United States Patent [19]

Naastepad

[11] **3,891,476**

[45] **June 24, 1975**

[54] **METHOD OF MAGNETIZING A BODY OF M_5R AT HIGH TEMPERATURES**

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[22] Filed: **Nov. 21, 1973**

[21] Appl. No.: **418,124**

[30] **Foreign Application Priority Data**

Dec. 15, 1972 Netherlands 7217051

[52] **U.S. Cl.** **148/103;** 148/31.57; 148/105; 148/108

[51] **Int. Cl.** **H01f 1/02**

[58] **Field of Search** 148/103, 105, 108, 31.57

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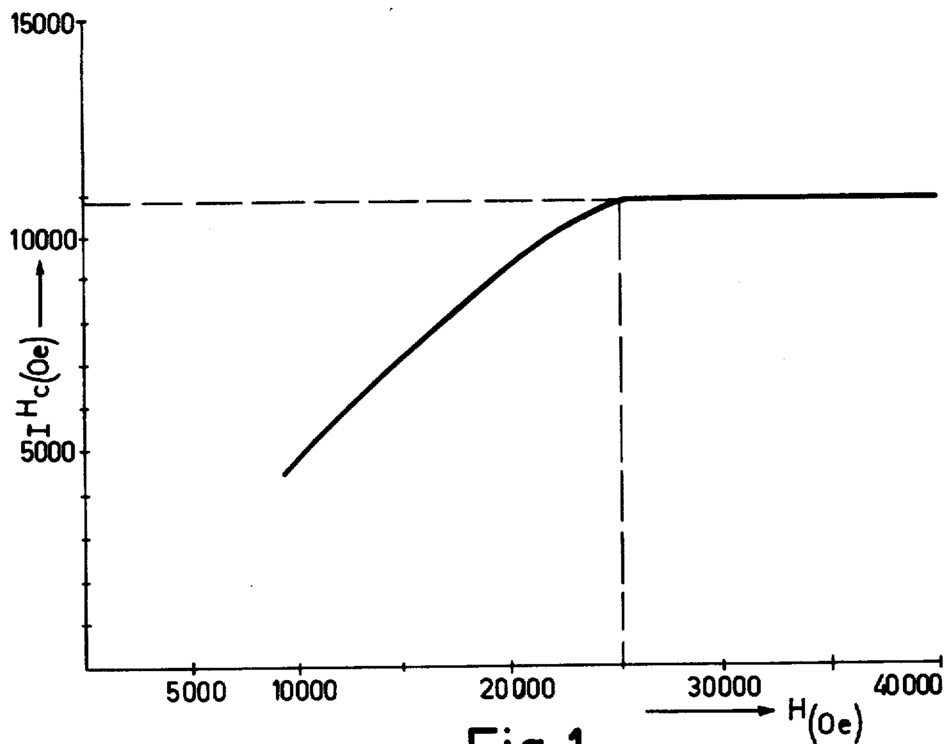
[57] **ABSTRACT**

A method for the magnetization of a sintered magnetic body mainly consisting of a material of the type M_5R, in which M may be cobalt and R a rare earth metal. The magnetization proceeds most easily when magnetization is carried out consistently in one direction or when magnetization is carried out at a temperature between 200°C and the Curie point. The body to be magnetized is preferably first annealed at a temperature between the sintering temperature and a temperature which is 300°C lower and magnetized during the subsequent cooling.

5 Claims, 4 Drawing Figures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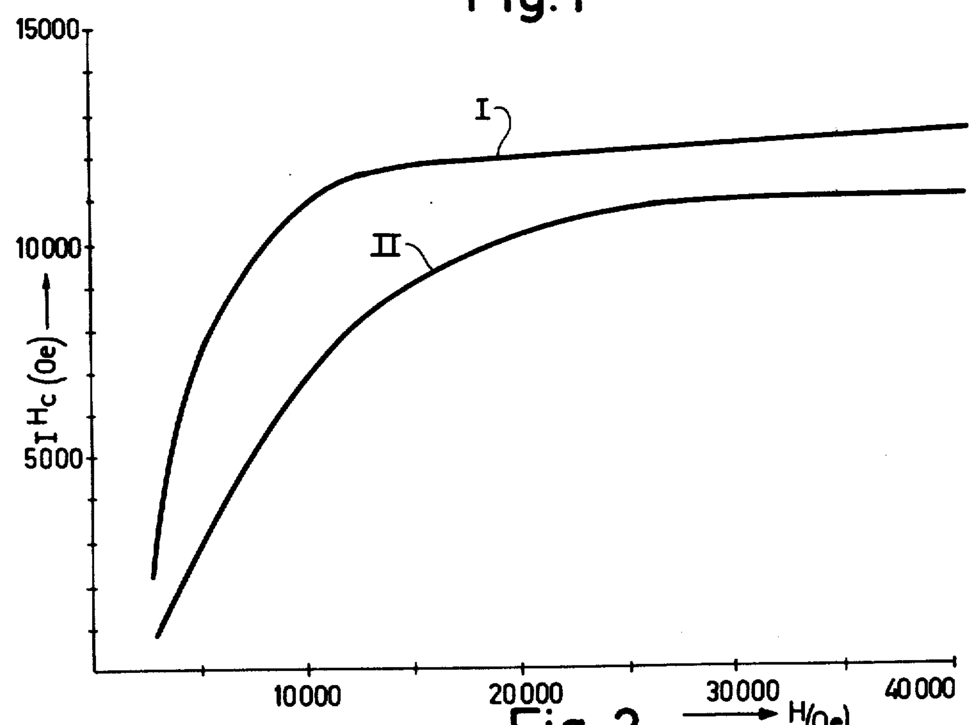
5000
10000
20000
30000
40000
H(Oe)

Fig. 1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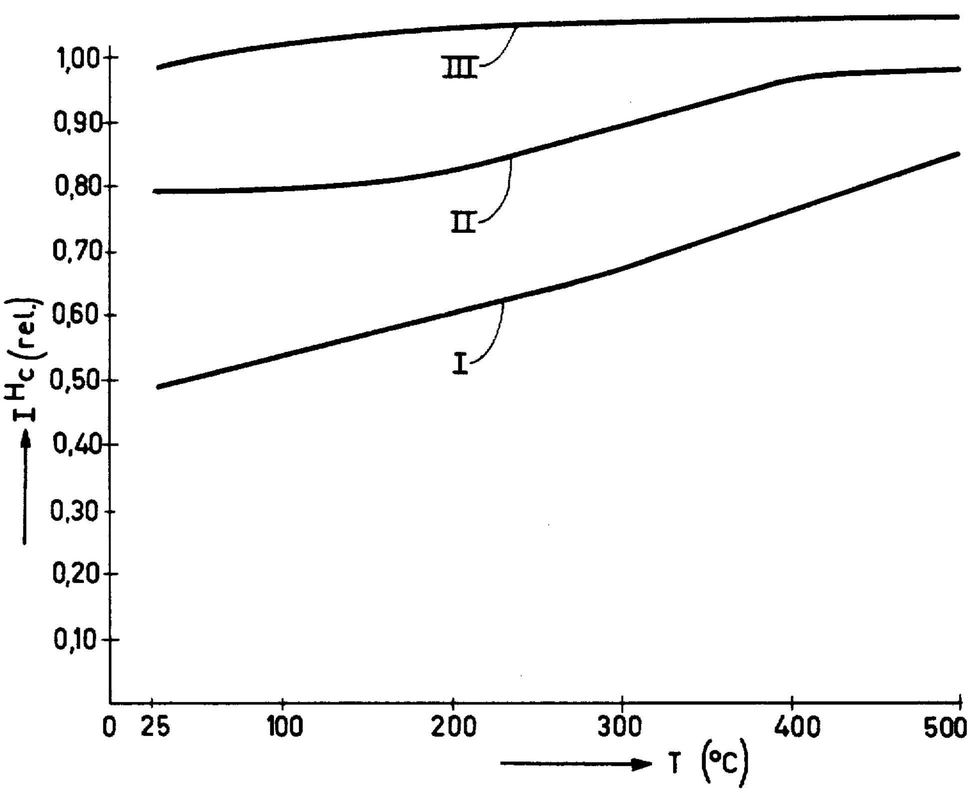
II
10000
20000
30000
40000
H(Oe)

Fig. 2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0,80
0,70
0,60
0,50
0,40
0,30
0,20
0,10
I Hc (rel.)
III
II
I
0 25 100 200 300 400 500
T (°C)

Fig. 3

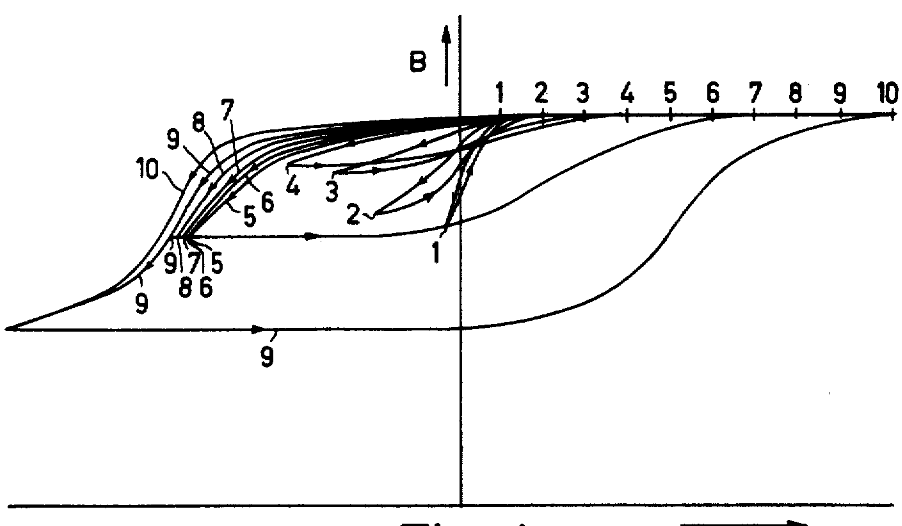
B
1 2 3 4 5 6 7 8 9 10
H

Fig. 4

METHOD OF MAGNETIZING A BODY OF M_5R AT HIGH TEMPERATURES

The invention relates to a method for the magnetization of a magnetic body principally consisting of a material of the type M_5R, in which M is Co or a combination of Co with at least one representative of the group consisting of Fe, Ni and Cu, and in which R is at least one representative of the group consisting of Y, Th and the rare earth metals.

Such a magnetic body is usually magnetized in a very strong magnetic field (two to three times the intrinsic coercive field strength of the material) so as to saturate the material in such manner that the hysteresis loop is closed. The intrinsic coercive field strength, for example, of $SmCo_5$ is approximately 12,000 Oe and it is usual to use a field of approximately 40,000 Oe for the magnetization. In practice, such a high field is difficult to realize in series production of permanent magnets so that one would have to be satisfied with a final product which does not have the optimum magnetic value. This problem is the more urgent when a magnet of the present type is to be incorporated in an apparatus in the demagnetized state. As a result of the attractive force which a previously magnetized magnet exerts, it may give rise to problems in assembling the various components. In such cases it is desirable to magnetize the magnet only in the assembled condition. The high field strength required for the magnetization can often then not be produced at the area of the magnet, mainly because the shape of the apparatus in which the magnet is mounted.

On the other hand it is also very difficult to demagnetize a permanent magnet of the present type, since for that purpose a very strong alternating magnetic field is necessary.

It is the object of the invention to provide a method which enables the use of a weaker field for the ultimate magnetisation and demagnetisation, respectively, in particular a field whose strength is less then twice the intrinsic coercive field strength of the material, than is necessary when using the known method.

A first embodiment of the method magnetically saturating a sintered magnetic body mainly consisting principally of a material of the type M_5R uses a field whose strength is less than two times the intrinsic coercive field strength of the material to magnetize the body.

In contra-distinction to what has heretofore been thought to be possible it has been found, a field strength equal to the intrinsic coercive field strength of the material is sufficient to magnetically saturate a body of M_5R, provided magnetization is carried out in only one direction. Magnetization with a field equal to the coercive field strength proves to be impossible when magnetization is not consequently carried out in one direction, but, for example, first in a first direction and then in the opposite direction. In that case, a field of at least two to three times the coercive field strength is necessary to magnetize the material to saturation.

A second embodiment of the method for magnetically saturating a sintered magnetic body consisting principally of a material of the type M_5R involves carrying out magnetization at a temperature between 200°C and the Curie point of the material in a field whose strength is less than two times the intrinsic coercive field strength of the material.

While it was known that sintered ferro-magnetic materials of the type having a magnetoplumbite structure can be magnetized at a temperature near their Curie point in a field which is considerably weaker than the field required at room temperature, this way of magnetisation, however, is not considered practical when magnetizing the present materials since they have Curie temperatures which are too high for that purpose. For example, the Curie temperature of $SmCo_5$ is approximately 730°C. It has surprisingly been found, however, that the M_5R-materials in question already can be magnetized at a temperature which is considerably below the Curie temperature, in particular at a temperature which is lower than 0.5 times the Kelvin temperature of the Curie point (that is to say below 500°C in the case of $SmCo_5$) in a comparatively weak field.

In addition to the economic advantage of magnetization by means of a weaker field, the use of the method according to the invention results in the advantage that magnetization can be carried out in certain cases in which this is not possible when using the usual method or when the latter would result in undesired complications. This is the case, for example, when the magnetization must be carried out in a place which is difficult to reach for the field to be applied or in manufacturing a multipolar magnet.

It has been found in particular that when using the above-mentioned method, a magnetization field is sufficient whose strength corresponds to or is even smaller than the intrinsic coercive field strength of the material, provided the magnetization is carried out at a sufficiently high temperature, in particular above 400°C.

When magnetization is carried out at a temperature above 200°C, according to a preferred embodiment of the method according to the invention, the magnetizing field, during the subsequent cooling to room temperature, is maintained to a temperature below 200°C, and preferably to room temperature. If this is not done, the possibility exists that the magnetized body demagnetizes itself entirely or partly.

According to a further preferred embodiment of the method according to the invention, the magnetic body is sintered and subsequently is annealed at a temperature between the sintering temperature and a temperature which is 300°C lower before it is introduced into the magnetizing field. A magnetic body pretreated in such manner is not only found to be easier to magnetize but in addition the resulting magnet has a higher intrinsic coercive force.

When the magnetic body is to be magnetized immediately after the annealing treatment, it is preferrable to cause the magnetisation field to influence the body during the cooling from the annealing temperature to room temperature. This makes an additional heating-/cooling phase superfluous.

FIG. 1 shows the dependence of the intrinsic coercive force $_IH_c$ as a function of various magnetization fields H.

FIG. 2 shows for magnets treated in various manners the dependence of the intrinsic coercive force $_IH_c$ as a function of various magnetizing fields H.

FIG. 3 shows for various magnetizing fields the dependence of the relative intrinsic coercive force $_IH_c$ (rel.) as a function of various magnetization temperatures T.

FIG. 4 shows a series of magnetisations with increasing field in one sense for an $SmCo_5$-magnet.

EXPERIMENT I

A compressed block consisting of powder particles of the compound $SmCo_5$ was sintered at 1,100°C. The resulting sintered body was magnetized at room temperature in a field of 45,000 Oe. The B-H curve of the thus magnetized body was measured. The intrinsic coercive force $_IH_c$ proved to be 11,000 Oe. The body was then demagnetized at 500°C in an alternating field having a maximum field strength of 2,000 Oe. It was then measured at room temperature to show how the $_IH_c$ depends upon the strength of the magnetizing field (FIG. 1). A magnetizing field of 25,000 Oe proved to be necessary to regain the $_IH_c$ of 11,000 Oe, that is to say to reach again the outer loop of the B-H curve. It is to be noted that the body was not always consistently magnetized in one direction.

EXPERIMENT II

The magnetic body used in the first experiment was heated at a temperature of 925°C for a few minutes. This temperature is above the Curie temperature (± 730°C) and the body was therefore demagnetized. After cooling to room temperature, the $_IH_c$ was measured as a function of the magnetization field H. From this results the curve I. The magnet was then demagnetised at 500°C in an alternating field and the $_IH_c$ was measured again as a function of the magnetization field H. From this results curve II. It is obvious that in both cases the maximum $_IH_c$ is reached after magnetization in a field of 25,000 Oe (compare experiment 1). It is striking that after the annealing treatment at 925°C a higher maximum $_IH_c$ is reached (namely 12,500 oe) than after the demagnetization at 500°C (11,000 Oe). In addition it is striking that the magnet can more easily be magnetized after the annealing treatment at 925°C (so-called thermal demagnetisation). Magnetization in a field of 10,000 Oe even results in a magnet having an intrinsic coercive force $_IH_c$ of 11,000 Oe. This effect is not found when the magnet has been subjected at 500°C to a demagnetization treatment in an alternating field (curve II). Magnetization in a field of 10,000 Oe then results only in a magnet having an $_IH_c$ of 7,000 Oe.

EXPERIMENT III

The $SmCo_5$ magnet used in the preceding experiments was demagnetized at 500°C in an alternating field and it was investigated in three different magnetization fields of 5,000 Oe, 8,000 Oe and 10,000 Oe, respectively, how the magnetization depends upon the temperature. FIG. 3 shows the results of the investigation. The relative $_IH_c$, i.e. the $_IH_c$ of the magnet divided by the $_IH_c$ after magnetization at room temperature in a field of 45,000 Oe is plotted on the vertical axis. The temperature T at which magnetization was carried out is plotted on the horizontal axis. Curve I shows the variation of the relative $_IH_c$ when using a magnetization

field of 5,000 Oe, curve II shows the variation when using a field of 8,000 Oe and curve III shows the variation when using a field of 10,000 Oe. So magnetization fields may be used which are much weaker than the field to be derived from FIG. 1 (which has a strength of 25,000 Oe), provided that a suitable magnetization temperature is chosen. However, this higher temperature is still far below the Curie temperature which is approximately 730°C).

FIG. 4 shows with reference to a number of B-H curves how in a certain experiment an SmCo5 magnetic body was consistently magnetized in one direction. The body was first introduced into a small field, said field was caused to decrease and then to grow in the original direction to a larger value than the initial value, caused to decrease again, and so on. In this manner one proceeds, while describing inner loops, in the direction of the outer loop of the B-H characteristic. It may be established from this experiment that the $_IH_c$ values of the successive inner loops are always much larger than the required magnetization fields. It is still to be noted that the direction of magnetization does not depend upon the material, but only upon the direction with which has been started.

What is claimed is:

1. A method of magnetizing a body consisting principally of a material of the composition M_5R, M consisting of an element selected from the group consisting of Co and Co in combination with one of the elements Fe, Ni, and Cu, and R being an element selected from the group consisting of Y, Th, and the rare earth metals comprising the steps of, subjecting said body to a magnetic field having a strength sufficient to magnetically saturate the material and less than twice the intrinsic coercive field strength of the material at a temperature between 200°C and 0.5 times the Kelvin temperature of the Curie point of said material.

2. A method as claimed in claim **1**, wherein at a temperature between 400°C and the Curie point the body is subjected to magnetic field having a strength which is not greater than the intrinsic coercive field strength of the material.

3. A method as claimed in claim **1**, wherein the magnetic body is subsequently cooled to room temperature and the magnetizing field is maintained to a temperature below 200°C.

4. A method as claimed in claim **1**, wherein the magnetic body is formed by compressing the material into a body which is heated at about 1,100°C and subsequently said body is annealed at a temperature between said temperature and a temperature which is 300°C lower before it is subjected to the magnetic field.

5. A method as claimed in claim **4**, wherein the magnetic body is subjected to the magnetic field during the cooling of the body from the annealing temperature to room temperature.

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