TITLE OF THE INVENTION

HEAT SHRINK BAND STEEL SHEET AND MANUFACTURING METHOD THEREOF

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a heat shrink band steel sheet and a method of manufacturing a heat shrink band steel sheet adaptable to a color cathode-ray tube of a television set and arranged to inwards clamp a panel of the cathode-ray tube.

DESCRIPTION OF PRIOR ART

Hitherto, a color cathode-ray tube of a television set or the like has a structure that electrons emitted from an electron gun are applied to a fluorescent member disposed on the internal surface of the panel portion to emit required light. To realize light emission, the inside portion of the tube composed of the panel and a funnel connected to the panel is made to be a high vacuum state having a pressure of 1.0×10^{-7} Torr so that movement of electrons is not obstructed by internal residual gas. When the inside portion of the tube is made to be the high vacuum state as described above, the surface of the panel is deformed into a concave shape because of the pressure of air.

If the surface of the panel is deformed, the position of the fluorescent member disposed on the inside of the panel is undesirably shifted. It leads to a fact that the position on the surface of the fluorescent member on which an electron

beam is made impact is relatively shifted. If the surface of the panel is deformed, color deviation sometimes takes place.

If the deformed surface of the panel cannot withstand air pressure, there arises a risk that an internal explosion takes place.

To prevent the foregoing problems, the color cathode-ray tube is provided with a heat shrink band. The heat shrink band is manufactured by forming a heat shrink band steel sheet into an elongated shape and disposed around the panel. The heat shrink band has an internal length somewhat shorter than the circumferential length of the panel at room temperatures.

The thus-formed heat shrink band is initially heated and expanded at about 500°C. The expanded heat shrink band is fitted around the panel. Substantially simultaneously with fitting of the heat shrink band, air is blown on the heat shrink band so that the heat shrink band is rapidly cooled. As a result of the rapid cooling process, the heat shrink band is contracted and caused to tightly clamp the outer surface of the panel.

As described above, the heat shrink band tightly clamps the outer surface of the panel to generate a tension with which deformation of the surface of the panel occurring attributable to air pressure can be corrected.

The heat shrink band has another function to reduce an influence of an external magnetic field including the

geomagnetism. That is, the heat shrink band is made of a material having a predetermined magnetic permeability to absorb the external magnetic field so as to prevent application of the magnetic field to the inside portion of the color cathode-ray tube.

A heat shrink band steel sheet of the foregoing type has been made of a mild steel sheet having a yield stress of about 24 kgf/mm^2. However, the heat shrink band, required to realize the tension for correcting the deformation of the surface of the panel occurring attributable to air pressure, must have a predetermined cross sectional area. Thus, the conventional heat shrink band for a 21-inch color cathode-ray tube has a weight of 700 g or heavier. As described above, the color cathode-ray tube for a television set suffers from a problem of excessively heavy weight because of the weight of the heat shrink band. To solve the above-mentioned problem, it might be feasible to use high tensile strength steel sheet having enough strength to reduce the thickness of the heat shrink band.

However, the magnetic shielding characteristic of the heat shrink band deteriorates in proportion to the reduction of the heat shrink band thickness. The reason for this lies in that the magnetic shielding characteristic of the heat shrink band is changed in accordance with the thickness and the magnetic permeability.

Thus, the heat shrink band must have raised magnetic permeability to compensate the reduced thickness. When the

weight of the heat shrink band is reduced by decreasing the thickness of the same, the magnetic permeability must be raised in addition to the necessity of strengthening the steel sheet for making the heat shrink band.

Since strengthening the heat shrink band steel sheet and raising of the magnetic permeability are generally contradictory to each other, they cannot simultaneously be achieved by the conventional method. What is worse, the magnetic shielding characteristic of the heat shrink band has not been investigated enthusiastically. As a result, there is no specific guideline to make the magnetic permeability to be an appropriate level to compensate the reduction in the thickness. It leads to a fact that the balance between the strength of the steel sheet and the magnetic permeability cannot easily be improved. That is, if the strength of the steel sheet is attempted to be enlarged to reduce the thickness of the heat shrink band in order to reduce the weight of the same, a heat shrink band having a satisfactory high magnetic permeability cannot be obtained. As described above, the conventional method suffers from a problem in that a heat shrink band steel sheet having a sufficiently reduced weight and satisfactory magnetic shielding characteristic cannot be obtained.

If a material having a high magnetic permeability and a satisfactory magnetic shielding characteristic is employed, the conventional method cannot realize a tension with which the deformation of the surface of the panel occurring due to

air pressure can be corrected because of unsatisfactory strength. Since no appropriate magnetic permeability with respect to the reduction in the thickness has been known, the balance between the strength of the material and the magnetic permeability cannot easily be improved.

On the other hand, methods of manufacturing a steel sheet having a tensile strength of about 65 kgf/mm^2 before a blackening process and a magnetic permeability of 600 or greater after the blackening process have been disclosed in Japanese Patent Laid-Open No. 58-45323 and Japanese Patent Laid-Open No. 59-171430. The foregoing steel sheet is attempted to serve as a steel sheet for inner magnetic shielding in the color cathode-ray tube. Thus, the steel sheet is arranged to some extent to satisfy required strength and the characteristic for magnetic shielding. The blackening process is also performed as annealing for improvement of the magnetic properties in such a manner that the steel sheet is heated to 550°C to 650°C for 10 minutes to 30 minutes. On the other hand, the heat shrink band is heated to, at most, 500°C for about 10 seconds. Therefore, if the above-mentioned steel sheet is employed to make the heat shrink band, only poor magnetic permeability of about 100 is obtained.

Methods of manufacturing an electrical steel sheet having high tensile strength for use in a rotor of a very high speed motor or the like has been disclosed in Japanese Patent Laid-Open No. 62-112723, Japanese Patent Laid-Open No.

64-225 and Japanese Patent Laid-Open No. 2-22442, the method being attempted to realize satisfactory strength and to prevent an iron loss. Although the above-mentioned methods are able to realize satisfactory strength and magnetic permeability, the cost of the slab cannot be reduced because several percents of Mn, Ni, Mo, W, Ti and Al must be added as the alloy elements. Moreover, addition of the alloy elements in the large quantity causes the slab to easily be cracked when a casting process is performed. What is worse, the edges will easily be cracked or the coil will easily broken. Thus, the manufacturing yield is unsatisfactory. If the above-mentioned problems are attempted to be solved, the continuous casting process cannot be performed and/or a warm rolling process must be performed. Thus, the productivity deteriorates and the manufacturing cost cannot be reduced. As described above, the above-mentioned manufacturing methods cannot solve the above-mentioned problems.

OBJECT AND SUMMARY OF THE INVENTION

In view of the foregoing, an object of the present invention is to provide a heat shrink band steel sheet which assure a tension sufficient to correct a panel surface deformation caused by air pressure and which has a satisfactory magnetic shielding characteristic even if the thickness of the heat shrink band is reduced, and a method for manufacturing such a heat shrink band steel sheet.

To achieve the above-mentioned object, the inventor of the present invention has energetically perform research and development. Thus, the inventor has found the following invention.

That is, when Si is used as alloying element of a material for making a heat shrink band steel sheet, the solution strengthening performance can be improved. Thus, the magnetic anisotropy can be reduced, causing the magnetic permeability to be raised. When the annealing condition is contrived when the heat shrink band is manufactured, the grain size of the steel sheet can be adjusted and the yield stress can be enlarged. When a cold rolling process with light reduction is performed for work hardening the steel sheet, the yield stress can be enlarged. The cold rolling process with light reduction deteriorates the magnetic permeability of the heat shrink band steel sheet. However, the present invention in which the annealing condition and the reduction ratio employed when the cold rolling process with light reduction is performed are appropriately combined with each other is able to satisfactorily prevent deterioration of the magnetic permeability even if the yield stress is enlarged.

According to one aspect of the present invention, there is provided a method of manufacturing a heat shrink band steel sheet, including the steps of: hot-rolling and cold-rolling the steel

containing elements in such a manner that C ≤ 0.005 wt%, 2.0 wt% ≤ Si ≤ 4.0 wt%, 0.1 wt% ≤ Mn ≤ 1.0 wt%, P ≤ 0.2 wt%, S ≤ 0.020 wt%, Sol.Al ≤ 0.004 wt% or 0.1 wt% ≤ Sol.Al ≤ 1.0 wt% and N ≤ 0.005 wt%; annealing the steel at 700°C to 900°C; and cold-rolling the steel with a reduction ratio of 3% to 15%. The method of manufacturing a heat shrink band steel sheet is able to manufacture the heat shrink band steel sheet having a structure that magnetic permeability μ satisfies $\mu \geq 250$ and yield stress YS satisfies YS ≥ 40 kgf/mm^2 after the steel has been heated and cooled after the cold rolling process with light reduction when the magnetic force of a magnetic field is 0.3 Oe.

Since the method of manufacturing a heat shrink band steel sheet according to the present invention is arranged in such a manner that the heat shrink band steel sheet is manufactured under the above-mentioned annealing condition and with the above-mentioned material, the manufactured heat shrink band steel sheet has a high magnetic permeability. Since the above-mentioned method is arranged in such a manner that the foregoing reduction ratio is employed in the cold rolling process with light reduction, the manufactured heat shrink band steel sheet has a large yield stress.

The manufactured heat shrink band steel sheet has the magnetic permeability μ satisfying the relationship as $\mu \geq$

250 and yield stress YS satisfies the relationship as YS ≥ 40 kgf/mm^2 after the steel has been heated and cooled after the cold rolling process with light reduction when the magnetic force of a magnetic field is 0.3 Oe as if the heat shrink band steel sheet is actually used. The method according to the present invention enables the high magnetic permeability to be realized when the external magnetic field is 0.3 Oe. Therefore, a heat shrink band steel sheet having a high magnetic permeability in a state where geomagnetism of about 0.3 Oe exists can be manufactured. Since the heat shrink band steel sheet according to the present invention has a large yield stress as described above, the thickness of the heat shrink band can be reduced. Thus, the weight of the heat shrink band steel sheet can be reduced.

According to a second aspect of the present invention, there is provided a heat shrink band steel sheet made using the above method.

According to a third aspect of the present invention, there is provided a heat shrink band made using the above method.

According to a fourth aspect of the present invention, there is provided a cathode ray tube having a heat shrink band steel sheet wound therearound.

According to a fifth aspect of the present invention,there is provided a cathode ray tube having a heat shrink band wound therearound.

According to a sixth aspect of the present invention, there is provided a television comprising a cathode ray tube.

Other features and advantages of the invention will appear more fully from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross sectional view showing an essential portion of a cathode-ray tube;

Fig. 2 is a perspective view showing the cathode-ray tube;

Fig. 3 is a graph showing the relationship between values of (t × μ) and amounts of drifts occurring attributable to the geomagnetism;

Fig. 4 is a graph showing the relationship between the amounts of restoration of the surface of the panel and the tensions of the heat shrink bands;

Fig. 5 is a graph showing the relationship among the quantity of Si, the yield stress and the magnetic

permeability;

Fig. 6 is a graph showing the relationship among the reduction ratios, the yield stress and the magnetic permeability; and

Fig. 7 is a graph showing the dependence of the magnetic permeability and the yield stress on the reduction ratio and the annealing temperatures.

DETAILED DESCRIPTION OF THE INVENTION

An embodiment of a heat shrink band steel sheet and manufacturing method thereof according to the present invention will now be described.

The heat shrink band steel sheet and manufacturing method thereof according to the present invention are employed when the heat shrink band steel sheet which is fitted to the outer surface of a panel forming a color cathode-ray tube of a television set is used to tightly clamp the outer surface of the panel.

The color cathode-ray tube having the heat shrink band which is manufactured by the method according to the present invention may be a CRT 1 structured as shown in Figs. 1 and 2. The CRT 1 has a panel 2, on which an image is displayed, and a funnel 3. The panel 2 and the funnel 3 are welded to each other by dint of frit glass (solder glass) so that a closed space is formed. The funnel 3 of the CRT 1 has a neck portion 3A having an end opposite to the portion of the funnel 3 which is welded to the panel 2, the neck portion 3A

having a diameter which is gradually reduced. An electron gun 4 is accommodated in the neck portion 3A.

Moreover, the CRT 1 has a fluorescent surface 5 formed on the inner surface of the panel 2 and an aperture grille 6 formed on the inside portion of the fluorescent surface 5. In addition, the CRT 1 has a frame 7 joined to the aperture grille 6 and an internal magnetic shield 8 disposed on the back of the frame 7.

In the CRT 1 having the above-mentioned structure, electron beams 9 emitted from the electron gun 4 are selected according to the color when the electron beams 9 are allowed to pass through slits formed in the aperture grille 6. Then, the electron beams 9 reach a landing point 10 of the fluorescent surface 5. Moreover, the inside portion of the CRT 1 formed by the panel 2 and the funnel 3 joined to the panel 2 is made to be a high vacuum state having pressure of about 1.0×10^{-7} Torr to permit free movements of electrons without any obstruction attributable to internal residual gas.

To make the inside portion of the CRT 1 is made to be the high vacuum state as described above, the pressure is reduced through the neck portion 3A of the funnel 3. The CRT 1 is provided with a heat shrink band 11 in order to prevent deformation of the front surface of the CRT 1 and to protect the CRT 1. The heat shrink band 11 is fitted to the outer surface of the panel 2 in such a manner that a predetermined tension can be generated by the heat shrink band 11. Note

that the heat shrink band 11 is usually fitted after the pressure has been reduced as described above.

The heat shrink band 11 corrects the deformation of the panel 2 occurring attributable to the difference between the vacuum pressure in the CRT 1 and the air pressure. If the heat shrink band 11 is not fitted, the panel 2 is undesirably deformed into a concave shape because the inside portion of the CRT 1 is made to be the high vacuum state. Since the heat shrink band 11 is fitted with a predetermined tension, the heat shrink band 11 inwardly applies predetermined pressure to the CRT 1. As a result, the heat shrink band 11 is able to correct the different between the vacuum pressure in the CRT 1 and the air pressure. Thus, the heat shrink band 11 prevents the deformation of the surface of the panel 2. The heat shrink band 11 as well as prevents internal explosion of the CRT 1. The heat shrink band 11 has another function to serve as a magnetic shield. Thus, the heat shrink band 11 is able to shield an external magnetic field even if the external magnetic field including the geomagnetism is applied to the CRT 1. As a result, the landing point 10 to which electrons emitted from the electron gun 4 is not deviated. Thus, a drift can be corrected and prevented in the CRT 1 so that color deviation is prevented.

The above-mentioned heat shrink band 11 is required to have a decreased thickness in order to reduce the weight while maintaining the realized magnetic shielding

characteristic. Since reduction in the thickness of the steel sheet forming the heat shrink band 11 and raising of the magnetic permeability of the steel sheet are generally contradictory to each other, an appropriate magnetic permeability corresponding to the thickness is required.

To obtain an appropriate magnetic permeability, three types of steel sheets having different balances between the thickness and the magnetic permeability were prepared, as shown in Table 1. The foregoing steel sheets were formed into heat shrink bands each having a width of 35 mm. Then, each heat shrink band was fitted to the panel of the 21-inch color cathode-ray tube so that the magnetic shielding characteristic was evaluated.

Table 1

Samples	Thickness t (mm)	Magnetic Permeability μ (emu)	t × μ
Conventional Material	1.6	233	373
Example (1)	0.8	333	266
Example (2)	0.8	133	106

magnetic Permeability μ: measured at the external magnetic field of 0.3 Oe after the steel sheet has been heated and cooled (500°C × 5s → AC)

The above-mentioned heat shrink bands 11 were fitted to the CRT 1 so that the magnetic shielding characteristic to be described later was evaluated.

The above-mentioned heat shrink band 11 were heated so as to be expanded, and then fitted to the outer surface of the surface of the panel 2. Substantially simultaneously with the fitting operation, the heat shrink band 11 is cooled and contracted so that the heat shrink band 11 tightly clamps the outer surface of the panel 2. The above-mentioned process is called a heat shrinking process. The amount of the heat expansion is enlarged in proportion to the temperature at which the heat shrinking process is performed. Thus, the amount of contraction is enlarged and thus an advantage can be realized to satisfactorily apply the tension. If the temperature is higher than 500°C, the steel sheet is excessively softened (recovery and recrystallization, and grain and precipitate coarsening) with heat. In this case, the yield stress is reduced excessively. Therefore, the temperature was determined to be 500°C. Since the circumferential length of the panel 2 is 1541.6 mm and the thermal expansion coefficient is 1.33×10^{-5}, the shortest length of the heat shrink band is obtained as follows:

$$1541.6/(1 + 1.33 \times 10^{-5} \times 500) = 1531.4$$

Since errors and manufacturing dispersion of the length

of the heat shrink band and the circumferential length of the panel 2 must be allowed, the shortest length was determined to be 1535.5 mm.

The magnetic shielding characteristic was evaluated in accordance with the amount of drift at the landing point for the electron beams caused by the geomagnetism. Specifically, the CRT 1 was turned by 360° in a state where the CRT 1 was applied with a vertical magnetic field of 0.35 Oe and a horizontal magnetic field of 0.3 Oe to measure the deviation (a landing error) of the landing point for the electron beams from a reference point. A peak-to-peak value was employed as the horizontal drift B_h. Moreover, a landing error occurring when the horizontal magnetic field was made to be 0 Oe and the vertical magnetic field was changed from 0 Oe to 0.35 Oe was employed as the vertical drift B_V.

Fig. 3 shows the relationship among the results of measured drifts of the landing errors and products ($t \times \mu$) of the thickness t (mm) of the steel sheets and the magnetic permeability μ (emu). Here, the magnetic permeability μ is defined as 0.3 Oe corresponding to the magnetic field applied when the amount of drift was evaluated. The magnetic permeability μ was measured after heating to 500°C for 5 seconds and the following cooling process were performed. As for the amount of drift of the landing error, a relative value obtained when the value of the conventional material was made to be 1 was evaluated.

As can be understood from Fig. 3, the horizontal drift B_h did not considerably depend upon the value of $t \times \mu$ in this investigation. Even if the value of $t \times \mu$ is reduced from 373, which is the value of the conventional material to 106 which is the value of the Example (2), a value of about 1.0, which is similar to that of the conventional material is maintained. On the other hand, the vertical drift B_v considerably depends upon the value of $t \times \mu$. To make the vertical drift B_v be the value similar to that of the conventional material, the value of $t \times \mu$ must be 200 or greater.

The magnetic permeability μ of the heat shrink band must arbitrarily be determined to correspond to the thickness of the heat shrink band in such a manner that the above-mentioned relationship is satisfied. However, the thickness of the heat shrink band must be 0.8 mm or smaller which is a half of 1.6 mm which is the thickness of the conventional material in order to reduce the weight to be a value not larger than the half of the conventional weight. In this case, the lower limit for the magnetic permeability μ is 250.

To reduce the thickness of the heat shrink band, the magnetic permeability must be an appropriate value. In addition, the yield stress of the steel sheet must have an appropriate value to correspond to the thickness of the steel sheet in order to correct the deformation of the surface of

the panel occurring attributable to the air pressure. The process for adjusting the yield stress will now be described.

The heat shrink band subjected to the heat shrinking process tightly and inwards clamp the panel 2. The applied tension generated by the heat shrink band corrects the deformation of the surface of the panel 2 occurring attributable to the air pressure. The amount of the foregoing correction will hereinafter be called an amount of restoration. The amount of restoration is defined as the position of the surface of the panel 2 after the heat shrink band 11 has been fitted in such a manner that the position of the surface of the panel 2 realized before the heat shrink band 11 is fitted is used as a reference. The relationship between the amount of restoration and the tension of the heat shrink band is shown in Fig. 4. The amount of restoration and the tension of the heat shrink band hold the substantially linear relationship which is expressed by the following equation:

$$T = 11 \times R$$

where T is a tension (kgf) of the heat shrink band and R is the amount (μm) of restoration.

The amount e (%) of strain provided for the heat shrink band attributable to the heat shrinking process will now be

described. Since the circumferential length of the panel 2 is 1541.6 mm and the length of the heat shrink band is 1535.5 mm, the amount of strain can be obtained by the following calculation:

$$e = ((1541.6 - 1535.5)/1535.5) \times 100 \fallingdotseq 0.4\%$$

Thus, the foregoing value corresponds to a plastic region of a stress-strain curve of the steel sheet. Therefore, the tension of the heat shrink band 11 can be estimated to be a value obtained by multiplying the cross sectional area of the heat shrink band 11 with the yield stress of the steel sheet. The relationship between the above-mentioned value and the amount of restoration is used so that the following relational expression between the yield stress of the steel sheet and the amount of restoration is obtained:

$$YS \times t \times w = 11 \times R$$

where YS is the yield stress (kgf/mm^2) of the steel sheet for making the heat shrink band which is measured after the steel sheet has been heated at 500°C for 5 seconds and then cooled to room temperature, t is the thickness (mm) of the steel sheet for making the heat shrink band, w is the width (mm) of the heat shrink band and R is the amount (μm) of

restoration.

The amount of restoration of the surface of the panel 2 must be an appropriate value in order to prevent the color deviation and internal explosion of the color cathode-ray tube. Specifically, it is preferable that the amount of restoration is 100 μm or greater. If the amount of restoration is smaller than 100 μm, the deviation of the landing point 10 for the electron beams and the amount of drift occurring attributable to the geomagnetism are enlarged. As a result, the color deviation becomes more critical. What is worse, the stress distribution acting on the surface of the panel 2 is made to excessively be nonuniform. In this case, the resistance of the color cathode-ray tube against explosion deteriorates. When the thickness of the heat shrink band 11 is attempted to be 0.8 mm or smaller and the weight of the heat shrink band is reduced to be a half or smaller, the relational expression between the yield stress and the amount of restoration causes the lower limit for the yield stress to be the following value:

$$YS = (11 \times R)/(t \times w) = (11 \times 100)/(0.8 \times 35) \fallingdotseq 40$$

Thus, a steel sheet having a yield stress not smaller than 40 kgf/mm^2 must be employed.

The amount of strain which is, in this embodiment,

provided for the heat shrink band 11 reaches the plastic region. If the yield stress of the steel sheet has a margin, the length of the heat shrink band may be elongated to obtain the appropriate tension in the elastic region.

As described above, it is preferable to employ the heat shrink band 11 arranged such that the magnetic permeability μ realized after the heating and cooling processes have been performed and when the magnetic field is 0.3 Oe is 250 or greater and the yield stress YS is 40 kgf/mm^2 or greater. Thus, the problems of the color deviation and the internal explosion can be prevented. Moreover, the thickness of the heat shrink band 11 can be reduced to be a half or smaller. Note that the reduction in the weight of the heat shrink band 11 is not limited to the reduction in the thickness. The thickness and width of the heat shrink band may arbitrarily be changed in accordance with the magnetic permeability and the yield stress of the steel sheet for making the heat shrink band 11 if the following relationship is satisfied:

$$t \times \mu \geq 200$$

With the heat shrink band steel sheet and manufacturing method thereof according to the present invention, the above-mentioned heat shrink band 11 can be manufactured.

The heat shrink band steel sheet and manufacturing method thereof according to the present invention include the

steps of hot-rolling and cold-rolling the steel containing elements in such a manner that C ≤ 0.005 wt%, 2.0 wt% ≤ Si ≤ 4.0 wt%, 0.1 wt% ≤ Mn ≤ 1.0 wt%, P ≤ 0.2 wt%, S ≤ 0.020 wt%, Sol.Al ≤ 0.004 wt% or 0.1 wt% ≤ Sol.Al ≤ 1.0 wt% and N ≤ 0.005 wt%; annealing the steel at 700°C to 900°C; and cold-rolling the steel with a reduction ratio of 3% to 15%. Note that expression "Sol.Al" means aluminum which is soluble in an acid.

The method according to the present invention uses Si as the alloying element and the combination of the annealing condition and the reduction ratio of the subsequent cold rolling are contrived. The contrivance will now be described. The relationship among quantity of Si, the yield stress and the magnetic permeability of the heat shrink band is shown in Fig. 5. The other elements forming the heat shrink band are as follows: C ≒ 0.0023%, Mn ≒ 0.25%, S ≒ 0.010%, Sol.Al ≒ 0.001% and N ≒ 0.0015%. When the heat shrink band was manufactured, Si was in various quantities mixed with the foregoing elements. Then, a continuous casting process was performed. Then, the steel sheet was hot-rolled and cold-rolled, and then annealed at 850°C for 60 seconds. Then, cold rolling was performed with the reduction ratio of 7% so that the thickness was made to be 0.8 mm. Thus, the heat shrink band was manufactured. The

thus-manufactured heat shrink band was heated to 500°C for five seconds. Then, the heat shrink band was cooled to room temperature to realize the condition under which the heat shrink band was actually used with the CRT 1. Then, the yield stress and magnetic permeability were measured. As can be understood from Fig. 5, both yield stress and the magnetic permeability are enlarged when Si is added. Thus, the satisfactorily large yield stress and the high magnetic permeability required for the heat shrink band can be obtained. Moreover, Si must be added by 2% or more to satisfy the magnetic permeability $\mu \geq 250$ and the yield stress $YS \geq 40$ kgf/mm^2 when the magnetic field is 0.3 Oe after the heating and cooling processes have been performed. If Si is added by 4% or more, coil breakage took place during the cold rolling process. Thus, Si is determined to be added by 2% or more to satisfy the magnetic permeability $\mu \geq 250$ and the yield stress $YS \geq 40$ kgf/mm^2 when the magnetic field is 0.3 Oe after the heating and cooling processes have been performed. To prevent coil breakage occurring during the cold rolling process, the upper limit for the quantity of Si must be 4%.

Then, the proper combination between the annealing temperature and the reduction ratio in the following cold rolling was examined.

Steel containing elements as follows was prepared by a

melting process: C ≒ 0.0035%, Si ≒ 2.78%, Mn ≒ 0.50%, P ≒ 0.013%, S ≒ 0.016%, Sol.Al ≒ 0.225% and N ≒ 0.0042%. The steel was continuously cast, and then hot rolled and cold rolled. Then, annealing and cold rolling with light reduction were performed so that a heat shrink band having a finishing thickness of 0.8 mm was obtained. Then, the heat shrink band was heated to 500°C for 5 seconds, and then cooled to room temperature. Thus, a condition under which the heat shrink band was actually used with the CRT 1 was realized. Then, the yield stress and magnetic permeability were measured.

Fig. 6 shows results of processes in which the annealing was performed at 800°C for 60 seconds, at 950°C for 60 seconds and the reduction ratio of the subsequent cold rolling process was varied. As can be understood from Fig. 6, the yield stress is enlarged in proportion to the rise in the reduction ratio in the cold rolling process. On the other hand, the magnetic permeability is lowered. However, the change in the magnetic permeability varies depending upon the annealing temperature. That is, when the annealing temperature is 800°C, reduction in the magnetic permeability occurring attributable to the enlargement of the reduction ratio is relatively small. When the annealing temperature is 950°C, the magnetic permeability is reduced considerably. Thus, when the annealing temperature is 800°C, the reduction ratio is made to be 3% to 15%. thus, the magnetic

permeability $\mu \geq 250$ and the yield stress YS $\geq$ 40 kgf/mm^2 when the magnetic field is 0.3 Oe after the heating and cooling processes can be satisfied. On the other hand, when the annealing was performed at 950°C, the foregoing requirements cannot be satisfied by the adjustment of the reduction ratio. It means a fact that an influence of the combination of the annealing temperature and the reduction ratio must be considered. Then, experiments were performed in such a manner that the combinations of the annealing temperatures and the reduction ratios were varied. Fig. 7 shows results of the experiments. Only when annealing was performed at 700°C to 900°C and then the cold rolling process was performed by 3% to 15%, magnetic permeability $\mu \geq 250$ and the yield stress YS $\geq$ 40 kgf/mm^2 when the magnetic field is 0.3 Oe after the heating and cooling processes were satisfied. The above-mentioned investigation was performed for steel samples having different composition. As a result, a fact was confirmed that an excellent result was obtained regardless of the composition of the steel if the combination of the annealing temperature and the reduction ratio satisfies the above-mentioned range. Since the annealing period of time does not determine the characteristic, any specification is not determined. To stabilize the characteristic and to prevent dispersion occurring due to the position in the coil, it is preferable that the time is 30

seconds or longer. On the other hand, it is preferable that the time is 300 seconds or shorter to save energy.

The other components and manufacturing condition will now be described.

Carbon (C) is an element which strengthens the heat shrink band 11. However, carbon is detrimental to magnetic permeability. To prevent the adverse influence, the upper limit must be 0.005%.

Manganese (Mn) must be added by 0.1% or more to improve ductility required for the hot rolling process. If manganese is added in a quantity exceeding 1.0%, the magnetic permeability deteriorates. Therefore, the upper limit must be 1.0%.

Phosphorus (P) is an element to strengthen the steel sheet. The phosphorus may be added as necessary. If the phosphorus is added in a quantity exceeding 0.2%, brittleness of the steel sheet cannot be prevented. In this case, a problem of breakage of coil occurs when the cold rolling process is performed. Therefore, the upper limit for the quantity of phosphorus must be 0.2%.

Sulfur (S) is detrimental to both ductility required for the hot rolling process and the magnetic permeability. Therefore, the quantity must be 0.020% or smaller.

Aluminum (Sol.Al) which is soluble in an acid forms AlN, causing grain refinement. Thus, the magnetic permeability deteriorates. To prevent the adverse influence, the quantity of Sol.Al must be 0.004% or smaller so that formation of AlN

is prevented. As an alternative to this, Sol.Al must be added by 0.1% or more to make AlN to sufficiently be coarse so that grain growth is not prevented.

Nitrogen (N) strengthens the steel sheet, similarly to carbon. However, nitrogen is detrimental to the magnetic permeability. To prevent the adverse influence, the upper limit must be 0.005%.

The other manufacturing condition following the melting process are not required if the following requirements are satisfied. Thus, the usual method may be employed. That is, the slab may be obtained by continuous casting or obtained by a cogging process performed after the ingot has been made. The hot rolling process may be performed in such a manner that a slab, the temperature of which has been lowered to room temperature, is again heated. As an alternative to this, a method may be employed in which the temperature of a slab cast continuously is not lowered and the slab is immediately hot-rolled. Another method may be employed in which the temperature of the slab cast continuously is lowered in a manner that the slab shall not be cooled down to room temperature and then the slab is again heated. When the slab is again heated, it is preferable that the slab is heated to a temperature not lower than 1050°C nor higher than 1300°C to prevent a scale loss and to reduce the load on the mill when the rolling process is performed. The finishing temperature in the hot rolling process may arbitrarily be determined to smoothly pass the steel sheet because the steel

sheet of the present invention has not α/γ transformation. It is preferable that the cooling temperature is not lower than 450°C nor higher than 750°C in view of realizing a satisfactory surface and shape condition of the steel sheet. The cold rolling process is performed after the hot rolling process and pickling process have been performed. It is preferable that the reduction ratio is the usual range between 30% to 90%. Although the hot-rolled steel sheet is not required to be annealed before the cold rolling process, the annealing process may, of course, be performed.

Examples

The heat shrink bands were manufactured by the method of manufacturing the heat shrink band according to the present invention. To make comparison with the above-mentioned heat shrink bands according to the examples of the present invention, heat shrink bands according to comparative examples were manufactured.

Initially, the composition was varied as shown in Table 2 so that steel samples A to G were manufactured.

Table 2

Steel Samples	C	Si	Mn	P	S	Sol.Al	N
A	0.0027	1.89	0.37	0.035	0.005	0.274	0.0022
B	0.0046	2.15	0.88	0.026	0.017	0.002	0.0018
C	0.0021	2.52	0.44	0.134	0.012	0.811	0.0026

D	0.0029	2.84	0.67	0.023	0.008	0.547	0.0015
E	0.0036	3.17	0.26	0.012	0.005	0.320	0.0044
F	0.0015	3.45	0.31	0.008	0.003	0.118	0.0034
G	0.0023	3.87	0.15	0.010	0.003	0.232	0.0023

The foregoing steel samples A to G were obtained by a melting process, and then continuously cast. Then, slabs were cooled to room temperature, and then again heated to 1200°C. Then, the steel sheets were hot-rolled in such a manner that the finishing temperature was 820°C and the coiling temperature was 680°C so that the thickness of each sample was made to be 3.2 mm. The thus-obtained hot-rolled steel sheets were pickled, and then cold-rolled. Then, the sample steels were annealed at various temperatures for 90 seconds, after which the steel sheets were cold-rolled with various reduction ratios. As a result, steel sheets each having a thickness of 0.8 mm was obtained. To realize the condition under which the heat shrink band was actually used, the foregoing steel sheets were heated to 500°C for 5 seconds, and then air-cooled to room temperature. Then, the yield stress was measured in conformity with JIS Z 2241 and the DC magnetic characteristic (the magnetic permeability when the magnetic field was 0.3 Oe and the coercive force when the steel sheets were magnetically excited to 0.5T) was measured in conformity with JIS C 2504. The foregoing steel sheets were formed into heat shrink bands each having a width of 35 mm and a length of 1535.5 mm (partially 1537.9 mm).

Then, each heat shrink band was heat-shrunk around the panel of the cathode-ray tube at a temperature of 500°C, and then the 21-inch cathode-ray tube was assembled. Then, the magnetic shielding characteristic and the amount of restoration of the surface of the panel were measured. As described above, the magnetic shielding characteristic was evaluated by measuring the relative values of the horizontal drift B_h and the vertical drift B_v of the landing point occurring attributable to the geomagnetism with respect to the value of the conventional heat shrink band.

The evaluated factors of the steel sheets are shown in Table 3, the factors being the yield stress, magnetic permeability, coercive force, horizontal drift B_h and vertical drift B_v of the landing point, the amount of restoration of the surface of the panel after the 21-inch cathode-ray tube was assembled. Moreover, sample steels, annealing temperature and the reduction ratio when cold rolling process was performed are shown in Table 3.

Table 3

No.	Steel	Annealing Temperature (°C)	Reduction ratio (%)	YS (kgf/mm^2)	μ (emu)	Hc (Oe)
1	A	730	12	51.2	123	2.73
2		780	5	34.9	285	1.91
3		870	8	38.3	199	2.60
4	B	720	3	42.6	573	1.64

5		750	10	50.5	282	1.81
6		880	15	52.8	267	1.84
7		750	1	33.1	397	1.37
8	C	720	13	58.4	265	1.72
9		835	7	45.6	315	1.75
10		890	3	43.7	562	1.52
11		675	13	59.7	133	2.70
12	D	715	12	60.1	302	1.85
13		805	8	52.8	417	1.56
14		885	4	41.6	512	1.40
15		885	2	35.3	425	1.47
16	E	725	15	64.4	261	1.83
17		825	7	51.6	443	1.33
18		875	5	43.5	457	1.45
19		925	5	38.2	226	2.21
20	F	730	5	51.3	452	1.38
21		775	8	57.7	411	1.42
22		880	14	60.6	256	1.92
23		730	17	67.3	213	3.01
24	G	710	3	47.5	651	1.12
25		835	10	59.6	343	1.44
26		885	13	61.2	280	1.66
27		680	10	64.0	202	2.53

No.	Drift Ratio of Landing Point		Amount of Restoration (μm)	Remarks
	Horizontal Drift B_h	Vertical Drift B_v		
1	1.07	1.32	130	Comparative Example

2	1.04	1.01	87	Comparative Example
3	1.05	1.12	96	Comparative Example
4	1.00	0.96	109	Example
5	1.03	1.01	126	Example
6	1.03	1.02	133	Example
7	1.01	0.99	82	Comparative Example
8	1.03	1.02	143	Example
9	1.03	1.00	116	Example
10	1.00	0.97	111	Example
11	1.06	1.29	152	Comparative Example
12	1.03	1.00	146	Example
13	1.02	0.99	138	Example
14	1.00	0.98	105	Example
15	1.01	0.98	86	Comparative Example
16	1.03	1.02	118	Example
17	1.00	1.02	130	Example
18	1.00	1.02	112	Example
19	1.04	1.10	95	Comparative Example
20	1.00	1.02	127	Example
21	1.01	1.00	142	Example
22	1.03	1.03	149	Example
23	1.06	1.10	171	Comparative Example
24	0.98	0.95	121	Example
25	1.02	1.00	145	Example

26	1.03	1.02	121	Example
27	1.06	1.12	164	Comparative Example

Length of Band: E-16, G-26: 1537.9 mm
The Other Samples: 1535.5 mm

Steel sheets according to the examples having the composition of the steel, the annealing temperature and the reduction ratio when the cold rolling process was performed resulted satisfactory yield stress of YS ≥ 40 kgf/mm^2 and the magnetic permeability $\mu \geq 250$. The horizontal drift B_h and the vertical drift B_v were 0.95 to 1.03 which were about 1.0. Also the amount of restoration of the surface of the panel was 100 μm or larger. The obtained values satisfied the values required for the cathode-ray tube. On the other hand, the steel sheets according to the comparative examples had the compositions, the annealing temperature and the reduction ratio when the cold rolling process with light reduction was performed, any one of which did not satisfy the scope of the present invention. The yield stress or magnetic permeability of the comparative examples cannot satisfy the required value. The amount of drift (the horizontal drift B_v) of the landing point was in a range from 1.1 to 1.3 which was an excessively large value. Moreover, the amount of restoration of the surface of the panel was smaller than 100 μm. Thus,

the required values for the cathode-ray tube cannot be satisfied. As described above, the heat shrink band steel sheet and manufacturing method thereof according to the present invention enable to obtain a heat shrink band steel sheet having a large yield stress and a high magnetic permeability to be manufactured. Thus, a satisfactorily high tension can be obtained from the heat shrink band steel sheet and a sufficient magnetic shielding characteristic can be realized. Thus, a heat shrink band steel sheet can be manufactured which is free from the problem of the color deviation and risk of the internal explosion and which is capable of reducing the weight of the cathode-ray tube.

Although the invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form can be changed in the details of construction and in the combination and arrangement of parts without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. A method of manufacturing a heat shrink band steel sheet, comprising the steps of:

hot-rolling and cold-rolling the steel containing elements in such a manner that $C \leq 0.005$ wt%, 2.0 wt% $\leq Si \leq$ 4.0 wt%, 0.1 wt% $\leq Mn \leq$ 1.0 wt%, $P \leq 0.2$ wt%, $S \leq 0.020$ wt%, Sol.Al ≤ 0.004 wt% or 0.1 wt% $\leq$ Sol.Al $\leq$ 1.0 wt% and $N \leq 0.005$ wt%;

annealing the steel at 700°C to 900°C; and

cold-rolling the steel with a reduction ratio of 3% to 15%, wherein

magnetic permeability μ satisfies $\mu \geq 250$ and yield stress YS satisfies YS $\geq$ 40 kgf/mm^2 after the steel has been heated and cooled after the cold rolling process when the magnetic force of a magnetic field is 0.3 Oe.

2. A heat shrink band steel sheet made using the method of claim 1.

3. A heat shrink band made using the method of claim 1.

4. A cathode ray tube having a heat shrink band steel sheet according to claim 2, wound therearound.

5. A cathode ray tube having a heat shrink band according to claim 3, wound therearound.

6. A television, comprising a cathode ray tube according to claim 4 or 5.

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