LT 21

Proceedings of the 21st International Conference on Low Temperature Physics
Prague, August 8-14, 1996
Part S1 - Quantum Fluids and Solids: Liquid Helium

A Study of Vibrating Wires for Viscometry in High Magnetic Fields

J.H. Naish[a], A.P.J. Voncken[a], D. Riese[b], R. König[b], J.R. Owers-Bradley[a], and F. Pobell[*]

[a] Dept. of Physics, University of Nottingham, University Park, Nottingham, P.O.Box, NG7 2RD, UK
[b] Physikalisches Institut, Universität Bayreuth, D-95440 Bayreuth, Germany

We report on a systematic study of the temperature and magnetic field dependence of the intrinsic damping and the resonance frequency of vibrating wires in magnetic fields up to 11.5 T and at temperatures $1\,\mathrm{mK} < T < 250\,\mathrm{mK}$. The aim is to test the applicability of various materials for viscometry in spin polarized ^{3}He-^{4}He solutions. The materials investigated are NbTi in the superconducting and normal state, the alloys Manganin and PtW, a gold plated glass wire, and three Ag wires where one has been exposed to a heat treatment. For all samples the impact of the magnetic field on the mechanical proporties of the wires is much larger than any temperature dependent effects.

1. INTRODUCTION

The use of a vibrating wire is one of the few options to investigate the viscosity of dilute helium solutions at low temperatures. In high magnetic fields, however, the intrinsic damping of the materials commonly used for vibrating wire measurements, increases and might become the dominant damping mechanism when the wire is immersed into a dilute ^{3}He$-^4$He solution. Clearly accurate viscometry then fails. Here we report on a systematic study on the temperature and magnetic field dependence of the intrinsic damping and resonance frequency of vibrating wires made of NbTi in its normal and superconducting state, Manganin, PtW, Ag, and gold plated fibre glass in fields up to 11.5 T. For a study on the temperature dependence of the internal damping in vibrating wires in low magnetic fields we refer to the work of Esquinazi *et al.* [1].

2. RESULTS AND DISCUSSION

A list of specific wire parameters like diameter d, length L, the vacuum resonance frequency f_r in 9 T, and the quality factors Q_0 and Q_9 in fields of typically 40 mT and 9T, respectively, is given in Table 1. An example of the temperature dependence of the internal damping, expressed in terms of $10^4/Q$, of the PtW wire in a 3 T field, is shown in Fig. 1. Below 40 mK the internal damping is smallest and constant, while it rises to a plateau at $T > 250\,\mathrm{mK}$. This behaviour can qualitatively be explained in terms of the two level tunneling model [1]. A similar temperature dependence is observed in all other wires investigated. However, the temperature at which the internal damping starts to rise as well as the position of the onset of the plateau differ for different wires. The relative increase in internal damping of the PtW wire at 10 mK to that at 250 mK is about 10 %. With increasing magnetic field this value decreases to about 1 % at 11.5 T. Clearly, the effect of the temperature on the internal damping is less pronounced at higher magnetic fields. This is an important result as the temperature dependence of the internal damping has to be accounted for in viscometry measurements.

Material	d/μm	L/mm	f_r/kHz	Q_0	Q_9
NbTi	100	4.0	7.79	4014	2800
NbTi	100	4.0	10.0	4034	2940
NbTi	100	9.5	4.57	3696	1620
Ag	25	7.0	2.70	–	100
Ag	125	12	2.47	3400	8
Ag(Annealed)	125	12	2.31	7800	8
Manganin	100	4.0	5.34	40800	4434
Manganin	60	7.0	3.42	42000	8000
Manganin	30	7.0	1.63	14400	5489
PtW	25	7.0	1.44	30000	11770
Glass	100	20	54.3	8620	4170

Table 1: *Characteristic parameters of the investigated wires: diameter d, length L, vacuum resonance frequency* f_r *in 9 T, and the quality factors* Q_0 *and* Q_9 *in 40 mT and 9.0 T respectively.*

The effect of the magnetic field on the internal damping at low temperatures ($T < 16\,\mathrm{mK}$) is shown

---

[*] New address: Forschungszentrum Rossendorf, D-01314 Dresden, Germany

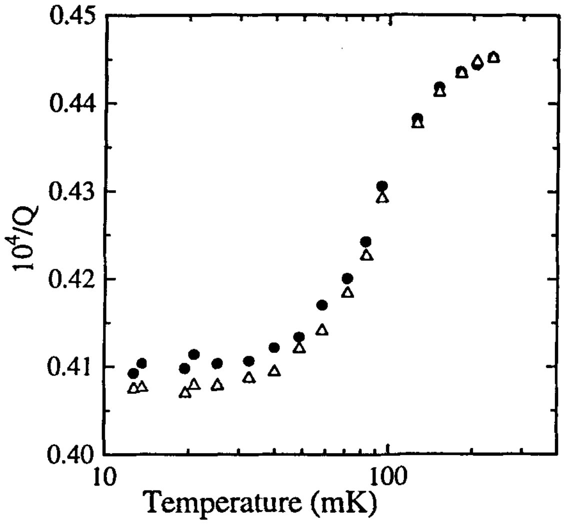

Figure 1: *Internal damping vs temperature for the PtW wire in 3 Tesla. • In phase, △ Quadrature fit.*

in Fig. 2. Here only the results with high Q-factors are presented, i.e. in the case of Ag only the low field values are shown. Annealing the Ag wire at 860° for two hours resulted in a reduction of the internal damping in low fields by roughly a factor of two but gave no noticable difference to the untreated wire in high magnetic fields. The type II superconductor NbTi also shows a sharp increase in damping with increasing magnetic field that levels off at about 6.5 T. The two NbTi wires with the same loop diameter have an almost equal magnetic field dependence. Changing the loop diameter from 4.0 to 9.5 mm, however, results in a strong increase in internal damping at fields above 2 T. The large change in the internal damping at low fields as well as the strong magnetic field dependence of the resonance frequency in these NbTi wires is attributed to the interaction of the flux lines with the magnetic field. The high resitivity materials like Manganin and PtW as well as the plated glass wire show an increase in internal damping varying as B^2, in good agreement with data of Ruesink *et. al.* [2]. However, contrary to their theoretical predictions we find that at high fields the resonance frequency of the resistivity alloys decreases. This effect is probably due to the magnetization of the material that must be included in the theoretical description. The highest Q-factor obtained in this investigation in 11.5 T was 9000 for the PtW wire.

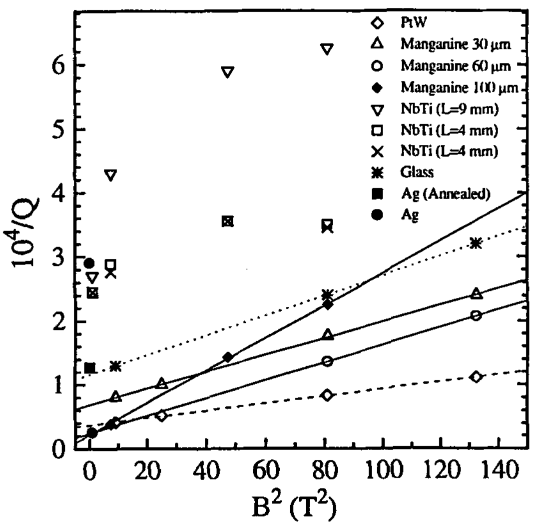

Figure 2: *Internal damping of several wires versus magnetic field below 16 mK. The lines in the graph serve as a guide for the eye.*

3. CONCLUSIONS

This study shows that the magnetic field has a much bigger influence on the properties of vibrating wires than the temperature. It is shown that for NbTi, which has a large increase in internal damping with magnetic field, the loop diameter has a big effect on the magnitude of the internal damping. Above 6.5T, however, the damping is more or less constant. The high resistivity alloys Manganin and PtW and the plated glass show an internal damping that increases as B^2. This behaviour can be understood in terms of eddy-current damping. As a result we conclude that high resistivity alloys, in particular PtW, are the best candidates for viscometers in high fields.

This work was supported by the Deutsche Forschungsgemeinschaft by grant Po 88/18 and by the Graduiertenkolleg Po 88/13, as well as the "Human Capital and Mobility: Large Scale Facility" Program of the EC and the EPSRC Great Britain.

REFERENCES

[1] P. Esquinazi, R. König, D. Valentin, and F. Pobell, *J. Alloys and Compounds* **211/212**, 27 (1994).

[2] W. Ruesink, J.P. Harrison, and A. Sachrajda, *J. Low Temp. Phys.* 70, 393 (1988).