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Method for Shock Wave Investigation of Magnetic Material*

D. E. GRADY†

Washington State University, Pullman, Washington 99163

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An experimental method developed for investigation of shock induced demagnetization in yttrium iron garnet is reported. The method was found reliable and quite easy to implement. It has the potential of being a useful experimental tool for further investigation of magnetic properties in shock wave studies.

INTRODUCTION

During the course of an investigation of shock induced demagnetization[1] in yttrium iron garnet, an experimental method capable of creating the induced demagnetization and performing the necessary magnetic measurements was developed. The technique was designed for use in conjunction with a gas gun.[2] Subsequent use of the method found it successful and easy to implement. It is believed that the technique could be quite readily used in impact studies for the investigation of this and other magnetic and magnetostructural properties of material. The purpose of this report is to present the details and analysis required for use of this method.

When magnetic material is subject to a strong shock wave and at the same time biased by an external magnetic field applied parallel to the shock front, a reduction in magnetization is observed. By this method shock waves are used to study the magnetic behavior of materials subject to extreme states of stress. In the present work demagnetization is produced by the mechanism of shock induced anisotropy.[1,3,4] Shock induced anisotropy is best understood by considering an infinite half-space of ferromagnetic material contained in the region $x>0$. Planar impact at the interface $x=0$ creates a plane shock wave propagating in the positive x direction. This creates in the region behind the shock wave an infinite slab of ferromagnetic material subject to a state of uniform uniaxial strain. During and following shock initiation, the ferromagnetic material is subject to a transverse magnetic field H_e sufficient to induce magnetic saturation in the material in front of the propagating shock wave. Behind the shock wave a reduction in magnetization occurs. This is a consequence of the magnetoelastic properties of the material which provide an axis of easy magnetization along the direction of shock propagation.

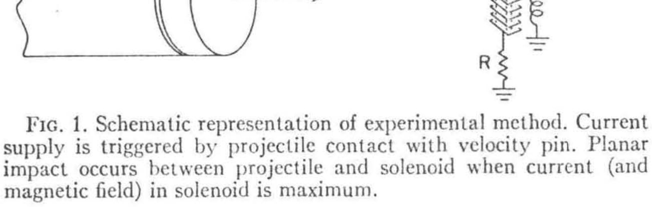

FIG. 1. Schematic representation of experimental method. Current supply is triggered by projectile contact with velocity pin. Planar impact occurs between projectile and solenoid when current (and magnetic field) in solenoid is maximum.

In this work the experimental effort was focused on creating the required state of strain and applied field and measuring the subsequent demagnetization.

A schematic representation of the experimental procedure is shown in Fig. 1. Briefly, the experimental sequence is as follows. A projectile, traveling at velocity V, triggers a current supply consisting of a large capacitance C charged to a voltage $\mathcal{E}_0$. The subsequent current produces a magnetic field in the solenoid which reaches a maximum when the projectile impacts the target. This rectangular solenoid is a single layer of copper ribbon which encloses the experimental sample of YIG. It is mounted in a target holder with one plane face oriented parallel to the projectile face. The impact produces a shock wave which propagates through the solenoid and into the YIG sample. This sample, initially in magnetic saturation, is demagnetized by the shock wave. The demagnetization develops an emf across a pickup coil which is recorded on the monitoring oscilloscopes. The magnetic state of the material behind the shock front is determined from these demagnetization records.

Pulsed solenoids for producing high magnetic fields are discussed elsewhere. Of interest in the present work are means of maintaining this field constant during solenoid collapse and shock demagnetization and passage of a shock wave through the solenoid with minimal deteriorating effect on the wave. Methods for accomplishing this are reported. Analysis of the shock demagnetization is determined in terms of relevant shock parameters.

This article is presented in the following order. In Sec. I operation of the current supply is explained. In Sec. II solenoid and target construction relevant to shock wave experimentation is reported. Section III is concerned with strain wave application. The demagnetization analysis is presented in Sec. IV. In Sec. V limits of the experimental method are considered in terms of shock strength and