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METHOD OF MANUFACTURING PERMANENT MAGNETS

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1 Claim. (Cl. 148—21.5)

My invention relates to the manufacture of permanent magnets and more particularly to the manufacture of permanent magnets from steels containing nickel, titanium, aluminium and possibly cobalt.

Magnet steels of the above type have been described in the French Patent No. 764,375 and in the article by Kotaro Honda, which appeared in the periodical "Metallwirtschaft, Wissenschaft und Technik" Vol. XIII, No. 24, page 425 of June 15, 1934. Such steels generally contains, in addition to other materials such as aluminum, the following constituents:

	Per cent
Nickel	3 to 50
Cobalt	0.01 to 50
Titanium	1 to 50

Although suitable permanent magnets can be made from such steel without the use of special heat treatment, this is only true to a limited extent and in some specific cases in which the steel has a special composition and in which the dimensions of the castings fall within certain limits and, even then, special provisions are needed for carrying the heat away from the mold. On the other hand, it is generally recognized that to obtain a hardening effect with "precipitation" hardening alloys, a thermal treatment consisting of several steps is necessary. This is the case, for instance, with Duralumin whose properties have been subjected to many years of thorough investigations.

In heat-treating magnet steel alloys based on "precipitation" hardening the following is the usual procedure. Bodies of such steel alloys are quenched to room temperature from high temperatures at which an increased dissolving capacity of the main phase for a heterogeneous phase occurs. The alloys are then aged for a longer or shorter time at temperatures which are considerably below the hardening temperature. In practice this method of heat treatment is often carried out by immersing the hot magnet body in an oil or a water bath and subsequently heating the body for some time at a higher temperature. Such heat treatment is fundamentally necessary and is generally used for this type of magnet steels. However, the exact quenching and aging temperatures, the aging time, and the quenching speed vary and depend upon the properties of the special alloy being used; the quenching speed being controlled by the selection of the cooling medium.

This commonly-used heat treatment has been found unsuitable for magnet steels of the above referred to type. Although it gives good magnetic results the difficulties are due to mechanical reasons which arise in the manufacture of the magnets because the high natural brittleness of this type of material, which are accentuated by such rough heat treatment. As a result, alloys of this type which are most promising because of the excellence of their magnetic properties, can not be used in the commercial manufacture of magnets at all, or involve so much waste as to make the cost prohibitive.

The object of my invention is to overcome such difficulties in the heat treatment of such alloy steels. According to my invention I quench the alloy, instead of to substantially room temperature, to a temperature which is substantially in the range of the usual aging temperatures, and may be even slightly higher. After the steel has completely acquired such a quenching temperature, it is permitted to gradually cool to room temperature; after this it is reheated to the aging temperature at which it is then allowed to age for a definite time.

If the quenching temperature used is higher than the required aging temperature, the above procedure may be somewhat modified as follows: The temperature of the quenched alloy instead of being reduced to room temperature and then again raised to the aging temperature, is gradually reduced from the quenching temperature to the aging temperature at which it is kept for a definite time interval, after which the steel is cooled down to room temperature.

Also when the quenching takes place at a temperature which is lower than the aging temperature—which is preferable in certain cases—the temperature of the steel may be raised from the quenching temperature to the aging temperature, or may first be cooled from the quenching temperature to room temperature and then heated to the aging temperature as has been previously stated.

The simplest heat treatment is obtained when the quenching and aging temperatures are the same, in which case the quenched steel is maintained at the quenching temperature also for aging and thereafter cooled to room temperature.

For quenching the magnet body I prefer to use as the cooling medium a metal or salt bath which is heated to the quenching temperature. For this purpose a bath consisting of molten tin or lead or a solution of potassium nitrate and sodium nitrate in a ratio of about 1:1 may be used. As stated when the quenching and the aging

temperatures are equal the magnet body may remain in this bath during the necessary aging time, which may vary from e. g. one minute to several hours dependent upon the temperature of the bath and the size of the magnet bodies. This dispenses with a separate heating operation.

I found that the magnetic properties of the alloy steels heat-treated in accordance with the invention are at least equal to and in many cases very much better than those of the same alloy steels which have been quenched to room temperature.

For a better understanding I may refer to experiments I have made with a composition obtained by pouring an alloy from 16% nickel, 28% cobalt, 12% titanium, 4½% aluminum, the remainder being iron. Test pieces of 10 x 28 x 32 mm. were used.

a. On quenching these pieces from about 1225° C. in oil down to room temperature and after aging for some hours at temperatures increasing up to 500 to 700° C. the following magnetic values were found; in which B_{rem} is the remanence, H_{coerc} is the coercive force, and BH_{max} is the product of the values for B and corresponding H for which the product BH is maximum.

B_{rem}	6900
H_{coerc}	720
BH_{max}	1,730,000

b. Furthermore similar pieces were quenched from about 1175° C. in water down to room temperature and subsequently aged for a comparatively long time (about 20 hours) at temperatures increasing up to 500 to 700° C.

The following magnetic values were found:

B_{rem}	4800
H_{coerc}	970
BH_{max}	1,710,000

The same steel having the same dimensions was subsequently treated according to the present invention, viz: *e*. the pieces were quenched from about 1175° C. in a tinbath of about 700° C. and were allowed to remain for about one minute therein, whereupon they were cooled down in the air. After aging for some hours at temperatures increasing up to 600–650° C. the following magnetic values were found:

B_{rem}	6900
H_{coerc}	920
BH_{max}	2,700,000

d. The pieces were quenched from about 1175° C. in a tinbath at a temperature of about 575° C. and left therein for about 2 minutes followed by cooling down in the air. After aging for a long time (about 20 hours) at temperatures increasing up to 575–660° C. the following magnetic values were found:

B_{rem}	6200
H_{coerc}	1000
BH_{max}	2,600,000

The important advantage of my invention is that at the same time when heat-treating magnets of the usual dimensions by the method of the invention, the danger of fissures, cracks and breakage occurring is minimized and the magnets can be manufactured without mechanical difficulties and with small waste.

As has been stated with previously used heat treatments this could not be achieved, and even in making small plain test magnets for measuring the magnetic properties of the alloy, there have been considerable difficulties due to brittleness. Only the heat-treating method of the invention made it possible to commercially manufacture such steel magnets.

According to the invention, quenching of the body is preferably effected from a temperature lying within the range of about 1300° C. to 1100° C. and takes place at a quenching temperature lying between 550° C. and 750° C. The quenching as stated takes place in a suitable metal or salt bath whose temperature lies within the latter range. The body may then be allowed to remain in this bath so as to be aged, or it may be subjected to a separate aging operation at a temperature of 650° C. to 680° C. after having being cooled to room temperature as above described.

In some cases a quenching bath may be used having a considerably lower temperature, for instance 100° C. to 200° C. The magnet body is then allowed to remain in this bath only until its temperature has been reduced from the initial temperature (of 1100°–1300° C.) to the required quenching temperature of, for instance, 700° C.

As an example from loudspeaker practice it is remarked that an annular magnet of the size used in present-day moving-coil loudspeakers and having a composition obtained by pouring an alloy of 16% Ni, 28% Co, 46% ferrotitanium (=26% Ti, 10% Al) the remainder being substantially iron, gave the following magnetic values which, however, should not be considered to be the maximum obtainable:

B_{rem}	6200
H_{coerc}	800

The magnet had the following dimensions:

	mm.
External diameter	74
Internal diameter	49
Height	35

Quenching was effected from about 1200° C. in a tin bath of 600 to 750° C. and it was left therein for about one minute, followed by cooling down in the air. After that it was aged at a temperature increasing up to about 670° C. and subsequently magnetised in the usual way.

While I have described my invention in connection with specific examples and application, I do not wish to be limited thereto but desire the appended claims to be construed as broadly as permissible in view of the prior art.

What I claim is:

In the manufacture of permanent magnet bodies from an alloy steel containing 10 to 30% Ni, 3 to 15% Ti, 2 to 13½% Al, 4½ to 30% Co, and the remainder substantially iron, the steps of drastically quenching the magnet body in a suitable bath from a temperature between 1,000° C. and 1,300° C. only to a temperature between 550° C. and 750° C., slowly cooling the body from the temperature of the bath to room temperature, aging the body at a temperature between 650° C. to 680° C., and cooling the body to room temperature.

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