Posudek práce

předložené na Matematicko-fyzikální fakultě
Univerzity Karlovy v Praze

❑ posudek vedoucího ☑posudek oponenta
☑ bakalářské práce ❑ diplomové práce

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Název práce: Low frequency oscillatory flow of cryogenic helium
Studijní program a obor: Physics, general physics
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Odborná úroveň práce:
☑ vynikající ❑ velmi dobrá ❑ průměrná ❑ podprůměrná ❑ nevyhovující

Věcné chyby:
☑ téměř žádné ❑ vzhledem k rozsahu přiměřený počet ❑ méně podstatné četné ❑ závažné

Výsledky:
❑ originální ☑ původní i převzaté ❑ netriviální kompilace ❑ citované z literatury ❑ opsané

Rozsah práce:
❑ veliký ☑ standardní ❑ dostatečný ❑ nedostatečný

Grafická, jazyková a formální úroveň:
☑ vynikající ❑ velmi dobrá ❑ průměrná ❑ podprůměrná ❑ nevyhovující

Tiskové chyby:
☑ téměř žádné ❑ vzhledem k rozsahu a tématu přiměřený počet ❑ četné

Celková úroveň práce:
☑ vynikající ❑ velmi dobrá ❑ průměrná ❑ podprůměrná ❑ nevyhovující

Slovní vyjádření, komentáře a připomínky oponenta:

This Bachelor thesis is an excellent, concise and clear report of professional standard. The activity of the student was to carry out an experiment to measure the damping of a torsionally oscillating disk immersed in superfluid helium-4, a technique which allows to information about the onset of turbulence in the superfluid component of helium, an important and current research topic.

Although this experiment is not entirely original – it is a quasi-replica of the cited work by Donnelly and Hollis Hallet – it is an improvement over it as it makes use of new and more advanced means of measuring the movement of the disk, it extends the range of the angular velocity (a key control parameter), and it takes the data analysis and interpretation to a deeper level. In this sense, with some additional measurements to further confirm the results here presented, this material is publishable on a research journal.

The student had a chance of, and proved to have the skills for, being involved in a number of tasks. Building original apparatus; acquire images of disk oscillations by camera recording; sophisticated treatment of these videos to enhance signal-to-noise ratio, intelligent data analysis to extract information which otherwise would be quite deep-seated in the raw data; derive a non-trivial analytic formula for damping coefficient and energy dissipation in a classical fluid, in some simplified limit of frequency and geometry, which however gives a remarkable agreement of a factor less than 2 with the measurements in the laminar flow regime.

The main message of this work is to have shown convincingly (with independent ways of plotting the data) that by observing the attenuation of the angular velocity of a disk freely oscillating in superfluid helium, it is possible to distinguish a laminar and turbulent regime, and that the turbulent regime, characterized by non-linear drag forces, must be due to turbulence in the superfluid component of helium, in the form of quantized vortex lines. It is also speculated that for sufficiently high amplitudes, coupling of normal and superfluid components via vortices may re-introduce laminar behavior in the system.

Regarding criticism, I have made many comments, questions for thought, and suggestions through the thesis, which is made available to the student for consideration. I summarize here the main criticism, which does not affect the overall high standard of this work.

- It would be useful to have further diagrams or pictures of the apparatus, especially of the disk.
- It would have been useful to give some examples of image treatment, e.g. show a raw video frame and the final contrast-enhanced image. This process must have been time consuming and difficult, and it involved also the writing of new software, so more attention could have been given to it.
- Similarly, it would be interesting to show a comparison of the raw $\Omega(t)$ data with the final treated signal.
- One aspect which is not clearly described is how the disk is set to motion, and whether or not the velocity amplitude can be controlled (for example for reproducibility tests), and to what extent the initial amplitude affects the later time evolution.

Some of these remarks will re-enter some of my questions below.

Případné otázky při obhajobě a náměty do diskuze:

1. (warm up question) Discuss some examples of historical experimental facts of He-II (relevant to your thesis, such as experiments which reveal viscous damping and those which show inviscid flow) and how they are explained by the two-fluid model.

2. (question on set-up and method) What is the role of the two plates above and below the disk? (You have a simpler theory which assumes infinite space, wouldn't it be best tested without these plates?). How is the disk driven? Can the maximum displacement angle be controlled? Does this satisfy the small angle approximation which neglects the non-linear term in the theory? Can the starting angular velocity be controlled? Does the initial amplitude of Ω affect the later time behavior?

3. From your discussion it seems that you started from very unclear video images, and later from very noisy $\Omega(t)$ data, and you did several steps of post-processing of both aspects, ending up with what actually seems very clean data. Could you please demonstrate some of these steps and critically explain what you consider reasonable treatment?

4. Fig. 3.5 shows that *at all temperatures* there is a transition to non-linear drag for high enough angular velocity, signaling turbulence in the superfluid component. This should correspond to a plateau in C vs Ω in Fig 3.11. Why this is clear only for the lowest temperature?

5. Your main observable is Ω as a function of time and temperature. But does the frequency of oscillation change with changing conditions? Wouldn't it be consistent to imagine that as temperature is lowered, in the laminar regime, the frequency of oscillation increases as the superfluid component becomes decoupled in the absence of vortices?

6. (open question, more speculative) In a sense you are trying to deduce critical angular velocity for turbulence onset from a decaying signal, where in the first initial transient there is probably a fast out of equilibrium annihilation of vortices. Would you agree it would be useful to study this problem in steady state, by driving the disk at controlled and variable angular velocity?

Práci
☑ doporučuji
❑ nedoporučuji
uznat jako diplomovou/bakalářskou.

Navrhuji hodnocení stupněm:
☑ výborně ❑ velmi dobře ❑ dobře ❑ neprospěl/a

Místo, datum a podpis oponenta:
Praha 29.08.2014