REPUBLIC OF AZERBAIJAN

On the rights of the manuscript

ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

APPLICATION OF GAS-LIQUID MEDIUM MECHANICS METHODS TO SOLVING SOME PROBLEMS OF SHIPPING

Specialty: **2003.01 – Liquid, gas and plasma mechanics**

Field of science: **Mechanics**

Applicant: **Gulshan Aghasaf kizi Akhundova**

BAKU – 2021

The work was performed at the department of "Applied Mechanics" of Azerbaijan State Maritime Academy and at the department of "Applied Mathematics" of the Institute of Mathematics and Mechanics of the Azerbaijan National Academy of Sciences.

Scientific supervisors: doctor of phys. and math. sci., prof.
Faig Bahman oglu Naghiyev

Official opponents: corr.-member of ANAS, doctor of tech. sci
Geilani Minhaj oglu Panahov

corr.-member of ANAS, doctor of tech. sci.,prof.
Ramiz Seyfulla oglu Gurbanov

cand. of phys. and math.sci., assoc. prof.
Mammad Samad oglu Aslanov

One time dissertation council BFD 3.04 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Mathematics and Mechanics of Azerbaijan National Academy of Sciences

Chairman of the one time Dissertation council:
corr.-member of ANAS, dr.of phys. and math. sci., prof.
Misir Jumail oglu Mardanov

Scientific secretary of the one time Dissertation council:
cand. of phys. and math. sci., assoc. prof.
Mahsati Akif kizi Rustamova

Chairman of the one time Scientific seminar:
corr.-member of ANAS, dr.of tech. sci

Geilani Minhaj oglu Panahov

GENERAL CHARACTERISTICS
OF THE RESEARCH WORK

Rationale of the topic and development degree. The lack of important analytical methods in the problems of shipping in liquid and gas mechanics necessitates a more accurate study of the events and processes that occur here. It should be noted the basic regulatities of the dynamic interaction of the ship's hull with the boundary layer of water containing gas bubbles have not been sufficiently studied. Therefore, there is a great need to study these regularities, as well as to develop analytical methods for modeling the processes that characterize the dynamics of the ship-liquid system based on them.

One of the most important issues and challenges in shipping is to provide maritime safety at the different periods of time.

The process of propagation of sound and acoustic waves in the ocean environment is very complex and has not been studied until the end. Knowledge of the laws of propagation of acoustic waves in the ocean is necessary both for specialists working in the field of Oceanology and for engineers operating various hydroacoustic apparatus and working on it.

Traditional water cooling systems in ships are unable to cope with high heat loads. This leads to a reduction of power of the low-speed engines(LSE) and consequently, the power of the ship or the excess of electricity for circulation. Therefore, the problem of increasing the efficiency of the cooling system of internal combustion engines is quite relevant.

Cavitation phenomena are likely to occur in the cooling shirt of cylindrical carvings due to high thermal and mechanical loads affecting the cylinder caps and parts of the cylinder-piston group.

The issue of upgrading cooling systems for high speed and advanced ICE is important due to the high probability of formation of cavitation events in high thermal and mechanical loads cooling jacket of cylinder-shaped thimbles influencing on the caps of the cylinder and the parts of the group of “a cylinder-piston”.

The issues investigated and resolved in the dissertation are relevant.

Object and subject of research. Application of gas-liquid medium mechanics methods to some problems of shipping

Goal and tasks of the research. The purpose of the work is to study the application of mechanical methods of gas-liquid environment to the solution of some shipping problems and the improvement of resource-saving and environmental performance in operational processes.

Investigation methods. Methods of two-phase environment mechanics were used in the structure of the mathematical models. The methods of excitement, separation of variables, as well as numerical integration of an ordinary differential equation system have been used to solve the problem.

The application of well-developed mathematical methods, as well as the fact that in special cases the results obtained in the dissertation coincide with the classical results of the theory of gas-liquid environment, confirms the reliability of the obtained solutions and extracts. The results of the proposed experimental studies to confirm the hypothesis about the cause of the anomalous shipwreck at sea were confirmed by the mathematical modeling in the dissertation.

Basic provisions for defense:

- the results of calculations confirming the description of the pressure and the state of the mixture in a wide range of gas volume concentration with the proposed model of the known state equation of bubble liquid in the dissertation;
- new state equations in the form of power functions and exponential functions of the gas-liquid mixture, which are in good agreement with a number of calculations obtained;
- description and physical interpretation of the basic laws of sound propagation and extinction in sea water;
- theoretical and practical confirmation of dropping process as a result of decrease in pressure and density in water with increase of flow rate around sea vessel with the help of proposed model;

- results of theoretical studies on the possibility of cavitation-corrosion spills
- the mathematical models describing the determination of the thermal and physical parameters that have a relatively significant effect on the cooling performance of explotation indicators of the ship's ICE ;

Scientific novelty of the research. New state equations have been proposed in the form of exponential and power functions of a gas-liquid mixture, which can be used in analytical researchs.

Physical interpretation of the basic regularities of sound propagation and switching off in gas-bubble sea water is given.

Theoretically and experimentally confirmed the assumption of a significant drop in pressure and a decrease in water density with an increase in the flow rate around a moving sea vessel due to the presence of gas bubbles.

The mathematical model has been proposed of an equation for determining the profile of fluid pressure near the vessel and the purine.

Mathematical researchs have been carried out and models have been drawn to detect the phenomena of "disappearance" of the sea are possible, which can increase the safety of navigation.

the criterions have been obtained which are theoretically makes it possible to select thermal - physical parameters of coolant water in order to improve the performance of vessel ICE.

Theoretical and practical significance of the study. The dynamics of gas bubbles studied in the work increases the regulatory capabilities of the eliminating of the effects of complications caused by safe movement in shipping issues of the regularities of their distribution of sound waves propagation in the binary system, the more effective form of the state equation, the mathematical model of the liquid viscosity and surface tension based on the bubble locking-cavitation processes, theoretical basis of the regulation of temperature changes in ICE, the consequences of safe movement of liquid and gas mechanics methods in shipping issues.

The work is practical importance as extensive and comprehensive research on finding a new composition that provides effective operation of sedimentation and cooling system in ICE, reflecting the regularities of prosesses occurring in the ship-liquid dynamic system, brings important and correct solutions in the field of shipping.

Approval of research results. The main results of the dissertation were reported at the scientific conference "Problems of application of mathematics" at Baku State University (Baku, 2006), VIII International scientific conference dedicated to the 90th anniversary of national leader Heydar Aliyev (Baku, May 2013), IX International scientific conference dedicated to the 91st anniversary of Heydar Aliyev (Baku, May 2014), at the Republican Scientific Conference dedicated to the 100th anniversary of the corresponding member of the Academy of Sciences (Baku, May 22, 2014), at the International Scientific Conference (Belarus, 2014), at the X International Scientific Conference dedicated to the 92nd anniversary of Heydar Aliyev (Baku, May 2015), All-Russian at the XIII inter-university scientific-practical conference (5th international) "Actual problems of economy and management in transport" (Vladivostok, May 22, 2015), at the XI International scientific conference dedicated to the 93rd anniversary of Heydar Aliyev (Baku, May 2016), Heydar Aliyev XII International Scientific Conference dedicated to the 94th anniversary (Baku, May 2017), VIII International Scientific-Practical Conference dedicated to the Year of Science (Gomel, 2017), Academician Azad Khalil oglu Mir Reported at the International Conference dedicated to the 90th anniversary of Zajanzade (Baku, 2020), 3rd International Conference on Mathematical Development and Applications (Istanbul, 2020).

Publications. 16 scientific works, 1 monograph were published in Republican and foreign scientific journals related to the topic of the dissertation work. 5 of the 10 articles were published in periodical scientific publications included in the list of single, including international summarizing and indexing, 5 articles and 3 of 5 theses were published abroad.

Institution where the dissertation work was executed. The dissertation work was performed at the Department of “Mechanics and mathematics” of the Azerbaijan State Maritime Academy and at the Department of "Applied Mathematics" of the Institute of Mathematics and Mechanics of ANAS.

Structure and volume of the dissertation (in signs, indicating the volume of each structural subsection separately)

The dissertation work consists of introduction, contents, three chapters, conclusion and list of literature in 111 titles referenced. The total volume of the dissertation work is 219466 signs (title page-353 signs, table of contents - 3190 signs, introduction - 37969 signs, chapter one - 38000 signs, Chapter Two - 56000 signs, Chapter Three - 84000 signs, results - 1035 points).

THE MAIN CONTENT OF THE DISSERTATION

In the **introduction**, the relevance of the topic of the dissertation, a summary of the work on the topic, the purpose of the research and a brief content of the work are given.

Chapter I called "Characteristics of sound propagation in a bubble liquid"**.** This chapter consists of 5 sub-chapters and is devoted to the derivation of state equations of bubbling liquid and the study of sound propagation properties in sea water. The calculation and study of the actual value of the speed of sound in seawater allows to determine the error of the passage of sound pulses in the depths of the sea and increase the accuracy of the measured depths.

In **1.1.** "The state equation of the insoluble bubbling liquid". The barotropic state equation $p = p(\rho)$ of bubbling mixture $v_1 = v_2$, $T_1 = T_2$, $p_1 = p_2 = p$ in thermodynamic balance is derived.

Here v_i, p_i, T_i ($i = 1,2$) are velocity, pressure and temperature of the i-th phase. Indices 1 and 2 represent the parameters of fluid and gas, respectively. It is considered that the bubbles have the same radius and are equally distributed. In this case

$$\frac{\rho}{\rho_0} = \frac{1}{\alpha_{10} + \alpha_{20}\dfrac{p_0}{p}} \quad \text{or} \quad \frac{p}{p_0} = \frac{\alpha_{20}}{\dfrac{\rho_0}{\rho} - \alpha_{10}} \qquad (1)$$

the case equation is obtained. Here α_1 və α_2 are the volume concentrations of liquid and gas.

In **1.2.** taking into account compressibility abilities of thermodynamic balance approximation and carrier phase, the state equation of the bubbling fluid fluid is derived as follows:

$$\frac{\rho}{\rho_0} = \frac{\dfrac{p}{p_0} + C}{1 + C\left(\alpha_{10} + \alpha_{20}\dfrac{p_0}{p}\right)}, \qquad C = \frac{c_1{}^2 \rho^{\circ}_{10}}{p_0} - 1 \tag{2}$$

Also is derived another state equation of the bubbling fluid taking into account the surface tension ($\frac{2\sigma}{R}$ laplace pressure). However, this time it was taken into account that the carrier phase is not compressible:

$$\frac{p}{p_0} = \frac{\alpha_{20}(1+S)\rho/\rho_0}{1-\alpha_{10}\rho/\rho_0} - S\cdot\sqrt[3]{\frac{\alpha_{20}\rho/\rho_0}{1-\alpha_{10}\rho/\rho_0}}, \; S = \frac{2\sigma}{R_0 p_0} \tag{3}$$

1.3. serves as a basis for the study of the dynamics of the bubble in the viscous liquid.

Under the condition of capillary effects, the Relay-Lamb equation is written as follows:

$$R\ddot{R} + \frac{3}{2}\dot{R}^2 = \frac{p_2 - p_c - 2\sigma/R}{\rho_{10}} - 4\nu_1\frac{\dot{R}}{R}, \; \frac{p_2}{p_0} = \left(\frac{R_0}{R}\right)^3 \tag{4}$$

$$t = 0: \; R = R_0, \; \dot{R} = 0$$

When the pressure far from the bubble with initial radius 10 micrometer in water increases with a jump from 1 atm to 1.1 atm, the dependences of the bubble radius and gas pressure on the time were given in Figures 1.1 and 1.2.

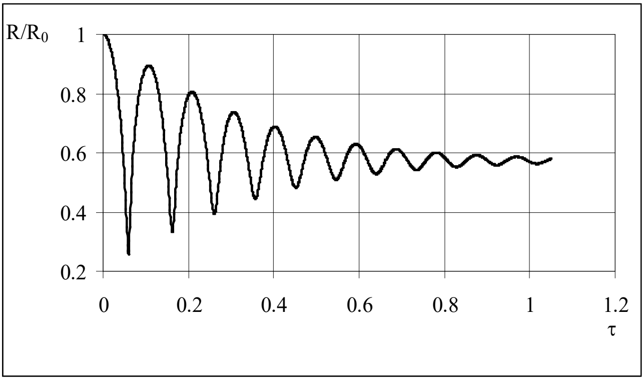

Fig. 1.

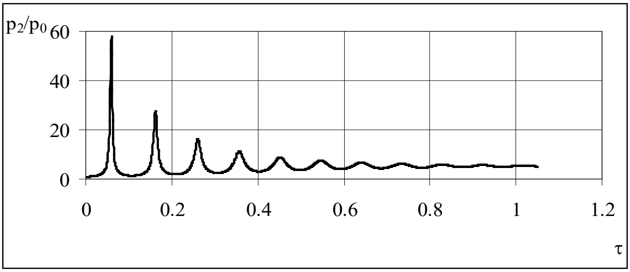

Fig. 2.

In 1.4. is shown that the extinction and absorption of sound waves in the sea does not end only because of the viscosity and thermal conductivity of the liquid.

The main gas bubbles for absorption of sound waves in seawater with a non-uniform environment are gas bubbles. This absorption occurs more strongly at resonant frequencies.

$$\frac{\delta_p}{\delta_\rho} \approx \frac{p_0}{\rho_0} \cdot \frac{C_1^2 \rho_{10}^0 / p_0}{\alpha_{10} + \alpha_{20} C_1^2 \rho_{10}^0 / p_0} \quad \text{or} \quad C_0 = \sqrt{\frac{p_0}{\rho_0} \cdot \frac{C_1^2 \rho_{10}^0 / p_0}{\alpha_{10} + \alpha_{20} C_1^2 \rho_{10}^0 / p_0}}$$

The calculations show that surface tension leads to an increase in pressure, a decrease in mixture's density, and an increase in the speed of sound. And the volume concentration of gas leads to a decrease in the speed of sound (Fig. 1.3)

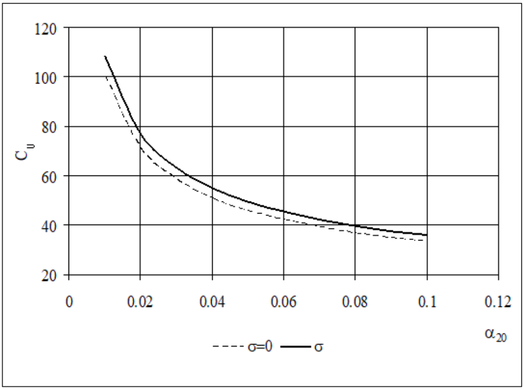

Fig. 3. Dependence of sound speed on gas concentration.

In **1.5** the expression of the average pressure with respect to the average of fluid around the equivalent cell denoted by the radius R_* of the bubble is given:

$$p_1 = p_2 - \frac{2\sigma}{R} - 4\mu_1\frac{\dot{R}}{R} - \rho_1^0\left[(1-\varphi_1)R\ddot{R} + \frac{3}{2}(1-\varphi_2)\dot{R}^2\right],$$
$$\varphi_1 = \frac{3}{2}\frac{\alpha_2^{1/3}-\alpha_2}{1-\alpha_2},\ \varphi_2 = \frac{\alpha_2^{1/3}(\alpha_2+2)-3\alpha_2}{1-\alpha_2},\ \alpha_2 = \alpha_{20}\left(\frac{R}{R_0}\right)^3 \qquad (5)$$

To determine the unknowns $R,\ P_2$, the system of equations of a two-temperature, two-pressure model describing the dynamics of insoluble gas bubbles in a liquid is written in dimensionless form:

$$\frac{d\theta}{d\tau} = \frac{3\theta}{Y_1P_2}\left[\gamma(1+S)G - (\gamma-1)P_2\dot{Y}_1\right],\qquad \frac{dY_1}{d\tau} = Y_2,\ \ \theta = T_2/T_0 \qquad (6)$$

$$\frac{dP_2}{d\tau} = \frac{3\gamma}{Y_1}\left[(1+S)G - P_2\dot{Y}_1\right],\ \ P_c = p_c/p_0,\ \tau = t/t_0, \qquad (7)$$

$$a_2 = \frac{\lambda_2}{\rho_{20} c_{p2}}, \; Pe_2 = \frac{R_0}{a_2}\sqrt{\frac{p_0}{\rho_1^0}}, \; \gamma = c_{p2} / c_{V2}$$

$$\frac{dY_2}{d\tau} = -\frac{3}{2}\cdot\frac{Y_2^2}{Y_1} + \frac{P_2 - P_c - S/Y_1}{Y_1}\cdot Pe_2^2 - L\cdot\frac{Y_2}{Y_1^2}, \;, \qquad (8)$$

$$G = sign(1-\theta)\cdot\sqrt{\frac{3(\gamma-1)\theta}{Y_1}\left|\dot{Y}_1(1-\theta)\right|}, \; Y_1 = R/R_0, \; P_2 = p_2/p_0,$$

$$Y_2 = \dot{R}/u_0, \; t_0 = R_0^2/a_2, \; S = 2\sigma/R_0 p_0, \; L = 4\nu_1/a_2, \; u_0 = R_0/t_0$$

$$\tau = 0 \text{ olduqda } \theta = 1, \; P_2 = 1 + S, \; Y_1 = 1, \; Y_2 = 0$$

Fig. 4 and Fig. 5 shows the dependence of radius of the air bubble, the air pressure in the bubble, and the temperature of the gas on time after the the pressure abruptly increasing in the water relately from *p0=1atm* to *p0=1,5atm* and from *p0=1atm* to *p0=0,7atm* at room temperature $T_0 = 293^0 K$. Here 1 -radius, 2 - gas temperature, 3 - air pressure.

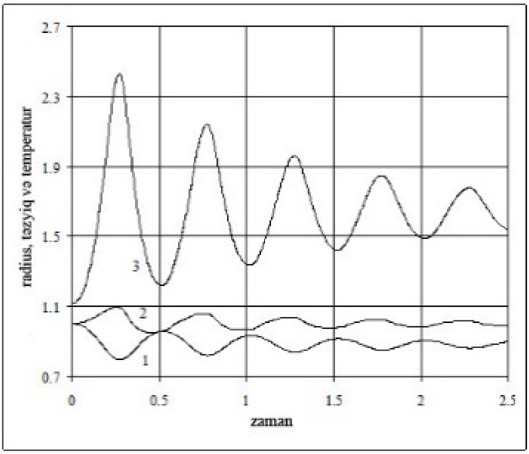

Figure. 4. The dependence of the radius, pressure and temperature of the air bubble on time when the water pressure rises from

Pc=1atm to *pc=1,5atm*

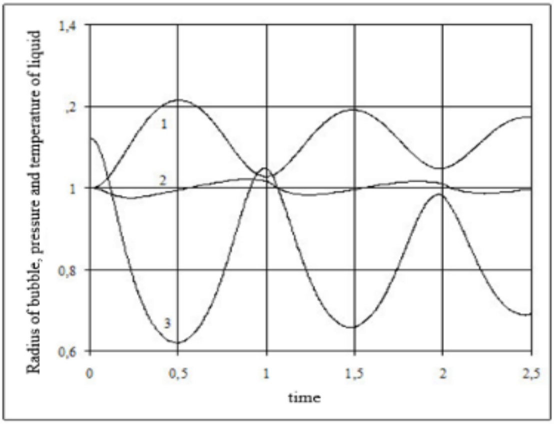

Figure. 5. The dependence of the radius, pressure and temperature of the air bubble on time when the water pressure rises from

Pc=1atm to *Pc=0,7atm*

Fig. 6 and Fig. 7 shows the comparisons of the curves obtained as a result of calculations based on the proposed formulas with the curves constructed by the equations of state proposed by R.I. Nigmatulin.

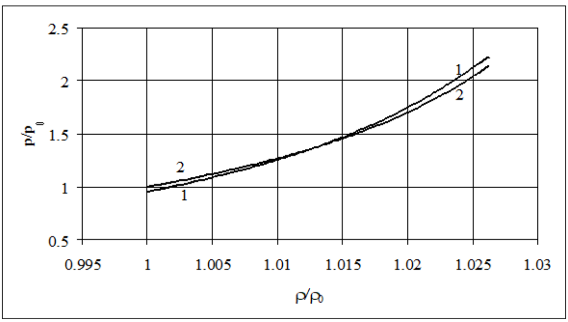

Fig. 6.

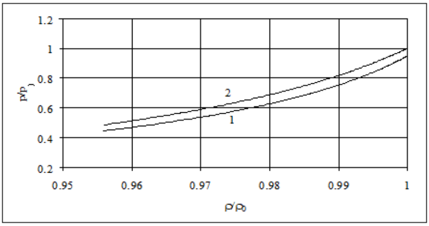

Fig. 7.

The second chapter of the thesis called “Application of gas-liquid mixture equations to shipping issues” and consists of four subchapters. The application of the state equations of gas-liquid mixture to some issues relevant to shipping has been studied.

In **2.1.** has examined application of Pade Aproximation. This subchapter is devoted to derivation of various forms of the state equation of bubble liquid by applying the Pade aproximation.

For different values of the volume concentration of gas in the liquid, the dependence of the pressure of the bubble mixture on the density of the mixture of water and gas bubbles is given.

The **2.2.** was devoted to derivation of the state equation of the bubbling fluid in the form of exponential function of taking into account the compressibility and surface tension of the carrier phase. The acceptance and reliability of fluid’s equation is veryfied.

Since the known state equation is not simple to obtain analytical results, the density dependence of the pressure in the work is presented in the form of exponential or power function series:

$$\frac{p}{p_0} = \frac{1}{2\alpha_{10}}\left\{\alpha_{10} - \alpha_{20} + \exp\left[\frac{2\alpha_{10}}{\alpha_{20}}\left(\frac{\rho}{\rho_0} - 1\right)\right]\right\} \qquad (9)$$

$$P = \frac{p}{p_0} = \frac{1}{\alpha_{10}\alpha_{20}^2}\left[\alpha_{10}^3 + (1 - 3\alpha_{10})\Re + \Re^2\right], \ \Re = \frac{\alpha_{10}\rho}{\rho_0} \qquad (10)$$

With the help of these models, the results of calculations showed that the dependence of the pressure on the density in the event of a sharp drop in the concentration of different volumes of gas and pressure in the liquid corresponds well with R.I. Nigmatulin's state equation of a bubble liquid(Fig. 8).

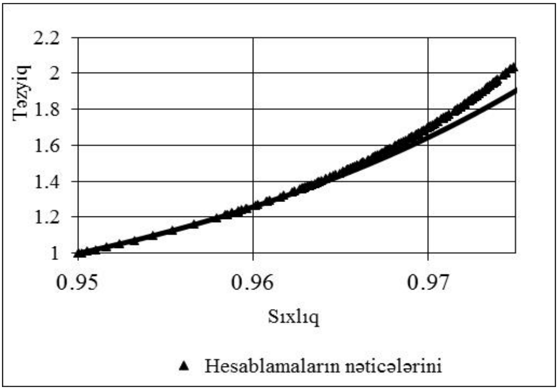

Fig. 8. Results of calculations $Pc=1,5atm$

In **2.3.** offered a mathematical model that confirms the hypothesis about the cause of abnormal shipwrecks.

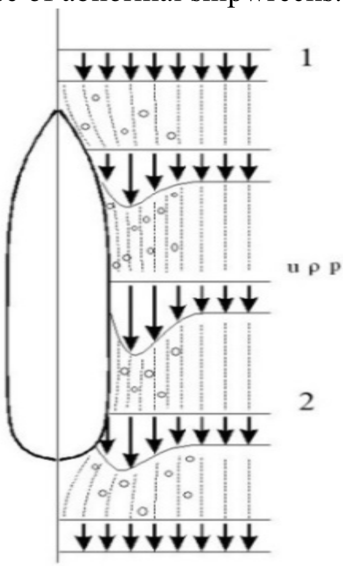

Fig. 9 Flow of bubble mixture between sections 1 and 2.

Estimates have been made to identify possible maritime areas in the disappearance event and to ensure the safety of the sailing.

Let us denote the values of all parameters of the medium in section 1 by the index "1", and in an arbitrary intermediate section by the index "2" (Fig. 9).

Here is determined the dependence of the dimensionless speed U_2 on the dimensionless density $\Re_2$:

$$U_2 = \sqrt{\frac{2\alpha\gamma}{e^{\alpha}}\left(\ln\left(\frac{\Re_1}{\Re_2}\right)+\sum_{k=1}^{\infty}\left[\frac{(\alpha\Re_1)^k}{k!\cdot k}-\frac{(\alpha\Re_2)^k}{k!\cdot k}\right]\right)+U_1^2}$$

Figures 10 and 11 depict the dependence of the density $\Re_2$ and the pressure P_2 of the mixture on the flow rate U_2. The volume of gas concentration is assumed to be $\alpha_{20} = 0{,}1$.

A comparison of the results of the calculations shows that taking into account of surface tension significantly enhances the effect of density and pressure drop with increasing velocity of the gas-liquid mixture flowing past the hull. (Fig. 10, Fig. 11).

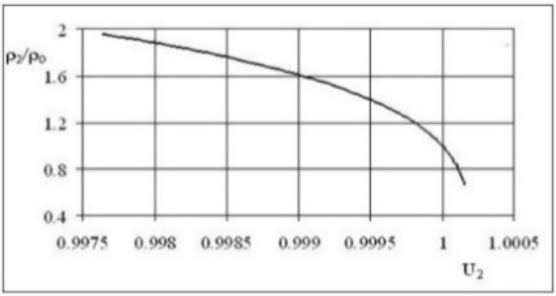

Fig. 10 Dependence of density on flow rate.

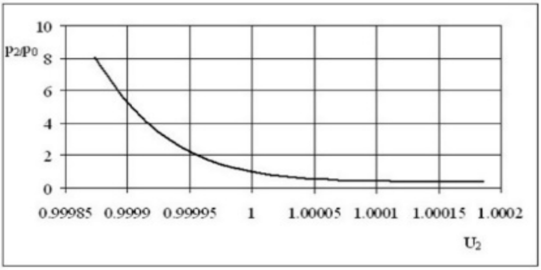

Fig. 11. Dependence of pressure on flow rate.

In addition to the laws of hydraulics, the onset of cyclones and tropical storms (especially noteworthy in the North Atlantic) also contributes to the reduction of pressure. In this case, the pressure of the upper layers of water on the lower layers is significantly reduced. Intensive bending of the upper surface leads to the formation of voids and the absorption of air over the water.

The proposed model allows to estimate theoretically the extent of ship collapse and the occurrence of bending on the surface of the sea around the moving ship.

In **2.4.** has described the main patterns of sound damping and propagation in the ocean and provides a physical interpretation of these regularities.

The effect of gas bubbles on absorbing sound waves is investigated. Continuity equation of one-dimensional motion and state equation of ocean water is written as follows:

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u)}{\partial x} = 0, \qquad \rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x}\right) + \frac{\partial p}{\partial x} = 0$$

$$\frac{p}{p_0} = \frac{\alpha_{20}(1+S)\rho/\rho_0}{1-\alpha_{10}\rho/\rho_0} - S\cdot\sqrt[3]{\frac{\alpha_{20}\rho/\rho_0}{1-\alpha_{10}\rho/\rho_0}}, \qquad S = \frac{2\sigma}{R_0 p_0}$$

The effect of gas bubbles in the liquid on the absorption of sound waves is studied. The equation of continuity of one-dimensional motion and the equation of state of ocean water are written in the following form:

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} = 0, \qquad \rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x}\right) + \frac{\partial p}{\partial x} = 0$$

$$\frac{p}{p_0} = \frac{\alpha_{20}(1+S)\rho/\rho_0}{1-\alpha_{10}\rho/\rho_0} - S\cdot\sqrt[3]{\frac{\alpha_{20}\rho/\rho_0}{1-\alpha_{10}\rho/\rho_0}}, \qquad S = \frac{2\sigma}{R_0 p_0}$$

Figures 12 and 13 show the absorption coefficient and the phase velocity dependence. The balanced radius of the bubbles was assumed to be 10 mkm and the volume concentration was 5%.

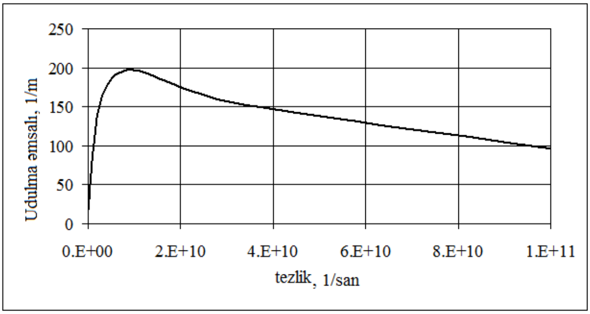

Fig. 12. Frequency dependence of absorption coefficient

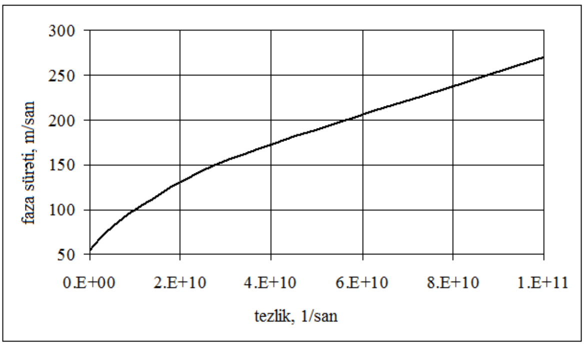

Fig. 13. Frequency dependence of phase velocity

Aanalysis of the researches shows that the damping factor increases with the increase in the viscosity coefficient according to the classical theory.

As can be seen from Fig. 12, there is a typical range for frequencies, which is sometimes called the "gloom" range due to the high damping values. This means that the wave will extinguish even more strongly in the " gloom " range.

The third chapter of the dissertation is entitled "Development of theoretical and experimental methods for increasing the effectiveness of coolants of vessel engines" consists of eight subchapters. This chapter discusses ways to improve cooling parameters to increase the reliability of a marine engine. Mathematical modeling of the processes described in the dissertation, development of theoretical methods of solving the given problems are given. The problem is solved with the help of the proposed model without running to experiments to obtain the necessary binary solution.

In **3.1.** investigated the effect of gas bubble excitation on the surrounding fluid pressure. During the study, the problems of metal collapse under the influence of cavitation were discussed.

The effective operation of the engine can be ensured if the metals from which the engine cooling system parts are made do not cause corrosion of the coolant, so that clogging, stratification, foaming and sedimentation do not occur for a long time.

In **3.2**. the effect of fluid viscosity and surface tension on the collapse of bubbles was investigated and a mathematical model was derived.

The profile of the description of the pressure around the moment of collapse of the bubbles of the gas-liquid mixture with the volume concentration of $\alpha_{20} = 0{,}05$ is shown below when $\tau = R / R_0 = 0{,}01$.

$$\frac{p - p_0}{\Delta p} = P = \left(\Sigma - L\sqrt{\frac{1}{\tau^3} - 1} \right)\frac{1}{\tau} + \frac{1}{\tau^3}\left[\tau^3 - \tau\xi + \frac{\tau\xi}{3}\left(1 - \tau^3\right)\left(4 - \tau^3\xi^3\right) \right]$$

$$\Sigma = \frac{2\sigma}{R_0 \Delta p},\ L = \frac{4\nu}{R_0}\sqrt{\frac{2}{3}\frac{\rho_1^0}{\Delta p}},\ \nu = \frac{\mu}{\rho_1^0},\ \Delta p = p_* - p_0,\ \sqrt[3]{\alpha_{20}} \le \xi \le 1/\tau$$

The results show that although the pressure around the bubble is high at the moment of collapse, the surface tension leads to a decrease in the value of the fluid pressure.

This chapter looks for methods to improve cooling parameters in order to increase the reliability of the naval engine. The effective operation of the engine can be ensured at the time when the metal parts of cooling system of the engine do not cause corrosion of coolants and incruptation, stratification, bubbling and sedimentation do not happen for a long time.

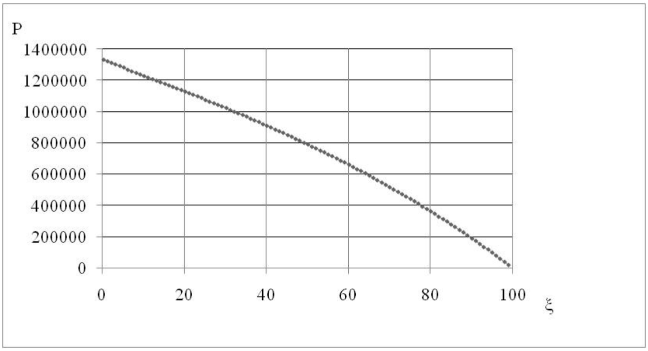

Fig. 14. The profile of the pressure around the bubbles during collapse.

In **3.3.** the available methods of obtaining coolants are investigated. Calculations for aqueous solutions as glycerin, methanol, ethanol, toluene, etc., as well as their comparison with known experimental data, confirmed the possibility of a theoretical prediction of the significant slowdown or stagnation of heat and mass exchange processes.

In **3.4.** examined the coolants used in the technique and their properties. The properties listed above are provided by the appropriate chemical composition of the heat carrier and its special handling.

On the basis of the analysis of the scientific and technical literature, the sum of the design, mode and hydrochemical parameters of cooling, which have a greater impact on the operational performance of ships, is determined.

Mathematical modeling of the processes described in **3.5.** development of theoretical solutions to the problems is given. The problem is solved with the help of the results of the proposed model without running to experiments to obtain the necessary binary solution.

$$\frac{\partial T_l}{\partial t} + w_l \frac{R^2}{r^2}\frac{\partial T_l}{\partial r} = \frac{a_l}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial T_l}{\partial r}\right) \quad (11)$$

$$\frac{\partial k}{\partial t} + w_l \frac{R^2}{r^2}\frac{\partial k}{\partial r} = \frac{D_l}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial k}{\partial r}\right) \quad (12)$$

$$R\dot{w}_l + \frac{3}{2}w_l^2 = \frac{p_{v1} + p_{v2} - p_\infty - 2\sigma / R}{\rho_l} - 4\nu_1 \frac{w_l}{R} \quad (13)$$

$$j_i = \rho_i\left(\dot{R} - w_l - w_i\right) \quad (14)$$

$$\rho_{l1} w_1 = -\rho_{l2} w_2 = -\rho_l D_l \left.\frac{\partial k}{\partial r}\right|_R$$

$$\dot{R} = w_l + \frac{j_1 + j_2}{\rho_l} \quad (15)$$

$$k_R j_2 - (1 - k_R) j_1 = -\rho_l D_l \left.\frac{\partial k}{\partial r}\right|_R \quad (16)$$

$$\frac{d}{dt}\left(\frac{4}{3}\pi R^3 \rho_{vi}\right) = 4\pi R^2 j_i \quad (17)$$

$$p_{v1} = p_{S1}(T_v) N_1(k_R), \quad p_{v2} = p_{S2}(T_v)[1 - N_1(k_R)] \quad (18)$$

$$p_{vi} = BT_v \rho_{vi} / \mu_i \quad (19)$$

$$\frac{dp_{Si}}{dT_v} = \frac{l_i \rho_{vi}}{T_v} = \frac{l_i \mu_i}{B}\frac{p_{Si}}{T_v}, \quad (i = 1,2) \quad (20)$$

$$\rho_{l1} + \rho_{l2} = \rho_l \quad k_1 = k = \rho_{l1} / \rho_l, \; k_2 = \rho_{l2} / \rho_l = 1 - k, \; k_1 + k_2 = 1$$

$$N_1(k_R) = \frac{\mu_2 k_R}{\mu_2 k_R + \mu_1(1 - k_R)}$$

where p_{v1} and p_{v2} - the pressures of the vapor components in the bubble, p_∞ - the pressure of the liquid away from the bubble, σ and ν_1 - the coefficient of surface tension and kinematic viscosity of the liquid, T_l - the temperature of the liquid, w_l - the radial velocity of the liquid on the surface of the bubble, $a_l = \dfrac{\lambda_l}{\rho_l c_l}$ - the temperature permeability of the liquid, D_l- diffusion coefficient, w_i - the diffusion rate of the components, k_R - is the concentration of the first component on the phase separation surface, T_v - is the temperature of the vapor, ρ_{vi} - is the density of the components of the vapor mixture in the bubble, μ_i - is the molecular weight, p_{Si} - is the saturation pressure.

$$N_{k_0} = \mu k_0 / (\mu k_0 + 1 - k_0), \quad N_{c_0} = \mu c_0 / (\mu k_0 + 1 - c_0), \quad \mu = \mu_2 / \mu,$$

μ_i - is the molecular weight of the liquids that make up the mixture.

In **3.6**. and **3.7.** examined the heat-mass transfer in a binary solution when periodic disturbances are propagated.

The solution of the system of equations (11) - (20) is sought as a real part of the following complex expression:

$$\varphi = 1 + \varphi^0 \exp(i\Omega_* \tau), \; J_i = J_i^0 \exp(i\Omega_* \tau), \; W = W^0 \exp(i\Omega_* \tau)$$

Here $\Omega_* = \Omega + i\Omega_{**}$. Ω_{**} is is the decrement of the dances that fade with time. This type of solution behaves like exponential excitements that fade with free time when $\Omega_{**} > 0$.

Logarithmic extinction decrement is equal to the ratio of the remaining amplitude A (τ) over time at the period $T = 2\pi / \Omega$.

$$\Lambda = \ln\frac{A(\tau)}{A(\tau+T)} = \ln e^{\Omega_{**}T} = 2\pi\frac{\Omega_{**}}{\Omega} \tag{21}$$

A characteristic equation with respect to Ω_* was obtained and analyzed:

$$\left(i\Omega_* + \frac{1}{\mathrm{Re}}\right)\left(i\Omega_* - \Psi_3 - \Psi_4\right) = \beta\left[(\alpha_1 + \alpha_2 L\mu)S_3\Psi_1 + \left(\frac{\alpha_1}{k_0\mu^2} - \frac{\alpha_2}{(1-k_0)\mu}\right)N_{10}\Psi_2 + \Sigma\right]$$

In **3.8**. are given the results of the calculations for concrete binary solutions using equation (21).

In many cases, the solutions must also be frost-resistant, or rather not freeze. In the language of mechanics, this means that the liquid must has a minimum rate of phases transformation (boiling, freezing). The composition and concentration of the components of such a binary solution are selected by experimental methods. The type of composition is changed so that the rate of phase transitions is minimal.

The problem is solved by the fact that in the method of obtaining a mixture with a minimum boiling rate, the composition of the binary solution and the concentration of its components are selected from the obtaining of maximum value of the $\frac{\xi}{\varsigma}(k_0)$ parameter and $\frac{\xi}{\varsigma}(k_0) >> 1$ conditions characterizing the relative effect of heat and mass exchange on the dynamics of bubbles.

$$\xi = \frac{S_{12}}{\mu\eta}\cdot\frac{\left(1-\chi_2^0\right)\left(\chi_1^0-1\right)\left[1-\chi_2^0+\mu\left(\chi_1^0-1\right)\right]\left[1-\chi_2^0+c_{l21}\mu\left(\chi_1^0-1\right)\right]}{\left[1-\chi_2^0+L\mu\left(\chi_1^0-1\right)\right]\left[\chi_1^0\left(1-\chi_2^0\right)+\mu\chi_2^0\left(\chi_1^0-1\right)\right]},$$

$$S_{12} = c_{l1}T_0/l_1,\ c_{l21} = c_{l2}/c_{l1}, \tag{22}$$

$$\varsigma = \frac{S_3 Le}{\eta}\cdot\frac{\left[\chi_1^0\left(1-\chi_2^0\right)+L\mu\chi_2^0\left(\chi_1^0-1\right)\right]^2\left[1-\chi_2^0+\mu\left(\chi_1^0-1\right)\right]}{\left(\chi_1^0-\chi_2^0\right)\left[1-\chi_2^0+L\mu\left(\chi_1^0-1\right)\right]\left[\chi_1^0\left(1-\chi_2^0\right)+\mu\chi_2^0\left(\chi_1^0-1\right)\right]}$$

Picture. 15 shows the maximum value of the dependence of function $\xi / \varsigma(k_0)$ on the k_0 for the mixture of water and ethylene glycol.

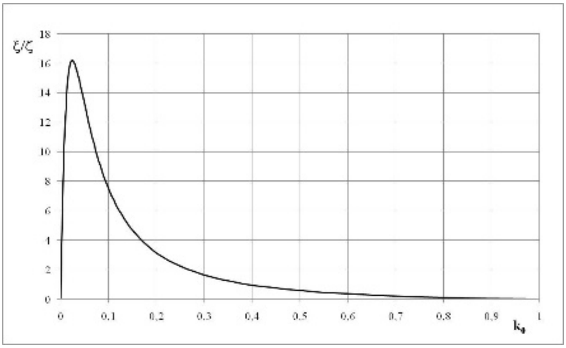

Fig. 15 Dependence of the parameter ξ / ς on the concentration of mixture k_0

As you can see from the picture, the dependence ξ / ς on concentration $k_0 \leq 0{,}4$ exceed the unit, so at the range $k_0 \approx 0{,}03$ water is in the obtains the maximum value that is apparent at the value corresponding to the volume concentration. Thus, this solution will have a minimum boiling capacity.

Generally, such a solution has minimal speed and condensation. The composition of the binary solution (liquids that make up the binary solution) and the concentration of the components must be obtained from condition $\xi / \varsigma >> 1$ to obtain the maximum value of parameters ξ / ς, which characterizes the effect of this solution on the dynamics of heat exchange and mass exchange bubbles.

MAIN RESULTS

1. Besides the fractional case equation of a gas-liquid mixture, new case equations in the form of power and exponential functions have been obtained, which allow them to be used for analytical research.
2. The basic regularities of sound propagation and extinction in a bubble fluid have been studied and given a physical interpretation.
3. Due to the presence of gas bubbles in the liquid, a significant decrease in the pressure of the liquid and a decrease in its density during the increase in the speed of water flow around the vessel have been theoretically and experimentally confirmed.
4. A model has been proposed that allows to theoretically estimate the degree of bending of the sea surface around the sinking and moving vessel.
5. A calculation method has been developed to reduce vibrations to protect the oar propeller and the hull from the effects of the shock wave.
6. Mathematical and practical bases of the method of obtaining binary coolant with optimal properties for internal combustion engines of the ship have been developed

The main results of the dissertation work were published in the following works:

1. Nağıyev, F.B., Axundova, G.A. Qabarcıqlı suda hərəkəti zamanı gəminin anomal çökməsi // - Bakı: Azərbaycan Dövlət Dəniz Akademiyasının Elmi Əsərləri, - 2014. № 2, - s.112-117
2. Nağıyev, F.B., Axundova, G.A. Bermud üçbucağına aid bir hipotezin elmi təsdiqi // "Mexanikanın klassik və müasir problemləri" adlı, Azərbaycanın görkəmli alimi, AMEA-nın müxbir üzvü, prof. Yusif Əmənoğlu Əmənzadənin anadan olmasının 100 illik yubileyinə həsr olunmuş Respublika elmi konfransının materialları, - Bakı -22 may, -2014, - s. 247-251.
3. Ахундова, Г.А. О кавитационной коррозии судового двигателя // «Актуальные проблемы экономики и управления на транспорте» 13-я Всероссийская межвузовская (5-й международный) научно-практическая конференция, - Владивосток: -22мая, - 2015, - с. 47-48.
4. Ахундова, Г.А. Об уравнениях состояния пузырьковой жидкости // – Bakı: - Azərbaycan Dövlət Dəniz Akademiyasının Elmi Əsərləri, - 2015. -№ 2, -s. 213-215.
5. Ахундова, Г.А. Исследование поглощения интенсивности акустической волны в океане // - Санкт-Петербург: - Вестник государственного университета морского и речного флота имени адмирала С.О. Макарова, ГУМРФ, -2015. -№ 3, -s. 36-41.
6. Нагиев, Ф.Б., Ахундова, Г.А. Некоторые задачи гидродинамики судна: / Ф.Б.Нагиев, Г.А.Ахундова. – Германия: LAP LAMBERT Academic Publishing, - 2015. -156 с.
7. Akhundova, G.A. The verifying authenticity and condition of applicability of the state of bubble liquid.//Transactions of ANAS, issue mathematics and mechanics, series of physical-technical & mathematical science, -2015. v.XXXV, №1, -p.109-113.
8. Nagiyev, F.B., Ismayilov, Z.O., Akhundova, G.A. Methods of system analysis in problems of navigation. // Transactions of

ANAS, issue mechanics series of physical-technical & mathematical science, -2015. v.XXXV, №7, -p. 58-67.
9. Nagiyev, F.B. Akhundova, G.A. A theoretical method of producing the coolant for marine engines.// Journal of Maritime Transport and Engeneering, Tallinn University of Technology Estonian Maritime Academy, -2015. v.4, №1, -s.54-66.
10. Ахундова, Г.А. Скорость звуковых волн в морской воде//"Dəniz nəqliyyatında innovativ texnologiyalar" XI Beynəlxalq elmi-texniki konfransının məruzə materialları, – Bakı: - 2016, -s.127-130.
11. Nağıyev, F.B., Axundova, G.A. Qaz-maye mühitin mexanikasinin bəzi məsələləri.// - Bakı: Azərbaycan Dövlət Dəniz Akademiyasının Elmi Əsərləri, -2016. № 2 -s. 255-260.
12. Nağıyev, F.B., Axundova, G.A. Динамика жидкостей в нанотрубках // - Bakı: Azərbaycan Dövlət Dəniz Akademiyasının Elmi Əsərləri, - 2017. №1, -s. 103-113.
13. Ахундова, Г.А. Flow Dynamics Caused by the Sudden Water Discharge Into the River // Проблемы безопасности на транспорте, Материалы VIII международной научно-практической конференции, посвященной году науки, - Гомель: -2017, -с.202-204.
14. Нагиев, Ф.Б., Ахундова, Г.А. Обеспечение безопасности судоходства при внезапном повышении уровня воды в реках.// - Bakı: Azərbaycan Dövlət Dəniz Akademiyasının Elmi Əsərləri, -2017. № 2(26) -s. 223-230.
15. Akhundova, G.A. Veracity and Satisfiability Condition of State Equation of Bubble Liquid.//Proceeding of 3rd International E-Conference on Mathematical Advances and Applications (ICOMAA-2020), Conference Proceeding Science and Technology. -2020, 3(1), p. 63–67
16. Axundova, G.A. Gəmilərdə istifadə olunan materialların korroziyasının kavitasiya məsələləri // -Bakı: Azərbaycan Dövlət Dəniz Akademiyasının Elmi Əsərləri, - 2020. №1(31), -s. 183-190.

Defense will be held on **07th of January, 2022** at **14.00** at the meeting of the one time Dissertation council BFD. 3.04 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Mathematics and Mechanics of ANAS.

Adress: AZ 1141, Baku, B. Vahabzadeh str., 9.

Dissertation is accessible at the scientific library of the Institute of Mathematics and Mechanics of ANAS.

Electronic versions of dissertation and its abstract are available on the official website of the Institute of Mathematics and Mechanics of ANAS

Abstract was sent to the required addresses
on **06th of December, 2021**

Signed for print: 03.12.2021

Paper format: A5

Volume: 36669

Number of hard copies: 20

Published by “Fuyuzat publishing palegraphy” LLC