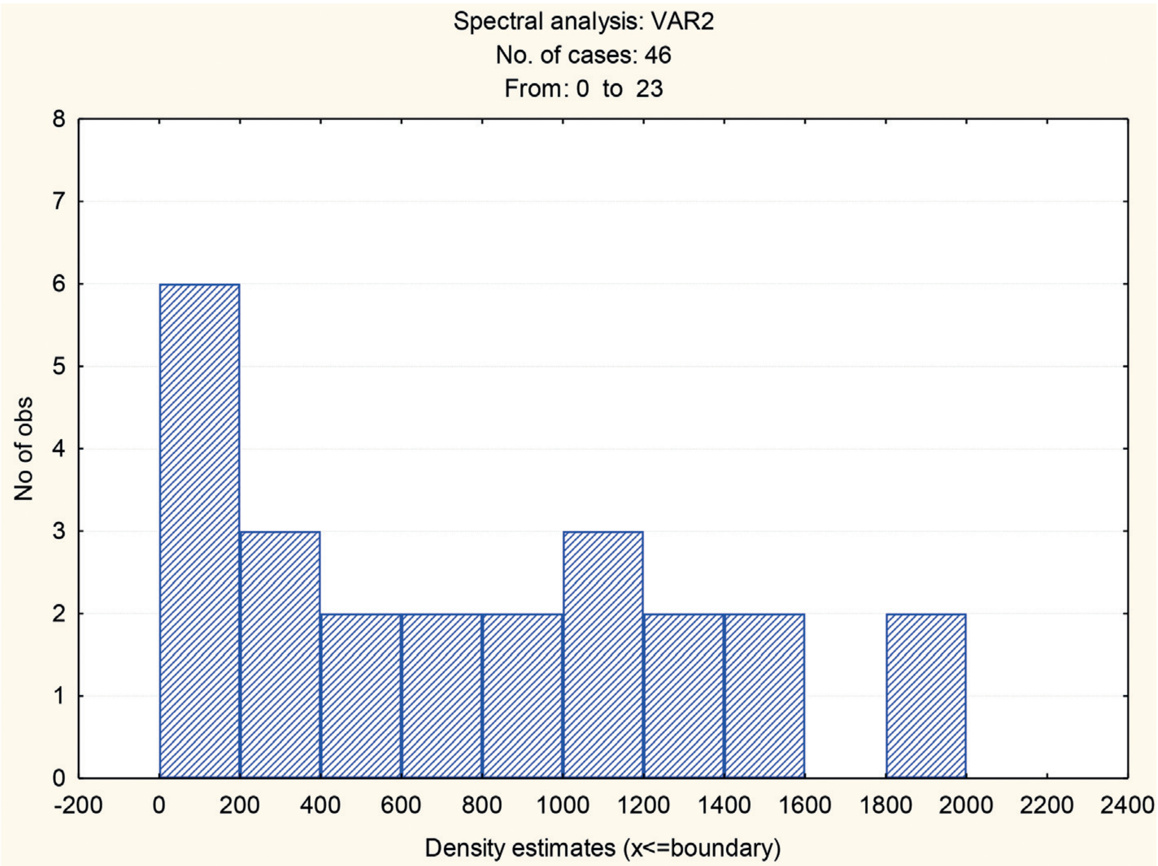

Figure 3. Vibration impact periodogram.

Mean mathematic amplitude B_K over a period of observation T shall be written as:

$$B_0 = \frac{1}{T}\int_0^T B_K(t)dt, \tag{24}$$

where $B_K(t)$ is a behavior of k-x components of vibration spectrum.

Vibration velocity can be written as:

$$V_l = \int_0^T a(t)dt = \int_0^T B_0 sin\omega t dt = B_0 n/2\pi f_K \tag{25}$$

where V_l is vibration velocity (mm/s); a is vibration acceleration (mm/s^2) with amplitude B_0; f_k is frequency of multiplicity factor k.

According to the standards of the Ministry of Gas Industry [6], an emergency vibration level is equal to the vibration speed V_e = 18 mm/s, and an alarm vibration level exceeds V_e = 41 mm/s. For pipeline sections more than 0.5 m, the vibration displacement span is restricted to 0.5 mm (refer to the standards of the National Compressor Engineering Association "Souzcompressmach") [2].

Based on the allowable strength from [2], the allowable amplitude of vibrations is calculated for the pipeline of 408 mm diameter and 17.5 mm wall thickness, and allowable stress is 255.6 MPa. The effective span length of the pipeline section under review is 30 m. Amplitude of forced vibrations Y_0 is 0.061 m. Safe vibration speed of the pipeline, which is excited kinematically on the moving platform, is 0.035 m/s.

7. Conclusion

Offshore pipelines can be regarded as new constructions in Russia. Industry-Specific Construction Standard specifies dynamic vibrations of the pipeline.

None of the private oil companies is interested in studying vibration strength of the pipelines; they make references to the existing standards. Offshore pipeline vibration analysis is very important and requires government involvement. Such researches should be performed by the large scientific institutes.

Private companies use a pipe burial method. The pipelines can be buried; however, it is not a way to solve the problem. Seismic impacts come from under the ground.

Vibrations of marine pipelines with a protective coating to decrease the interaction of the pipeline with the coating result in cracking in the coating.

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