Modified Bogolyubov's derivation of the two-fluid hydrodynamic equations for superfluid helium

P. Shygorin and A. Svidzynskij

Lesia Ukrainka Volyn National University, Theoretical and Mathematical Physics department, 13 Voly Av., 43009 Lutsk, Ukraine, E–mail: pashyg@univer.lutsk.ua

The two-fluid hydrodynamic equations for the superfluid 4He in the phenomenological consideration were constructed by Landau in 1941 [1]. At the microscopic level these equations were derived by Bogolyubov in 1963 [2]. Starting point in this paper is a set of equation of motion for local quantities (particle density, momentum density and energy density), which easy follows from Heisenberg equations for both creation and annihilation operators; as well as the equation for anomalous average $\langle\psi\rangle$. Thus, from the last follows a hydrodynamic equation for superfluid velocity.

For transition from formal equations of motion to hydrodynamic equations consider such stage of evolution of the system when it is approximate to equilibrium. Then it is possible to assume that in system is established the local equilibrium. At close to the thermodynamic equilibrium these parameters are slowly changed in space and time, therefore their gradients are small. Procedure of expansion by the gradients is formulated by introduction in equations of motion of the so-called parameter of homogeneity. Then an expansion by the gradients coincides with expansion by the "parameter homogeneities". Introduction of this parameter is carried out a formally way.

Our paper imitates the Bogolyubov's article [2], but we work with equations of motion for the correlation functions which are written in the mixed Wigner representation. It allows the expansion by the gradients directly realize, very easy and with the rigorous mathematic. In this paper we also developed method for calculation of the hydrodynamic flows. This formalism may be used for microscopic derivation two-fluid hydrodynamics of the superconductor and superfluid helium with pair condensate. This work was supported by SFFR of Ukraine (project No. F25.2/011).

1. L.D. Landau, Zh. Eksp. Teor. Fiz. 11, 592 (1941).
2. N.N. Bogolyubov, Preprint JINR D-1395, (1963).