The method of the description of the flow of a liquid or gas in the tubular devices applied in ferrous metallurgy

I. N. Beloglazov, I. I. Beloglazov, Y.V. Sharikov
Saint Petersburg State Mining Institute (Technical University)

techno@inteco.spb.ru

The system for the motion in the main part of the tube, where there are no changes in velocity profile and where the boundary-layer thickness is equal to the radius is as follows for distances greater than the initial length i_{in}=0.03 R_e , where the flow profile is variable [1]:

$$\frac{\partial w}{\partial x}=0;$$

$$\frac{\partial p}{\partial y}=\frac{\partial p}{\partial z}=0;$$

$$\frac{\partial w}{\partial \tau}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\left(\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right),$$

where dependence can be represented as

$$\frac{\partial p}{\partial x}=\mu\left(\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}-\rho\frac{\partial w}{\partial \tau}\right), \qquad (1)$$

where w is velocity, τ time, ρ density, p pressure, ν and μ corresponding the kinematic and dynamic viscosites, and x, y, and z spatial coordinates.

Large amounts of computer time are involved in solving differential equations numerically [2], so considerable importance attaches to methods of representing such equations in a form convenient for direct engineering use. Such a form is one that describes the resistance as $Eu=\varphi(\mathrm{Re})$ or $La=\varphi(Eu,\mathrm{Re},\Gamma)$, where Eu, Re and La are the Euler, Reynolds, and La-grange numbers.

The laws describing laminar flow have been derived subject to simplifications, where we use the simplex method.

Laminar flow in a cylindrical tube is described in this way by transforming the equations to dimensionless form by a simplex technique [3–5],

$$\frac{\partial^n y}{\partial x^n}=\frac{y\ln^n S_y}{\Delta x^n}, \qquad (2)$$

where y and x are parameters, Δx is a range, and S_y is a simplex composed of the variable y.

We substitute expression (2) into (1) to get

$$Eu=2\frac{\ln^2 S_w}{\ln S_p}\Gamma\frac{1}{\mathrm{Re}}=2C_{w,p}\Gamma\frac{1}{\mathrm{Re}}\cdot$$

where

$$Eu=\frac{P}{\rho w^2},\Gamma=\frac{\Delta x}{\Delta l},\ \mathrm{Re}=\frac{w\Delta l}{\nu},\frac{1}{\Delta l^2}=\frac{1}{2}\left(\frac{1}{\Delta y^2}+\frac{1}{\Delta z^2}\right).$$

This equation is similar to [1]

$$\Delta p=\frac{64}{\mathrm{Re}}\frac{l}{d}\frac{\rho w^2}{2}$$

or in dimensionless form [1]

$$Eu=32\Gamma\frac{1}{\mathrm{Re}}$$

where $Eu=\Delta p/pw^2$ is the Euler number, Re = wd/v the Reynolds number, d diameter, l length, ρ density, $\nu=\mu/\rho$ cinematic viscosity, μ dynamic viscosity, Δp pressure difference, and w flow speed.

It follows that

$$C_{w,p}=\frac{\ln^2 S_w}{\ln S_p}=16$$

so

$$\ln^2 S_w=16\ln S_p$$

and thus

$$S_w=\exp\left(4\ln^{0.5} S_p\right).$$

On the other hand, La = EuRe [1] (where $\mathrm{La}=\Delta p\iota/\mu w$ is the Lagrange number), so can be written finally as

$$\mathrm{La}=2C_{w,p}\Gamma\cdot$$

When we use cylindrical coordinates $y=r\cos\theta$ and $z=r\sin\theta$ with $r=\sqrt{y^2+x^2}$ and $\theta=\arctan(z/y)$, where r is radius ($r\le R$,tube radius) and θ is the angle formed by the velocity vector with the spatial coordinates

$$\frac{\partial p}{\partial x}=\mu\left(\frac{\partial^2 w}{\partial r^2}+\frac{1}{r}\frac{\partial w}{\partial r}+\frac{1}{r^2}\frac{\partial^2 w}{\partial \theta^2}\right).$$

If the motion is symmetrical with respect to the x axis, $\frac{\partial^2 w}{\partial\theta^2}=0$, and becomes

$$\frac{1}{\mu}\frac{dp}{dx}=\frac{d^2 w}{dr^2}+\frac{1}{r}\cdot\frac{dw}{dr}.$$

The simplex method gives

$$\frac{p}{\rho w^2}\ln S_p=\frac{\mu\,\Delta x}{w\rho\Delta r^2}\ln S_w\left(\ln S_w+\frac{\Delta r}{r}\right).$$

The boundary conditions are

$$\frac{dw}{dr}=0,\text{ at r = 0}$$

or

$$\frac{w}{\Delta r}\ln S_w = 0$$

and becomes

$$\frac{p}{\rho w^2}\ln S_p = \frac{\mu\,\Delta x}{w\rho\,\Delta r^2}\ln S_w\left(\ln S_w + \frac{\Delta r}{r}\right)\cdot$$

and consequently

$$\mathrm{Eu}\ln S_p = 2\ln^2 S_w\,\Gamma_{\Delta d}\frac{1}{\mathrm{Re}},$$

where $\mathrm{Eu} = \dfrac{p}{(\rho w^2)}$, $\mathrm{Re} = \dfrac{w\rho\,\Delta r}{\propto}$, $\Gamma_{\Delta d} = \dfrac{\Delta x}{(\Delta d)}$, $\Delta d = 2\Delta r$

or

$$Eu = 2\frac{\ln^2 S_w}{\ln S_p}\Gamma\frac{1}{\mathrm{Re}} = 2C_{w,p}\Gamma\frac{1}{\mathrm{Re}}\cdot$$

In general, can be put as

$$\mathrm{Eu} = 2\frac{\ln^2 S_w}{\ln S_p}\Gamma\frac{1}{\mathrm{Re}} - \frac{\ln S_w}{\ln S_p}\frac{1}{\mathrm{Ho}}$$

or

$$\mathrm{Eu} = 2\frac{\ln^2 S_w}{\ln S_p}\Gamma_{\Delta d}\frac{1}{\mathrm{Re}} + 2\frac{\ln S_w}{\ln S_p}\Gamma_d\frac{1}{\mathrm{Re}} =$$

$$= 2\frac{\ln S_w}{\ln S_p}\left(\ln S_w + \Gamma'_d\right)\Gamma_{\Delta d}\frac{1}{\mathrm{Re}},$$

where $\Gamma_{\Delta d} = \dfrac{\Delta x}{\Delta d}$, $\Gamma_d = \dfrac{\Delta x}{d}$. Ho is the homochronicity number.

If the flow is unsymmetrical about the axis, gives

$$\mathrm{Eu} = 2\frac{\ln S_w}{\ln S_p}\left[\ln S_w + \Gamma'_d + \left(\frac{\Gamma'_{\text{в}}}{\Delta\theta}\right)\ln S_w\right]\Gamma_{\Delta d}\frac{1}{\mathrm{Re}},$$

Then equations are universal equations for flow in cylindrical tubes under laminar conditions; the resistance law in the interpretation used enables one to provide a more exact relationship between the parameters in the most complicated cases, can be used in computing flow hydrodynamics of the flow of a liquid or gas in the tubular devices applied in ferrous metallurgy.

REFERENCES

1. *Romankov P. G., Kurochkina M. I.* Hydromechanical Processes in Chemical Technology, Khimiya, Leningrad, 1982.
2. *Ortega J. M., Poole V. G.* An Introduction to Numerical methods for Differential Equations, Pitman, Marshfield, Massachusetts, 1981.
3. *Beloglazov I. N.* Engineering Methods of Designing Solid-State Extractors, Khimiya, Leningrad, 1985.
4. *Beloglazov I. N.* Method of Transforming Differential Equations for Hydrodynamic Phenomena and for Heat and Mass Transfer by Means of Simplexes, All-Union Institute of Scientific and Technical Information (VINITI), deposited paper No. 5570-81; Dep. Nauch. Rab., No. 2, 1982.
5. *Beloglazov I. N., Beloglazov N. K.* Simplex Method of Describing Laws of Processes in Chemical Technology, Scientific-Research Institute of Technical and Economic Investigations of the Chemical Industry, deposited paper No. 596-86; Dep. Nauch. Rab., No. 9, 1986.
6. *Beloglazov I. N., Kurochkina M. I.*, Zh. Prikl. Khim., 58, No. 7, 1504-1508, 1985.
7. *Beloglazov I. N., Kurochkina M. I.*, Zh. Prikl. Khim., 58, No. 10, 2250-2253, 1985.

I. N. Beloglazov, S. N. Saltykova, R. V. Kurtenkov
Saint Petersburg State Mining Institute (Technical University), LenNIIgiprokhim
techno@inteco.spb.ru

Analysis of statistical data of composition of the alloyed steels

Influence of a chemical compound on the carbon contents in a steel is analyzed and the mathematical model is received in the course of processing of month basic data. Optimum significances of source parameters at the carbon contents in a steel – 0,08 % have been found.

The task is the influence analysis of input data on output function. Data analysis files amounted to 31 smelting during one month. The table 1 shows average chemical composition of steel, produced at «OMZ – Spets`stal`» Ltd.

Literature and practical data gives us the idea of the impact of every element on steel properties. For example:

– Nickel makes steel high corrosion-resistant;
– Silicon is used as attached foreign material (silicon content ≤ 0.37% has no influence on the steel properties);
– Molybdenum provides increase of elasticity, oxidation resistance at high temperature;
– Manganese is used as attached foreign material (with content ≤0.8%) to avoid the detrimental steel effect;
– Copper increases corrosion-resistant properties

Change properties of the alloyed steels not only depends on the nature and the number of alloy elements but also on mutual influence and the interaction between the alloyed steels and carbon.