Iterative algorithm for large hydraulic problems.

O. V. Chepurnoi, R. T. Faizullin, Omsk State Technical University, r.t.faizullin@mail.ru

Let us consider problem of hydraulic characteristic definition for large pipe network (1).

It's well known problem related with solution of nonlinear system of algebraic equations where part of equations are linear such as first Kirhgoff law while others may be nonlinear (second Kirhgoff law).

$$
\begin{gathered}
a_{11}x_1 + ... + a_{1n}x_n = 0 \\
\cdots \\
a_{k1}x_1 + ... + a_{kn}x_n = 0 \\
\cdots \\
a_{(k+1)1} \mid X_1 \mid x_1 + ... + a_{(k+1)n} \mid X_n \mid x_n = E_1 \\
a_{n1} \mid X_1 \mid x_1 + ... + a_{nn} \mid X_n \mid x_n = E_{n-k}
\end{gathered} \tag{1}
$$

where x_i is flow rate for pipe i, a_{ij} is equal to 1 or -1 for first Kirhgoff law equation , and defined by viscosity parameter and domain of Re for nonlinear part of system. X is equal to $\mid x_i \mid^{\nu}$. For example for part of range parameters we have $\nu = 1$.

Proposition 1

Let's introduce x – vector on which we have

$$A(x)x = f$$

where matrix $A(x)$ are defined in (1).

But system of equations describes physical flow in pipe network with zero "pressure" on right part. We can find way where the fluid circulates in a closed orbit but strong positive sum of viscous losses is equal to zero right part.

Proposition 2 There is only one solution of

$$A(x)x = f$$

Then we can imply iteration method:

$$A(\mid (\alpha_k x_{n-k} + .. + \alpha_1 x_{i-1}) \mid) x_i = H \tag{2}$$

where $\alpha_k + .. + \alpha_1 = 1$. Iterative scheme converges to unique solution when $k \to \infty$ and $\alpha_k \to 0$. It can be considered as 'averaging' which converges to solution. For practical cases k can be chosen equal to 3 or 4.

For the fast convergence to solution we can find x^0 for laminar flow and then solve equations for every component k: $x^0_k = sign(x^0_k) \sqrt[\nu+1]{x^0_k}$. Program was designed and introduced to use the heat network of Omsk city and Academgorodok of Novosibirsk city. Program functions are following: system database keeps information on the composed (elements, their features, topology of network) hydraulic systems. Suitable graphic interface ensures quick and userfriendly access to these data, allows to produce their change and addition. After some years of use no wrong calculations was detected and this appeared to very helpful for minimization of energy losses.

Next application can be related to the problem of optimal petroleum transfer regimes seeking for oil pipelines. There are usually two or more pipes with several petroleum intake and outlet points. Figure 2 shows part of the one of Trans-Siberian oil pipelines. Program was applied and now is in daily use for search of optimal and safe work regimes for pipeline pumps. On the Figures 3, 4 one can see results of calculations for pressure of two branches of oil pipeline Anjerskaja-Ribnaja, Anjerskaja-Omsk. There are limitations set on the pressure and calculation of necessary choking are since that emerging.

There are needs for calculations on two scales. One scale is on order of 5-10 km and second scale is on order of 100 km and more. Find optimal regime we should calculate about nearly 10^5 variants of regimes. In order to find optimal regime we can divide power on equal parts along pipeline distance as initial approximation (2).Now program is in industrial daily use as a dispatcher tool for optimal regimes search.

References

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