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TREATMENT OF MATERIAL FOR HYSTERESIS APPLICATION

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This invention relates to ferrous base alloys, and more particularly to material which is suitable for use as rotors on hysteresis motors and the like.

Materials which are desirable for rotors of hysteresis motors, generally referred to as hysteresis materials, are characterized by having high hysteresis efficiency and superior hysteresis loss at relatively low magnetizing fields. (Hysteresis loss is measured in units of energy per unit volume. Some commonly used units are gauss-oersteds, joules per cubic centimeter, or joules per cubic inch; hysteresis efficiency is defined as the hysteresis loss per cycle divided by the peak magnetizing force.) There are several excellent, prior art hysteresis materials, but most of them require a final high temperature heat treatment after they are formed into rotors or rotor parts to develop their hysteresis properties. This heat treatment cannot be performed before the parts are formed, since this heat treatment also increases the hardness of the material, thus making it difficult or impossible to stamp or form successfully. These heat treatments are critical, if reproducible properties are to be obtained, and are therefore expensive; also, the cost of scrapping a part is high if the heat treatment is improperly performed, since finished or semi-finished parts are involved. Additionally, many of the prior art hysteresis materials contain appreciable amounts of carbon as an essential element, thus rendering the material subject to decarbonization during heat treatment, which will reduce the hysteresis characteristics obtained. Further, some prior art materials are subject to a change in hysteresis properties at even slightly elevated temperatures normally encountered in the operation of hysteresis motors.

It is therefore a principal object of this invention to provide a ferrous base alloy which, when properly treated, will have outstanding hysteresis characteristics.

Yet an additional object of this invention is the provision of a method of processing an iron-manganese alloy to provide outstanding hysteresis characteristics.

Still a further, more particular object of this invention is the provision of a hysteresis material which does not require high temperature heat treatment after forming to develop hysteresis properties.

Still another object of this invention is the provision of a substantially carbon-free alloy and method of processing which will yield outstanding hysteresis characteristics.

Yet a further object of this invention is the provision of a hysteresis material which, when processed, will exhibit little change in characteristics at normal motor operating temperatures.

These and other objects, together with a fuller understanding of the invention, will become apparent from the following description when taken in conjunction with the appended claims.

In iron base alloys, a metallographic structure which is a mixture of ferrite and austenite with a substantial amount of, and preferably at least about 50%, ferrite provides excellent hysteresis properties. I have found that an alloy consisting essentially of a mixture of iron and from about 7% to about 15% manganese will produce excellent material for hysteresis applications if the alloy is properly warm worked. In this warm working operation the material must be reduced in cross sectional area at least 99% while the material is maintained in the temperature range of from about 800° F. to about 950° F. When an alloy within the above composition range is warm worked in this temperature range, the mechanical working will produce a metallographic structure which is a mixture of austenite and ferrite, and the austenite will be retained upon cooling to ambient temperature. For a given temperature of warm working, the lower the manganese content the higher the percentage of ferrite that will be formed, and for a given manganese content, the higher temperature at which warm working takes place the lower the percentage of ferrite that will be formed. At the lower percentages of manganese and lower working temperatures, at least 50% ferrite will be formed. At higher working temperatures and/or higher percentages of manganese, there is a greater percentage of austenite formed and retained, although there is still an appreciable amount of ferrite present, probably as particles or as platelets dispersed in the austenite matrix.

The properties of the material may be developed by any suitable method of working such as by rolling, swaging, drawing or extruding, but regardless of the form of working chosen, the material must be reduced in cross sectional area at least 99% in the temperature range of from 800° F. to 950° F.

Table I below shows the magnetic properties of various compositions of warm worked material. The specimens were produced by warm rolling a slab of each material to the final thickness indicated. The rolling was done in several passes, with the material being heated to between 850° F. and 950° F. for the rolling, and with reheating being done as required to maintain the material in this temperature range. The total reduction in area in each case was between 99.1% and 99.6%.

TABLE I.—MAGNETIC PROPERTY DATA

Spec. No.	Nominal Composition		Peak Magnetizing Force (Oersteds) H_p	Hysteresis Loss per Cycle, E_h 10^6 g.-oe. E_h	Hysteresis Efficiency Joules, Oersted-cm.^{3} E_h/H_p	Maximum Flux Density B_m (Gauss)	Residual Induction B_r (Gauss)	Coercive Force H_c (Oersteds)	Normal Permeability B_m/H_p, μ
	Mn	Fe[1]							
HMR-23 (0.015″ Ring)	7.3	Bal.	30	0.51	0.136	8,500	6,620	18.0	283
			40	1.05	0.208	12,680	11,000	24.0	317
			50	1.20	0.191	13,600	12,000	25.0	272
			70	1.35	0.153	14,600	12,900	25.0	209
			80	1.39	0.138	14,810	13,100	26.0	185
HMR-24 (0.015″ Ring)	7.3	Bal.	30	0.57	0.150	8,750	7,250	19.0	291
			40	1.04	0.206	12,560	10,750	24.0	314
			50	1.22	0.194	13,620	12,000	24.5	272
			70	1.32	0.141	14,600	12,700	25.5	209
			80	1.36	0.135	14,700	12,750	25.5	183
HMR-25 (0.015″ Ring)	8.4	Bal.	30	0.45	0.120	8,190	6,370	16.0	273
			40	0.87	0.172	11,750	9,750	21.0	294
			50	1.06	0.169	13,250	11,125	22.0	205
			70	1.23	0.140	14,500	12,100	23.5	207
			80	1.24	0.123	14,750	12,250	23.0	184

TABLE I.—MAGNETIC PROPERTY DATA—Continued

Spec. No.	Nominal Composition		Peak Magnetizing Force (Oersteds) H_p	Hysteresis Loss per Cycle, E_h 10^6 g.-oe. E_h	Hysteresis Efficiency Joules, Oersted-cm.[3] E_h/H_p	Maximum Flux Density B_m (Gauss)	Residual Induction B_r (Gauss)	Coercive Force H_c (Oersteds)	Normal Permeability B_m/H_p, μ
	Mn	Fe [1]							
HMR-26 (0.015" Ring)	8.4	Bal.	30	0.495	0.131	8,750	6,870	17.0	291
			40	0.895	0.177	12,370	10,250	21.0	309
			50	1.06	0.169	13,500	11,350	21.5	270
			70	1.18	0.134	14,620	12,500	22.0	209
			80	1.22	0.121	15,000	12,500	23.0	187
HMR-27 (0.015" Ring)	10.0	Bal.	40	0.576	0.114	7,750	6,000	20.0	193
			50	0.972	0.155	10,430	8,430	26.5	208
			60	1.16	0.155	11,560	9,680	29.5	193
			70	1.28	0.145	12,190	10,375	30.0	174
			90	1.44	0.127	12,990	10,940	30.2	144
			100	1.47	0.117	13,190	11,180	30.5	132
HMR-28 (0.015" Ring)	10.0	Bal.	40	0.558	0.111	7,750	5,870	22.0	193
			50	0.947	0.151	10,370	8,370	27.0	207
			60	1.19	0.157	11,620	9,620	29.0	194
			70	1.30	0.147	12,200	10,370	31.0	174
			90	1.41	0.125	13,000	11,000	30.0	144
			100	1.48	0.117	13,200	11,000	31.0	132
HMR-29 (0.015" Ring)	12.2	Bal.	60	0.192	0.025	2,750	1,190	26.0	45.5
			70	0.382	0.043	3,750	2,500	34.0	53.5
			80	0.63	0.062	4,870	3,250	43.0	61.0
			100	1.10	0.087	6,500	4,930	51.0	65.0
HMR-30 (0.015" Ring)	12.4	Bal.	60	0.189	0.025	2,750	1,250	23.0	46.0
			70	0.372	0.042	3,810	2,250	33.5	54.5
			80	0.688	0.068	5,090	3,430	42.0	62.6
			100	1.08	0.085	6,620	4,930	50.0	66.2
HMR-31-32 (0.025" Strip in R.D.).[2]	7.3	Bal.	30	0.78	0.208	8,620	7,870	25.5	287
			40	1.49	0.298	14,370	13,600	27.5	371
			50	1.61	0.255	14,750	14,000	28.0	294
			70	1.66	0.188	15,250	14,250	28.5	218
			80	1.68	0.167	15,500	14,250	28.5	193
HMR-33-34 [2]	8.4	Bal.	30	0.86	0.228	10,000	9,000	23.5	333
			40	1.35	0.268	13,750	13,000	26.0	343
			50	1.46	0.232	14,370	13,370	26.5	287
			70	1.53	0.174	14,870	14,000	27.0	212
			80	1.55	0.154	15,120	13,870	27.0	189
HMR-35-36 (0.025" Strip).[2]	10.0	Bal.	40	1.01	0.200	8,500	7,750	32.0	212
			50	1.65	0.262	12,250	11,500	35.5	245
			60	1.81	0.240	13,120	12,370	36.5	218
			70	1.89	0.233	13,370	12,500	37.0	191
			90	1.98	0.175	13,750	12,870	37.5	152
			100	2.00	0.159	14,000	12,870	37.5	140
HMR-37-38 (0.025" Strip).[2]	12.2	Bal.	50	0.076	0.0121	1,120	500	23.0	22
			60	0.349	0.046	2,750	1,750	44.0	45
			70	0.941	0.107	5,120	4,370	55.0	73
			80	1.45	0.144	6,750	6,000	58.5	84
			100	2.02	0.161	8,620	7,870	63.0	86
HMR-40 (0.015" Strip).[2]	12.2	Bal.	70	0.326	0.037	2,500	1,500	45.0	36
			80	0.860	0.086	4,620	3,500	58.0	58
			100	2.03	0.161	8,120	7,250	70.0	81
			120	2.65	0.176	9,620	8,620	75.0	80
			180	3.21	0.142	10,870	9,620	78.0	60
HF-41 (0.015" Strip in R.D.)	15.2	Bal.	50	0.017	----------	200	----------	----------	4
			80	0.038	----------	440	----------	----------	5.5
			100	0.105	0.008	700	----------	----------	7.0
			150	0.385	0.0204	1,550	940	84	10.6
			200	0.571	0.0226	1,950	1,250	92	9.7
			300	0.855	0.0226	2,550	1,500	100	8.5
			450	1.09	0.0192	3,200	2,100	110	7.1
HMR-39 (0.015" Strip in R.D.).[2]	8.4	Bal.	30	0.158	0.042	3,375	1,875	16.0	112
			40	1.01	0.200	10,370	8,620	28.0	259
			50	1.46	0.232	13,120	11,620	31.0	262
			70	1.75	0.197	14,620	13,000	32.0	209
			80	1.77	0.176	15,120	13,120	32.0	189

[1] Including residual impurities of S, Si, P, C and others normally present in steel making.
[2] Average value of two tests in the direction of rolling.

It can be seen from an examination of Table I that each of the samples, except the 15.2% manganese specimen, possesses excellent hysteresis properties, particularly as measured in the rolling direction, although the ring tests, which gave a somewhat lower value, also show very good hysteresis properties. The alloy containing 7.3% manganese attains a peak efficiency at a very low magnetizing force, usually about 30 to 40 oersteds, whereas the alloy containing 10% manganese reaches peak efficiency at about 50 to 60 oersteds and the 12.2% manganese specimens do not reach their peak efficiency until greater than 120 oersteds. As the manganese content is increased beyond about 15%, as in the 15.2% manganese sample, this peak magnetizing force becomes prohibitively high for hysteresis applications, and also the induction values and the value of the hysteresis efficiency fall off sharply when the alloy contains more than 15% manganese. Hence, the maximum permissible manganese content is about 15%. If the alloy contains less than about 7% manganese, its warm workability is impaired and the alloy tends to crack before full reduction can be achieved; hence the minimum manganese value is 7%. An alloy containing in the neighborhood of about 12% manganese is the most desirable for hysteresis applications because of its combination of relatively high hysteresis loss and hysteresis efficiency at reasonably low peak magnetizing forces.

The warm working temperature, in order to produce the desired properties, must be at least 800° F. or the hysteresis loss and the actual value of the hysteresis efficiency are too low for the material to be useful as a hysteresis material. On the other hand, if the warm working temperature exceeds about 950° F., there is a change in the metallurgical structure which results in a decrease in the coercive force and also a decrease in the residual induction, thus making the material unsuitable for hysteresis applications. The exact reason for such metallurgical change is not completely understood; however, it is believed it is due at least in part to a tendency toward particle coarsening, or growth of the ferrite particles or platelets immediately after working which, in effect, counteracts the effect of the mechanical working by returning the particles to the same size as they were previous to working. Whatever the reason, however, the material cannot be warm worked above about 950° F. and provide suitable material for hysteresis application. Also, to develop suitable hysteresis properties, the material must be warm reduced at least 99% in thickness, and preferably about 99.6% to about 99.8%, since the maximum hysteresis loss and maximum coercive force of the material increases as the percent reduction is increased to about 99.8%, but both drop off rather sharply with reductions greater than 99.8%.

Although the primary constituents of the alloy of this invention are iron and manganese, it is to be understood that there will normally be present other elements as residual impurities such as carbon, silicon, sulfur and phosphorus; however, these and other normal impurities, when present only in residual amounts, will not affect the basic properties of the alloy to any appreciable extent.

An alloy processed according to this invention has its hysteresis properties fully developed in the as-processed condition and does not require any high temperature heat treatment to develop these properties after the material is formed into rotors. The material in the as-processed condition is soft and ductile enough to be formed by stamping or other operations.

Although several embodiments of this invention have been shown and described, various adaptations and modifications may be made without departing from the scope and appended claims.

I claim:

1. A method of producing a material suitable for rotors in hysteresis motors comprising the steps of, producing

a material having from about 7.0% to about 15% manganese, the balance essentially iron and residual impurities, and reducing said material at least 99% in cross sectional area, said reduction in area being carried out with the material between about 800° F. and 950° F.

2. The method of claim 1 wherein the reduction in cross sectional area is effected by rolling in successive passes.

3. A method of producing a material suitable for rotors in hysteresis motors comprising the steps of, producing a material having from about 7% to about 15% manganese, the balance essentially iron and residual impurities, and reducing said material at least 99% and not more than 99.8% in cross sectional area, said reduction in area being carried out with the material between about 800° F. and 950° F.

4. The method of claim 3 wherein the material is reduced at least 99.6% in cross sectional area.

5. A material suitable for rotors in hysteresis motors comprising, from about 7% to about 15% manganese, the remainder essentially iron and residual impurities, said material having been reduced in cross sectional area at least 99% at temperatures between about 800° F. and 950° F., said material being characterized by a relatively high hysteresis efficiency and hysteresis loss at relatively low peak magnetizing fields.

6. The material of claim 5 and in which said reduction of cross sectional area is at least 99.6%.

7. The method of claim 1 wherein the material produced thereby is further subjected to a physical forming operation without further high temperature heat treatment to produce a rotor part therefrom.

8. The method of claim 7 wherein the forming operation is a stamping operation.

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