

UNITED STATES PATENT OFFICE

2,207,685

PERMANENT MAGNET ALLOY AND METHOD
OF MAKING THE SAME

Howard Willis Russell and Lloyd Ross Jackson,
Columbus, Ohio, assignors, by mesne assign-
ments, to The Indiana Steel Products Com-
pany, Chicago, Ill., a corporation of Indiana

No Drawing. Application July 17, 1939,
Serial No. 284,920

2 Claims. (Cl. 148—21.5)

This invention relates to permanent magnet alloys and articles machined therefrom and to methods of making such alloys and articles. More particularly, the invention pertains to cast alloys containing nickel, aluminum, cobalt, copper and iron within certain rather definite limits of proportions, and to methods of sequentially heat treating castings of such alloys in conjunction with a machining step to enable such castings to be made into machined articles of superior magnetic properties for use, after being magnetized, as permanent magnets.

It has heretofore been proposed, as in British Patent No. 431,660 to make permanent magnet alloys containing nickel, aluminum, cobalt, copper and iron. While the preferred proportions of these alloying ingredients, as given in that patent, result in an alloy having satisfactory magnetic properties, the alloy, whether in its as-cast condition or in its condition after the heat treatment specified therein, cannot readily be machined or drilled to make said alloy into the particular form or shape that may be required to meet the specifications of a given permanent magnet and that may be unattainable by a casting step per se.

British Patent No. 478,126 purports to describe processes suitable for improving the machinability and magnet properties of iron-nickel-aluminum alloys, but the temperature ranges specified therein, according to our studies, are not operative up around their upper limits, nor are they operative within their narrower limits for the treatment of all, or even many of the alloys coming within the limits of analysis referred to therein.

Contrary to the teachings of these two British patents, we have found that not only must the composition of the alloys be kept within rather narrow limits but that the heat treatments to improve the machinability and magnetic properties of the alloys must also be kept below certain maximum temperatures, certainly well below the maximum temperatures specified in the later British patent for these two heat treatments. The limits as to analysis of alloy and as to temperature ranges for heat treatments which we have found to be operative to give optimum properties are surprisingly critical and it required a great deal of experimental research to determine their correlation to each other.

It is, therefore, an object of the present invention to provide a ferrous alloy containing nickel, aluminum, cobalt, copper and iron in such correlated proportions that said alloy can be heat

treated under certain specified conditions to render the alloy suitable for use in permanent magnets.

Another object of the present invention is to provide methods of heat treating such alloys to attain optimum results with respect to machinability and magnetic properties.

Other and further objects of this invention will become apparent to those skilled in the art from the following detailed description and from the appended claims.

Non heat-treated castings of ferrous alloys containing nickel, aluminum, cobalt and copper are not readily machinable. We have now found that castings of ferrous alloys containing definitely limited amounts of said four alloying metals can be made machinable by heat treatment and thereafter invested with the desired coercive force and remanence by another and different heat treatment.

From the standpoint of heat treatment, the broadest useful range of nickel content is from 16.0 to 18.5 per cent; of aluminum content, from 8.5 to 10.5 per cent; of cobalt content, from 9.0 to 12.5 per cent, and of copper content, from 4.0 to 7.0 per cent. Ferrous alloys of these metals outside of the proportions indicated are not amenable to heat treatment to give the desired degree of machinability, although if machinability is not essential, the nickel content, for instance, can go as high as 22%.

The variations in composition possible within the limits indicated influence the machinability and magnetic properties obtained on heat treatment as follows: A high nickel content gives a greater coercive force at the expense of remanence and machinability. A high aluminum content decreases machinability. There is an optimum combination of remanence and coercive force at 9.0 per cent aluminum and similarly at 10% cobalt. Higher percentages of cobalt lower the machinability, while higher percentages of copper favor coercive force and machinability at the expense of remanence.

A preferred composition range, therefore, is from 17.5 to 18.5 per cent nickel; from 8.5 to 9.5 per cent aluminum; from 9.5 to 10.5 per cent cobalt, and from 5.0 to 7.0 per cent copper, the remainder being substantially iron. The term "iron" as used herein signifies iron itself or iron with a content of impurities such as are usually present in commercial iron and steel.

In preparing alloys for casting, it is convenient first to melt the iron and nickel and then to add the cobalt. After the cobalt has been melted, the

copper is added and finally the aluminum. The resulting melt is then brought to the desired pouring temperature and poured.

To obtain coarse-grained castings, the melt should be poured at temperatures not over 2700° F. nor below 2620° F. Temperatures above the indicated upper limit cause the alloy to remain molten too long after pouring, with consequent segregation of aluminum. To obtain fine-grained castings, the melt should be poured at temperatures not over 2560° F. Castings poured at 2620° F. or above are composed of grains around 0.125 inch in diameter, while castings poured at 2550° F. have grains less than 0.01 inch in diameter. The machining properties of the castings, regardless of the temperature of pouring, are extremely poor in the as-cast condition.

The first step in the processing cycle to which as yet untreated castings of the compositions disclosed are subjected is a heat treatment for rendering said castings machinable. This heat treatment includes heating to and annealing in a temperature range of from 1550° F. to 1800° F. for from 1 to 3 hours, followed by cooling from the high temperature to about 950° F. at an average over-all rate of 0.4° F. to 2.0° F. per minute, and then cooling from 950° F. to room temperature or thereabouts in a furnace. Heating to 1800° F. or higher does not improve machinability. In general, the slower the cooling the better the resulting machinability.

A preferred heat treatment for machinability consists in heating in a range of from 1575° F. to 1675° F. for 1 to 3 hours, cooling to 950° F. at an average over-all rate of from 0.5° F. to 1° F. per minute, and finally furnace cooling to about room temperature, or at least below about 200° F.

Such a heat treatment renders castings of the composition disclosed hereinabove capable of being center-drilled with a high speed steel drill and of being machined, if not with tools of ordinary high speed steel, then at least with a Simmons cobalt tool or with a carbide tool.

At this stage, the machinable castings are then drilled, sawed, turned, milled, cut, faced off or otherwise machined as may be required to give them whatever shape may be desired.

The machined castings are finally heat treated to confer on them the necessary magnetic qualities. This treatment comprises initial heating in a range of from 2000° F. to 2300° F. for from 15 minutes to 1 hour, rapid cooling to room temperature, reheating in a range of from 1000° F. to 1250° F. for from 1 to 10 hours, and air cooling to room temperature.

Rates of cooling of from 5° F. to 100° F. from the initial high temperature are operative. Decreasing the cooling rate increases the coercive force but decreases the remanence. If desired, the cooling can be interrupted and reheating commenced at 1150° F., instead of continuing the cooling all the way to room temperature. Such interruption effects a slightly higher coercive force at the cost of a decreased remanence. In the final reheating step, a temperature of about 1100° F. will yield a higher coercive force, but a lower remanence than a temperature of 1150° F.

A preferred heat treatment for magnetic qualities comprises initial heating in a range of from 2100° F. to 2200° F. for from 45 minutes to 1 hour, cooling to room temperature at a rate of from 7° to 50° F. per second, reheating in a range of from 1100° F. to 1200° F. for from 3 to 8 hours, and air cooling to room temperature.

Another preferred heat treatment for magnetic

qualities comprises initial heating in a range of from 2100° F. to 2200° F. for from 45 minutes to 1 hour, cooling to 1150° F. at a rate of from 10° F. to 60° F. per second, heating at about 1150° F. for from 3 to 8 hours, and air cooling to room temperature.

These heat treatments for magnetic qualities leave the castings not readily machinable.

All the hereinabove disclosed heat treating steps, both those conferring machinability on as yet untreated castings and those for improving the magnetic qualities of machined castings, relate either to castings shaped as rods slightly more than 4 inches long and slightly more than ½ inch in diameter or to machined rods shaped as cylinders 3.95 inches long and 0.50 inches in diameter. In order to bring about identical heat treating results in other castings of different sizes and shapes, it may be necessary to vary the details of any given heat treatment to compensate for variations in size or shape, for, as is known, identical heat treatments of differently sized and shaped metallic objects do not necessarily yield identical results.

In other words, heat treatments according to the present invention, if relating to other castings than rods about 4 inches long and ½ inch in diameter, are not confined to the limits disclosed hereinabove, but permit variations necessary to compensate for differences in size or shape of the castings being treated. The heat treatments of the present invention are therefore properly defined as heat treatments equivalent to those involving the heating of a rod about 4 inches long and ½ inch in diameter, as disclosed hereinabove.

To illustrate the application of the principles of this invention by an example, one method of fabricating an article suitable for use as a permanent magnet according to this invention is described hereinbelow.

An alloy containing 18.0 per cent nickel, 9.2 per cent aluminum, 10.0 per cent cobalt, and 5.0 per cent copper, the remainder being substantially iron, is prepared by melting the indicated amounts of iron and nickel together, and then adding, one at a time, the cobalt, copper and aluminum. Each ingredient is melted completely before the next ingredient is added. The resulting melt is poured at 2550° F., to yield castings slightly more than 4 inches long and slightly more than ½ inch in diameter.

Such castings are heated at 1600° F. for 3 hours, cooled to 950° F. at an average over-all rate of 0.5° F. per minute (if desired, in steps), and cooled from 950° F. to room temperature in a furnace.

An alternative heat treatment comprises heating to 1600° F. for 3 hours, cooling to 1500° F., and maintaining this temperature 3 hours, cooling to 1400° F., and maintaining that temperature for 16 hours, cooling to 1300° F., and holding this temperature for 7 hours, and cooling to room temperature in a furnace.

The heat treated castings are then center-drilled with a drill of high speed tool steel, faced off to exactly 0.50 inch diameter, and cut off to 3.95 inch length with tools of ordinary high speed tool steel.

The machined castings are thereafter heat treated to improve their magnetic qualities. The castings are first heated to 2150° F. and held there for 1 hour, then cooled to room temperature at an average over-all rate of about 17° F. per second, thereafter reheated to 1150° F., held

there for 4 hours, and air cooled to room temperature. .

An alternative heat treatment involves heating at 2150° F. for 1 hour, cooling to 1150° F. at an average over-all rate of about 34° F. per second, maintaining a temperature of 1150° F. for four hours, and air cooling to room temperature.

Thus treated castings are characterized by a coercive force of about 415 Oersteds and a remanence of about 8000 Gauss. They are eminently suitable for use as permanent magnets after magnetization..

As pointed out hereinabove, numerous details may be varied without departing from the principles of this invention, and it is, therefore, not the purpose to limit the patent granted hereon otherwise than necessitated by the scope of the appended claims..

We claim as our invention:

1. A magnetizable article adapted for use as a permanent magnet which comprises a casting of an alloy of substantially the following composition::

	Per cent
Nickel.....	17.5 to 18.5
Aluminum.....	8.5 to 9.5
Cobalt.....	9.5 to 10.5
Copper.....	4.0 to 6.0
Iron.....	Balance

said casting having been cast at a temperature below 2700° F. and thereafter subjected to a processing cycle comprising an initial heat treatment including heating in the range or from 1550° F. to 1800° F. for from 1 to 3 hours and cooling therefrom to below 950° F. at a rate such that the average over-all rate of cooling is not greater than 2° F. per minute, a subsequent machining

step, and a final heat treatment including heating within the range of from 2000° F. to 2300° F. for from 15 minutes to 1 hour, cooling to below 1250° F. at a rate of from 5° F. to 100° F. per second, subsequently holding said casting within the temperature range of from 1000° F. to 1250° F. for from 1 to 10 hours and air cooling therefrom.

2. The method of making a magnetizable article adapted for use as a permanent magnet which comprises casting, at a temperature below 2700° F., an alloy of substantially the following composition:

	Per cent
Nickel.....	17.5 to 18.5
Aluminum.....	8.5 to 9.5
Cobalt.....	9.5 to 10.5
Copper.....	4.0 to 6.0
Iron.....	Balance

improving the machinability of the resulting casting by subjecting the same in as cast condition to a heat treatment including heating in the range of from 1550° F. to 1800° F. for from 1 to 3 hours and cooling therefrom to below 950° F. at a rate such that the average over-all rate of cooling is not greater than 2° per minute, machining said casting, and improving the magnetic properties thereof by subjecting the same in machined condition to a heat treatment including heating within the range of from 2000° F. to 2300° F. for from 15 minutes to 1 hour, cooling to below 1250° F. at a rate of from 5° F. to 100° F. per second, subsequently holding said casting within the temperature range of from 1000° F. to 1250° F. for from 1 to 10 hours and air cooling therefrom.

HOWARD WILLIS RUSSELL.
LLOYD ROSS JACKSON.