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MAGNETIC PRODUCT AND METHOD OF MAKING THE SAME

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My invention relates to magnetic products and to a method of making the same, more particularly, to a magnetic nickel-iron alloy and a method of treating the same to obtain desirable characteristics therein.

It is among the objects of my invention to provide a nickel-iron alloy which shall have a high permeability at low inductions and which shall have a relatively low hysteresis loss.

It is another object of my invention to provide a heat treatment for nickel-iron alloys, which shall fully develop all the desirable magnetic characteristics thereof.

In my copending application, Serial No. 665,406, filed September 28th, 1923, for radio transformers, I have described an alloy of approximately equal proportions of iron and nickel, which is rolled into thin sheets and applied as the laminations of the core of a radio transformer. This material has a high permeability at low inductions and has a low hysteresis loss, making it very valuable for use in radio circuits carrying extremely small amounts of energy.

In rolling this material to the proper thickness, (about 14 mils) strains are set up which require an annealing operation to relieve. I have noted that, after an ordinary heat treatment of this material, the magnetic characteristics thereof are not uniform and, in a large number of cases, the electrical characteristics have been detrimentally affected, whether the material was rolled hot or cold. For instance, the alloy as cast, had a maximum permeability of 21,000 and a hysteresis loss of about 360 ergs per centimeter cube per cycle for B=10,000 gausses. After rolling and then annealing at 1000° C. in a box annealing apparatus, the maximum permeability was reduced to 3,000 and the hysteresis loss was increased to 900 to 1,060.

After a considerable amount of experimentation, I concluded that the detrimental effect of rolling and annealing was probably owing to oxidation of the rolled material. I therefore, devised a method of heat treating the rolled material which eliminated the effects of oxidation and, in addition thereto, beneficially affected the characteristics of the material.

In practicing my invention, I provide an alloy of nickel and iron in approximately equal proportions, for example, 40 to 60% nickel and 60 to 40% iron, preferably utilizing an alloy containing 50% of each ingredient. I place the rolled material in a sealed furnace in an atmosphere of hydrogen, and heat the same to about 1000° C., maintaining the temperature for from two to eight hours to complete the annealing and to reduce the oxides in the steel. I then slowly cool the material to 500° C. at a rate not to exceed 500° C. per hour. I prefer to cool the material in the furnace at the rate of about 30° C. to 100° C. per hour, down to a temperature of about 500° C. The furnace may then be opened, precaution having first been taken to remove the hydrogen therefrom by any suitable means, such as displacement by nitrogen, to prevent explosions in the air. The material is then allowed to cool either in the furnace or in air to room temperature without attempting to control the rate of cooling.

By this treatment, I have been enabled to increase the maximum permeability of 14 mil sheets to a value ranging from 20,000 to 80,000, and to decrease the hysteresis loss to as low as 250 to 600 ergs per cubic centimeter per cycle for B=10,000 gausses.

Similar results may be obtained by varying the factors in the annealing operation, such as time and temperature. For instance, I may use higher temperatures than 1000° C., up to 1400° C., and thus considerably shorten the annealing operation and obtain better results at the expense of the higher cost of the higher temperature furnace operation. Or, I may use lower temperatures for longer periods of time, for instance, 900° C., at which temperature a relatively long time is necessary to obtain the results obtainable in a few hours at 1000° C.

My material compares favorably with a material known as permalloy, containing 78½% nickel and the remainder iron. My alloy, since it contains very much less nickel, is considerably cheaper than permalloy and has the great advantage of having over twice

the electrical resistivity of the same. The resistivity of my material is 45 ohms per centimeter cube, compared to 22 for permalloy. The maximum permeability for the two materials is of the same order but my material has a saturation value which is 50% greater than that of permalloy. Furthermore, my material is less sensitive in the heat treatment, and the control of the annealing operation does not require specially skilled operators and need not be exact. Results may be duplicated very readily.

Although I have described my invention setting forth a specific method of treating my alloys, my invention is not limited to the details set forth. It will be apparent that the compositions of the alloys may be varied within a considerable range and the details of the rolling and annealing operations may be varied, as will be apparent to those skilled in the art.

I claim as my invention:

1. A magnetic product of an alloy of nickel and iron in approximately equal proportions, having a maximum permeability greater than 40,000.

2. A magnetic product of an alloy of nickel and iron in approximately equal proportions, having a maximum permeability greater than 40,000 and a hysteresis loss of less than 400 ergs per cubic centimeter per cycle for B=10,000 gausses.

3. A magnetic product of an alloy of nickel and iron in approximately equal proportions, having a maximum permeability of approximately 50,000–60,000 and a hysteresis loss of less than 400 ergs per cubic centimeter per cycle for B=10,000 gausses.

4. A magnetic product of an alloy of nickel and iron in approximately equal proportions, having a maximum permeability of approximately 50,000–60,000, a hysteresis loss of less than 400 ergs per cubic centimeter per cycle for B=10,000 gausses and a resistivity of about 45 ohms per centimeter cube.

5. A method of making a magnetic product which comprises working an alloy composed of nickel and iron in approximately equal proportions, and annealing the same in the presence of a reducing gas which will not introduce impurities in the product.

6. A method of making a magnetic product which comprises working an alloy composed of nickel and iron in approximately equal proportions, and annealing the same in the presence of hydrogen.

7. A method of making a magnetic product which comprises rolling an alloy composed of nickel and iron in approximately equal proportions, and annealing the same in the presence of hydrogen at a sufficiently high temperature for a sufficient length of time to reduce the hysteresis loss to less than 400 ergs per centimeter cube per cycle for B=10,000 gausses.

8. In the method of making a magnetic product the steps which comprise working an alloy composed of nickel and iron in approximately equal proportions, and annealing the same in the presence of hydrogen to a temperature of at least 900° C. for at least four hours.

9. A method of making a magnetic product which comprises rolling an alloy composed of nickel and iron in approximately equal proportions, annealing the same in the presence of hydrogen to a temperature of at least 900° C. for at least four hours and then slowly cooling the same to about 500° C.

10. A method of making a magnetic product which comprises rolling an alloy composed of nickel and iron in approximately equal proportions, annealing the same in the presence of hydrogen to a temperature of at least 900° C. for at least four hours and then cooling the same at about 30° C. per hour to about 500° C.

11. In the method of making a magnetic product the steps which comprise rolling an alloy composed of nickel and iron in approximately equal proportions, and annealing the same in the presence of hydrogen to a temperature of about 1000° C. for about eight hours.

12. A method of making a magnetic product which comprises rolling an alloy composed of nickel and iron in approximately equal proportions, annealing the same in the presence of hydrogen to a temperature of about 1000° C. for about eight hours and then slowly cooling the same to about 500° C.

13. A method of making a magnetic product which comprises rolling an alloy composed of nickel and iron in approximately equal proportions, annealing the same in the presence of hydrogen to a temperature of about 1000° C. for about eight hours and then cooling the same at about 30° C. per hour to about 500° C.

14. A method of making a magnetic product which comprises rolling an alloy composed of nickel and iron in approximately equal proportions, annealing the same in the presence of hydrogen to a temperature of about 1000° C. for about eight hours, cooling the same at about 30° C. per hour to about 500° C. and then cooling rapidly in air to room temperature.

15. A method of making a magnetic structure of a body of alloy containing iron as one of the main constituents thereof and 40% to 60% nickel which comprises providing a sheet of said alloy rolled to the desired thickness, heating said sheet to 900° to 1400° C. in a hydrogenous atmosphere and then cooling to 500° C. at a rate not exceeding 500° C. per hour.

16. A method of making a magnetic structure of a body of alloy containing iron as one of the main constituents thereof and 40% to

60% nickel which comprises providing a sheet of said alloy rolled to the desired thickness, heating said sheet to 900° to 1400° C. in a hydrogenous atmosphere and then cooling to 500° C. at the rate of about 30° C. per hour.

17. A method of making a magnetic structure of a body of alloy containing iron as one of the main constituents thereof and 40% to 60% nickel which comprises providing a sheet of said alloy rolled to the desired thickness, heating said sheet to 900° C. to 1400° C. in a hydrogenous atmosphere and then cooling to 500° C. at the rate of 30° to 100° C. per hour.

18. A heat-treated body of a magnetic alloy comprising iron as one of the main constituents thereof and 40% to 60% nickel, said body having a maximum permeability at least as great as a cast body of said alloy and a hysteresis loss of 250 to 600 ergs per cubic centimeter per cycle for B=10,000 gausses.

19. A heat-treated sheet of a magnetic alloy comprising iron as one of the main constituents thereof and 40% to 60% nickel, said sheet having a maximum permeability at least as great as a cast body of said alloy and a hysteresis loss of 250 to 600 ergs per cubic centimeter per cycle for B=10,000 gausses.

20. A heat-treated sheet of a magnetic alloy comprising iron as one of the main constituents thereof and 40% to 60% nickel, said sheet having a maximum permeability greater than a cast body of said alloy and a hysteresis loss of 250 to 600 ergs per cubic centimeter per cycle for B=10,000 gausses.

21. A heat-treated sheet of a magnetic alloy comprising iron as one of the main constituents thereof and 40% to 60% nickel, said sheet having a maximum permeability greater than a cast body of said alloy and a hysteresis loss less than 600 ergs per cubic centimeter per cycle for B=10,000 gausses.

22. A method of making a magnetic product which comprises providing an alloy composed of nickel and iron in approximately equal proportions, rolling the same to the desired thickness and annealing the rolled material to reduce the hysteresis loss thereof to at least as low as that of the unrolled material, said annealing consisting of heating said rolled material to a temperature substantially above 1000° C., cooling the material in the furnace to a temperature of 500° C. and then cooling in air to room temperature.

23. A method of making a magnetic product which comprises working an alloy composed of nickel and iron in approximately equal proportions and annealing the worked alloy in the presence of a reducing gas which will not introduce impurities in the product at a temperature of at least 900° C. for at least four hours.

24. An alloy comprising iron and nickel which has been heat treated in the presence of a reducing agent to impart thereto a low hysteresis loss.

25. An alloy comprising iron and nickel which has been heat treated in the presence of a reducing agent to impart thereto a high maximum permeability.

26. The method of making a magnetic product which comprises heat treating an alloy comprising iron and nickel in the presence of a reducing agent to impart thereto a high maximum permeability.

27. The method of making a magnetic product which comprises heat treating an alloy comprising iron and nickel in the presence of a reducing agent to impart thereto a low hysteresis loss.

In testimony whereof, I have hereunto subscribed my name this 24th day of March, 1924.

TRYGVE D. YENSEN.