

Application of wave coagulation of the aerosol in technology of gasification of cryogenic liquids

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Abstract. Process of acoustic coagulation of a polydisperse gas-suspension under the influence of a nonlinear wave field in relation to technology of gasification and cryostatting of the liquefied natural gas and hydrogen is investigated. The gas-suspension of polydisperse structure is formed in the stream proceeding through Laval's nozzle then the bearing and disperse phases are divided in an inertial separator. For increase of efficiency of division of phases between a cut of a nozzle and an entrance of a separator the working site in which on the polydisperse environment acoustic impact is made settles down.

In work [1] was offered power - and resource-saving technology of gasification and cryostatting of the liquefied methane. The technological scheme of installation is given in figure 1. Liquid from the heat tank 1 moves in the heat exchanger 2 where liquid heats up to temperature of T_1 , below boiling point temperature and moves in Laval's nozzle where in the vicinity of the minimum section there is its low-temperature boiling up to the subsequent inversion of structure of a stream and formation in the extending part of a nozzle of polydisperse vapor-drop current. Experiments show that temperature, which is below triple-point temperature, might be acquired by variation of nozzle inlet temperature, pressure drop over nozzle and nozzle profile. As a result, in the extending part of a nozzle the disperse phase will consist of liquid drops and firm particles with a temperature, lesser than temperature of liquid in capacity storage. Then vapor - drop stream moves in an inertial separator where the bearing environment - gaseous methane separates from a disperse phase which then downloads the pump 8 in storage and lowers the liquid temperature that reduces intensity of losses and increases a possible period of storage of methane in a liquid state. The bearing phase - vaporous methane goes to the heat exchanger 5 where heats up to temperature of T_2 which is required for operation of the power station 7.

Efficiency of process is defined by quality of separation of the bearing and disperse phases. Experimental data show that at the exit of a nozzle there are particles with sizes vary from micron to tens microns. At the same time, inertial separators are capable to separate a disperse phase from the bearing environment if the sizes of particles exceed about 5 microns. In this regard there is a decrease in efficiency of technological process – in capacity the smaller number of the cooled disperse fraction



which partially gets to the heat exchanger 5 where on its heating to melting temperature, on melting process, having heated to evaporation temperature downloads, the subsequent evaporation and heating to temperature of T_2 are required additional expenses of energy. Therefore, on a site between day offsection of a nozzle and entrance

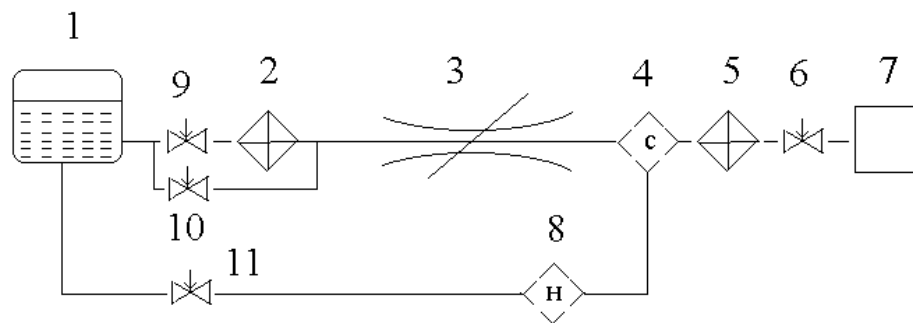


Figure 1. The scheme of installation for gasification and cryostatting of the liquefied methane: 1-heatisolated capacity with the liquefied natural gas; 2- heat exchanger heater of liquid; 3- nozzle of Laval; 4-inertial separator; 5- heat exchanger heater of steam; 6, 9-11-gates; 7-power station; 8- pump.

of an inertial separator (figure 2) it is necessary to change dispersion of vapor - drop stream, having reduced the mass maintenance of fine fractions due to coagulation of particles. One of possible ways of acceleration of coagulation is wave impact on vapor - drop stream [2]. Thus the choice of intensity of wave influence is limited to critical number of Weber [2] in order that coagulation of particles at impact prevailed over their crushing. The model in which the fraction [3, 4] is compared to each size of particles is applied to the description of dynamics of a coagulating polydisperse gas-suspension.

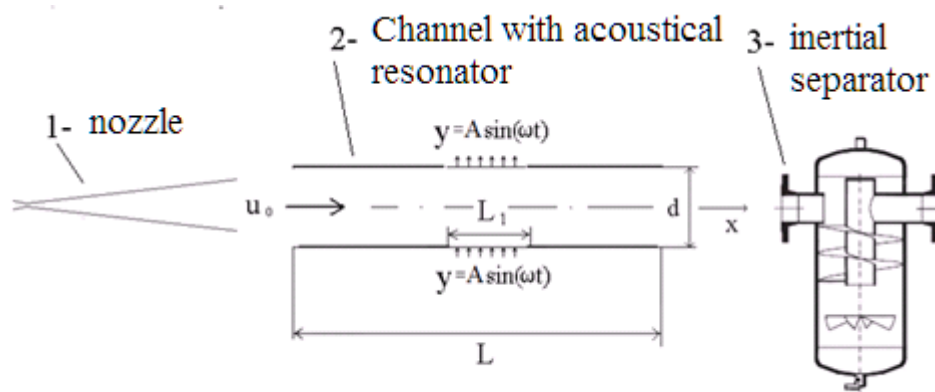


Figure 2. The scheme of an arrangement of a nozzle - the steam generator, the channel with the acoustic resonator and an inertial separator.

The bearing phase is described by system of the equations of Navier-Stokes considering an exchange of an impulse and energy with the disperse phase including n of fractions each of which described by system from the continuity equation for the average density, the equations of preservation which are working out an impulse and the equations of preservation of internal energy [4-6]. Coagulation of particles is described by the Lagrangian model considering an exchange of weight, an impulse and

energy between fractions as a result of impact of particles [2, 4]. In an initial time point of $t=0$ vapor-drop mix from five fractions of drops of liquid methane with radiuses of particles of $r_{10}=1\text{mkm}$, $r_{20}=5\text{mkm}$, $r_{30}=10\text{mkm}$, $r_{40}=15\text{mkm}$, micron $r_{50}=20$, moves with u_0 speed, evenly filling the flat channel (fig. 2). At $t>0$ process of inphase fluctuations of a cross component of speed of sites of the top and lower walls of the channel $((L-L_1)/2 < x < (L+L_1)/2, y=0)$, $((L-L_1)/2 < x < (L+L_1)/2, y=d)$ under the law $v(t)=A \cdot \sin(\omega t)$ (fig. 2), leading to generation of fluctuations in the bearing and disperse phases with the first own frequency of rather cross section of the channel $\omega = \pi c/d$, where $c = (\gamma RT)^{1/2}$ – assessment for sound speed in methane vapors at the set temperature.

In figure 3, a, b dependences of cross and longitudinal components of speed of the bearing and disperse phase (5 fractions) on time in a stream which the field of a standing wave with an amplitude of fluctuations of a cross component of speed on $A=0,0005\text{m}$ walls locally influences are presented. Radiuses of particles of all fractions, except the smallest, grow eventually (figure 3, c). The average density of fraction with a radius of particles of 1 micron decreases eventually and by the time of $t=0,035\text{ c}$ with becomes close to zero. The average density of larger fractions (5, 10, 15 microns) at first reaches the greatest value then decreases. The average density of the largest fraction continuously grows eventually (figure 3, d). The highest speed of reduction of concentration of particles owing to coagulation in an acoustic field at the smallest fraction. In the vicinity of a source of acoustic fluctuations concentration of particles with a radius of 1 micron at $t = 0,01$ with falls approximately on 4 orders (figure 3, e). Effective radius of particles of all fractions except for the smallest quickly increases in the same area and the zone extended down a stream in which the average density of the fine decreases is formed fractions the average density of fraction of the largest particles from $R_0=20$ microns also increases (figure 3, e).

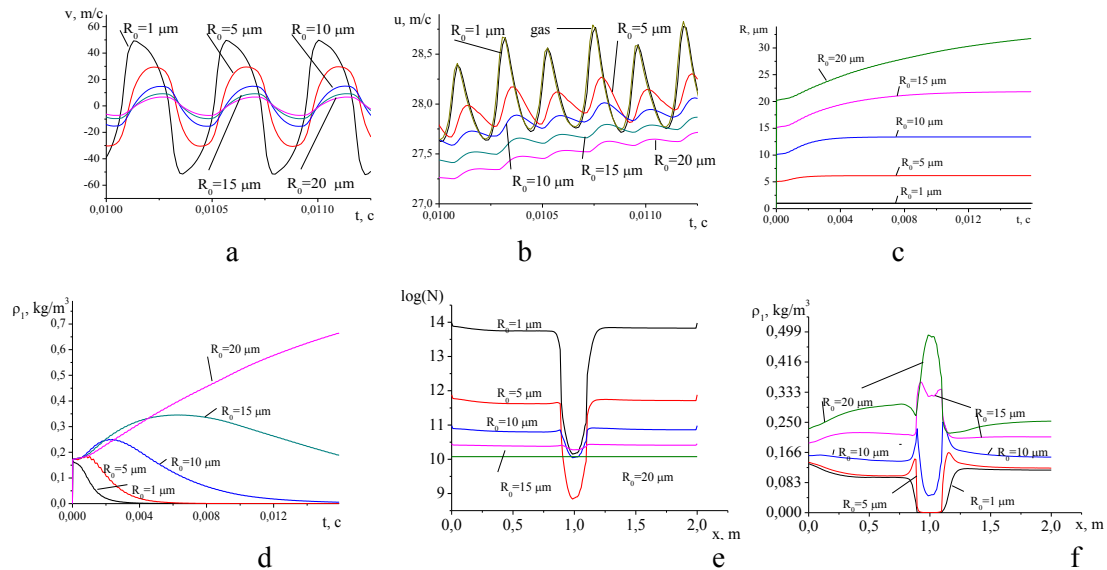


Figure 3. Dependence on time cross (a) and axial (b) the making speed of particles, their effective radius (c) and the average density of fractions (d) in a point $(x=L/2, y=d/2)$, concentration (e) and average density (f) particles of fractions along a channel axis.

Thus, impact on vapor -drop stream of poly-disperse structure resonant wave fields allows to reduce concentration of fine fractions of mix due to coagulation of particles of different fractions. For this reason between a cut of a nozzle generator of a poly-disperse gas-suspension and an entrance flange of an inertial separator expediently placement of the acoustic channel resonator in which there

is an integration of particles due to coagulation that increases quality of division of the bearing and disperse phase in inertial separators.

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References

- [1] Tonkonog V G and Arslanova S N Sistema of supply of cryogenic fuel in the power station. *Patent Russian Federation for the invention of Ru.* No. 2347934. Date of issue 10.06.2009.
- [2] Alemasov V E and Dregalin A F and Tishin A P and Khudyakov V A 1971 *Termodinamicheskiye and heatphysical properties of products of combustion. The reference book in five volumes.T.1. Calculation methods.* Moscow VINITI production publishing combine
- [3] Kutushev A G 2003 *Mathematical modeling of wave processes in aero disperse and powdery environments* St. Petersburg Publishing house Subsoil
- [4] Tukmakov A L 2015 *Journal of Engineering Physics and Thermophysics* **88** 9-17
- [5] Saifutdinov A I, Saifutdinova A A, Kashapov N F and Fadeev S A 2016 *J. Phys.: Conf. Ser.* **669** 012045
- [6] Saifutdinov A I, Fadeev S A, Saifutdinova A A and Kashapov N F 2015 *JETP Lett.* **102** 637–642