Institute of Thermomechanics
Academy of Sciences of the Czech Republic, v. v. i.

Fluid Dynamics Department

Review of the Thesis

Title: Investigations of cryogenic helium flows using mechanical oscillators
Author (Candidate): David Schmoranzer
Department: Department of Low Temperature Physics
Supervisor: Professor RNDr. Ladislav Skrbek, DrSc.

Overview

The Thesis represents itself the summary of 5-years work of the Candidate on problems related to experiments with oscillating structures in cryogenic helium and other types of fluids.

In Chapter 2, the transition to turbulence was examined both in classical cryogenic helium fluids and in water at room temperature. Two completely different experimental methods were used in these experiments. Firstly, measuring the drag force acting on tuning fork resonators was performed and the scaling law of the critical velocity was deduced. To prove and interpret the results of this method, which has been later applied also in superfluids, the visualization verification has been carried out. Two methods of visualization were employed, the Baker technique and the Kalliroscope solution. The results of experiments are related to laminar-turbulent transition of the flow.

The experiments performed in classical fluids were extended to the superfluid helium in Chapter 3. A phenomenological model was formulated, based on gradual coupling of the normal and superfluid components due to the mutual friction force acting through the presence of quantized vortices. The model was derived for the normal component of He II above 1 K reflecting the hydrodynamic regime. Its extensions to lower temperatures is suggested, however this is based on different physics.

In Chapter 4 a different dissipation mechanism in flowing fluid is investigated. Acoustic emission seems to be important dissipation mechanism for high frequency tuning forks. This mechanism was studied systematically and three models of acoustic emission by tuning forks were formulated. Reflecting boundaries are incorporated in the models as well. The models were compared with experimental data. Importance of acoustic emission and viscosity for other types of oscillators resonating at different frequencies has been estimated.

In Chapter 5 the study Andreev reflection of thermal excitations on a configuration of quantized vortices in rotating 3HeB is given. The related experiments have been carried out in the Low Temperature Laboratory of the Aalto University in Espoo, Finland, Candidate has taken part in them. Steady heat flux from a black body radiator was analyzed and the thermal resistance due to the tiny orifice in the radiator was found to be affected by the presence of quantized vortices. This behavior was expected from the theory describing Andreev reflection of balistically propagating excitations. The results were double-checked by analyzing the thermal relaxations of the same volume and by a numerical simulation of the excitation trajectories. Good agreement was found.
The 5 principal publications from journals form attachment of the Thesis.

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Question and comments

As my field of expertise is classical fluid mechanics, I will concentrate on those parts of the Thesis dealing with this subject.

Comments:

Relation of the drag force scaling low to the laminar or turbulent flow structure is not straightforward. According to classical fluid mechanics, this phenomenon is connected with either skin friction drag (linear Stokes law) or pressure drag (separation of boundary layers – bluff body). Both flow regimes could be of laminar or of turbulent nature, depending on various additional factors. The decisive parameter for laminar/turbulent structure is Reynolds number based on boundary layer thickness adjacent to the body surface or free shear layer thickness, which is formed from the separated boundary layer. This physical principle is not analyzed in the Thesis in adequate extend, in my opinion.

The boundary layer thickness adjacent to the body surface depends on the surface length in the streamwise direction. As the relevant Reynolds number is evaluated using spanwise dimension of the body (width), the aspect ratio of the fork cross-section is very important parameter in laminar/turbulent flow indication. Unfortunately, this parameter is not taken into account in large-scale fork modeling.

Questions:

1. Error analysis is missing. Especially systematic errors could influence scaling law. Could you please indicate approximate errors of the physical quantities evaluated from electrical signals?

2. Please specify possible role of standing waves in water aquarium (experiments in Ch2).

3. What is the Knudsen number for the quartz fork in various fluids? It is known that for Kn not sufficiently small, the interaction is very different (e.g. no-slip condition does not hold).

Conclusions

The text of the Thesis indicates good orientation of the Candidate in the field of fluid mechanics.

The attachments with publications in journals demonstrate the fact that the Candidate has become an important member of several international research groups dealing with cryogenic flow experiments.

The Candidate has demonstrated an accurate and systematic approach in designing experiments and data analysis.

The Thesis ends up with clear and logical conclusions and contributes a small piece to the development of our understanding of superfluidity and quantum turbulence.

Formally, the Thesis is comprehensive with minimal misprints, clear figures, and good graphic layout.

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In my opinion the submitted Thesis comply with all formal and informal rules. I therefore suggest this Thesis for defense. After successful defense procedure I suggest to award the Candidate PhD title.

In Prague, August 2, 2011

Doc.Ing. Václav Uruba, CSc.

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