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Characteristic Features of Unsteady Fluid Motion in Thermal Main

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ABSTRACT: In the article explores the nonstationary flow of liquid in heat main, transporting hot water, which arise on account of manipulation of valves or regulation of water supply by pump – in the form of a hydraulic hammer

KEYWORDS: liquid, pressure, pressure, elasticity, inertial push, hydraulic hammer, shock wave, sound speed, local acceleration, the nonstationary flow process, trunk pipelines, undiluted gases, dearation, corrosion.

I.INTRODUCTION

The widespread use in the technique of unsteady transient processes that occur during starting conditions of pipelines and their shutdown explains the increasing to the theory of unsteady flow of liquids.

A feature of the transient fluid motion is that usually this physical phenomenon is studied from two fundamentally different positions. First, the one-dimensional flow of an incompressible fluid is considered, whence the concept of "inertial pressure" appears:

$$h_u = \frac{1}{g}\int_0^l \frac{dv}{dt}\, dx, \qquad (1)$$

where l- the length of the pipe section on which the differential h_u.

The inertial pressure is the pressure required to communicate the local acceleration of the fluid in the pipe. In other words, formula (1) expresses Newton's second law.

Further, formula (1) is used to solve practical problems, and then its unsuitability is revealed with a high change in speed (for example, when you close the shutter instantly $h_u \to \infty$). This justifies the need to take into account the elasticity of the liquid and the pipe walls, i.e. transition to water hammer. When considering the physical picture of the phenomenon of hydraulic shock, it becomes possible in an elementary way to obtain the Zhukovsky formula [1] for direct hydraulic shock, equating the kinetic energy of the fluid to the work of deformations

$$h_y = \frac{cv}{g}, \qquad (2)$$

where v - the magnitude of the change in the fluid flow rate, which is the cause of the flow disturbance and the occurrence of water hammer, м/c (damping velocity);

c- shock wave propagation velocity along the pipeline, м/c.

Then, on the basis of the same physical picture, a formula is derived for the maximum value of indirect hydraulic shock

$$h_y = \frac{2vl}{gT_з}, \qquad (3)$$

where $T_3 > \frac{2l}{c}$ - shutter closing time.

It is advisable to add considerations on the physical connection of formulas (1) and (2) of the material above, otherwise it may appear that water hammer and unsteady flow of an incompressible fluid are two different phenomena [2] that are not interconnected. In fact, water hammer has the same inertial origin as the inertial pressure, since for any combination of direct and reflected waves, the increase in pressure at the point of compressible fluid is still determined by Newton's second law. Consequently, the integral (1) exists in the case of water hammer, only under the sign of the integral should there be a more complex function $\frac{dv}{dt}(x)$ of the compressible fluid. This integral is equal to the pressure of the water hammer, since when integrating the differential equations of water hammer in a pipe of constant diameter,

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only local acceleration $\frac{dv}{dt}$, is taken into account, neglecting the convective component v $\frac{\mathrm{dv}}{\mathrm{dt}}$. The resulting error is estimated by $\frac{v}{c}$, i.e. small enough. [3]

The pressure that arises in a pipeline during a hydraulic shock with any type of liquid depends on many factors and, basically, its value in most cases does not contradict that N.E. Zhukovsky [2], the famous formula:

$H=H_0\pm\Delta H$

where: H_0 - pressure in the pipeline before the occurrence of water hammer, m;

ΔH - additional pressure due to water hammer, m:

$$\Delta H = \frac{C \cdot \Delta V}{g}$$

where: *A.V* - the magnitude of the change in the fluid flow rate, which is the cause of the flow disturbance and the occurrence of water hammer, m/s;

g - gravitational acceleration, м^2/c (g=9,81 м^2/c);

The speed of movement of the shock wave C according to the recommendation of N.E. Zhukovsky is determined by the Korteweg formula [2], which has the form:

$$C = \frac{\varepsilon}{\sqrt{1 + \frac{D \cdot E_{ж}}{\delta \cdot E_{тр}}}}, \quad (4)$$

where: ε - sound propagation velocity in a liquid,m/s:

$$\varepsilon = \sqrt{\frac{E_{ж}}{\rho_{ж}}}, \quad (5)$$

here: $E_{ж}$ - *bulk modulus of fluid, Pa;*

$\rho_{ж}$ - *fluid density, кг/м^3;*

D, δ - respectively, the diameter of the pipe and the thickness of its walls, mm; Etr - modulus of elastic deformation of the pipe walls, Pa.

Many researchers has repeatedly tested the formula (4) with fast closing of the tap at the end of the cold water pipeline experimentally.

When designing heat pipelines transporting hot water, in addition to the basic calculations of pipelines, verification calculations should be carried out on the possibility of the occurrence of unsteady flow regimes in such systems with a hydraulic shock. The water temperature during operation of such systems [10] is 80-90 ° C, and during testing of pipelines it can reach 130 ° C. At this temperature, the conventional water values included in the water hammer formulas change.

Materials dedicated to the water hammer indicate that the speed of sound propagation in water is ε = 1425 m / s at 10 ° C. Unfortunately, no one focuses on the fact that for hot water mains, ε can be of great importance as well as the water temperature in them reaches 80-90 ° C, and when testing pipes even up to 130 ° C.

It is known from the physics reference book [4] that in liquids the speed of sound, as a rule, decreases with increasing temperature. Water in which the speed of sound increases by 2-4 m / s with a temperature increase of 1 ° C and reaches a maximum at a temperature of 74 ° C (which corresponds to the operation mode of water heating

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networks), and decreases with a further increase in temperature is an exception from this rule . Therefore, at a temperature of transported water T-20 ° C, the averagespeed of sound will be ε-1457 m / s, and at T-74 ° C -ε = 1634 m / s. Consequently, with increasing temperature of the transported medium, its elastic properties increase, which means that in such systems the velocity of the hydraulic shock wave and the additional pressure due to its manifestation will have greater values than in the same systems, but transporting cold water.

In heat mains, emergencies caused by hydraulic shocks can be observed more often and have greater negative consequences than for cold water supply systems due to another factor, namely, cold gases always contain undissolved gases (conditionally called “air”), which, according to many studies [6-9], significantly reduce the increase in pressure during hydraulic shocks. In hot water systems, in order to protect pipes from corrosion the water is often subjected to special deaeration to remove undissolved gases from it[10]. Moreover, this even toughens the effect of hydraulic shocks, while according to the results of experiments, even the presence of 1.5 ... 2% of undissolved gas in water can reduce the pressure during a hydraulic shock by 25 ... 30% [11].

Consequently, non-stationary processes of fluid flow in the heat pipelines transporting hot water, arising from the manipulation of valves or regulating the water supply by pumps, are accompanied by a greater increase in pressure than in cold water supply systems [12]. And as a result, pipe ruptures more often occur in hot water conduits. It is the destruction of pipes in hot water systems that often leads to disastrous consequences - hot water erodes the soil. To prevent the danger of such situations, the pressure pipelines of the heat mains must necessarily rely on the possibility of hydraulic shocks in them and based on this, appropriate measures of protection against catastrophic consequences should be developed.

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