Patented June 29, 1937

2,085,118

UNITED STATES PATENT OFFICE

2,085,118

MAGNETIC MATERIAL AND MANUFACTURE THEREOF

Franz Noll, Berlin-Siemensstadt, Germany, assignor to Siemens and Halske Aktiengesellschaft, Siemensstadt, near Berlin, Germany, a company of Germany

No Drawing. Application July 28, 1933, Serial No. 682,669. In Germany August 11, 1932

5 Claims. (Cl. 148—12)

This invention relates to magnetic alloys of the nickel-iron type and an object thereof is to achieve magnetic alloys and methods of manufacture thereof which have a high constancy of permeability at low magnetizing forces together with a high specific resistivity and a permeability sufficiently high for use in loading coils and similar magnetic devices.

The present invention relates to the class of magnetic alloys used in the cold rolled condition and more particularly to those having 30 to 50% nickel, 4 to 11% copper, 1 to 7% manganese and the balance essentially iron. It has been found that these alloys have the property that after a cold working treatment which reduces them in cross-section to $\frac{1}{10}$ or less of the cross-section before working that they show not only a reduction in hysteresis losses but an increase in the permeability at very low magnetizing forces.

It is an object of the present invention to provide compositions which have magnetic properties similar to those mentioned in the foregoing paragraph but of higher specific resistance.

It is also an object to provide magnetic alloys otherwise desirable in which the permeability is practically linear for a range of magnetizing forces up to as high as 3 Gauss.

According to one feature of the invention the magnetic alloys have a composition of over 30% Ni and over 1% Mn, remainder iron and are used in cold-treated condition. Preferably the nickel content amounts to between 30 and 50%, and the manganese content over 6% to 25%. These alloys with up to 11% manganese showed special advantages.

The cold-treated materials are worked into a form for use without a final annealing process, that is, for example, in Krarup conductors the cold-rolled band is spiralled upon the conductor, without previous annealing of the band. The wrapped Krarup conductors also are not annealed before their insulation and application in the cable. In the manufacture of band and wire cores, for example, for Pupin coils, the wires or bands are wound ring-shaped, with the interposition of insulation, but the magnetic wires and bands are not annealed either before or after wrapping. Preferably the bands or wires, before arriving in the final condition for use, are worked without intermediate annealing to a thickness below $\frac{1}{10}$ of their previous cross-section and/or their previous thickness, for example, by drawing, rolling, hammering or the like. The mechanical treatment of the magnetic wires or bands may be done as follows: A magnetic alloy of, for example, 50% nickel, 39% iron and 11% manganese, is rolled, with intermediate annealing, into a round wire of 4 mm. cross-section. After annealing, the wire is brought by drawing or rolling to a square cross-section with 1.2 mm. edge length, and thereupon rolled into band form without intermediate annealing, to a thickness of 0.08 mm. and a width of several millimeters. The reduction of thickness without intermediate annealing amounts in this case to $\frac{4}{50}$ of the original thickness. The tape or strip is then ready for the wrapping of a conductor or for winding in the form of a core consisting of strips bound together. The following table shows that with increasing cold working, not only does the hysteresis loss drop, but the permeability rises. The alloys are characterized by an extremely small rise in permeability as the magnetizing force increases in the range of field intensity chiefly used for weak current purposes.

Composition	Band thickness in mm.	μ_0	h	Field in which magnetizing force is practically linear	Specific resistance
35 Ni 1.5 Mn residue Fe	0.15	76	200	1.5	0.80
	0.08	83	93	2.5	
35 Ni 3 Mn residue Fe	0.15	71	210	1.7	0.85
	0.08	86	170	3.0	
35 Ni 6 Mn residue Fe	0.15	64	290	1.5	0.91
	0.08	72	210	3.0	
35 Ni 9 Mn residue Fe	0.15	52	300	1.5	0.93
	0.08	63	35	1.5	
40 Ni 9 Mn residue Fe	0.15	60	200	1.5	0.99
	0.08	78	120	2.0	
45.5 Ni 9 Mn residue Fe	0.15	55	130	1.5	0.81
	0.08	78	110	2.5	

The alloys indicated in the table were rolled to a cross-section of 4 mm. diameter and thereupon annealed at 800° C. for about two to three hours in a hydrogen atmosphere before being finished by rolling and drawing.

The table shows in the first column the composition of the alloys, in the second column the thickness to which the strips or tapes are brought, the third column the initial permeability measured in annular core form, the fourth column the hysteresis constant, and the fifth column the field in which the rise of permeability can be regarded as linear. The last column, finally, gives the ohmic resistance.

A further feature of the invention comprises magnetic materials containing 30% to 50% nickel, 4% to 11% copper and 1% to 7% manganese with the balance essentially iron.

A following table shows by several examples the properties of the iron-copper-nickel alloys with an addition of manganese if a cold working treatment, such as previously described, is employed. The measurements given below are made on toroidal core coils of bands.

Composition	Thickness of band mm.	μ_a	h	Specific resistance
45 Ni 43 Fe 10 Cu 2 Mn	8/100	95	70	0.5
35 Ni 55 Fe 8.5 Cu 1.5 Mn	8/100	60	40	0.7
45 Ni 43 Fe 6 Cu 6 Mn	15/100	55	280	0.8
45 Ni 43 Fe 6 Cu 6 Mn	8/100	80	180	0.8
40 Ni 50 Fe 5 Cu 5 Mn	15/100	84	100	0.8
40 Ni 50 Fe 5 Cu 5 Mn	8/100	97	70	0.8

From the table it will be seen that even with the addition of manganese to iron-nickel-copper alloys extremely low values of the hysteresis constant can be obtained with relatively high initial permeabilities. In two of the alloys cited it is shown that by increasing the degree of working an improvement is obtained both in the initial permeability and also of the hysteresis constant.

Although an increased specific electrical resistance is obtained by the manganese content, by further small additions of chromium, molybdenum, tungsten, vanadium and similar substances, a further increase in the specific resistance of any of the alloys herein mentioned can be effected without substantially impairing the magnetic properties.

What is claimed is:

1. A method of preparing magnetic material of the class including alloys of 30 to 50% nickel, 1 to 11% manganese and the balance chiefly iron, but not excluding minor proportions of other metallic substances, which comprises rolling the material with intermediate annealing into a round wire, annealing the said round wire in a hydrogen atmosphere at approximately 800° C., cold drawing and rolling the wire into a square cross-section, and then rolling it without intermediate annealing into band form, the cross-section of said band being less than $\frac{1}{10}$ of the cross-section possessed by the material before the cold working.

2. An article of manufacture comprising magnetic material in the form of an elongated strip and in final form for use, said material being composed of an alloy comprising 30 to 50% nickel, 1 to 11% manganese, and the balance chiefly iron but not excluding minor proportions of other metallic substances characterized in that the strip, after annealing at a high temperature, has been forcibly elongated as by rolling or drawing in the cold state as the final step of its manufacture, sufficiently to reduce its cross-section below $\frac{1}{10}$ of the cross-section possessed by it before the cold working.

3. A magnetic material in final physical form for use consisting of an alloy of 30 to 50% nickel, 4 to 11% copper, 1 to 7% manganese, and the balance chiefly iron, characterized in that the material has first been annealed at a high temperature and then put into final form for use by a treatment in which the final step of its manufacture consists of a forcible elongation of the material to such an extent that its cross-section is reduced to below $\frac{1}{10}$ of the cross-section possessed by it before the cold working.

4. A method of preparing a magnetic material composed of 30 to 50% nickel, 1 to 7% manganese, and the balance chiefly iron, which comprises annealing the material in hydrogen at a temperature above the magnetic transition temperature and subsequently as the final step of its manufacture reducing the material to a form suitable for use by a process of forcible elongation of the cold material to reduce its cross-section to not more than $\frac{1}{10}$ of its previous cross-section.

5. A method of preparing magnetic material composed of 30 to 50% nickel, 4 to 11% copper, 1 to 7% manganese, and the balance chiefly iron, alloyed together for use, which comprises annealing the material in hydrogen at a temperature above the magnetic transition temperature and subsequently as the final step of its manufacture reducing the material to a physical form suitable for use by a process of cold rolling to reduce its cross-section to not more than $\frac{1}{10}$ of the cross-section before the cold rolling.

FRANZ NOLL.