Experimental Study on Shock Wave Phenomena in Superfluid Helium

超流動ヘリウム中の衝撃波の実験的研究

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March 2000

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Contents

Abstract

The superfluid shock tube facility has been developed as a versatile tool for the general experimental researches in low-temperature thermo-fluid dynamic phenomena of superfluid helium ($HeII$). The shock tube is designed to be operated with the $HeII$-filled test section immersed in superfluid helium. In this thesis, the general superfluid thermodynamic performance of shock waves in the facility is investigated to verify the validity of the facility under wide range of experimental condition. And the primary research targets are two modes of shock waves, that is a compression and a thermal shock waves, and the λ-phase transition from $HeII$ to HeI induced by shock compression. As a general conclusion from the performance test, it is demonstrated that the facility can be applied in the wide range of experiments in low-temperature thermo-fluid dynamics.

In the experimental facility, a compression and a thermal shock waves are generated in $HeII$ by the impingement of a gasdynamic shock wave propagating through helium vapor onto a $HeII$ free surface. Furthermore, $HeII$ can be shock-compressed to convert to HeI across the λ-line in the case of $HeII$ initially at temperatures rather close to the λ-temperature. Piezo-type pressure transducers and high response superconductive temperature sensor are used to measure the transient variations of them.

It is found that the compression shock wave propagates through $HeII$ at the shock Mach number about $1.00 \sim 1.15$, which indicates they are rather strong shock waves in liquids, and that the waveform of the thermal shock wave is of a single peak shape which implies the significant effect of high density quantized vortices. The two modes of shock waves are visualized with Schlieren visualization method, too. The highly transient λ-phase transition is detected by the superconductive temperature sensor, where the temperature variation is positive, in striking contrast to the temperature drop that occurs during $HeII$ shock compression without the λ-transition.