Doctoral thesis review

Title: Experimental investigations of liquid helium flows

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Content of the thesis

The thesis is devoted to turbulence and role of the vortical structures in flowing fluids having superfluidity features. The superfluid phase of the liquid He, i.e. He II, is used in experiments. The 3 different tasks are studied. The steady thermal counterflow in channels, counterflow jets and macroscopic vortex rings, respectively. Experimental approach is applied in all presented studies.

The thesis has a clear concept. The theoretical introduction is given in the first part "Superfluidity and quantum turbulence". The second chapter is devoted to "Methods of investigation". In the next 3 chapters the particular problems characterized above are addressed in detail. In "Conclusions" summary of the presented works are shown including generalization of the presented results.

Subject topicality

The work is kind of pioneering one in my opinion, as used experimental techniques based on particle tracking are commonly used in normal, viscous fluid mechanics, application in superfluids is rather new. However, the work is not the first on its kind, in the Prague laboratory has been completed several studies using this technique. The presented study represents logical continuation of this long-time research work.

The turbulent state of the flowing fluid is a typical behavior, representing the most observable state of matter in nature. This obviously concerns any fluid including the superfluids, however there are substantial differences in physical mechanisms behind this behavior in various media. Study those phenomena is of importance both from theoretical and practical reasons. This process is far from being completed, so any contribution in this sense is of a big value. This is the case of the submitted thesis.

Methods and procedures

Substantial part of the study is devoted to experimental methods and techniques used, as interpretation of results is far from being standard and straightforward in the given conditions. As a mean experimental technique, the particle tracking was chosen allowing to study the flow field both qualitatively, the flow topology, and quantitatively, evaluate the vector velocity field. Next, the second sound attenuation technique is employed.

Particle tracking technique is adopted, choice of particles is presented, effects of measuring point size and particles mass are addressed in detail. As a summary, the ideas concerning interpretation of the obtained observations in context of the fluid behavior are drawn.

The key problem is interpretation of the particles' behavior in the context of the two-fluid model of the medium. The thesis offers some new ideas in this area. The "filtering effect" of the particles due to their physical size and mass is addressed in detail, the method of compensation is suggested.

The obtained data was analyzed preferably using statistical methods in the thesis. The information containing topological aspect has not been exploited.

The experimental methods are adequate, in my opinion. However, the further analysis of the obtained data is possible.

Significance for the field, theory and applications

New fundamental information on behavior of the quantized vortex tangle have been acquired and presented in the thesis. Those findings could be used for validation of the theoretical and numerical models and results, which are currently available in literature.

The practical outcomes from the thesis I see in information on features of superfluids which are relevant for prediction of their dynamical behavior. The similarities and differences between the normal viscous fluids and superfluids are pointed out in the thesis. The means of energy transport in turbulent flows of He II are found to be different from those taking place in turbulent flows of normal viscous fluids.

Achievements, results, fulfilment of the goals

The obtained experimental results are of high quality and could form the basis for the consequent studies in the field of turbulence in superfluids. There is always lack of good experimental results, especially in such technically exhaustive fields as the low-temperature physics is. The presented thesis represents an important contribution to the study of turbulence in superfluids.

The presented thesis contributes to the understanding of several aspects of turbulent flows of He II. In particular, the 3 cases under study are analyzed in detail. However, in the thesis some new questions raised, they are to be addressed in future.

I have not found the explicit formulation of the thesis' goals in the text.

Form of the thesis

The thesis is submitted in classical form of a compact report containing all necessary parts and all relevant information. However, the scientific content is covered by the 5 supplied papers, which form an integral part of the thesis. Thus, the thesis complies with both classical form of thesis based on an independent report and the set of scientific papers accompanied by an explanatory text.

Formal side of the text is on a good level. The thesis is written in English. The quality of English language is good in my opinion, however not being a native speaker, I am not the competent person to approve that.

Figures are of the standard quality as well as the graphical redaction of the thesis.

List of quantities is missing; it could make the thesis reading easier.

I recognized careful redaction of the manuscript with minimum misprints.

Strong and weak points

The strong side of the thesis is represented by application of the innovative experimental methods in this tough research field and obtaining new information on the physical background of the studied processes. This approach allows for obtaining new information on the problem under study, which is turbulence in superfluids. I recognize as a very positive the fact, that several parts of the thesis result from real international collaboration with excellent foreign laboratories in the field. The student performed several research-working stays abroad during his study.

On the other hand, in my opinion not complete information from the acquired data was retrieved. The study is oriented more on the point statistical characteristics than on typical patterns of the fluid behavior. I miss more findings on flow topology, especially on the tangles' geometry.

Student's publications

The 5 publications with direct link to the thesis subject are included in the thesis itself as an attachment. The full list of student's publication list includes 9 papers in the top-level journals in the field. The student's publication activity is well above-average in my opinion.

Conclusion

Mr. Švančara has shown excellent knowledge of state-of-art in the field of superfluidity mechanics and experimental research in this field including the key physical phenomena behind this process. Based on this knowledge he succeeded in acquiring the new information and he brings his interpretation on it. He attested his ability of systematic and accurate research work, being a member or even leader of an international research team assigned to a scientific task. The submitted dissertation thesis proves the applicant's readiness for independent scientific work.

I recommend acceptance of the thesis and after successful defense conferring the title PhD on the student.

Questions:

- Could you present any general or particular information on the tangle geometry based on your data?
- Transition to turbulence is a process which is characterized by several phases: onset, a few stages of development and in the very end by presence of the “well developed turbulence”. This scenario is well documented in normal viscous fluids. Could you please characterize this process in brief in the superfluid environment?

In Plzeň, September 6th, 2021

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