TEMPERATURE HYSTERESIS OF THE REMANENCE
IN HIGH-COERCIVITY ALLOYS

D. A. Laptei, A. I. Drokin, and G. P. Zhilin

It is shown that the temperature behavior of the remanence and the value of the hysteresis depend on the position of the operating point on the demagnetization curve and the structural state of the specimen. Both alternating and constant magnetic fields of different sign have different effects on the value of the temperature hysteresis. An explanation of the results is given on the basis of vector rotation processes in single-domain regions.

Numerous papers have been devoted to the temperature hysteresis of ferromagnetic materials, most of which were published in the fifties. The materials investigated were mainly soft magnetic materials [1]. Some work has been carried out on ferromagnetic dielectrics [2] and high-coercivity alloys [3, 4]. The main attention was given to studying the processes which occur in the magnetic structure of the material when there is a cyclical change in its temperature. The results obtained found a satisfactory interpretation for soft ferromagnetic materials but difficulties arose in the case of materials which possessed a high coercive force. In addition to its scientific interest, investigations of the temperature hysteresis is also of practical value. In this paper we present the results of an investigation of the change in the remanence of the high-coercivity alloys Alnico and Ticonal under cyclical temperature conditions when alternating and constant external magnetic fields are present.

EXPERIMENTAL METHOD

The measurements were made on an astatic magnetometer using the null method. The specimens were magnetized in a special magnet at room temperature, which was the initial temperature for all the measurements. An alternating (50 Hz) or constant field in a given direction was set up in the magnetizing coils of the magnetometer. The value of the external field did not exceed 160 Oe. The temperature variations of the specimens were produced by a bifilarly wound oven and liquid nitrogen vapor in the cycle +20°-100°-+100°-+20°C.

The investigations were made on specimens which are known in the technical literature as YuNDK-24, YuNDK-25-BA, and YuNDK-35-T5. The specimens were made by the electric-spark method from industrial alloys, and were in the form of parallelepipeds. The dimensions of the specimens were chosen from

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Alloy</th>
<th>Structure</th>
<th>B/H</th>
<th>H_r</th>
<th>B_r</th>
<th>\Delta B_r</th>
<th>\Delta B_r / B_r</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>YuNDK-24</td>
<td>polycrystalline</td>
<td>28.6</td>
<td>340</td>
<td>0.95</td>
<td>37.0</td>
<td>0.38</td>
</tr>
<tr>
<td>2</td>
<td>YuNDK-25</td>
<td>.</td>
<td>14.8</td>
<td>600</td>
<td>0.84</td>
<td>136.4</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>YuNDK-24</td>
<td>.</td>
<td>11.8</td>
<td>330</td>
<td>0.39</td>
<td>22.7</td>
<td>0.58</td>
</tr>
<tr>
<td>4</td>
<td>YuNDK-85-T5</td>
<td>columnar</td>
<td>11.65</td>
<td>310</td>
<td>0.36</td>
<td>9.8</td>
<td>0.28</td>
</tr>
<tr>
<td>5</td>
<td>YuNDK-85-BA</td>
<td>.</td>
<td>7.1</td>
<td>790</td>
<td>0.50</td>
<td>71.6</td>
<td>0.29</td>
</tr>
<tr>
<td>6</td>
<td>YuNDK-85-T5</td>
<td>.</td>
<td>12.5</td>
<td>750</td>
<td>0.87</td>
<td>28.0</td>
<td>0.32</td>
</tr>
</tbody>
</table>
Fig. 1. Change in the remanence as a function of temperature (the numbers indicate the number of the specimen in the table).

Fig. 2. Change in the remanence as a function of the temperature for the alloy YuNDK-24: a) in a magnetic screen, b) in a field \( H = 8 \text{ Oe} \), c) in a field \( H = -8 \text{ Oe} \), d) after stabilization by a field \( H = 72 \text{ Oe} \), e) in an alternating field \( H = +72 \text{ Oe} \), f) in a constant field \( H = +72 \text{ Oe} \), g) in a constant field \( H = -72 \text{ Oe} \).

an analysis of the demagnetization curves, using the expression given by Evershed [5]

\[
\frac{B}{H} = K \frac{L S^2}{A},
\]

where \( L \) is the length, \( A \) is the area of the transverse cross section, \( S \) is half the surface area of the specimen, and \( K = 1.47 \). The ratio \( B/H \) represents the position of the operating point of the specimen on the demagnetization curve.

The remanence, the temperature hysteresis in absolute and relative values after passing through the temperature cycle, the position of the operating point of the specimens, and the value of the internal demagnetizing field at room temperature are shown in the table for some of the alloys investigated, for which graphs are presented below of the change in the remanence with temperature. Specimens No. 3 and 4 were cut perpendicular to the direction of \( H_T \) (the field applied during the thermal processing), and the remanence was along \( H_T \).

RESULTS

We must first dwell on the nature of the change in the remanence of high-coercivity alloys for a cyclical change in the temperature. The form of the curves, as already noted in [4], depends considerably on the position of the operating point on the demagnetization curve. The behavior of \( \Delta B_r(t) \) differs little from rectilinear both on the heating branch and on the cooling branch for specimens with an operating point which lies above the state \( (B \times H)_{\text{max}} \). For specimens with a lower operating point the temperature behavior of the change in remanence becomes more complex, forming a maximum in the negative-temperature region (Fig. 1, A, B, C).

When the operating point is changed the value of the temperature hysteresis changes. This value is greater the lower the working point. For specimens with the same values of \( B/H \) specimens of YuNDK-24 alloy possess the greatest hysteresis, followed by YuNDK-25-BA, and YuNDK-35-T5. Specimens cut perpendicular to the direction of \( H_T \) have a much lower hysteresis. Figure 2 shows the effect of external magnetic fields on the temperature hysteresis of the remanence. Data is given for only one alloy, but the results are typical for all the specimens investigated.

The results obtained can be explained if we bear in mind the crystalline state of the specimens investigated. The thermomagnetic processing used for these alloys leads to a very pronounced anisotropy of their magnetic properties. The high value of the coercive force is largely determined by the dispersion