CUSTOM TRANSLATION GDA

PHYSICS

EFFECT OF UNIFORM ALL-ROUND ~~PRESSURE~~ COMPRESSION ON THE SATURATION MAGNETIZATION OF IRON AT THE TEMPERATURE OF LIQUID NITROGEN (E)

F. Gal'perin, S. Larin, and A. Shishkov

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The effect of high pressures on the magnetic properties of ferromagnetics has so far been little studied; for example, the effect of uniform compression on the saturated magnetization of pure metals has only been considered in two experimental investigations /1, 2/. The authors of these papers directly determined the effect (the change in the magnetic flux.....through the ferromagnetic, see formula (2)) due to uniform compression. The change inthe saturated magnetization was calculated from the formula

.....R.p. 419 (1)

where.....and..... are respectively the saturated magnetization ~~xxx~~ of unit mass and the ~~mg~~ magnetic flux at pressure p_o, while..... and.....are the same quantities at a pressure p, and.....is the compressibility.

We see from Table 1 that the numerical values of the effect as given in the papers cited differ both in absolute magnitude and sign ; according to /1/ the latter is negative, and according to /2/ it may be either negative or positive. We are therefore here primarily concerned with establishing the sign of the effect more reliably.

Table 1

Key

1) atm^{-1}

2) or

3) * Calculated from formula (2)

4) ** Calculated from formula (1).....atm^{-1}

5) Experimental conditions

6) Oe

7) Source

8) This paper

9) Formula (4)

Furthermore, the work described in /1, 2/ was carried out at room temperature, whereas low temperatures are preferable in order to eliminate the influence of the para process, etc., on the effect in question. We therefore carried out our own experiments at liquid-nitrogen temperature (-196°C), as well as at room temperature (20°). The magnetic field was H = 1800 to 2000 Oe, which was adequate for the saturation of Armco iron. The compressing medium was a gas not solidifying at 77°K and 2000 atm. Oil was used for this purpose in /1, 2/.

The arrangement of the apparatus is shown in Fig. 1. The sample under test, 1, a machined Armco iron rod 570 mm long and 5.75 mm in diameter*, lies freely in the chamber 3 (the gap between the

* The sample is annealed in hydrogen at 1340°C for 15 min, heated in vacuum to 900°C, and cooled in the furnace,

Fig. 1. Arrangement of apparatus for studying the effect of uniform compression on the saturated magnetization at low temperatures. 1) Sample, 2) measuring coil, 3) compression chamber made of nonferromagnetic bronze, BrAZhM, 4) magnetizing coil, 5) Dewar vessel, 6) reducer, 7) upper tube, 8) gas-inlet valve, 9) compression cylinder, 10) manometer, 11) T joint, 12) lower tube, 13) compensating coil, 14) hydrocompressor, 15) transformer oil, 17) valve.

KEY

1) Pressure drop
2) Gas from cylinder

rod and inner walls of the chamber is about 0.2 mm) ; this enables the rod to be compressed on all sides. The high pressure in the chamber is achieved by reducing the original volume of the gas in the inside of the apparatus by forcing the transformer oil 16 into the compression cylinder 9 through the tube 12 by means of the hydrocompressor 14. The chamber containing the sample and the measuring coil C_m (2) fitting over the chamber* are placed in a Dewar vessel 5 filled with liquid nitrogen.

The principle of the electrical-measuring circuit appears in Fig. 2. The magnetizing field H inside the magnetizing solenoid C_H is created by a steady current of up to $i_{max} = 20$ A ;

* The measuring coil was placed inside the chamber in /2/.

$H_{max} = Ki_{max} = 2440$ Oe.

The measuring circuit consists of C_m, C_c, R_{sh}, and Fl (fluxmeter), as shown in Fig. 2. Coils C_m and C_c are connected in opposition so as to remove any interference associated with changes in the field due to fluctuations of the current in C_H. The shunting rheostat R_{sh} serves to adjust the compensation. The effect in question is measured by reference to the deflection of the light spot of the fluxmeter Fl. When the pressure is removed slowly, in addition to the change in magnetic flux associated with the fall in pressure, there is also a certain amount of "creep" in the light spot of the fluxmeter, mainly due to the torsional moment of the suspension fiber. An allowance for the "creep" of the light spot is made by ordinary calibration of the fluxmeter, but in addition to this the flux varies smoothly, at a definite velocity. Different measuring coils ($n_1 = 3960$ and $n_2 = 6240$ turns respectively) are used at 20 and -196°C so that the resistance in the fluxmeter circuit should be low (under 30 Ω) while maintaining a large enough number of turns in C_M. *

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* The measurements are made in the following order : 1) Gas from the supply cylinder is introduced into the apparatus through the valve 8 up to a pressure of p_o = 150 atm ; the valve 17 is closed. 2)Oil 16 is forced into the compression cylinder 9 to a pressure of about 2000 atm. 3) There is a 10-min delay in order to establish the temperature. 4) With the fluxmeter switched on, the solenoid is connected to the dc supply. Using rheostats R (Fig.2),

Long footnote completed on next page

a current sufficient to produce a field of 2000 Oe is established. 5) Fl is switched on ; using R_{Sh}, the change in external magnetic field due to the artificial change of current in the magnetizing solenoid is compensated. 6) By slow rotation of the handle of valve 17, oil is allowed to run smoothly out of the compression cylinder until reaching a pressure p_o. The pressure thus falls uniformly at a rate of 1000 atm/min . With this rate of fall we may neglect the change in the temperature of the massive sample. The change in the magnetic flux through the sample is measured by reference to the deflection of the lightspot of the fluxmeter.

end of long footnote

Fig. 2. Arrangement of the electrical part of the apparatus. C_H is the magnetizing coil (open solenoid with natural air cooling) ; the solenoid constant K is 122 Oe/A ; the internal ~~dam~~ diameter, length, and region of homogeneous field of the solenoid are 60, 670, and 200 mm respectively. C_m is the measuring coil (length of winding 160 mm) ; C_c is the compensating coil ; R_{Sh} is a rheostat shunting C_c ; Fl is a fluxmeter of the Grassot type with a flux constant of $c_{\psi} = 380 \pm 5$ Mx/division and a permissible external resistance of $R_{ext} \leq 30\,\Omega$. Distance to the scale about 3 m.

Key

1) V
2) Sample
3) C_H
4) Fl
5) C_m
6) C_c
7) R_{Sh}

The value of the effect under consideration is calculated from the formula

.....R.p. 421 (2)

where....., n is the number of turns in C_m, α is the deflection of the fluxmeter in scale divisions, and.....(atm).

For the iron sample studied, $I_s = 1690$ G and $S = 0.26$ cm^2. From the 22 measurements made we found..... ; from this, according to (2):

.....R.p. 421 [illegible]

and finally, from (1) : ..... .

Let us compare the value obtained from (1) with that calculated from the formula for the atomic magnetic moment of pure ferromagnetic metals given in /3/ :

.....R.p. 421 (3)

whwre $m_o = n_d - 2$, n_d = the number of unpaired d electrons in the isolated atom. For iron.....and $K_2 = 3.85$ magnetons/kxu, d_1 and d_2 ~~at~~ are the distances between the atom and ~~the~~ its nearest and next-nearest neighbors respectively (for iron $d_1 = 2.478$ kxu and $d_2 = 2.86$ kxu), and D is an empirical constant characteristic of the particular transition metal, being 2.73 kxu for iron. The negative sign in front of the ~~thrid~~ third term is (3) is taken if d_2.....D (as it is for iron). Putting the numerical values for iron into (3), we find that m = 2.23 magnetons (experiment gives 2.22). Formula (3) leads to the conclusion : For uniform compression (d_1 and d_2 become smaller), m must fall, and for uniform expansion it must increase.

It is well known that this conclusion is confirmed qualitatively by experiment /1, 2, 4/. For a quantitative estimate of the effect we differentiate (3). We obtain

.....R.p. 422 (4)

In (4) it is supposed that..... . Putting the numerical values for iron (see above) into (4), we obtain.....atm^{-1}, which agrees satisfactorily with our own data at the temperature of liquid nitrogen (lines 4 and 5 in Table 1), but disagrees considerably with /1/ (lines 1 and 5 in Table 1).

L ITERATURE CITED

/1/.....

/2/ F. Gal'perin, DAN..... ; P. Oreshkin, Dissertation /in Russian/, MGU, 1951.

/3/ F. Gal'perin, Izv. AN SSSR, ser. fiz., ...; DAN.....

/4/ K. Belov, ZhÉTF.....; DAN.....