Results of calculations from a linear source with variable noise characteristics along the length

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Abstract. Results of calculations from a linear source with variable noise characteristics along the length are discussing. On one hand, the issues of calculations from linear sources are well studied and the results are presented in many works. On the other hand, problems of calculations from linear sources with variable characteristics along the length have not been studied enough, and there are no results of calculations from linear sources with variable characteristics along the length. This article deals with the case when the radiated sound energy along the length of a linear source is not constant but varies along its length. Results of calculations from a linear source with variable noise characteristics along the length are given. Various factors that affect to calculation results are discussed. The results have of practical interest. For example, this concerns the calculation of noise from a gas pipeline after a gas control point (GCP). The noise from it along the length of the pipeline decreases. The results of calculations allow to make the necessary decisions to create a low-noise object and select the necessary measures for its sound attenuation.

1. Introduction
On one hand, the issues of calculations from linear sources are well studied and the results are presented in many works. On the other hand, problems of calculations from linear sources with variable characteristics along the length have not been studied enough, and there are no results of calculations from linear sources with variable characteristics along the length.

The results of calculations have of practical interest. For example, this concerns the results of calculations from a gas pipeline after a gas control point (GCP). Noise from GCP and gas pipelines after it is formed by valve noise and noise of gas velocity in the gas pipeline channel. The main source of GCP is valve noise. Noise from it radiates along the length of the pipeline. The noise from it along the length of the pipeline decreases. The results of calculations allow to make the necessary decisions to create a low-noise object and select the necessary measures for its sound attenuation.

2. Calculations
The theory of calculating noise from linear sources is presented in many books and handbooks [1-5]. For example, in [5] the issues of calculating sound pressure levels (sound level) from linear sources of finite length in relation to road and railway transport. In the article [6], we have got theoretical formula to a linear source with variable noise characteristics along the channel.

The formula is obtained for the following conditions.
The distance from pipeline is a constant ($R=10$ m). Noise from the flow velocity of gas in the channel is made substantially less noise than the valve’s noise. Here the noise along the length of the pipeline is reduced at a constant distance from it. At the same time, the noise from the gas velocity in the channel is substantially less than the noise from the valve. This assumption is true for most real objects. The linear source has a finite length.

The formula for changing sound pressure along the length of a gas pipeline with variable characteristics along the length of the channel was obtained in [6]:

$$p^2_{\varepsilon}(\varepsilon, N) = \frac{\rho c W_0}{4\pi R} \left( e^{-k l} \arctg \left( \frac{1}{R} \right) + \arctg \left( \frac{\varepsilon}{R} \right) \left[ 1 - e^{-k l} \right] \right)$$  \hspace{1cm} (1)

where $W_0$— noise power in the start point; $l$—gas pipeline length; $\rho$ — density; $c$ — sound speed; $R$— linear distance from the source to the calculated point; $\varepsilon$ — point along the length of a finite length of the segment $l$; $k$ — coefficient characterizing the decrease in the noise level along the length.

From (1), if $\varepsilon=0$ sound pressure level (sound level) will be determined

$$L(\varepsilon = 0, R) = L_0 + 10 \log \left( e^{-k l} \arctg \left( \frac{1}{R} \right) \right) - 10 \log \left( l g \frac{R}{R_0} \right) - 10 l g 8 \pi$$  \hspace{1cm} (2)

From (1), if $\varepsilon=l$ sound pressure level (sound level) will be determined

$$L(\varepsilon = l, R) = L_0 + 10 \log \left( e^{-k l} \arctg \left( \frac{1}{R} \right) + \arctg \left( \frac{\varepsilon}{R} \right) \left[ 1 - e^{-k l} \right] \right) - 10 \log \left( l g \frac{R}{R_0} \right) - 10 l g 8 \pi$$  \hspace{1cm} (3)

The difference in sound pressure levels from the point $\varepsilon = 0$ (2) to the point $\varepsilon = l$ (3) will be

$$\Delta L = L(\varepsilon = l, R) - L(\varepsilon = 0, R) = 4.34 kl$$  \hspace{1cm} (4)

From (4) it can be seen that $\Delta L$ depends on the length of the gas pipeline $l$ and coefficient $k$.

In order to find the coefficient $k$, we use the experimental data [7]

$$\Delta L = 14.7 l g \left( l / 10 \right)$$  \hspace{1cm} (5)

Formula (5) was obtained by approximating the results of acoustic measurements at a distance of 10 m from GCP’s pipeline. The length of the gas pipeline after GCP is 1000 m. Noise is caused by the passage of natural gas in the valve, which is substantially more than the noise of the natural gas flow, even at the maximum speeds allowed by SP 42-101-2003 for TPPs. SP 42-101-2003 [9] limits the speed of natural gas for low pressure gas pipelines to 7 m / s, for medium pressure gas pipelines to 15 m / s, and for high pressure gas pipelines to 25 m / s. Therefore, the main source of noise in the gas pipeline of GCP is the noise from regulating valves with significant natural gas consumption.

From (4) and (5) we obtain

$$k = \frac{3.387}{l} l g \left( l / 10 \right)$$  \hspace{1cm} (6)

The coefficient $k$ in a complex way depends on $l$. Formula (6) is valid for $l > 10$ m.

Figure 1 shows the change in the coefficient $k$ from $l$. It can be seen that the coefficient $k$ varies from 0.54 to 0.0068 with a change in $l$ from 30 to 1000 m, respectively.
3. Results of calculations

The results of calculations have a practical importance for noise reduction measures from gas pipelines of GCP of thermal power plants (TPS). Natural gas is currently the main type of fuel in the power industry for TPS. Natural gas is used in power boilers due to a decrease in the gas pressure in the main before the burners to the necessary level, usually from 1 – 1.2 to 0.05 – 0.12 MPa in gas distribution stations. GCP’s at large thermal power stations are in separate buildings. According to design regulations, 1200 MW TPPs and 900 MW TPPs have one GCP; for TPSs of higher capacity, there can be two or more GCPs. For example, the measured noise level is 110 – 125 dBA inside the GCP and 100 – 105 dBA outside [7]. The length of the pipeline can be from 100 to more than 1000 m.

Noise requirements to GCP and its pipelines are formulated in [9]. The permissible workplace noise is 80 dBA. Decreasing the pressure in GCP increases the noise level. TPPs are usually located in the immediate proximity to residential areas where the sanitary requirements are much more stringent. For example, the night sanitary limit for residential areas is 45 dBA. Thus, a GCP and its pipelines can substantially exceed the sanitary limits for workplaces and residential areas.

From formula (4) we obtain a decrease in sound level along the length of the gas pipeline. Figure 2 shows the calculation results. The sound levels vary along the length of the pipeline from 10 dB to almost 30 dB with an increase in length from 50 to 1000 m.

The resulting formula allows to calculate the sound pressure levels (sound level) and make the necessary solutions to creating a low-noise power facility [10] and select the necessary measures for sound attenuation [11].

4. Conclusion
1. Formula (6) is obtained for calculating the change in sound pressure levels from linear sources with variable noise characteristics along the length at a constant distance from the gas pipeline.
2. A formula has been obtained for finding the coefficient k depending on length. This is allows one to calculate sound pressure levels from gas pipelines after GCP.
3. Calculation results are obtained for various lengths of GCP’s gas pipelines. The obtained results allow you to make the necessary decisions on the creation of a low-noise object and select the necessary measures for sound attenuation.
Figure 2. Sound reduction depending on the relative length $\xi/l$ of gas pipelines of different lengths $l$ at a distance $R = 10$ m.

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References

[1] Crocker M 2007 Handbook of Noise and Vibration Control. (N.Y.: John Wiley and Sons)
[2] Yudin E Ya 1985 Industrial Noise Control (Mashinostroenie, Moscow) [in Russian]
[3] Ivanov N I 2017 Protection against noise and vibration (“NICHE ART” Publishing House) [in Russian]
[4] Ivanov N I 2013 Engineering acoustics. Theory and practice of noise control: textbook (M.: Logos) [in Russian]
[5] Shubin I L, Tsukernikov I E, Nikolov N, Pisarski A 2015 Fundamentals of the design of noise protection screens. (M.: Publishing House "BASTET") [in Russian]
[6] Tupov, V.B. 2019 Calculation of noise level from a linear source with variable noise characteristics along the length, AKUSTIKA, 32 pp 64-66,
[7] Tupov V B, Tupov B V, Skvortsov V S 2018 Features of Noise Emission from Gas Distribution Stations and Gas Pipelines Power Technology and Engineering, 52 4 pp 448-450
[8] Rules and Regulations SP 42-101-2003. 2004 General Principles of the Design and Construction of Gas Distribution Systems from Metal and Polyethylene Pipes [in Russian].
[9] Sanitary Code SN 2.2.4_2.1.8.562–96. 1997 Noise at Workplaces, in Premises of Residential and Public Buildings, and in Residential Areas (Minzdrav, Moscow) [in Russian]
[10] Tupov V and Tupov B 2017 Solutions to creating a low-noise power facility 24th International Congress on Sound and Vibration, London, UK
[11] Tupov V B 2013 A package of measures to reduce the noise from thermal power plants Power Technology and Engineering 47 3 pp 217-221