<7> The Fe-based amorphous alloy ribbon according to any one of <1> to <6> having an iron loss, under conditions of a frequency of 60 Hz and a magnetic flux density of 1.45 T, of 0.160 W/kg or less, and an exciting power, under conditions of a frequency of 60 Hz and a magnetic flux density of 1.45 T, of 0.200 VA/kg or less.

<8> The Fe-based amorphous alloy ribbon according to <7>, consisting of Fe, Si, B, and impurities, wherein a content of Fe is 80 atom% or more, a content of B is 12 atom% or more, and a total content of B and Si is from 17 atom% to 20 atom% when a total content of Fe, Si, and B is 100 atom%.

<9> The Fe-based amorphous alloy ribbon according to any one of <1> to <8> having a magnetic flux density B0.1, under conditions of a frequency of 60 Hz and a magnetic field of 7.9557 A/m, of 1.52 T or more.

<10> The Fe-based amorphous alloy ribbon according to any one of <1> to <9>, for use at an operating magnetic flux density Bm, wherein a ratio of operating magnetic flux density Bm/saturated magnetic flux density Bs, is from 0.88 to 0.94.

[0010] <11> A method of producing an Fe-based amorphous alloy ribbon, comprising

a step of preparing a material ribbon comprising an Fe-based amorphous alloy and having a free solidified surface and a roll contact surface, and

a step of forming a plurality of laser irradiation mark rows each configured from a plurality of laser irradiation marks on at least one surface of the free solidified surface or the roll contact surface of the material ribbon, by laser processing, thereby obtaining an Fe-based amorphous alloy ribbon having a plurality of laser irradiation mark rows,

wherein the Fe-based amorphous alloy ribbon has:

a line interval of from 10 mm to 60 mm, the line interval being defined as a centerline interval in a middle section in a width direction, between mutually adjacent laser irradiation mark rows of a plurality of such laser irradiation mark rows arranged in a casting direction of the Fe-based amorphous alloy ribbon, the width direction being orthogonal to the casting direction,

a spot interval of from 0.10 mm to 0.50 mm, the spot interval being defined as an interval between center points of the plurality of laser irradiation marks in each of the plurality of laser irradiation mark rows, and

a number density D of the laser irradiation marks of from 0.05 marks/mm^2 to 0.50 marks/mm^2, provided that the line interval is d1 (mm), the spot interval is d2 (mm), and the number density D of the laser irradiation marks is $D = (1/d1) \times (1/d2)$.

[0011] <12> The method of producing an Fe-based amorphous alloy ribbon according to

1.45 T, of 0.160 W/kg or less, and an exciting power, under conditions of a frequency of 60 Hz and a magnetic flux density of 1.45 T, of 0.200 VA/kg or less.

<20> The Fe-based amorphous alloy ribbon according to <19>, consisting of Fe, Si, B, and impurities, wherein a content of Fe is 80 atom% or more, a content of B is 12 atom% or more, and a total content of B and Si is from 17 atom% to 20 atom% when a total content of Fe, Si, and B is 100 atom%.

<21> The Fe-based amorphous alloy ribbon according to any one of <16> to <20>, having a magnetic flux density B0.1, under conditions of a frequency of 60 Hz and a magnetic field of 7.9557 A/m, of 1.52 T or more.

Advantageous Effects of Invention

[0014] One aspect of the disclosure provides an Fe-based amorphous alloy ribbon reduced in iron loss in a condition of a magnetic flux density of 1.45 T and suppressed in an increase in exciting power in a condition of a magnetic flux density of 1.45 T, and a method of producing the Fe-based amorphous alloy ribbon.

Another aspect of the disclosure provides an iron core and a transformer each having excellent performance by use of the Fe-based amorphous alloy ribbon according to the above one aspect.

BRIEF DESCRIPTION OF DRAWINGS

[0015] Fig. 1 is a graph illustrating a relationship between a magnetic flux density and an iron loss with respect to each of four Fe-based amorphous alloy ribbons.

Fig. 2 is a graph illustrating a relationship between a magnetic flux density and an exciting power with respect to each of four Fe-based amorphous alloy ribbons.

Fig. 3 is a schematic plan view schematically illustrating a free solidified surface of an Fe-based amorphous alloy ribbon piece laser-processed in Example 1.

Fig. 4 is an optical micrograph illustrating one example of a coronal laser irradiation mark.

Fig. 5 is an optical micrograph illustrating one example of an annular laser irradiation mark.

Fig. 6 is an optical micrograph illustrating one example of a flat laser irradiation mark.

Fig. 7 is a schematic diagram illustrating each location before equal dividing, of an Fe-based amorphous alloy ribbon divided equally into eight parts in the width direction.

enhancement in saturated magnetic flux density Bs and an enhancement in magnetic flux density B0.1.

[0064] The content of Si is preferably 2.0 atom% or more, more preferably 2.4 atom% or more, still more preferably 3.5 atom% or more.

The upper limit of the content of Si is preferably 6.0 atom%, while depending on the total content of B and Si.

[0065] A more preferable chemical composition as the above chemical composition A of the Fe-based amorphous alloy ribbon consists of Fe, Si, B, and impurities, from the viewpoint of more improvements in iron loss and exciting power described below, in which the content of Fe is 80 atom% or more, the content of B is 12 atom% or more, and the total content of B and Si is from 17 atom% to 20 atom% in a case in which a total content of Fe, Si, and B is 100 atom%.

[0066] The chemical composition A contains impurities.

In such a case, the chemical composition A may contain one or more impurities.

Examples of such impurities include any elements other than Fe, Si, and B, and specific examples include C, Ni, Co, Mn, O, S, P, Al, Ge, Ga, Be, Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, and rare-earth elements.

Such element(s) can be contained in a total amount range of 1.5% by mass with respect to the total mass of Fe, Si, and B. The upper limit of the total content of such element(s) is preferably 1.0% by mass or less, still more preferably 0.8% by mass or less, still more preferably 0.75% by mass or less. Such element(s) may be added in such any range.

[0067] <Thickness>

The thickness of the Fe-based amorphous alloy ribbon of the disclosure is not particularly limited, and the thickness is preferably from 20 μm to 35 μm.

A thickness of 20 μm or more is advantageous in terms of suppression of waviness of the Fe-based amorphous alloy ribbon and then an enhancement in lamination factor.

A thickness of 35 μm or less is advantageous in terms of embrittlement suppression and magnetic saturation properties of the Fe-based amorphous alloy ribbon.

The thickness of the Fe-based amorphous alloy ribbon is more preferably from 20 μm to 30 μm.

[0068] <Iron Loss>

As described above, the Fe-based amorphous alloy ribbon of the disclosure is reduced in iron loss under conditions of a frequency of 60 Hz and a magnetic flux density of 1.45 T by segmentalization of a magnetic domain with laser processing (formation of laser

In Formula, d1 represented the line interval (unit: mm) and d2 represented the spot interval (unit: mm).

[0099] The processing conditions of the pulsed laser were as follows.

Processing Conditions of Pulsed Laser-

A laser oscillator used was pulse fiber laser (YLP-HP-2-A30-50-100) from IPG Photonics. The laser medium of the laser oscillator was a glass fiber doped with Yb, and the oscillation wavelength was 1064 nm.

The outgoing beam diameter through a collimator at a fiber end of the laser oscillator was 6.2 mm.

The laser spot diameter on the free solidified surface of the sample piece was adjusted to 60.8 μm. The beam diameter was adjusted using a beam expander (BE) as an optical component and a condenser lens (focal length 254 mm) (fθ: f 254 mm).

The beam mode M2 was 3.3 (multimode).

The laser pulse energy was 2.0 mJ, and the laser pulse width was 250 nsec.

The magnification of beam by BE was 3 times, and the Focus was 0 mm.

The Focus here means the difference (absolute value) between the focal length (254 mm) of the condenser lens and the actual distance from the condenser lens to the free solidified surface of the ribbon.

The incident diameter D and the spot diameter D_0 satisfy a relationship of $D_0 = 4\lambda f/\pi D$ (where λ represents the laser wavelength and f represents the focal length), and thus the spot diameter D_0 tends to be decreased as the beam magnification BE is increased (namely, as the incident diameter D is increased).

[0100] In a case in which the value obtained by dividing the laser pulse energy (2.0 mJ) by the laser beam diameter (60.8 μm) on the free solidified surface of the sample piece was defined as the energy density in the processing conditions, the energy density was 0.689 J/mm^2 expressed in unit of J/mm^2.

The energy density (0.689 J/mm^2) is shown in Table 4.

[0101] <Measurement and Evaluation>

The Fe-based amorphous alloy ribbon laser-processed (ribbon 10 in Fig. 3) was subjected to the following measurement and evaluation. The results are shown in Table 1.

[0102] (Maximum Cross-sectional Height Rt in Non-laser-processed Region)

The maximum cross-sectional height Rt with respect to a portion of the free solidified surface of the Fe-based amorphous alloy ribbon laser-processed, the portion (namely, non-laser-processed region) being other than the laser irradiation mark rows 12, was

cross-sectional height Rt, of 3.0 μm or less.

The results are shown in Table 1 and Table 2.

[0108] [Comparative Example 5]

The same evaluation as in Comparative Example 1 was performed except that the pressure, at which the molten metal was ejected, and the nozzle gap were adjusted so that the maximum cross-sectional height Rt was more than 3.0 μm. The results are shown in Table 2.

Any wavy irregularities were formed on the free solidified surface of the Fe-based amorphous alloy ribbon of Comparative Example 5.

[0109] [Table 1]

<Influence of spot interval>

	Free solidified surface of ribbon					Magnetic characteristics				
	Region not laser-processed	Laser pulse energy (mJ)	Region laser-processed (laser irradiation mark rows)		Number density of laser irradiation marks (marks/mm^2)	Iron loss CL (W/kg) at 1.45 T 60 Hz	Exciting power VA (VA/kg) at 1.45 T 60 Hz	Magnetic flux density B0.1 (T) at 7.9557 A/m 60 Hz	Iron loss CL (W/kg) at 1.50 T 60 Hz	Exciting power VA (VA/kg) at 1.50 T 60 Hz
	Rt (μm)		Spot interval SP1 (mm)	Line interval LP1 (mm)						
Comparative Example 1	1.0	-	-	-	0	0.168	0.183	1.51	0.176	0.244
Comparative Example 2	1.0	2.0	0.05	20	1.00	0.088	0.518	1.48	0.098	0.789
Example 1	1.6	2.0	0.10	20	0.50	0.104	0.200	1.52	0.113	0.293
Example 2	1.2	2.0	0.15	20	0.33	0.095	0.165	1.54	0.107	0.267
Example 3	1.1	2.0	0.20	20	0.25	0.108	0.140	1.55	0.122	0.211
Example 4	1.3	2.0	0.25	20	0.20	0.108	0.134	1.55	0.118	0.192
Example 5	1.5	2.0	0.30	20	0.17	0.124	0.146	1.55	0.131	0.209
Example 6	2.4	2.0	0.40	20	0.13	0.119	0.143	1.54	0.135	0.230
Example 7	1.6	2.0	0.45	20	0.11	0.138	0.160	1.54	0.150	0.216
Example 8	1.3	2.0	0.50	20	0.10	0.147	0.160	1.54	0.161	0.199

[0110] [Table 2]

<Influence of line interval>

	Free solidified surface of ribbon					Magnetic characteristics				
	Region not laser-processed	Laser pulse energy (mJ)	Region laser-processed (laser irradiation mark rows)		Number density of laser irradiation marks (marks/mm^2)	Iron loss CL (W/kg) at 1.45 T 60 Hz	Exciting power VA (VA/kg) at 1.45 T 60 Hz	Magnetic flux density B0.1 (T) at 7.9557 A/m 60 Hz	Iron loss CL (W/kg) at 1.50 T 60 Hz	Exciting power VA (VA/kg) at 1.50 T 60 Hz
	Rt (μm)		Spot interval SP1 (mm)	Line interval LP1 (mm)						
Comparative Example 1	1.0	-	-	-	0	0.168	0.183	1.51	0.176	0.244
Example 9	1.3	2.0	0.20	60	0.08	0.146	0.170	1.52	0.168	0.238
Example 10	1.7	2.0	0.20	50	0.10	0.136	0.148	1.55	0.151	0.231
Example 11	1.4	2.0	0.20	40	0.13	0.130	0.153	1.55	0.142	0.253
Example 12	2.0	2.0	0.20	30	0.17	0.123	0.136	1.54	0.130	0.154
Example 3	1.1	2.0	0.20	20	0.25	0.108	0.140	1.55	0.122	0.211
Example 13	1.4	2.0	0.20	15	0.33	0.099	0.149	1.55	0.106	0.196
Example 14	1.2	2.0	0.20	10	0.50	0.085	0.145	1.56	0.094	0.187
Comparative Example 3	1.7	2.0	0.20	7.5	0.67	0.079	0.210	1.50	0.091	0.282
Comparative Example 4	1.4	2.0	0.20	5	1.00	0.075	0.255	1.48	0.085	0.329
Comparative Example 5	3.2	-	-	-	0	0.101	0.214	1.51	0.117	0.316

The shape in planar view of such each laser irradiation mark in each of the Fe-based amorphous alloy ribbons of Examples 1 to 14 was observed by an optical microscope.

As a result, the shape in planar view of such each laser irradiation mark in all the Examples was a coronal shape.

The "coronal shape" here means a shape in which marks due to scattering of the molten alloy remain on an edge portion of such each laser irradiation mark.

[0114] Fig. 4 is an optical micrograph illustrating one example of a coronal laser irradiation mark.

Two coronal laser irradiation marks can be confirmed in Fig. 4. It can be seen that marks due to scattering of the molten alloy remain on an edge portion of such each laser irradiation mark.

[0115] [Examples 15 to 19]

The same operation as in Example 3 was performed except that the laser pulse energy in Example 3 was changed as shown in Table 3. The results are shown in Table 3.

Table 3 shows not only the results in Examples 15 to 19, but also the results in Example 3 and Comparative Example 1 for comparison.

[0116] [Table 3]

<Influence of laser pulse energy>

	Free solidified surface of ribbon					Magnetic characteristics				
	Region not laser-processed	Laser pulse energy (mJ)	Region laser-processed (laser irradiation mark rows)		Number density of laser irradiation marks (marks/mm^2)	Iron loss CL (W/kg) at 1.45 T 60 Hz	Exciting power VA (VA/kg) at 1.45 T 60 Hz	Magnetic flux density B0.1 (T) at 7.9557 A/m 60 Hz	Iron loss CL (W/kg) at 1.50 T 60 Hz	Exciting power VA (VA/kg) at 1.50 T 60 Hz
	Rt (μm)		Spot interval SP1 (mm)	Line interval LP1 (mm)						
Comparative Example 1	1.0	-	-	-	0	0.168	0.183	1.51	0.176	0.244
Example 15	2.1	0.4	0.20	20	0.25	0.154	0.173	1.53	0.162	0.244
Example 16	1.3	0.6	0.20	20	0.25	0.138	0.159	1.55	0.149	0.235
Example 17	1.5	0.8	0.20	20	0.25	0.125	0.151	1.54	0.139	0.230
Example 18	1.2	1.0	0.20	20	0.25	0.120	0.132	1.55	0.136	0.219
Example 19	1.5	1.5	0.20	20	0.25	0.112	0.131	1.56	0.119	0.199
Example 3	1.1	2.0	0.20	20	0.25	0.108	0.140	1.55	0.122	0.211

[0117] As shown in Table 3, it was confirmed that the effect of a reduction in iron loss was obtained by laser irradiation even in a case in which the laser pulse energy was decreased from 0.4 mJ to 1.5 mJ (Examples 15 to 19). The iron loss CL and the exciting power VA at 60 Hz and 1.45 T were 0.120 W/kg or less and 0.140 or less, respectively, in Examples 18 and 19, and Example 3, in which the laser pulse energy was from 1.0 mJ to 2.0 mJ. The iron loss CL and the exciting power VA at 60 Hz and 1.45 T were 0.112 W/kg and 0.131, respectively, in Example 19, in which the laser pulse energy was from 1.3 mJ to 1.8 mJ (1.5 mJ).

[0118] [Examples 101 to 105]

<Experiment 1 with Respect to Laser Processing Conditions>

The same operation as in Example 3 was performed except that the laser processing conditions (specifically, the magnification of beam by BE and the Focus) were changed as shown in Table 4.

The shape in planar view of such each laser irradiation mark in the Fe-based amorphous alloy ribbon of each Example was observed by an optical microscope. The results are shown in Table 4.

Table 4 shows not only the results in Examples 101 to 105, but also the results in Example 3 and Comparative Example 1 for comparison.

[0119] [Table 4]

	Free solidified surface of ribbon										Magnetic characteristics				
	Region not laser-processed	Laser processing conditions					Region laser-processed (laser irradiation mark rows)				Iron loss CL (W/kg) at 1.45 T 60 Hz	Exciting power VA (VA/kg) at 1.45 T 60 Hz	Magnetic flux density B0.1 (T) at 7.9557 A/m 60 Hz	Iron loss CL (W/kg) at 1.50 T 60 Hz	Exciting power VA (VA/kg) at 1.50 T 60 Hz
	Rt (μm)	BE	Fucus (mm)	Laser pulse energy (mJ)	Spot diameter (μm)	Energy density (J/mm^2)	Spot interval SP1 (mm)	Line interval LP1 (mm)	Number density of laser irradiation marks ($marks/mm^2$)	Shape of laser irradiation mark					
Comparative Example 1	1.0	-	-	-	-	-	-	-	0	-	0.168	0.183	1.51	0.176	0.244
Example 3	1.1	3x	0	2.0	60.8	0.689	0.20	20	0.25	Coronal	0.108	0.140	1.55	0.122	0.211
Example 101	1.8	3x	1.5	2.0	60.8	0.689	0.20	20	0.25	Annular	0.101	0.145	1.54	0.107	0.196
Example 102	1.4	3x	2.5	2.0	60.8	0.689	0.20	20	0.25	Flat	0.102	0.143	1.55	0.112	0.223
Example 103	1.7	1x	0	2.0	182.4	0.077	0.20	20	0.25	Flat	0.111	0.149	1.54	0.122	0.227
Example 104	1.2	1x	1.5	2.0	182.4	0.077	0.20	20	0.25	Annular	0.101	0.131	1.56	0.115	0.175
Example 105	1.6	1x	2.5	2.0	182.4	0.077	0.20	20	0.25	Annular	0.102	0.158	1.55	0.115	0.249

[0125] [Table 5]

	Free solidified surface of ribbon	Roll contact surface of ribbon				Magnetic characteristics				
		Laser pulse energy (mJ)	Region laser-processed (laser irradiation mark rows)		Number density of laser irradiation marks (marks/mm^2)	Iron loss CL (W/kg) at 1.45 T 60 Hz	Exciting power VA (VA/kg) at 1.45 T 60 Hz	Magnetic flux density B0.1 (T) at 7.9557 A/m 60 Hz	Iron loss CL (W/kg) at 1.50 T 60 Hz	Exciting power VA (VA/kg) at 1.50 T 60 Hz
	Rt (μm)		Spot interval SP1 (mm)	Line interval LP1 (mm)						
Example 20	1.4	2.0	0.20	20	0.25	0.102	0.155	1.54	0.116	0.231

[0128] [Table 6]

	Free solidified surface of ribbon						Magnetic characteristics				
	Region not laser-processed	Laser processing position *1	Laser pulse energy (mJ)	Region laser-processed (laser irradiation mark rows)		Number density of laser irradiation marks (marks/mm^2)	Iron loss CL (W/kg) at 1.45 T 60 Hz	Exciting power VA (VA/kg) at 1.45 T 60 Hz	Magnetic flux density B0.1 (T) at 7.9557 A/m 60 Hz	Iron loss CL (W/kg) at 1.50 T 60 Hz	Exciting power VA (VA/kg) at 1.50 T 60 Hz
	Rt (μm)			Spot interval SP1 (mm)	Line interval LP1 (mm)						
Comparative Example 6	1.5	Wa	-	-	-	0	0.137	0.707	1.27	0.162	1.212
Example 21	1.7	Wa	2.0	0.20	20	0.25	0.128	0.753	1.25	0.145	1.310
Comparative Example 7	1.7	Wb	-	-	-	0	0.140	0.162	1.49	0.162	0.304
Example 22	1.4	Wb	2.0	0.20	20	0.25	0.100	0.154	1.51	0.110	0.236
Comparative Example 8	1.2	Wc	-	-	-	0	0.165	0.180	1.51	0.169	0.249
Example 23	1.5	Wc	2.0	0.20	20	0.25	0.103	0.129	1.54	0.114	0.194
Comparative Example 9	1.3	Wd	-	-	-	0	0.171	0.185	1.51	0.175	0.257
Example 24	1.7	Wd	2.0	0.20	20	0.25	0.100	0.147	1.52	0.109	0.254

※1: Laser processing positions Wa to Wd represent four ribbon positions (namely, positions of laser irradiation marks) from one end in the width direction of a ribbon in the case of the ribbon divided equally into eight parts in the width direction, as illustrated in Fig. 7.

[0131] [Table 7]

	Free solidified surface of ribbon						Magnetic characteristics				
	Region not laser-processed	Angle inclined to width direction of laser irradiation mark rows	Laser pulse energy (mJ)	Region laser-processed (laser irradiation mark rows)		Number density of laser irradiation marks (marks/mm^2)	Iron loss CL (W/kg) at 1.45 T 60 Hz	Exciting power VA (VA/kg) at 1.45 T 60 Hz	Magnetic flux density B0.1 (T) at 7.9557 A/m 60 Hz	Iron loss CL (W/kg) at 1.50 T 60 Hz	Exciting power VA (VA/kg) at 1.50 T 60 Hz
	Rt (μm)			Spot interval SP1 (mm)	Line interval LP1 (mm)						
Example 25	1.4	15° Adjacent rows parallel to each other	2.0	0.20	20	0.25	0.125	0.182	1.52	0.143	0.253
Example 26	1.8	15°/165° Adjacent rows alternately different	2.0	0.20	20	0.25	0.119	0.197	1.49	0.132	0.349

[0132] As shown in Table 7, the iron loss CL and the exciting power VA in a condition of a magnetic flux density of 1.45 T were reduced even in a case in which the direction of the laser irradiation mark rows was inclined at 15° to the width direction.

[0133] (Examples 27 to 29)

Each Fe-based amorphous alloy ribbon of an alloy composition (having a chemical composition of $Fe_{82}Si_4B_{14}$, and having a thickness of 25 μm and a width of 210 mm) was obtained in the same manner as in Example 1. Thereafter, a sample piece of 25 mm in width was processed from the middle section of the ribbon and the free solidified surface of the sample piece was subjected to laser processing by pulsed laser, whereby laser irradiation mark rows were formed. The laser processing conditions here were as shown in Table 8 below.

The spot interval SP1 and the line interval LP1 in the laser irradiation mark rows were 0.20 mm and 20 mm, respectively, and the number density of the laser irradiation mark rows was 0.25 mm^2. The laser irradiation mark rows were formed in the entire region in the width direction of the ribbon piece, and respective laser irradiation marks were formed so as to be parallel to each other.

[0134] [Table 8]

	Free solidified surface of ribbon						Magnetic characteristics				
	Region not laser-processed	Pulse width (nsec)	Laser pulse energy (mJ)	Region laser-processed (laser irradiation mark rows)		Number density of laser irradiation marks (marks/mm^2)	Iron loss CL (W/kg) at 1.45 T 60 Hz	Exciting power VA (VA/kg) at 1.45 T 60 Hz	Magnetic flux density B0.1 (T) at 7.9557 A/m 60 Hz	Iron loss CL (W/kg) at 1.50 T 60 Hz	Exciting power VA (VA/kg) at 1.50 T 60 Hz
	Rt (μm)			Spot interval SP1 (mm)	Line interval LP1 (mm)						
Example 27	1.3	100	1.0	0.20	20	0.25	0.140	0.165	1.53	0.146	0.276
Example 28	1.3	250	1.0	0.20	20	0.25	0.120	0.132	1.55	0.136	0.219
Example 29	1.4	500	1.0	0.20	20	0.25	0.109	0.145	1.54	0.121	0.252

[0141] [Table 9]

	Free solidified surface of ribbon wound in an overlapping manner					Magnetic characteristics			
	Region not laser-processed	Laser pulse energy (mJ)	Region laser-processed (laser irradiation mark rows)		Number density of laser irradiation marks (marks/mm^2)	Iron loss CL (W/kg) at 1.45 T 60 Hz	Exciting power VA (VA/kg) at 1.45 T 60 Hz	Iron loss CL (W/kg) at 1.50 T 60 Hz	Exciting power VA (VA/kg) at 1.50 T 60 Hz
	Rt (μm)		Spot interval SP1 (mm)	Line interval LP1 (mm)					
Comparative Example 10	1.4	-	-	-	0	0.261	0.548	0.280	0.729
Example 30	1.3	2.0	0.20	20	0.25	0.162	0.457	0.181	0.643

content of B is 11 atom% or more, and a total content of B and Si is from 17 atom% to 22 atom% when a total content of Fe, Si, and B is 100 atom%.

6. The Fe-based amorphous alloy ribbon according to any one of claims 1 to 5, having a thickness of from 20 μm to 35 μm.

7. The Fe-based amorphous alloy ribbon according to any one of claims 1 to 6, having an iron loss, under conditions of a frequency of 60 Hz and a magnetic flux density of 1.45 T, of 0.160 W/kg or less, and an exciting power, under conditions of a frequency of 60 Hz and a magnetic flux density of 1.45 T, of 0.200 VA/kg or less.

8. The Fe-based amorphous alloy ribbon according to claim 7, consisting of Fe, Si, B, and impurities, wherein a content of Fe is 80 atom% or more, a content of B is 12 atom% or more, and a total content of B and Si is from 17 atom% to 20 atom% when a total content of Fe, Si, and B is 100 atom%.

9. The Fe-based amorphous alloy ribbon according to any one of claims 1 to 8, having a magnetic flux density B0.1, under conditions of a frequency of 60 Hz and a magnetic field of 7.9557 A/m, of 1.52 T or more.

10. The Fe-based amorphous alloy ribbon according to any one of claims 1 to 9, for use at an operating magnetic flux density Bm, wherein a ratio of operating magnetic flux density Bm/saturated magnetic flux density Bs, is from 0.88 to 0.94.

11. A method of producing an Fe-based amorphous alloy ribbon, comprising

a step of preparing a material ribbon comprising an Fe-based amorphous alloy and having a free solidified surface and a roll contact surface, and

a step of forming a plurality of laser irradiation mark rows each configured from a plurality of laser irradiation marks on at least one surface of the free solidified surface or the roll contact surface of the material ribbon, by laser processing, thereby obtaining an Fe-based amorphous alloy ribbon having a plurality of laser irradiation mark rows,

wherein the Fe-based amorphous alloy ribbon has:

a line interval of from 10 mm to 60 mm, the line interval being defined as a centerline interval in a middle section in a width direction, between mutually adjacent laser irradiation mark rows of a plurality of such laser irradiation mark rows arranged in a casting

direction of the Fe-based amorphous alloy ribbon, the width direction being orthogonal to the casting direction,

a spot interval of from 0.10 mm to 0.50 mm, the spot interval being defined as an interval between center points of the plurality of laser irradiation marks in each of the plurality of laser irradiation mark rows, and

a number density D of the laser irradiation marks of from 0.05 marks/mm^2 to 0.50 marks/mm^2, provided that the line interval is d1 (mm), the spot interval is d2 (mm), and the number density D of the laser irradiation marks is $D = (1/d1) \times (1/d2)$.

12. The method of producing an Fe-based amorphous alloy ribbon according to claim 11, wherein the laser irradiation marks are formed using a laser with a pulse energy of from 0.4 mJ to 2.5 mJ.

13. The method of producing an Fe-based amorphous alloy ribbon according to claim 11 or 12, wherein the laser irradiation marks are formed using a laser with a pulse width of laser for forming the laser irradiation marks of 50 nsec or more.

14. An iron core, comprising a layered Fe-based amorphous alloy ribbon that includes a plurality of the Fe-based amorphous alloy ribbons according to any one of claims 1 to 10, and that is bent and wound in an overlapping manner,

wherein the iron core has an iron loss, under conditions of a frequency of 60 Hz and a magnetic flux density of 1.45 T, of 0.250 W/kg or less.

15. A transformer, comprising an iron core that is formed using the Fe-based amorphous alloy ribbon according to any one of claims 1 to 10, and a coil wound around the iron core,

wherein the iron core is formed by layering the Fe-based amorphous alloy ribbon and bending and winding the layered Fe-based amorphous alloy ribbon in an overlapping manner, and has an iron loss of 0.250 W/kg or less, under conditions of a frequency of 60 Hz and a magnetic flux density of 1.45 T.