Definition Factors Cubic Approximating Polynomial for Locking Characteristics of Steel Pipelines

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Abstract* – *An important part of mathematical models of hydraulic state engineering grids is locking ratio. Traditionally it represent a cubic approximation polynomial, which adequately reproduce locking characteristics of pipelines of various diameters and materials. Defined simple functions to determine the factors of the approximation polynomial based on the diameter. These functions are a convenient tool to obtain baseline data necessary in mathematical models of engineering grids.

Key words – engineering grid, hydraulic condition, locking ratio, approximation polynomial.

I. Introduction

Usually hydraulic state of engineering grid describe the contour or nodal mathematical models. These models include the equation of the first and second rules Kirchhoff and equations of branches [1]. Contour mathematical model has the form

$$\begin{cases} \mathbf{A}\vec{X} = -\vec{F} \\ \mathbf{B}\vec{Y} = 0 \\ \vec{Y} = \vec{E} - \Delta\vec{p} \end{cases} \qquad (1)$$

where **A**, **B** – incidence and circle matrix; $\vec{X}$, $\vec{Y}$ – column vectors of flow environment and pressure drop of branches; $\vec{F}$ – column vector of flow environment in nodes; $\vec{E}$ – column vector of efforts of branches; $\Delta\vec{p}$ – column vector of pressure loss (includes pressure loss due to friction, change of speed and inertia pressure).

Linear equations of this contour model (1) complementary nonlinear locking ratio

$$\Delta p = f(X), \qquad (2)$$

which usually approximated by a equation of cubic polynomial [2]

$$\Delta p(X) = \gamma\left(s_1|X| + s_2|X|^2 + s_3|X|^3\right)\operatorname{sgn}(X), \qquad (3)$$

where s_1, s_2, s_3 – factors of approximation polynomial; γ – specific volume environment, sgn – sign function (characteristic needed to continue in the third quadrant).

Cubic polynomials adequately reproduce locking characteristics of pipelines. But the values factors of this polynomial s_1, s_2, s_3 are unknown.

II. Setting Objectives

Cubic approximation polynomial (3) has a number of advantages:

- fidelity real locking characteristics;
- reproduction locking characteristics of pipelines for different materials (steel, plastic, etc.) and performance.

He also has a number of shortcomings:

- coefficients of cubic approximating polynomial unknown;
- these factors should be determined for each diameter pipeline for their real locking characteristics.

To remove these shortcomings need to determine the analytical dependence, which would allow to easily identify approximating polynomial coefficients depending on the value of the diameter of the pipeline.

Each pipeline has its own locking characteristics. Graphic representation of the set of characteristics for steel pipes of different diameters in a logarithmic scale, shows that a pattern available (Fig. 1).

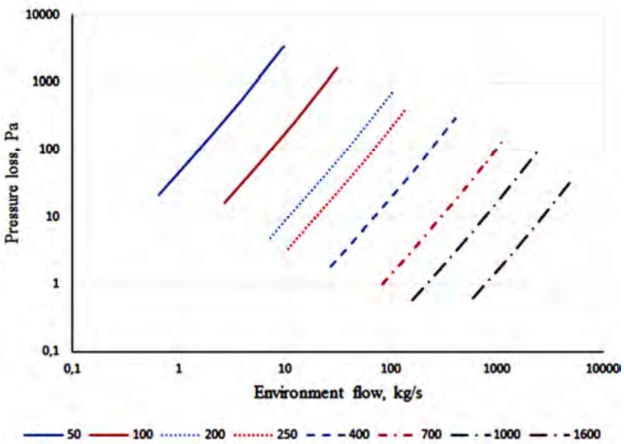

Fig. 1. Locking characteristics of steel pipelines

You must express this law and express it in an analytical form.

III. The Solution to these Objectives

As in [2] search approximating polynomial factors for locking characteristics of steel pipelines perform weighted least squares method.

By the weighted least squares method [3] criterion for selecting components s_1, s_2, s_3 parametric vector approximation function is

$$R = \sum_{i=1}^{m} w_i^2 \left(f(x_i) - F(x_i, \vec{s})\right)^2 \Rightarrow \min, \qquad (4)$$

where $f(x_i)$ – the real values of the function at the points x_1, x_2, …, x_m; $F(x_i, \vec{p})$ – approximating function values in appropriate points (approximating cubic polynomial); w_i – weights characterizing the relative importance of each $f(x_i)$. Accuracy approximation estimated relative terms – coefficient of variation [4]

$$k_v = \frac{\sqrt{D}}{\overline{X}} 100\ \%, \qquad (5)$$

and maximum relative error

$$\delta f_{max} = \max \frac{f(x_i) - F(x_i, \vec{p})}{f(x_i)} 100\%, \quad (6)$$

where $D = \sum_{i=1}^{m} \left(f(x_i) - F(x_i, \vec{p}) \right)^2 / m$ – residual variance; $\overline{X} = \sum_{i=1}^{m} f(x_i) / m$ – average value.

The results of calculating the factors of the cubic approximation polynomial locking characteristics of steel pipes (GOST 10704-63) for different diameters is provided in Table 1. The polynomial factors (3) inversely proportional to the size of the diameter – with increasing diameter factors decreases.

TABLE 1

FACTORS CUBIC POLYNOMIAL APPROXIMATION OF SET PIPES

Diameter, mm	Factors cubic polynomial approximation		
	s_1	s_2	s_3
50	1.29E+01	3.27E+01	2.14E-01
100	2.19E+00	1.49E+00	4.48E-03
200	2.48E-01	6.24E-02	3.09E-05
250	1.17E-01	1.99E-02	3.44E-06
400	2.58E-02	1.68E-03	1.72E-07
700	4.47E-03	9.91E-05	3.30E-09
1000	1.38E-03	1.54E-05	2.42E-10
1600	3.65E-04	1.22E-06	2.28E-11

For all sets pipelines coefficient of variation varies 0.48-1.42 %, maximum relative error – within 2.4-4.75 %. Moreover error calculation does not depend on the diameter of the pipeline (Fig. 2).

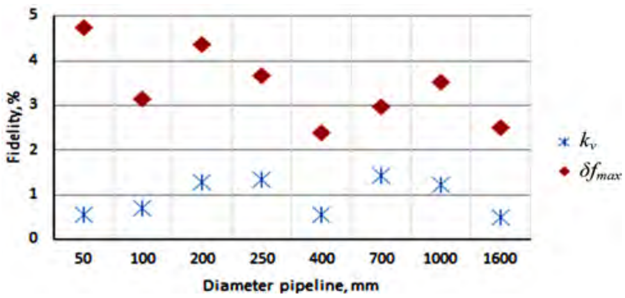

Fig. 2. Dependence fidelities locking characteristics of the diameter of the pipeline

This dependence factors on the diameter can be reproduced using power function. Power function provides adequate reproduced all three relationships (Fig. 3).

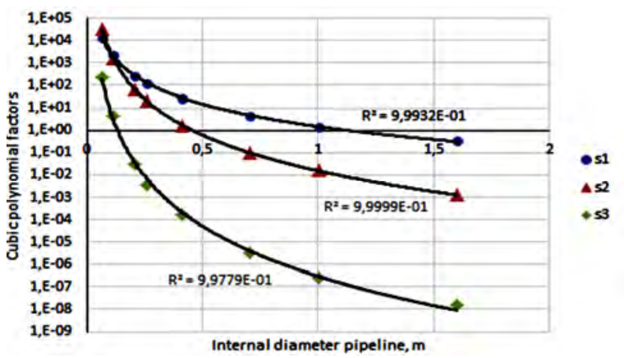

Fig. 3. The dependence of the approximation polynomial factors to the diameter of the pipeline

Approximating power function is determined in relation to the internal diameter of the pipelines. Analytical expression functions to determine factors of the cubic approximation polynomial (3), is as follows

$$s_1 = 1.4823 \cdot 10^{-3} d_{in}^{-3.3127},$$
$$s_2 = 1.5345 \cdot 10^{-5} d_{in}^{-5.3255}, \quad (7)$$
$$s_1 = 3.3241 \cdot 10^{-10} d_{in}^{-7.3553},$$

where d_{in} – internal diameter of pipeline.

For all sets pipelines coefficient of variation varies 1.2-3.5%, maximum relative error – within 3.4-4.7%.

We may be apply functions (7) in general

$$s = a d_{in}^{b}, \quad (8)$$

where *a*, *b* – coefficients of function.

Then factors such functions can be summarized in tabular form (Table. 2).

TABLE 2

ODDS FUNCTION (8)

The cubic polynomial factors	*a*	*b*
s_1	1.483E–03	–3.3127
s_2	1.535E–05	–5.3255
s_3	3.324E–10	–7.3553

The proposed functions are easy to use. They are a convenient tool to obtain baseline data for nodal or contouring mathematical models of hydraulic state engineering grids.

Conclusion

In this paper identified common depending for factors of cubic approximating polynomial from the diameter of the pipeline.

Such dependence easily determine all the necessary parameters of mathematical models of network grid with purpose analysis and optimization of hydraulic state.

Further development of this research is to disseminate information on pipelines made of other materials.

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