IMPROVING THE DISTRIBUTION OF MAGNETIC PROPERTIES IN RARE EARTH-COBALT MAGNETS BY THE USE OF SELECTIVE THERMAL STABILIZATION

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Abstract - Typical production rare earth-cobalt permanent magnets have a nominal variation of ±5% for remanence and ±10% for energy product. A technique is described for improving the distribution of these properties using stabilizing temperatures which are a function of the measured properties of the as-magnetized magnet and its operating point. It is possible to achieve a 90% yield at a ±1% tolerance band of remanence. Data are given for two lots of production magnets, to which this technique has been applied.

INTRODUCTION

Several applications of rare earth-cobalt permanent magnets require an especially narrow distribution of energy product or remanence, compared to normal production distributions. The nominal variations for energy product and remanence are ±10% and ±5%, respectively. Examples of these applications are particle beam focusing devices and free electron lasers, which require magnets with good piece-to-piece consistency.[1]

The irreversible losses in rare earth-cobalt magnets are a function of operating point, H_k and time at temperature.[2,3,4] Exposing magnets to elevated temperatures (100 to 300°C for 1 to 5 hours) is an established technique for improving long term stability.

This paper describes a technique for improving the distribution of remanence and energy product in production magnets, using stabilizing temperatures which are a function of the measured properties of the as-magnetized magnet and its operating point. This technique can be used to narrow the width of the distribution to achieve acceptable yields for sorting magnets to a $\pm\frac{1}{2}$% or ±1% band for remanence.

EXPERIMENT

Two lots, each of approximately 100 $SmCo_5$, Crucore 18 disc magnets, were used in the experiment. These were production magnets. No attempt was made to improve the piece-to-piece uniformity, before the selective stabilization technique was applied. The first lot of magnets had a length to diameter ratio, L/D=0.5, while the second lot had an L/D=1.0. These ratios correspond to load lines, B/H of about 1.1 and 2.2, respectively.[5] The magnetic properties of samples taken from both groups were:

B_r= 8400 Gauss; H_c= 8250 Oersted; H_k= 13,800 Oersted; H_{ci}= 18,000 Oersted; and $(BH)max$= 17.2×10^6 Gauss - Oersted

After being saturated in a pulsed field of 40,000 Oersted, each magnet had its open-circuit magnetization measured using a Helmholtz coil detection system.[6] When no external field is applied to the magnet, this method determines the remanence, for these operating points. The distribution of readings, before stabilization, and the stabilizing temperatures applied for each group are shown in Figures 1a and 1b. An arbitrary reference reading of 200 is used for each lot. The distributions were broken down into quartiles, although other breakdowns are possible. For each quartile, a stabilizing temperature was chosen so that the higher the measured remanence, the higher the stabilizing temperature, and consequently, the higher the irreversible losses.[2,3,4] The data of Bachmann and Weinmann[3] used for determining stabilizing temperatures is plotted in Figure 2. The minimum temperature of 100°C was chosen arbitrarily. However, in practice, the lowest stabilizing temperature should be chosen to exceed the maximum anticipated operating temperature of the magnet. Stabilizing each quartile at a different temperature has the effect of narrowing the distribution of remanence and energy product.

The magnets were stabilized for two hours at temperature. A second Helmholtz coil measurement was made to check the results of selective stabilization. The results are shown in Figure 3.

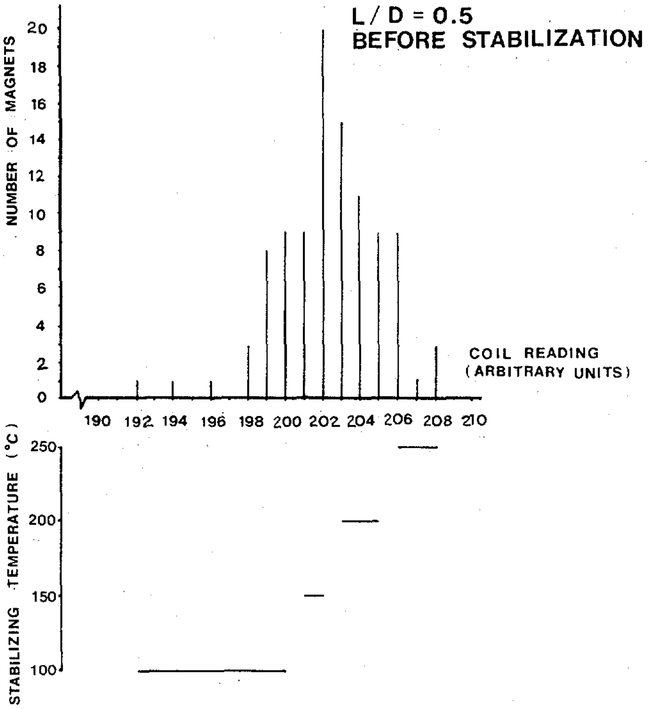

Fig. 1a. Histogram of Helmholtz coil readings before stabilization and plot of stabilizing temperatures selected for the histogram for L/D=0.5.

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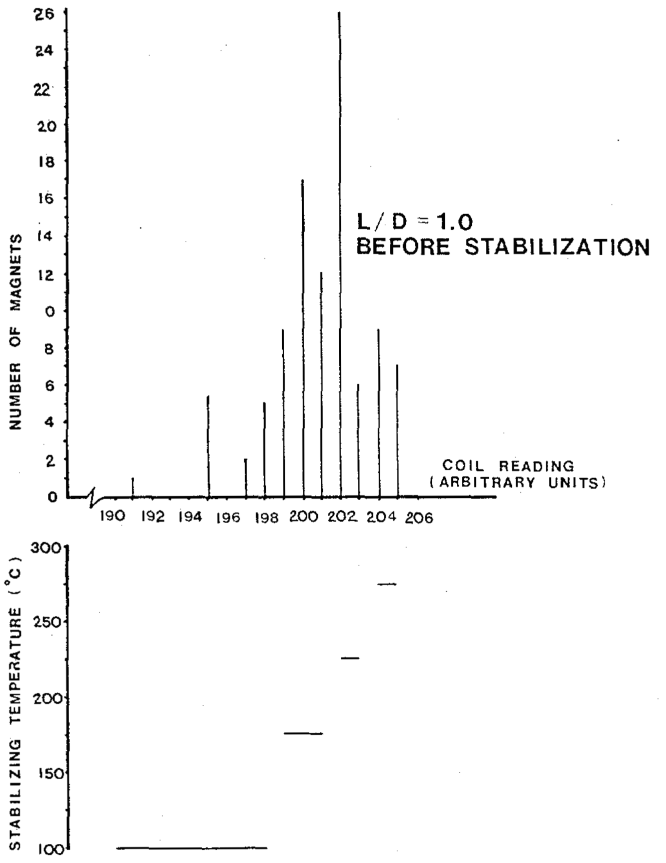

Fig. 1b. Histogram of Helmholtz coil readings before stabilization and plot of stabilizing temperatures selected for the histogram for L/D=1.0.

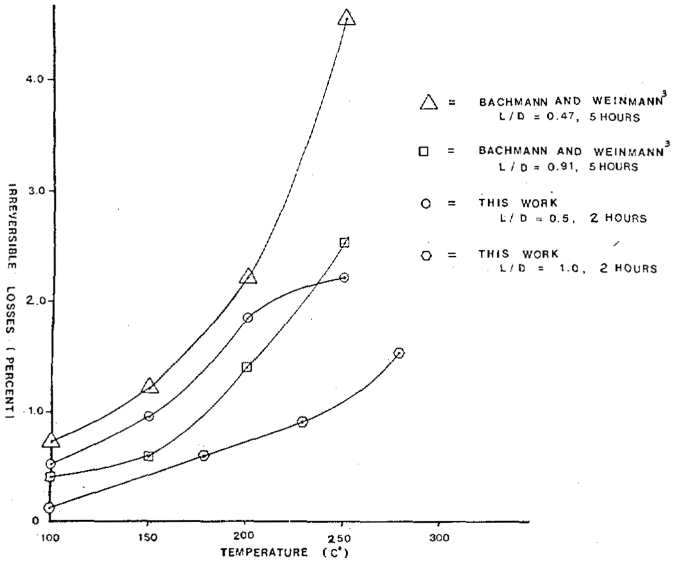

Fig. 2. Irreversible loss vs. stabilizing temperature data. The Bachmann and Weinmann data are for L/D=0.45 and L/D=0.91 for 5 hours. The data from this experiment are for L/D=0.5 and L/D=1.0 for 2 hours.

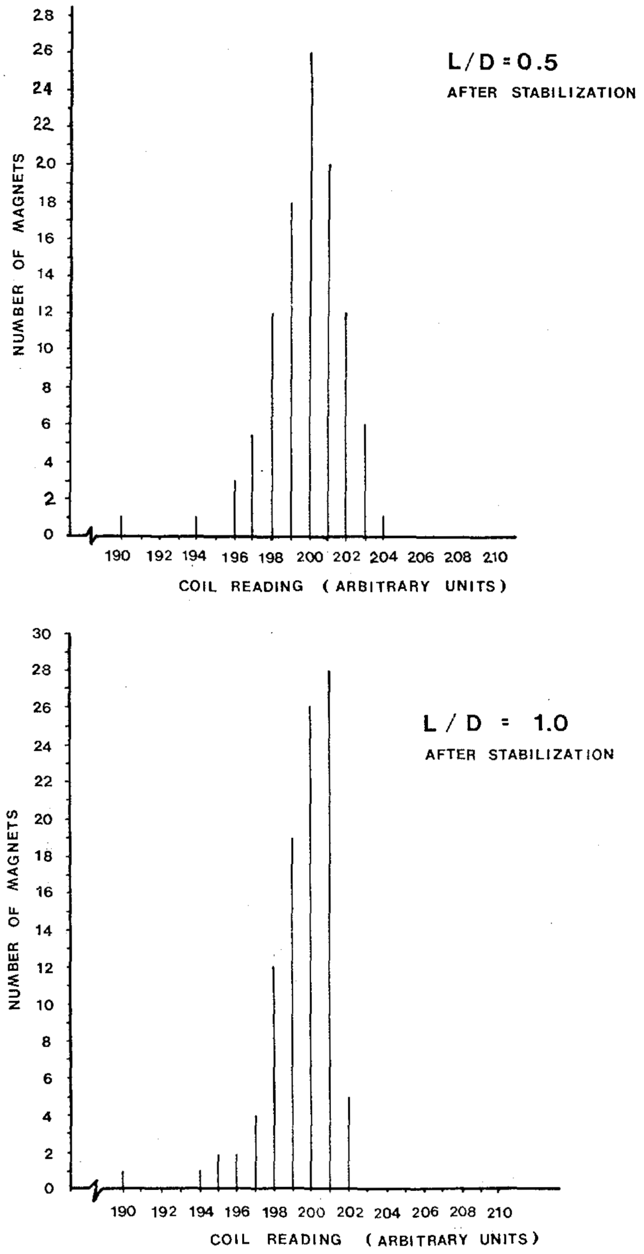

Fig. 3. Histograms of Helholtz coil readings after selective stabilization, for L/D=0.5 (3a) and L/D=1.0 (3b).

DISCUSSION

Figures 3a and 3b show the narrowing of the distribution of remanence due to selective stabilization. The data are presented in Table 1 to show the improvement in yield at different tolerance bands on the remanence. The corresponding tolerance bands for energy product are broader by a factor of two, since, in this case, energy product is proportional to the remanence squared. There is a significant increase in the yield at the 0.5% and 1.0% levels, for both lots. The improvement at the 1.5% and 2.0% levels is not as good. These results are due to the particular temperatures chosen for this experiment. The technique would have been more efficient had loss vs. temperature data been available for recent production magnets, but the data of Bachmann and Weinmann[3] are the best available, yet are not identical to this situation due to: 1) the slight difference in magnet size, where L/D=0.45 and 0.91; 2) the longer stabilizing time, five hours, and; 3) the production improvements, since the time

L/D	TOLERANCE ON B_r	YIELD BEFORE STABILIZING	YIELD AFTER STABILIZING
0.5	± 0.5%	43%	59%
0.5	± 1.0%	62%	81%
0.5	± 1.5%	81%	93%
0.5	± 2.0%	94%	96%
1.0	± 0.5%	59%	73%
1.0	± 1.0%	73%	90%
1.0	± 1.5%	87%	96%
1.0	± 2.0%	93%	99%

Table 1. Tabulation of the yield for different tolerance bands of remanence, before and after stabilization.

when the Bachmann and Weinmann samples were made, have improved long term stability. A comparison of the loss data measured in this work and the data of Bachmann and Weinmann is plotted in Figure 2.

As a technique for calibrating magnets, selective thermal stabilization has an advantage over the use of magnetic field knock-down which has been the conventional method for tuning magnets. Since selective stabilization is thermal rather than magnetic, no further significant losses are expected as long as the magnets do not exceed their stabilizing temperature or are not exposed to adverse magnetic fields such that the applied field and the demagnetizing field exceed H_k. With magnetic knock-down it is possible, by excessive knock-down, to have magnets which are not stable and will, with time, increase their magnetization. This situation is unpredictable, since it is not always possible to know in advance when this instability will occur. The instability of magnetic knock-down can be avoided by using selective stabilization and by controlling the operating temperatures of the magnets.

CONCLUSION

Selective stabilization has been demonstrated as a technique for improving the distribution of remanence and energy product in rare earth-cobalt magnets. The data show a 90% yield can be obtained when sorting magnets to a 1.0% tolerance band for remanence or a 2.0% band for energy product.

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