A METHOD FOR MANUFACTURING AN IRON-NICKEL-BASED ALLOY THIN STRIP

Technical Field

The present invention relates to a method for manufacturing an iron-nickel-based alloy thin strip used for lead frame materials, lead materials and so on.

Background of the Invention

Various methods have been disclosed hitherto for manufacturing a lead frame made of an iron-nickel-based alloy strip. Among them, the documents which focus on heat shrinkage and residual stress include JP-A-05-109960 and JP-A-06-145811, for example.

JP-A-5-109960 discloses a manufacturing method comprising steps of:

(1) cold-rolling an iron-nickel alloy or an iron-nickel-cobalt alloy to a sheet having a product thickness;

(2) then, slitting the sheet into strips having a product width; and

(3) then, annealing them for removing a stress due to the slitting, at a temperature of 600 to 700°C for 1 to 3 minutes while a tension of 5 kg/mm^2 or less, preferably 2 kg/mm^2 or less, are applied thereto.

On the other hand, JP-A-06-145811 discloses a manufacturing method comprising steps of:

(1) rolling a sheet for finishing;

(2) then, slitting it into strips;

(3) then, annealing the strips sufficiently for removing a stress due to the slitting at a temperature in a range of 630 to 700°C; and

(4) subsequently, straightening the strips by a leveler,

as opposed to the following processes which had been theretofore employed:

(1) hot-rolling a plate of an iron-nickel alloy;

(2) then cold-rolling it;

(3) then annealing it once for softening;

(4) then rolling it for finishing at a reduction rate of 50% or less;

(5) then shearing (slitting) it to manufacture strips having a predetermined width; and

(6) subsequently, annealing the strips at 600°C or less for removing a stress due to the slitting.

Summary of the Invention

As described above, the methods have been conventionally employed in which a steel strip with a product width is annealed for removing a stress due to slitting. These manufacturing methods have the following problems.

The technical idea of the conventional manufacturing methods intends that the stress due to the slitting and cold-rolling are reduced by a heat

treatment as the last process. However, when the strip is heat-treated after being slit to the product width, an undulating deformation occurs by a release of the stress, which result in degrading a flatness of the strip.

In addition, when a plurality of strips of the materials after being slit to the product width are heat-treated at the same time, tensions vary among the strips, so that it is difficult to control them stably. In addition, it is unavoidable that the strips are deformed and damaged, because the strips meander in a furnace. When the strips are heat-treated one after another, the problems of the tension control and the meandering do not arise, but productivity is significantly reduced.

Thus, it is a worst disadvantage of the conventional manufacturing method in which strips are annealed for removing a stress after slitting, that a stable heat shrinkage due to a stable tension control and a flatness required for lead frame materials can not be obtained, although the stress due to the slitting can be reduced by the heat treatment.

In JP-A-06-145811, straightening by a leveler is subsequently performed in order to ensure the flatness. However, the heat shrinkage can not be controlled stably as described above. In addition, a local residual stress is generated in the steel strips slit to the product width, through straightening the

deformed parts in the heat treatment with the leveler, which may lead deformation after stamping or etching for fabricating a lead frame.

When the strip has a conventional narrow width in the order of 30 mm or less, the strip can be used even for a lead frame material, for example, although it has some undulations. However, because widening of the strip is required due to a recent increased efficiency of ICs, the width is 60 mm or more so that a requirement for flatness becomes stringent. Therefore, it is very difficult to ensure the flatness by the conventional manufacturing methods.

It is an object of the present invention to provide a method for manufacturing an iron-nickel-based alloy thin strip used for lead frame materials, lead materials and so on, which can particularly solve the problem of the heat shrinkage and realize a superior flatness even for a wide width of, for example, 60 mm or more.

The present invention is provided in view of the above described problems.

The present invention provides a method for manufacturing an iron-nickel-based alloy thin strip, wherein the method comprises: straightening a finally cold-rolled sheet by a leveler; then annealing the straightened sheet for removing a stress thereof in a continuous annealing furnace; and then slitting the sheet into strips.

Preferably, a tension of not more than 20 N/mm^2 is applied to the sheet when the sheet is annealed for removing the stress in the continuous annealing furnace.

More preferably, the sheet is annealed for removing the stress at a temperature in a range of 400 to 750°C.

Furthermore, in the present invention, it is preferable that the sheet is slit with a cooperating pair of upper and lower circular cutters and that each circular cutter has a diameter of 750 times or more of a thickness of the iron-nickel-based alloy sheet to be slit.

More preferably, in slitting into strips, an overlap of the upper and lower circular cutters is 5 to 50% of the thickness of the iron-nickel-based alloy sheet to be slit.

A preferable composition of the iron-nickel-based alloy in the present invention consists of, by mass percent, not more than 0.1% of carbon, not more than 1.0% of silicon, not more than 1.2% of manganese, 30 to 50% of nickel, and the balance being essentially iron.

By applying a manufacturing method according to the present invention, the problem of the heat shrinkage can be more certainly solved, and an iron-nickel-based alloy thin strip with a superior flatness can be obtained. Consequently, an iron-nickel-based

alloy thin strip used for lead frame materials, lead materials and so on, which is inevitably subjected to micro-fabricating, can be readily obtained.

The limitations defined in the present invention will be described in detail below.

According to the present invention, a finally cold-rolled sheet is straightened by a leveler to straighten the iron-nickel-based alloy thin strip used for lead frame materials, lead materials and so on in order to ensure the flatness thereof, and thereafter the sheet is annealed for removing a stress thereof in a continuous annealing furnace.

The "leveler" referred to herein is an apparatus for applying certain tensile stress to a steel sheet in the longitudinal direction over the entire width thereof so as to cancel a difference of the length in the strip. The leveler actually used in the present invention is preferably a tension leveler in consideration of the thickness of the iron-nickel-based alloy thin strip. A combined leveler for both bending and tension may be also used. The tension may be in a range of 50 to 500 N/mm^2.

According to the present invention, an iron-nickel-based alloy sheet having a wide width, for example of 300 to 1200 mm, can be annealed for removing a stress in a continuous annealing furnace, because it is annealed before being slit into strips having the product width. Thereby, only the sheet's own weight is

loaded over the entire width of the iron-nickel-based alloy sheet, which allows easy control of the tension as compared with the case when a plurality of steel strips with narrow widths are passed at the same time in the furnace.

As a result, conventional local variations of the heat shrinkage in the iron-nickel-based alloy sheet can be suppressed, so that a stable heat shrinkage is obtained. Furthermore, meandering of the material can be also easily controlled as compared with the case when a plurality of iron-nickel-based alloy thin strips are passed at the same time in the furnace, and thereby the possibility for deformation and damage thereof can be also eliminated.

While a typical continuous annealing furnace in the present invention can be vertical or horizontal, a tension can be controlled in both furnaces to achieve the advantage of improving productivity.

Particularly, when a vertical continuous annealing furnace is used in which the longitudinal direction of the steel sheet is vertical, the slack of the steel sheet can be suppressed so that a more stable heat shrinkage is obtained.

It is preferable that a tension of not more than 20 N/mm^2 is applied to the sheet in the furnace when the sheet is annealed for removing the stress. If the tension is in this range, the heat shrinkage generated during an intermediate heat treatment

performed in press stamping or during manufacturing of semiconductor packages can be minimized so that a defect due to dimensional variations is more certainly prevented.

If the tension in the furnace is more than 20 N/mm^2, the heat shrinkage increases when the intermediate heat treatment is performed in the press stamping, for example, so that the defect due to the dimensional variations is likely to occur. Therefore, the tension in the furnace is limited to be not more than 20 N/mm^2.

On the other hand, the lower limit of the tension changes to some extent depending on whether a continuous annealing furnace to be used is vertical or horizontal. For example, when a vertical furnace is used, a sheet can be annealed without tension, because it may hang down by its own weight without applying an additional tension. However, in view of stability of the process, 0.5 N/mm^2 may be the lower limit for both vertical and horizontal furnaces, and a tension in a range of 1 to 15 N/mm^2 is preferably employed to obtain the above described effects more certainly.

It is preferable that the above described annealing for removing the stress is performed at a temperature in a range of 400 to 750°C.

In this temperature range, an effect of relaxation of the stress introduced in cold-rolling and straightening can be obtained. A preferable

temperature range is 500 to 700°C. The annealing time may be 10 to 120 seconds, while the time is not specifically limited here.

In addition, this annealing may be performed in a reducing atmosphere having a dew point of -70 to -5°C or in an inert gas such as nitrogen. The atmosphere can be selected depending on required properties of the sheet. For example, if it is important to improve corrosion resistance primary, it is more advantageous to anneal it in an inert gas, while an effect of preventing a surface thereof from oxidation can be primary provided when annealing it in a reducing atmosphere.

According to the present invention, after being annealed as described above for removing the stress, the sheet is slit into strips, for example having the product width.

In the present invention, because both the flatness and the heat shrinkage are improved before slitting into strips, it is desirable that a stress is not excessively applied to the sheet in slitting into strips. Any method in which the sheet can be slit into strips with a small stress, for example by a laser beam machining, may be used, but it is convenient to slit the sheet with a cooperating pair of upper and lower circular cutters.

Each of the upper and lower circular cutters for slitting has preferably a diameter of 750 times or

more of the thickness of the iron-nickel-based alloy sheet. This is because a shear angle may become large so that residual stress increases in slitting into strips, if the diameters of the cutters are less than 750 times of the sheet thickness.

Thus, in the present invention, the diameters of the upper and lower circular cutters are 750 times or more, preferably 900 times, of the thickness of the iron-nickel-based alloy sheet in order to significantly reduce the stress due to the slitting.

In addition, an overlap of the upper and lower circular cutters may be 5 to 50% of the sheet thickness to further reduce the stress due to the slitting. If the overlap increases, a shear angle becomes larger and thereby the residual stress due to the slitting increases. If the overlap is too small, the cutters can not cut the sheet completely, which results in slit defects.

The "iron-nickel-based alloy" referred to herein means an alloy including iron and nickel as major elements. The typical composition is such as an alloy comprising 27 to 52% of nickel by mass percent and the balance being essentially iron, an alloy further including not more than 7% of chromium, or an alloy of substituting not more than 20% of cobalt for the above described nickel.

Among them, an alloy consisting essentially of iron and nickel is preferable. The preferable

ranges of the elements included therein and reasons therefor will be described below.

Carbon: not more than 0.1%

Carbon is an element impairing the etching property of an iron-nickel-based alloy thin strips which may be subjected to etching. Therefore, the upper limit of carbon is defined to be not more than 0.1%. The preferable upper limit of carbon is 0.03%.

Silicon: not more than 1.0%, and manganese: not more than 1.2%

Trace amounts of silicon and manganese are contained in an iron-nickel-based alloy for the purpose of deoxidation. If they are excessively added, they are likely to be segregated. Therefore, silicon is defined to be not more than 1.0%, and manganese is defined to be not more than 1.2%.

Nickel: 30 to 50%

Nickel is an element significantly affecting the low thermal expansion property, because it acts to adjust a coefficient of thermal expansion, when the iron-nickel-based alloy thin strip is used as a lead frame, for example. If the amount of nickel is less than 30%, or more than 50%, an effect of lowering the coefficient of thermal expansion disappears. Therefore, the range of nickel content is defined to be 30 to 50%, preferably 40 to 45%.

The balance being essentially iron

Although the balance is essentially iron

except for the above described elements, impurities exist which are inevitably contained in the material in manufacturing. Additionally, 0.005% to 0.020% of a element for improving a free-cutting property such as sulfur may be contained in order to improve the press stamping property, or 0.0005 to 0.0050% of an element for improving a hot working property such as boron may be contained.

Brief Description of the Drawings

Fig. 1A shows a schematic top view illustrating a method for measuring a stress due to slitting.

Fig. 1B shows a schematic side view illustrating a method for measuring a stress due to slitting.

Detailed Description of the Invention

The present invention will be described in detail with the following examples.

An iron-nickel-based alloy plate for cold-rolling, which is used for a lead frame, was manufactured by vacuum melting, forging and hot-rolling. Then, annealing and cold-rolling were repeated to the iron-nickel-based alloy plate in a reducing atmosphere to manufacture an iron-nickel-based alloy sheet having a thickness of 0.125 mm and a width of 700 mm. An annealing temperature was 950°C, and a

reduction ratio of the final cold-rolling was 25%. A tension leveler was used by which a tension was applied in a range of 200 to 400 N/mm^2.

Then, iron-nickel-based alloy thin strips for lead frame materials are manufactured from this iron-nickel-based alloy sheet by the method according to the present invention and by conventional methods. Each sheet was slit into strips with a cooperating pair of upper and lower circular cutters. All slit widths of the strips were 100 mm.

In comparative examples thin strips were annealed after being slit from the sheet. In processes No.7 and No.8, three strips were annealed for removing a stress at the same time, while in process No.9, the strips were annealed one after another.

Table 1 shows a chemical composition and Table 2 shows manufacturing conditions.

Table 1

(mass%)

C	Si	Mn	Ni	S	Balance
0.007	0.11	0.45	40.89	0.003	Fe and inevitable impurities

Table 2

	No	Process	Annealing conditions					Slit conditions	
			Temperature (°C)	Time (sec)	Gas (*)	Tension (N/mm^2)	Furnace (**)	Diameter of Cutter (mm)	Overlap; Ratio to sheet thickness (%)
Method of the present invention	1	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	600	30	H_2	1.5	Vertical	250	15
	2	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	520	45	N_2	11.4	Horizon -tal	190	10
	3	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	650	25	AX	15.7	Vertical	250	25
	4	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	670	30	AX	1.5	Vertical	120	7

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Method of the present invention	5	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	580	60	AX	2.5	Vertical	190	35
	6	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	480	75	N_2	11.4	Horizon-tal	120	20
Comparative example	7	Final cold-rolling → Slitting → Annealing for removing stress → Leveler	600	20	AX	29.4	Horizon-tal	80	20
	8	Final cold-rolling → Slitting → Annealing for removing stress	620	30	AX	19.6	Horizon-tal	80	50
	9	Final cold-rolling → Slitting → Annealing for removing stress	650	30	AX	17.6	Horizon-tal	80	35

*) Notation of gas H_2: H_2 pure hydrogen, N_2: N_2 pure Nitrogen, AX: 75% H_2+25% N_2

**) Annealing for removing stress were preformed in a continuous annealing furnace.

After slitting, amounts of heat shrinkage were measured for the iron-nickel-based alloy thin strips for lead frame materials manufactured under each manufacturing condition.

In the measurement of the amounts of heat shrinkage, gauge marks were provided on each sample. A distance therebetween was 180 mm in the rolling direction, and it was measured with a toolmaker's microscope. After the sample was heated at 650°C for 10 minutes (in a hydrogen gas), the distance were measured again with the toolmaker's microscope to determine an amount of shrinkage. The amount of shrinkage was divided by the distance between the marks before heating and multiplied by 100 to represent an evaluation value.

An amount of stress due to the slitting was measured by providing incisions 4 for 150 mm in length by a wire cutter at positions of 1.5 mm distant from slit edges 2A and 2B of the iron-nickel-based alloy thin strip 1 for a lead frame material, and then placing the strip 1 after cutting on a surface plate 3 to measure a rise R of a tip of the slit edge 2A and 2B with a scale, as shown in Figs. 1A and 1B.

In order to measure the flatness, after cutting the sample for 500 mm in length, it was placed on the surface plate to measure the maximum rise (in millimeter) with a laser distance sensor.

Each six iron-nickel-based alloy thin strips

for lead frame materials which were slit from each sheet were measured. Table 3 shows the measurement results.

Table 3

	No	Process		Product characteristics			
				Amount of Heat shrinkage (%)	Amount of Stress (mm)		Flatness (mm)
					Edge A (2A)	Edge B (2B)	
Method of the present invention	1	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	1	0.021	4	8	0.08
			2	0.021	7	4	0.08
			3	0.020	8	3	0.10
			4	0.022	4	5	0.09
			5	0.021	9	7	0.06
			6	0.024	4	6	0.09
	2	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	1	0.027	8	10	0.07
			2	0.027	5	4	0.06
			3	0.028	9	8	0.08
			4	0.030	11	4	0.10
			5	0.029	9	7	0.07
			6	0.029	6	8	0.08
	3	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	1	0.025	3	6	0.10
			2	0.022	8	7	0.12
			3	0.024	2	8	0.15
			4	0.025	7	9	0.11
			5	0.020	5	4	0.10
			6	0.021	7	8	0.12

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Method of the present invention	4	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	1	0.011	9	12	0.15
			2	0.009	14	6	0.17
			3	0.012	7	10	0.12
			4	0.012	11	8	0.15
			5	0.009	8	6	0.16
			6	0.011	11	5	0.14
	5	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	1	0.015	10	10	0.12
			2	0.015	7	9	0.12
			3	0.016	11	8	0.14
			4	0.016	10	4	0.10
			5	0.014	7	12	0.14
			6	0.013	5	9	0.15
	6	Final cold-rolling → Tension leveler → Annealing for removing stress → Slitting	1	0.027	11	15	0.06
			2	0.029	12	7	0.08
			3	0.030	5	8	0.10
			4	0.030	9	14	0.08
			5	0.028	13	9	0.09
			6	0.028	12	10	0.10
Comparative Example	7	Final cold-rolling → Slitting→ Annealing for removing stress → Leveler	1	0.043	20	23	0.29
			2	0.041	25	20	0.31
			3	0.045	27	22	0.27
			4	0.048	18	27	0.29
			5	0.039	20	24	0.35
			6	0.049	25	19	0.27

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Compara-tive Example	8	Final cold-rolling → Slitting→ Annealing for removing stress	1	0.030	24	29	0.37
			2	0.035	28	23	0.39
			3	0.028	27	21	0.40
			4	0.029	22	28	0.41
			5	0.030	24	25	0.38
			6	0.027	26	24	0.47
	9	Final cold-rolling → Slitting→ Annealing for removing stress	1	0.027	23	27	0.48
			2	0.028	24	22	0.50
			3	0.030	20	25	0.52
			4	0.028	27	28	0.48
			5	0.033	27	20	0.47
			6	0.029	24	27	0.58

As shown in Table 3, the iron-nickel-based alloy thin strips for lead frame materials manufactured according to the method of the present invention have small amounts of heat shrinkage of not more than 0.03%.

In the comparative examples in which annealing for removing a stress is performed after slitting, the amounts of shrinkage are large in the process No. 7. This is because a high tension was applied in annealing for removing the stress, and an additional stress was introduced by a leveler.

In the process No. 8, some samples have amounts of heat shrinkage of not more than 0.03%, but lot-to-lot variations are large. This is because the tension can not be independently controlled for each strip when a plurality of strips are passed in the furnace at the same time.

In the process No. 9, lot-to-lot variations are relatively small because the strips are passed one after another in annealing for removing a stress. However, because the strips are annealed for removing the stress after slitting, the stress is released so that the flatness of the strip is deteriorated.

In the measurement of the stress due to the slitting, the iron-nickel-based alloy thin strips for lead frame materials manufactured under the slitting condition according to the present invention have small amounts of stress due to the slitting of not more than 15 mm.

With regard to the flatness, the flatness of not more than 0.2 mm is accomplished for a width of 100 mm according to the method of the present invention, while rises of 0.27 to 0.58 mm are generated in the comparative example. This is because there is no environmental constresst when a stress is released in each thin strip through a heat treatment after slitting, and thus the thin strip is undulated readily. Particularly, in a wide material such as having a width of 100 mm in this case, a notable difference of the flatness is seen.

The present invention has superior characteristics of low heat shrinkage and low stress due to the slitting, and therefore it can be applied to the applications using an iron-nickel-based alloy thin strip which is inevitably subjected to micro-fabrication.

CLAIMS:

1. A method for manufacturing an iron-nickel-based alloy thin strip used for lead frame materials or lead materials, wherein the method comprises:

straightening a finally cold-rolled sheet by a leveler;

then annealing the straightened sheet for a stress relief thereof in a continuous annealing furnace, at a temperature of not higher than 750°C; and

then slitting the sheet into strips.

2. The method according to claim 1, wherein a tension of not more than 20 N/mm^2 is applied to the sheet, when the sheet is annealed for stress relief in the continuous annealing furnace.

3. The method according to claim 1 or 2, wherein the sheet is annealed for stress relief at a temperature of not lower than 400°C.

4. The method according to anyone of the preceding claims, wherein the sheet is slit with a cooperating pair of upper and lower circular cutters, each circular cutter having a diameter of 750 times of a thickness of the iron-nickel-based alloy sheet to be slit.

5. The method according to anyone of the preceding claims, wherein the sheet is slit with a

cooperating pair of upper and lower circular cutters, and, wherein an overlap of the upper and lower circular cutters is 5 to 50 percent of the thickness of the iron-nickel-based alloy sheet to be slit.

6. The method according to anyone of the preceding claims, wherein the iron-nickel-based alloy consists of, by mass percent,

carbon: not more than 0.1 percent

silicon: not more than 10 percent

manganese: not more than 1.2 percent

nickel: 30 to 50 percent, and

the balance being essentially iron.