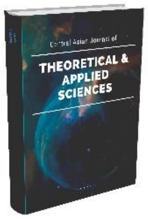

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Prediction of Cavitation Phenomena in Engineering Communications

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Abstract: *The article considers the type and intensity of the "agitation effect" of cavitation in the development stage. I adhere to the opinion that moving fluids are multiphase, and there is mutual understanding and interaction between the phases of the media. The interpenetration and movement of two or more media is modeled as the movement of a liquid in a porous medium.*

Keywords: *cavitation, cavitation phenomenon, h.a. rakhmatullin model, agitation impact, cavitation cavity, supercavitation, cavities.*

Introduction: Centralized systems of engineering communications include water supply, sewerage, heat supply, gas supply and energy supply systems, of which, in hydrodynamic terms, the sewer systems and the heat supply system of large cities are of the greatest interest. The main volume of energy and financial costs is noted in these two systems of engineering communication. In heat supply systems, the working fluid consists of a two-phase flow, i.e. a water and vapor phase, in which interphase interpenetration and interaction occur. Depending on the temperature regime, phase transitions can occur and the patterns of hydraulic resistance of these phases change [1,4].

Main body: In order to ensure the efficient operation of a centralized communication system, it is necessary that in all its sections the transporting capacity of the flow corresponds to the extremely saturated state. And the conveying capacity of the flow depends on many hydrodynamic parameters of the transported flow in the system. Unfortunately, the lack of fundamental laws to establish the transporting capacity of the flow is the main obstacle to the implementation of applied research and development of scientific and technical measures to improve the efficiency of centralized sewer systems.

As is known, all fluid flows occur in a multiphase medium, and the moving fluids themselves are multiphase. During the movement of these media, mutual understanding and interaction between the phases of the media occurs.

The interpenetrating motion of two or more media can be considered as their motion in a porous medium. For any of these gases (media), the rest will be a porous medium in which it moves. Therefore, the properties of a porous medium are essential for us[2,6].

Academician H.A. Rakhmatulin proved that in a homogeneous porous medium, volumetric porosity and surface porosity are equal, i.e.:

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$$m_W = m_S \qquad (1)$$

If some liquid with true density moves in a porous medium ρ_i, and with medium density ρ_c this liquid, i.e. ρ_c there is an apparent density, which is obtained with a uniform distribution of the mass of the liquid throughout the volume in the absence of a porous medium. From the definition of porosity and average porosity follows:

$$m_W \rho_i = \rho_c \qquad (2)$$

If the velocity field is defined by a vector $\vec{V}$ with projections u, v, w, obviously, movement in a porous medium at a speed of $\vec{V}$ and density ρ_i, it is identical to movement in a free medium with a speed of $\vec{V}$ and density ρ_c. The flow rate per unit surface is equal to $\rho_i V_n m_S$, through the average density, we get that the same flow rate is equal to $\rho_c V_n$ [1,4,6].

The model of H.A. Rakhmatullin is used for studies of cavitation and vibration of water supply tracts. The main role in the appearance of cavitation is played by the multiphase of the liquid, as is known, during interpenetration and interaction, the velocity vector of different phases is directed in different directions, and these velocities collide. These collisions are mainly the causes of bubbles in the liquid.

The intensity of the "agitation effect" depends on the stage of cavitation development. According to structural features, there are stages: small-bubbly and supercavitation. The shallow bubble stage is characterized by the accumulation of cavitation bubbles (spherical and irregular in shape) floating freely in the fluid flow and forming a cavitation torch (cavitation cavity).. As the pressure decreases, the concentration of bubbles in the cavity increases and as a result, water is completely removed from the cavitation area. At the same time, a stationary cavity filled with steam is formed in the area of the trace behind the streamlined body, which has a clear boundary between the vapor—liquid phases. This type of flow characterizes the supercavitation stage.

When designing a spillway, taking into account the prevention of cavitation, the engineering calculation consists in determining the beginning of cavitation when comparing alternative designs of its elements.

The prediction of the onset of cavitation, depending on the indicator by which the onset of cavitation is judged, is carried out by the following methods: absolute pressure; limiting combinations of characteristic pressure and velocity; critical parameters.

According to other signs, methods for predicting the onset of cavitation are divided into: calculated, based either on the use of theoretical (hydromechanical) or empirical dependencies; experimental, based on the use of laboratory research data performed for a specific model.Classification of types, stage and forms of cavitation development. The phenomenon of cavitation attracted attention back in the XIX century, when it was noticed that an increase in the number of revolutions or the size of propellers after reaching certain critical values does not lead to an increase in the thrust of the propellers, and consequently, the speed of ships. In addition, under certain conditions, intensive destruction of the metal surface of the nails of the screw blades was observed. The appearance of vessels built on the dynamic principle of maintenance (hydrofoils), as well as the creation of powerful pumps for pumping liquids have increased the relevance of this problem. Extensive research has been carried out in the field of cavitation, although many issues and tasks have remained unclear and incomplete.

Types of cavitation. Currently, there are no established principles for the classification of cavitation types. First of all, cavitation is divided according to the reasons that cause it. Based on this, hydrodynamic and acoustic cavitation are distinguished. In the first case, a decrease in pressure below the critical one is caused by the value of the velocity of movement by its shape and orientation in space relative to the velocity vector.

In the second case, the cause of cavitation is vibration effects on the liquid, for example, during the operation of vibrators of hydroacoustic stations.

The occurrence and development of ruptures in the liquid can be facilitated by feeding (blowing) gas into liquid. Therefore, it is possible to distinguish natural cavitation, which occurs only when a moving solid interacts with a liquid; also artificial, caused and supported by the forced supply of gas to some areas of the flow.

The phenomenon of cavitation caused by a decrease in pressure, of course, depends on the speed of movement of the body in the liquid: the higher the speed, the greater the vacuum and, consequently, the more intense the cavitation should be. Therefore, they talk about different stages of cavitation. Usually, the initial and developed stages of cavitation are distinguished. Various forms of cavitation can be specified within each stage.

So, at the initial stage, a bubble or film form may occur, as well as cavitation in vortex cords. An external sign of this stage is the appearance of a large number of small bubbles in the area of low pressure (on the surface of the phases or in the core of vortex cords), followed by their collapse in the area of high pressure. The bubbles sometimes merge and form films.

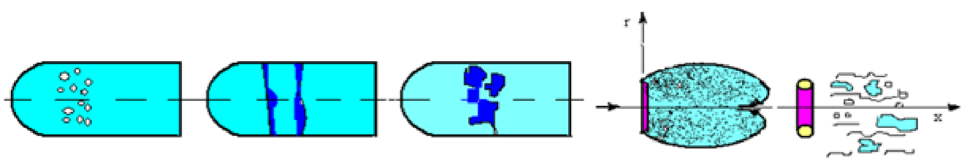

Fig.1.With developed cavitation, large cavities (cavities) are formed in the liquid, filled with a vapor-gas mixture and adjacent to a moving body.

Caverns can close on the body (partial cavitation) or extend behind the body downstream. The configuration and dynamics of the cavity depend on many factors: the speed and depth of movement of the body; its shape; the state of the boundary layer before the point of disruption of liquid jets; the presence and absence of blowing. We will provide a simplified scheme of natural developed cavitation. At the initial site, the walls of the cavity are stable and transparent. In the aft part, collapse occurs, accompanied by the formation of an oncoming trickle, periodic destruction of the walls of the cavity and the separation of individual volumes of the vapor-gas mixture.

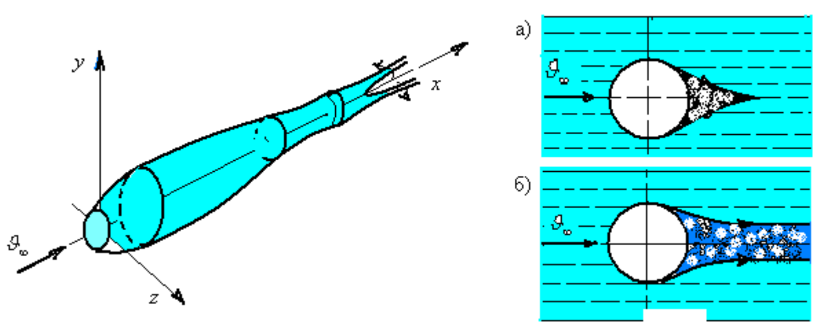

Fig.2.The current in the aft part is essentially unsteady, its boundaries are blurred. A two-phase flow is observed behind the cavern

A similar pattern exists under certain conditions and in the presence of a blowout (ventilation).

At the same time, with artificial cavitation, there is also a fundamentally different type of cavern closure - quasi-stationary closures on two longitudinal vortex cords.

Cavitation on the body of rotation. The development of cavitation in the nasal part of the body of rotation, which is a nasal combination of a cylindrical body with spherical blunting, is shown in Fig. 1. Bubble cavitation occurs in the zone of maximum rarefaction corresponding to the junction of cylindrical and spherical surfaces.

Film cavitation is installed somewhat downstream. Sometimes a single belt of film cavitation is divided into a number of spots.

The flow with developed cavitation in the aft part of the bodies of rotation can be most clearly illustrated by the example of a disk flow installed across the flow (Fig.2)

During natural cavitation, an ellipsoid-shaped cavity forms behind the disk. A return trickle occurs in the aft part. Due to disturbances, this trickle pulsates, changes the direction of movement, interacts with the walls of the cavity periodically destroying them.

Large-scale toroidal vortices are observed in the flow, the separation of gas cavities, which are further fragmented and a two-phase foam-like trace is formed behind the cavity. The specified form of gas entrainment is

called gas entrainment by annular vortices. With artificial cavitation, in addition to the above, another mechanism of gas entrainment from a ventilated cavity is possible, namely through longitudinal vortex cords (Fig.3).

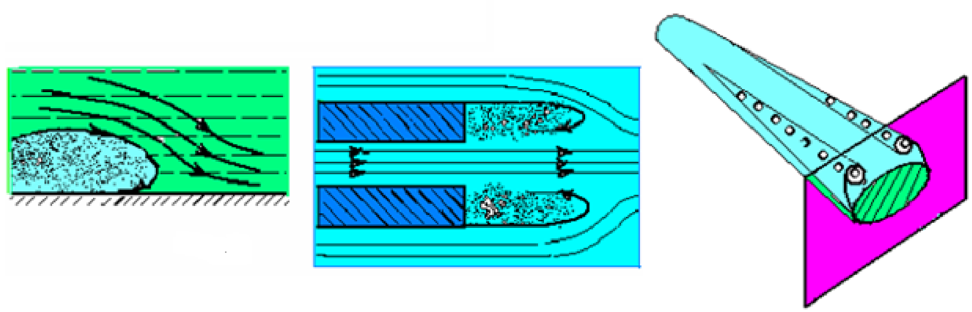

Fig.3.The theory predicts the possibility of the existence of stationary zones of finite dimensions in the flow with increased pressure compared to the pressure in the incoming flow.

Such caverns are called caverns with points of sharpening (Fig.3). With an increase in the flow rate of the blowing gas, such a cavern collapses and the usual jet entrainment of gas from the aft part is observed.

In case of partial cavitation, the closure of the cavity occurs on any element of the moving apparatus: on the body, on the liquid jet. The flow mechanism is basically similar to the flow with a return trickle discussed above (Fig.3). However, the selection of geometry and parameters of the flow of the return trickle can be avoided. When the bodies of rotation flow around, a vortex form of cavitation can also be observed. It can occur when the body of rotation moves with large angles of attack (15 ...20°), when intense vortices break off from the body (Fig. b) [3,5]..

Cavitation on bearing surfaces. Considering the flow of a conventional profile by an incoming flow with increasing speeds, several characteristic modes can be noted (Fig.4.). In the design mode (low speeds and angles of attack), the profile provides continuous flow with minimal drag (mode a). When the speed is exceeded, bubble cavitation begins to form on the upper surface in the area of minimum pressure (mode b).[10,11,12,13,14]

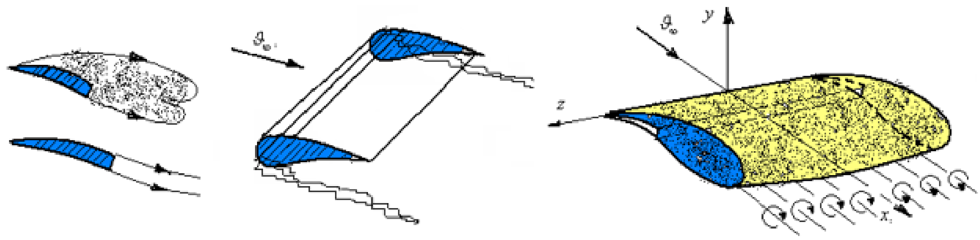

Fig.4.Cavitation on bearing surfaces.

In the future, the number of incipient bubbles increases, they drift to the trailing edge, to the area of increased pressure, where they collapse (mode b). This mode is characterized by high erosion of the profile surface. If the speed increases even more, the bubbles merge into a single cavity, which closes in the area of the trailing edge (mode d). Since the flow in the aft part of the cavity is non-stationary, in this case there is a strong shaking (cavitation bafting). A further increase in speed leads to a significant increase in the length of the cavity; shaking disappears, developed cavitation occurs (mode d).[6,7,8,9]

Conclusion: To eliminate the adverse effects associated with the origin of cavitation, special supercavitating profiles were proposed for high speeds of movement. An example of this type of profiles (wedge-shaped profiles) is shown in Fig.4. And in conclusion, we present a scheme of cavitation flow around a wing of finite span. 9. Film cavitation is conventionally shown on the upper surface, and in the end vortices cavitation in vortex cords is shown. shows the flow around the wing in the developed cavitation mode.

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