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METHOD OF MAKING CAST MAGNETIC ALUMINUM-IRON ALLOYS AND PRODUCT THEREOF

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This invention relates to magnetic materials and more particularly to cast alloy magnets consisting essentially of iron alloyed with approximately 0.8 to 6.2 percent by weight, aluminum based on the weight of the total alloy, and having high permeability, with varying specific resistance, and very low hysteresis loss.

Magnetic materials consisting principally of iron with up to 10 percent content of aluminum are known. These alloys have been used as magnetic cores in various electrical machines and apparatus such as transformers, loading coils and the like. To obtain the desired magnetic properties, the known alloys have been subjected to a hot or cold rolling process by annealing with or without subsequent heat treatment.

The present invention is based on the discovery that iron-aluminum alloys having good magnetic properties can be obtained in the as-cast condition without any working by a suitable heat treatment of the cast material. As a result, it is possible to obtain magnetic products at a low cost through simple operations.

The alloys with which the present invention is concerned, as mentioned above, consist of a major proportion of iron and from 0.8 to 6.2 percent aluminum. The alloy should be substantially carbon-free and silicon-free, that is, it should contain a maximum of 0.35 percent silicon, a maximum of 0.05 percent carbon and only a trace of manganese at the most.

I have found especially good permeability at high flux densities in iron containing approximately 1 to 6 percent aluminum. These properties are obtainable in the cast material after a proper heat treatment. For example, I have found in the 1 percent aluminum iron maximum permeabilities of 20,000 at a flux density of 11,000 lines per square centimeter. The coercive forces Hc and residual magnetism Br are also low in this material; Hc being .3 to .36 oersted, with Br of 8900 to 9100 gauss,

with peak B of 10,000 gauss. In the 6 percent aluminum irons, there is obtained a maximum permeability of 18,000 at a flux density of about 8,700. The Hc and Br figures are .27 to .30 oersted and 7,300 to 8,000 gauss, respectively.

These heat-treated cast aluminum iron alloys present much better magnetic properties than any presently used cast iron-base material. For example, the better steel castings have permeabilities in the order of magnitude of 4,000 with values of Hc and Br of 2.5 to 3.0 oersteds and 7,000 to 8,000 gauss, respectively.

In producing the alloys of the present invention, the metals are melted and alloyed in any suitable apparatus as through the use of an induction furnace or the like. The molten mass may then be cast in a suitable mold. Thereafter, it is heat-treated or annealed, the temperature of this operation depending on the aluminum content of the alloy. Thus, it has been determined that the optimum temperature is 900° C. for the 1 percent aluminum alloy, 950° C. for the 2 and 4 percent, and 1,000° C. for the 6 percent material. The cooling rate, if it does not exceed 150° C. per hour, is not critical. It has further been determined that heat treating from four to eight hours at the appropriate temperature will develop the optimum magnetic properties. Times much shorter or longer than this will in most cases either not develop, or will destroy, the optimum properties.

For the purpose of illustrating the improved properties of the instant heat-treated alloys and for purposes of comparison with other cast alloys, the following data is presented.

TABLE I

Material	Max. permeability	Intrinsic saturation	H (Oersted) B=15,000	Br B=10,000	Hc B=10,000	Resistivity microhm, cm./cm.²
Cast 1% Al-iron	20,000	20,700	2.5	8,900	.30	25.3
Cast 2% Al-iron	20,000	20,100	10.0	8,400	.28	36.0
Cast 4% Al-iron	22,750	19,100	20.0	8,350	.25	54.2
Cast 6% Al-iron	18,000	18,100	55.0	7,400	.24	70.6
Cast .3% C Steel	1,060	20,300	45.0	7,500	3.25	19.0
Grey cast iron	385	16,300	750.0	4,750	6.20	70–100
Ductile cast iron	1,675	16,900	150.0	6,200	2.3	60–80
Malleable iron	2,100	18,600	175.0	6,350	1.48	30–45
Cast 2% Si-iron	6,700	20,400	9.0			
Cast 4% Si-iron	4,400	19,300	35.0			

In the above table, all of the aluminum-iron alloys were subjected to the afore-mentioned heat treatment for 8 hours, specifically at 900° C. for the 1 percent aluminum, at 950° C. for the 2 and 4 percent aluminum and 1000° C. for the 6 percent aluminum.

As another step in this investigation, eighty-pound ingots of about 1, 2, 4 and 6 percent aluminum iron alloys, killed with 0. 3 percent silicon, were made, machined and tested. Analysis of the heats showed them to have the following compositions:

Heat No.	C	Si	Mn	Al	Fe
2168	0.016	0.25	0.06	1.02	Bal.
2169	0.028	0.27	0.03	1.99	Bal.
2170	0.020	0.23	0.04	4.00	Bal.
2171	0.022	0.26	0.06	6.21	Bal.

Results of D.-C. normal-induction and hysteresis tests are shown in Table II.

TABLE II

Magnetic and physical test results on heats 2169 through 2171

Heat No. and Treatment	Max. μ	at B	B H=100	H B=10,000	H B=15,000	Sat. H	Bs Intrinsic	B $Bs+H$	Br B=10,000	Hc B=10,000
2168A as cast	4,550	8,550	17,900	2.22	10.0	800	20,500	21,300	8,200	1.14
2169A as cast	5,500	8,000	17,200	1.85	20.0	800	20,000	20,800	7,700	0.72
2170A as cast	8,425	5,000	16,700	1.37	27.0	900	19,150	20,050	6,000	0.28
2171A as cast	9,100	4,500	16,000	3.34	55.0	800	18,100	18,900	4,200	0.44
2168B, 800° C., 8 hrs., line H_2	13,100	10,000	18,000	0.81	2.8	800	20,700	21,500	9,050	0.39
2168E, 850° C., 8 hrs., line H_2	19,250	11,000	18,000	0.58	2.3	800	20,500	21,300	9,400	0.36
2168A, 900° C., 8 hrs., line H_2	20,250	11,250	17,900	0.56	2.5	1,000	20,700	21,700	8,900	0.30
2168F, 950° C., 8 hrs., line H_2	16,500	10,000	17,900	0.56	4.7	800	20,550	21,350	9,150	0.36
2168C, 1,000° C., 8 hrs., line H_2	13,200	11,750	17,900	0.81	3.3	1,000	20,500	21,500	9,100	0.43
2168D, 1,100° C., 8 hrs., line H_2	12,000	11,500	18,000	0.81	3.2	800	20,700	21,500	9,100	0.45
2169B, 800° C., 8 hrs., line H_2	9,400	7,500	17,200	1.04	9.0	800	20,100	20,900	7,950	0.36
2169E, 850° C.,* 8 hrs., line H_2	11,200	7,000	17,100	0.97	10.0	800	20,050	20,850	8,600	0.34
2169A, 900° C., 8 hrs., line H_2	17,300	10,500	17,300	0.60	7.0	800	20,100	20,900	6,950	0.19
2169F, 950° C., 8 hrs., line H_2	20,000	10,000	17,200	0.54	10.0	800	20,050	20,850	8,400	0.28
2169C, 1,000° C., 8 hrs., line H_2	17,000	10,250	17,200	0.56	8.0	800	20,100	20,900	7,400	0.31
2169C, 1,100° C., 8 hrs., line H_2	17,600	10,500	17,100	0.57	8.0	1,000	20,150	21,150	6,500	0.24
2170B, 800° C., 8 hrs., line H_2	12,200	9,000	16,300	0.88	39.0	600	19,100	19,700	7,000	0.30
2170E, 850° C., 8 hrs., line H_2	18,800	9,500	16,400	0.58	33.0	800	19,150	19,950	8,300	0.30
2170A, 900° C., 8 hrs., line H_2	19,000	10,500	16,600	0.53	24.0	800	19,100	19,900	8,000	0.29
2170F, 950° C., 8 hrs., line H_2	22,750	11,000	16,900	0.47	20.0	800	19,100	19,900	8,350	0.25
2170C, 1,000° C., 8 hrs., line H_2	19,200	9,500	16,300	0.58	37.0	800	19,200	20,000	7,250	0.27
2170D, 1,100° C., 8 hrs., line H_2	22,750	9,750	16,400	0.45	35.0	600	19,100	19,700	8,300	0.26
2171B, 800° C., 8 hrs., line H_2	10,100	7,000	16,100	1.23	47.0	600	18,100	18,700	6,750	0.34
2171E, 850° C., 8 hrs., line H_2	11,400	6,000	16,100	1.15	47.0	1,000	18,200	19,200	6,500	0.30
2171A, 900° C., 8 hrs., line H_2	11,400	9,750	16,000	0.94	52.0	800	18,100	18,900	7,300	0.39
2171F, 950° C., 8 hrs., line H_2	17,600	8,750	16,200	0.57	43.0	600	18,150	18,750	8,000	0.27
2171C, 1,000° C., 8 hrs., line H_2	18,300	8,750	15,900	0.66	55.0	600	18,100	18,700	7,400	0.24
2171D, 1,100° C., 8 hrs., line H_2	18,250	7,250	15,700	0.89	65.0	600	18,150	18,750	7,700	0.24

*Original 850° C., 8-hours anneal gave very erratic and spotty results; therefore samples were reannealed for additional 4 hours at 850° C. These are the values reported. 850° C. seems to be the lowest critical temperature for treatment.

The resistivities of the 1, 2, 4 and 6 percent aluminum alloys are 25.3, 36.0, 54.2 and 70.6 microhms per cm.[3] respectively.

From the results set forth in the tables, it can be seen that, through proper heat treatment, a maximum permeability of 18,000 to 22,500 and good coercive forces are obtainable in the cast aluminum-iron alloys.

The physical properties of the cast and heat-treated aluminum alloys are also good. For example, the 1% aluminum alloy had a tensile strength of 36,000 p. s. i. with a 32% elongation while the 6% alloy had a tensile strength of 62,000 p. s. i. with a 17% elongation.

The present low Al-iron alloys can primarily be employed to replace high purity iron, such as Armco iron, which is now used for solenoid parts, cores, magnetic frames, etc. The 6 percent material which has a relatively high resistivity may also be used in magnetic applications where laminated cores have formerly been used.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Substantially carbon- and silicon-free magnetic alloy cast articles consisting essentially of 0.8 and 6.2 percent aluminum, a maximum of 0.05 percent carbon, a maximum of 0.35 percent silicon and the remainder iron, prepared by casting the said alloys and subsequently heat treating said cast alloy articles without working said articles at about 900° C. to 1000° C. for a period of four to eight hours.

2. The method of obtaining good magnetic properties in cast substantially carbon- and silicon-free magnetic alloys consisting essentially of 0.8 to 6.2 percent aluminum, a maximum of 0.05 percent carbon, a maximum of 0.35 percent silicon and the remainder iron, which consists of the steps of casting the alloy and then subjecting the cast alloy to a heat treatment of about 900° to 1000° C. for a period of four to eight hours.

3. The method of obtaining good magnetic properties in a cast substantially carbon- and silicon-free magnetic alloy consisting essentially of approximately one percent aluminum, a maximum of 0.05 percent carbon, a maximum of 0.35 percent silicon and the remainder iron, which consists of the steps of casting the alloy and then subjecting the cast alloy to a heat treatment of about 900° C. for a period of four to eight hours.

4. The method of obtaining good magnetic properties in a cast substantially carbon- and silicon-free magnetic alloy consisting essentially of approximately two percent aluminum, a maximum of 0.05 percent carbon, a maximum of 0.35 percent silicon and the remainder iron, which consists of the steps of casting the alloy and then subjecting the cast alloy to a heat treatment of about 950° C. for four to eight hours.

5. The method of obtaining good magnetic properties in a cast substantially carbon- and silicon-free magnetic alloy consisting essentially of approximately four percent aluminum, a maximum of 0.05 percent carbon, a maximum of 0.35 percent silicon and the balance iron, which consists of the steps of casting the alloy and then subjecting the cast alloy to a heat treatment of about 950° C. for four to eight hours.

6. The method of obtaining good magnetic properties in a cast substantially carbon- and silicon-free magnetic alloy consisting essentially of six percent aluminum, a maximum of 0.05 percent carbon, a maximum of 0.35 percent silicon and the balance iron, which consists of the steps of casting the alloy and then subjecting the cast alloy to a heat treatment of about 1000° C. for four to eight hours.

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