J. Non-Equilib. Thermodyn.
Vol. 18 (1993), pages 147–156

The Link Between Heat Flux and Stress Deviator in Extended Thermodynamics of an Ideal Monoatomic Superfluid

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Abstract

In a previous paper a monofluid continuum theory of liquid helium II was formulated, by imposing entropy conservation on the Extended Thermodynamics of an ideal monoatomic inviscid fluid with infinite thermal conductivity. The resulting nonlinear relation between stress deviator and heat flux is studied in this work. It is shown that this relation is the same as the one derived as a constitutive equation for the stress deviator in an extended thermodynamic theory where this field is not considered as an independent variable. Finally, this relation is compared with the corresponding one derived from the two-fluid model of Landau.

1. Introduction

The two-fluid model of liquid helium II proposed by Landau [1], allows the explanation of many typical phenomena of this quantum liquid. However, this model is not completely satisfactory from a theoretical point of view; furthermore, some nonlinear effects, such as the evolution of thermal shock profiles, are not quantitatively explained within the framework of this model [2].

The most characteristic nonlinear phenomenon in helium II is the link between heat flux and stress, discovered by Kapitza in 1941, [3]. The heat left a thermally isolated bulb via a capillary tube, and a small vane placed across it was deflected. At a later time Hall [4], found that the force experienced by a hanging plate is proportional to the square of the heat flux. The power-dependence, temperature-dependence, and the order of magnitude of the observed force were in agreement with the two-fluid theory.

In a previous paper [5], entropy conservation was imposed on the extended thermodynamic theory of an ideal monoatomic inviscid fluid with infinite thermal conductivity. The fluid so obtained, called Ideal Monoatomic Superfluid (I.M.S.), presents most of the properties of liquid helium II.