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(19)

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(54) METHOD OF PRODUCING SOFT THIN STEEL SHEET BY CONTINUOUS ANNEALING

(71) We, TOYO KOHAN COMPANY LIMITED, a body corporate organised under Japanese law of 4—3 Kasumigaseki 1-Chome, Chiyoda-Ku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of producing soft low carbon thin steel sheet of particular application in the production of soft tin plate and black plate.

There are two types of annealing processes for the annealing of cold rolled low carbon steel strip. One is a continuous annealing process and the other is a box annealing process.

The continuous annealing process was originally developed for the production of steel strip for tin plate and black plate.

Tin plate and black plate are used for various purposes, and plates of different tempers are used according to the properties required in the finished article.

According to Japanese Industrial Standard (hereinafter referred to as "JIS") G3303—1969 "Tin plate and Black plate", the temper of tin plate and black plate is best designated by the numerical value of the Rockwell 30T hardness (HR 30T). It points out that the term "temper" when applied to tin plate and black plate does not indicate any single mechanical property, but that the Rockwell 30T hardness test value is chosen as one of the most effective guides of interrelated mechanical properties.

Furthermore, in A 623—1973 of the American Society for Testing and Materials Standard (hereinafter referred to as "ASTM"), the following is said of the term "temper" "7.1 Single-Reduced Tin Mill Product, Temper—the term temper when applied to single-reduced tin mill products summarizes a combination of interrelated mechanical properties. No single mechanical test can measure all the various factors which contribute to the fabrication characteristics of the material. The Rockwell 30T hardness value has come into general use as a quick test which serves as a guide to the properties of the plate".

The temper of tin plate and black plate is thus designated by the numerical value of the Rockwell 30T hardness and this numerical value serves as a guide in the production of tin plate and black plate. The temper ranges of tin plate and black plate, represented by the Rockwell 30T hardness values for commercial production are divided into seven classifications in the JIS as shown in Table I which follows. The classification of the temper according to the ASTM is similar to that shown in Table I but T—2½ is missing. In Table I, tin plate or black plate of tempers T—1 and T—2 is extremely soft and is therefore utilized for severe forming. Tin plate or black plate of tempers T—4, T—5, T—6, T—4—CA, T—5—CA, T—6—CA is utilized when stiffness and hardness is especially required.

Tin plate with temper T—2½ and T—3 properties are most suitable for the production of can bodies and can closure ends as well as for various other purposes. T—2½ and T—3 materials are used on the largest scale.

TABLE I

Temper values of tin plate according to the JIS

Box annealing process		Continuous annealing process	
Temper designation	Aim HR 30T	Temper designation	Aim HR 30T
T – 1	49 ± 3		
T – 2	53 ± 3		
T – 2½	55 ± 3		
T – 3	57 ± 3		
T – 4	61 ± 3	T – 4 – CA	61 ± 3
T – 5	65 ± 3	T – 5 – CA	65 ± 3
T – 6	70 ± 3	T – 6 – CA	70 ± 3

However, tin plate or black plate with temper T—2½ or T—3 properties has not yet been produced by a conventional continuous annealing process but only by a box annealing process (viz. Table I).

Steel strip for black plate is cold rolled to reduce the thickness by more than 80% Steel strip after cold rolling is very hard, has low ductility and a fibrous structure. It is therefore necessary to anneal the cold rolled strip to change the crystal structure, cause grain growth, convert the fibrous structure into a granular structure, and give softness and workability.

In the box annealing process, coils of steel strip are piled into one or more stacks inside an inner container filled with a slightly reducing gas atmosphere and surrounded by a Bell-type heating furnace which heats the inner container. The box annealing heat cycle, i.e. the heating process, the soaking process and the cooling process together last several days.

Deformation of the steel strip and furthermore annealing stickers sometimes occur during box annealing. These defects lead to steel strip of inferior shape and also to a low product yield. Furthermore, box annealed products show a considerably variation in their mechanical properties because of the localized heat application and the non-uniformity of heat distribution within coils and between coils. However, the long heating and soaking time in the box annealing cycle lead to an appropriately large grain size and the long cooling time leads to a nearly complete precipitation of carbon and nitrogen dissolved in the ferrite matrix during soaking. Consequently, box annealed products are soft and have excellent formability as well as reasonably low tendency to ageing due to low dissolved carbon and nitrogen content.

A continuous annealing furnace for tin plate is divided into four main zones, a heating zone, a soaking zone, a slow cooling zone and a fast cooling zone. The steel strip passes around a number of rolls positioned at the top and bottom of each zone. The cold rolled steel strip is fed from a pay-off reel to a cleaning section where rolling lubricants are removed and then runs between the upper and bottom rolls in strand. The steel strip is then recoiled at room temperature after the whole cycle of heating, soaking, slow cooling and fast cooling. The whole process takes only a few minutes.

Throughout this annealing process the strip is protected from oxidation by a protective gas atmosphere. The continuously annealed product shows uniform mechanical properties because of the uniformity of heat distribution throughout the steel strip. Furthermore the tension on the strip in the furnace section results in a product of superior shape. In addition products can be produced in a short time by continuous annealing. However, grain growth in the course of recrystallization is insufficient because of the very short heating time and soaking time. Moreover, carbide and nitride do not precipitate sufficiently. Nearly all the carbon and nitrogen dissolved in the ferrite matrix during the soaking period remain in a supersaturated solid solution after annealing because of the extremely short cooling time compared with that in box annealing. Consequently, continuously annealed steel strip has adequate strength but has a slightly poorer workability and shows a tendency to ageing.

JIS lists type MR steel and type MC steel as representative of the raw materials for tin plate and black plate. The chemical compositions of cast type MR and MC steels are shown in the following Table II.

TABLE II

Chemical composition of base-metal steel

Base-metal Steel type	Cast chemical composition, max., %					
	C	Si	Mn	P	S	Cu
MR	0.13	0.01	0.60	0.020	0.050	0.20
MC	0.13	0.01	0.70	0.150	0.050	0.20

Type MR steel is a normal low carbon steel, and type MC steel is a low carbon steel rephosphorized in order to increase its strength. Black plate with temper T—1, T—2, T—2½ or T—3 is usually produced from type MR material using the box annealing process. On the other hand, black plate with temper T—4, T—5 or T—6 is usually produced from type MC steel or type MR steel renitrogenized with a minimum of 0.007% nitrogen. The continuous annealing process is suited to the production of black plate having good stiffness together with high strength. Type MC steel or type MR steel renitrogenized with a minimum of 0.007% nitrogen has been used to produce black plate with temper T—6—CA or T—5—CA using the continuous annealing process, and type MR steel to produce black plate with temper T—5—CA or T—4—CA. However, it has not heretofore been possible to produce black plate with temper T—2½ or T—3 by a conventional continuous annealing process.

Recently new techniques have been developed in applying the continuous annealing process to the production of normal cold rolled steel sheet thicker than tin plate gauge.

In these new developments the steel strip is held at some intermediate temperature after or in the course of cooling from the recrystallization temperature to promote the precipitation of carbide dissolved in the iron matrix at the recrystallization temperature thereby promoting a softening of the iron matrix. This treatment for the promotion of softening by the precipitation of carbides is called "overageing treatment" or "shelf-treatment".

Thus, for example, Japanese Patent Application No. Sho 49—35218 describes a method of producing low carbon steel strip having a low yield strength, a high Lankford's r value, and a good conical cup value by a continuous annealing process. Raw materials suitable for this process have a low manganese content (≦0.30%), a low nitrogen content (≦20 ppm) and should also satisfy the following formula

$$0 \leqq (\text{Mn}\%) - \frac{\text{atomic weight of Mn}}{\text{atomic weight of O}} \times (\text{O}\%) - \frac{\text{atomic weight of Mn}}{\text{atomic weight of S}} \times (\text{S}\%) \leq 0.15$$

The hot steel strip is coiled at temperatures of from 600—800°C after hot-strip rolling, is heated and soaked to effect recrystallization and then undergoes the overageing treatment in a continuous annealing line after cold-rolling. German Offenlegungsschrift 2,064,487 relates to the same process but includes the restriction that the manganese content is 0.25% and has no restriction on the nitrogen content.

Japanese Patent Specification No. Sho 49—1968 describes a second method which is as follows: Cold rolled low carbon steel strip is rapidly cooled to below 200°C with a cooling rate of more than 20°C/sec when the soaking temperature is lower than the

A_1 point. When the soaking temperature is higher than the A_1 point, the cold rolled low carbon steel strip is slowly cooled to just below the A_1 point with a cooling rate of less than 20°C/sec and is then rapidly cooled to below 200°C with a cooling rate of more than 20°C/sec. After rapid cooling, the cold rolled low carbon steel strip is re-heated to an overageing temperature and kept at this temperature for a few minutes (3—5 minutes in the Examples). A low carbon steel strip having a low yield strength and excellent elongation is obtained.

Japanese Patent Application No. Sho 47—26313 describes a third method in which a carbon steel ingot ($0.02\% \leqq C \leqq 0.10\%$) is rolled to a slab, is hot-strip rolled and coiled at ambient temperature or at higher temperature (above 630°C), and is then cold rolled. The cold rolled low carbon steel strip is heated to a temperature between the recrystallization temperature and 850°C in a continuous annealing furnace, and is then slow cooled to a temperature in the range from 600°C to the A_1 point, and is finally rapidly cooled to ambient temperature with a cooling rate of from 200°C/sec—10,000°C/sec. The steel strip rapidly cooled to room temperature is re-heated to a temperature of from 300°C to 530°C and is kept for more than 10 seconds at this temperature. Low carbon steel sheet having excellent drawability and a low tendency to ageing can be efficiently produced by this continuous annealing process and its drawing and ageing properties are said to be equal to or better than box annealed products.

The newly developed continuous annealing methods mentioned above enable soft steel strip with excellent workability to be produced by continuous annealing. However, these methods involve more than two additional stages including overageing and are thus costly to carry out. In addition the continuous annealing equipment used is complicated and the length of the whole line is much longer than the length of the conventional continuous annealing line for tin plate and black plate. The disadvantages of these new processes are thus as follows:

(1) There are severe restrictions on the chemical composition of the steel to be treated;
(2) Hot-coiling at considerably higher temperatures after hot-strip rolling is required;
(3) An "overageing treatment" is necessary;
(4) The overageing time is long; and
(5) Rapid cooling prior to the overageing treatment is necessary.

Furthermore, steel strip for tin plate and black plate must be very thin, and therefore a reduction by cold rolling of more than 80% is needed even when thin (2.0 mm thick) hot-rolled steel strip is used. Consequently, the steel strip for tin plate or black plate produced is somewhat inferior from the point of view of workability after annealing to conventional cold rolled steel sheet which is cold rolled with a reduction of from 60 to 70%.

After annealing, black plate is temper rolled and electroplated in an electrolytic tinning line followed by subsequent heating to above 232°C in a "flow brightening" step. Alternatively the black plate is dipped into molten tin at a temperature of more than 300°C in a hot-dip process. Thus, after annealing, the steel strip is strained and then heated during the tin plating process. Tin plate products are therefore strain-aged and hardened and consequently have an inferior workability to that in the "as annealed state".

There are thus difficulties in the production of extremely soft tin plate having temper T—1 or T—2 properties even by the newly developed continuous annealing processes for thicker steel sheet mentioned above with conventional low carbon steel strip. According to the Journal of the Iron and Steel Institute of Japan Vol. 60 (1974) No. 4, S 331, cold-rolled type MR steel strip for tin plate (0.32 mm thick) having been subjected to a reduction of more than 80%, continuously annealed as in Japanese Patent Application No. Sho 47—26313, temper rolled with an elongation of 1.5% and then artificially aged by a heat cycle similar to "flow-brightening" in an electrolytic tinning process yields a product having temper T—2½. It therefore appears that these new continuous annealing processes for thicker cold rolled steel strip utilizing overageing treatments can only be used for the production of tin plate as soft as temper T—2½ at best.

There is thus a need for a new process for the production of soft tin plate and black plate having temper T—3 or T—2½ properties which can be used on most of the conventional raw materials for tin plate and black plate.

According to the present invention we provide a method for the production of soft thin steel sheet comprising heating a steel strip, which has been hot rolled and then cold rolled, to a soaking temperature in the range from the recrystallization temperature of the steel to 900°C in a continuous annealing furnace, holding the steel strip at that temperature for a short time, slowly cooling to about 500°C and then cooling at a substantially faster rate to ambient temperature, said steel strip containing up to 0.05% carbon, up to 0.50% manganese, up to 0.025% sulphur, up to 0.0030% nitrogen, up to 0.012% phosphorus and optionally chromium and/or vanadium, the balance (except for incidental constituents and impurities) being iron and the manganese, oxygen and sulphur contents satisfying the following relationship

$$\left\{(\mathrm{Mn}\%)-\frac{55}{16}(0\%)\right\}\Big/_{(\mathrm{S}\%)} \geqslant 20$$

The continuous annealing cycle used includes a conventional continuous annealing cycle for tin plate stock.

In the present invention, coiling at high temperature after hot-strip rolling is not essential and a very long furnace for overageing is also unnecessary. It is thus possible to use a conventional continuous annealing line for tin plate and black plate without any major adjustment. Therefore the present invention is particularly appropriate for continuously annealing steel strip for tin plate and black plate.

The method according to the invention will now be described in greater detail with reference to the following drawings in which

Fig. 1 is a schematic representation of a conventional continuous annealing line commercially used to anneal steel strip for tin plate and black plate;

Fig. 2 is a time/temperature diagram showing a continuous annealing heat cycle A for tin plate or black plate;

Fig. 3 is a diagram showing the relation between [Mn]/S (as herein defined) in the steel strip and the Rockwell 30T hardness of the final tin plate product; and

Fig. 4 is a diagram showing the relation between the phosphorus content of steel strip and the Rockwell 30T hardness of the tin plate product.

In the conventional continuous annealing line represented in Figure 1, a cold rolled steel strip 8 is fed from a pay-off reel 1, through a cleaning section 2 to the annealing furnace which comprises a heating zone 3, a soaking zone 4, a slow cooling zone 5 and a fast cooling zone 6. The strip 8 from the furnace is re-coiled at ambient temperature by a re-coiler 7.

Inside the furnace the steel strip 8 runs between and around rollers located at the top and the bottom of each treatment zone. The total length of the steel strip stored in each zone is calculated from three factors; the diameters of the top and bottom rolls, the distance from the top rolls to the bottom rolls and the number of passes (number of strands). An annealing cycle in a continuous annealing line is, in practice, determined by the temperature in each zone, the operating speed and the length of the cold rolled steel strip stored in each zone. The ratio of the time in seconds taken for the steel strip to pass through each of the said four zones is constant and independent of the operating speed of the continuous annealing line.

The cycle A in Fig. 2 shows an annealing cycle in a conventional industrial continuous annealing line used in the manufacture of tin plate and black plate (this line being hereinafter referred to as No. 1 CAL) with the following conditions, soaking temperature: 730°C, operating speed: 366 m/min (1200 fpm). This No. 1 CAL line has a heating zone with 10 passes, a soaking zone with 8 passes, a slow cooling zone with 10 passes and a fast cooling zone with 10 passes. In the operation shown as cycle A in Fig. 2, the steel strip is heated from room temperature (point a in Fig. 2) to 730°C in 25 seconds during its passage through the heating zone (point b in Fig. 2), soaked at this temperature for 20 seconds (point c in Fig. 2), slow cooled to 480°C in 25 seconds at a cooling rate of 10°C/sec (point d in Fig. 2) and then fast cooled to room temperature in 25 seconds at a cooling rate of about 19°C/sec. (Point e in Fig. 2). In this cycle, the strip is cooled in about 20 seconds from 550°C to 250°C, and the total annealing time (i.e. the total time for heating, soaking and cooling including any overageing), is 95 seconds. No. 1 CAL lines are operated commercially with a speed in the range from 458 m/min (1500 fpm) to 305 m/min (1000 fpm); and the corresponding cooling times from 550°C to 250°C are in the range from 16 to 24 seconds respectively and the total times for annealing are from 76 to 114 seconds respectively. A normal continuous annealing cycle for black plate according to the method according to the invention has the following characteristics; (1) total annealing time within 2 minutes and (2) time needed to cool from 550°C to 250°C: within 30 seconds. The cycle A shown in Fig. 2 is a typical example of this category.

We have carried out the following studies in which cold rolled steel strip of various composition ranges was annealed by cycle A and other similar cycles falling within the present invention. The tests were carried out using both the model testing apparatus hereinbefore described and the industrial continuous annealing lines No. 1 CAL and No. 2 CAL for tin plate and black plate. The steel strip after annealing was temper rolled by 1.5%, electrolytically tinned in a sulfonic acid bath and then flow melted (heated to above the melting point of tin) to bring the steel strip to a fully aged state. Sample discs are cut from the steel strips, and their Rockwell 30T hardness values were tested using the Rockwell T superficial hardness tester.

Fig. 3 shows the relation between the Rockwell 30T hardness (Rockwell T superficial hardness: HR 30T) of tin plate products and the value of

$$\left\{ (\mathrm{Mn}\%) - \frac{55}{16} (0\%) \right\} \Big/ (\mathrm{S}\%)$$

(this formula being hereinafter referred to as [Mn]/S) calculated from the composition of the steep strip. Low carbon rimmed or capped steel strip was used. Zone A in Fig. 3 contains the Rockwell 30T hardness values of tin plate manufactured using cycle A (in Fig. 2) having carbon content ≦0.05%, manganese content ≦0.50%, nitrogen content ≦0.0030% and phosphorus content ≦0.012%.

In the formula

$$[\mathrm{Mn}]/\mathrm{S} = \left\{ (\mathrm{Mn}\%) - (\frac{55}{16})\ (0\%) \right\} \Big/ (\mathrm{S}\%)$$

(Mn%), (0%) and (S%) are weights of manganese, oxygen and sulphur contained in the steel strip respectively, and [Mn] represents the quantity of manganese in the steel strip that is available for combination with sulphur to form manganese sulphide. The broken line X correspond to the centres of the temper T—3 range. As shown in Fig. 3, a clear connection between the Rockwell 30T hardness of tin plate and the value [Mn]/S can be recognised in zone A. With increase in the value of [Mn]/S the Rockwell 30T hardness is reduced. In the region in zone A where [Mn]/S ≥ 20, even those samples in the upper parts of the region fall within the temper T—3 grade, and so it becomes possible to produce soft tin plate having temper T—3 properties from this material. Point 3a in Fig. 3 is the Rockwell 30T hardness value of tin plate with 0.009% vanadium annealed using cycle A of Fig. 2. Point 4a in Fig. 3 is the Rockwell 30T hardness values of tin plate with 0.19% chromium annealed using cycle A of Fig. 2. From these results it is clear that a small amount of a carbide forming element e.g. chromium or vanadium in the steel is effective in case of annealing using cycle A of Fig. 2 to lower the Rockwell 30T hardness by 2—3 units over that of normal steel without special elements similarly treated.

Fig. 4 shows the relation between the phosphorus content and the Rockwell 30T hardness of tin plate. Zone A contains the Rockwell 30T hardness values of tin plate produced by annealing steel strip with carbon content ≦0.05%, managanese content ≦0.50%, the value of [Mn]/S ≥ 20 and nitrogen content ≦0.0030% using cycle A of Fig. 2. The broken line X corresponds to the centre of the temper T—3 range. As shown in Fig. 4 a clear relationship exists between the Rockwell 30T hardness of tin plate and its phosphorus content. As the phosphorus content decreases the Rockwell 30T hardness decreases in zone A. In zone A, the reduction in the Rockwell 30T hardness with the decrease in the phosphorus content is particularly remarkable. Zone A′ contains the Rockwell 30T hardness values of tin plate annealed using cycle A of Fig. 2 using steel strip having a higher carbon content (>0.05%) and a phosphorus content below 0.012%, and it can be seen that the hardness values are much higher than those in zone A. It is therefore necessary to restrict the composition of the steel to [Mn]/S ≥ 20, P ≦ 0.012% and C ≦ 0.05% in order to guarantee the formation of soft tin plate having temper T—3 properties by means of cycle A of Fig. 2.

When the carbon content in the steel strip is more than 0.05%, the Rockwell 30T hardness of the product rises as shown into the region of zone A′ of Fig. 4. Hence the carbon content must not be higher than 0.05%.

A low sulphur content is also desirable because the sulphur segregates remarkably in the steel ingot and retards the recrystallization during the annealing of cold rolled strip. Thus, an upper limit on the sulphur content of 0.025% is set, this figure representing a compromise between the requirement of a good quality product and the commercial limitation set by the cost of removing sulphur from molten steel.

A low nitrogen content is also preferred and the nitrogen content is thus restricted to $\leqq$0.0030% considering the use of normal low carbon MR steel strip. The manganese content in the steel strip is restricted to $\leqq$0.50% for the same reason. The higher the oxygen content in the steel strip the lower the value of the expression

$$(\mathrm{Mn}\%) - \frac{55}{16} \times (0\%),$$

and hence also the lower the value of [Mn]/S. It is therefore desirable to reduce the oygen content as far as possible.

As shown in Figs. 3 and 4 certain tin plate samples from steel strip of compositions outside the requirements of the method according to the invention still have temper T—2½ or T—3 grade. However, in order to guarantee the manufacture of tin plate with temper T—2½ or T—3, the compositions of the steel strip used should satisfy the restrictions mentioned above.

Concerning the steel types, rimmed or capped steel produced by the top-blown oxygen process is preferred. In the manufacture of capped steel ingot, it is desirable to minimise the oxygen content of the steel. Open-hearth steel should be avoided because it is impossible to remove the impurities originating from the scrap metal and the steel produced has a higher nitrogen content, resulting in a tin plate of higher Rockwell 30T hardness when produced from open-hearth steel.

However, steels manufactured by any other steel fabrication process adapted to produce steel which is as free of impurities as that produced by the top-blown oxygen process can be used. The following Examples serve to illustrate the new method of producing soft thin steel sheet according to the invention.

EXAMPLE 1.

Rimmed or capped steel was rolled from an ingot to a slab, hot rolled into a hot band of 2 mm thickness, after picking cold rolled to 0.32 mm (cold reduction 84%), then annealed in a continuous annealing furnace by means of the cycle A shown in Fig. 2, temper rolled with 1.5% elongation and finally electrolytically tinned. The surface tin was then flow-melted. The compositions of the steel strips employed are shown in Table V. Both the Rockwell 30T hardness after annealing and the Rockwell 30T hardness of the tin plate products obtained were as shown in Table VI. Samples No. 1 to No. 8, No. 15 and No. 16 have compositions within the requirements of methods (a) and (b) and show temper T—3 properties by the cycle A of Fig. 2. Samples Nos. 9 to 14, 17 and 18, which have compositions which do not fall within the present invention show temper T—4 properties by the cycle A of Fig. 2 and show properties at the lower end of the temper T—4 range. Sample No. 15 contained added vanadium and Sample No. 16 added chromium. The addition of vanadium or chromium is especially beneficial with cycle A of Fig. 2. The steel sheet obtained shows temper T—2½ properties with cycle A even though the value of [Mn]/S (by analysis) is at the lowest end of the range required for the present invention.

Samples Nos. 17 and No. 18 show the effect of the coiling temperature after hot rolling of the strip. Increasing the coiling temperature from 600°C to 680°C results in a tendency to reduce the Rockwell 30T hardness using cycle A of Fig. 2, but this effect was not found to be significant.

TABLE V

Chemical composition of the steel (%)

sample No.	steel type	C	Si	Mn	P	S	O	N	[Mn]/S	Cr	V
1	rimmed	0.027	0.01	0.33	0.008	0.011	0.018	0.0014	24		
2	rimmed	0.043	0.01	0.37	0.006	0.016	0.012	0.0022	21		
3	rimmed	0.048	0.01	0.40	0.012	0.015	0.021	0.0025	22		
4	rimmed	0.050	0.01	0.41	0.008	0.010	0.020	0.0025	34		
5	rimmed	0.036	0.01	0.37	0.010	0.012	0.016	0.0023	26		
6	rimmed	0.042	0.01	0.38	0.007	0.011	0.029	0.0025	25		
7	rimmed	0.034	0.01	0.35	0.009	0.010	0.024	0.0024	27		
8	rimmed	0.035	0.01	0.33	0.010	0.012	0.018	0.0010	22		
9	capped	0.050	0.01	0.34	0.016	0.020	0.065	0.0024	6		
10	rimmed	0.069	0.01	0.36	0.016	0.026	0.027	0.0039	10		
11	rimmed	0.041	0.01	0.34	0.015	0.021	0.027	0.0028	12		
12	capped	0.036	0.01	0.29	0.013	0.030	0.054	0.0017	3		
13	rimmed	0.051	0.01	0.26	0.009	0.019	0.027	0.0026	9		
14	capped	0.028	0.01	0.20	0.010	0.020	0.063	0.0023	–1		
15	rimmed	0.030	0.01	0.31	0.007	0.014	0.008	0.0027	20	0.016	0.009
16	rimmed	0.050	0.01	0.33	0.006	0.014	0.008	0.0014	22	0.19	0.005
17	capped	0.040	0.01	0.28	0.011	0.022	0.065	0.0026	3		
18	capped	0.040	0.01	0.27	0.014	0.025	0.065	0.0024	2		

TABLE VI

Chemical composition and hardness

sample No.	steel type	[Mn]/S	P	Rockwell 30 T hardness (HR 30T) cycle A after annealing	Rockwell 30 T hardness (HR 30T) cycle A tin plate	note
1	rimmed	24	0.008	52.4	57.6	steel compositions within requirements of the present invention
2	rimmed	21	0.006	52.7	57.7	
3	rimmed	22	0.012	53.0	58.0	
4	rimmed	34	0.008	52.9	57.9	
5	rimmed	26	0.010	52.9	58.7	
6	rimmed	25	0.007	52.7	57.7	
7	rimmed	27	0.009	53.3	59.5	
8	rimmed	22	0.010	52.8	58.1	
9	capped	6	0.016	56.1	61.2	steel compositions outside requirements of the present invention
10	rimmed	10	0.016	55.5	61.3	
11	rimmed	12	0.015	55.0	60.5	
12	capped	3	0.013	55.8	61.1	
13	rimmed	9	0.009	53.4	60.5	
14	capped	−1	0.010	54.7	61.5	
15	rimmed	20	0.007	53.3	56.6	vanadium added
16	rimmed	22	0.006	53.8	55.2	chromium added
17	capped	3	0.011	54.2	61.0	coiled at normal temperature (600°C)
18	capped	2	0.014	55.3	60.4	coiled at higher temperature (680°C)

As mentioned above in detail, proper restriction of the amount of carbon, manganese, sulphur, nitrogen and phosphor in the steel strip together with the value of [Mn]/S make it possible to fabricate continuously annealed soft tin plate with temper T—3 properties with cycle A of Fig. 2.

The addition of a trace of carbide former e.g. chromium or vanadium is effective in the softening, and in particular the addition of these carbide formers increases the effectiveness of cycle A of Fig. 2.

Preferred upper limits for the amounts of chromium and/or vanadium are 0.20% and 0.03% respectively since above these limits the workability and the anisotropy in the crystal structure of the annealed product deteriorates.

On the other hand, the preferred lower limits on the amounts of chromium and/or vanadium added are 0.02% and 0.005% respectively in order to give a sufficient number of carbide former nuclei to serve as targets or sites for the diffusion and precipitation of carbon atoms.

Coiling at higher temperature after hot rolling of the steel strip has a slight effect on the softening of continuously annealed products, but descaling in the pickling of the hot strip before cold rolling represents a drawback of higher-temperature-coiled products and sometimes results in a deterioration in the surface appearance of tin mill products. Therefore coiling at high temperature is not essential.

It is unnecessary for the steel strip to be treated according to the invention to have undergone any special treatment in the processes of ingot processing, slab rolling and hot-strip rolling.

WHAT WE CLAIM IS:—

1. A method for the production of soft thin steel sheet which comprises heating a steel strip, which has been hot rolled and then cold rolled, to a soaking temperature in the range from the recrystallization temperature of the steel to 900°C in a continuous annealing furnace, holding the steel strip at that temperature for a short time, slowly cooling to about 500°C and then cooling at a substantially faster rate to ambient temperature, said steel strip containing up to 0.05% carbon, up to 0.50% manganese, up to 0.025% sulphur, up to 0.0030% nitrogen, up to 0.012% phosphorus and optionally chromium and/or vanadium, the balance (except for incidental constituents and impurities) being iron and the manganese, oxygen and suphur contents satisfying the following relationship

$$\left\{(\mathrm{Mn}\%) - \frac{55}{16}(\mathrm{O}\%)\right\} \Big/ (\mathrm{S}\%) \geqslant 20$$

2. A method as claimed in claim 1 wherein the steel used is rimmed or capped steel produced by the top-blown oxygen process.

3. A method as claimed in claim 1 or claim 2 wherein the steel contains from 0.02 to 0.20% chromium and/or from 0.005 to 0.03% vanadium.

4. A method as claimed in any one of the preceding claims wherein the steel strip is annealed in a conventional continuous annealing No. 1 CAL line (as herein defined) operated at a speed of from 458 to 305 m/min.

5. A method as claimed in any one of the preceding claims wherein the total annealing time (as herein defined) does not exceed 2 minutes.

6. A method as claimed in claim 5 wherein the total annealing time is from 76 to 114 seconds.

7. A method as claimed in any one of the preceding claims wherein the time taken to cool the steel strip from 550 to 250°C does not exceed 30 seconds.

8. A method as claimed in claim 7 wherein the time taken to cool the steel strip from 550 to 250°C is from 16 to 24 seconds.

9. A method as claimed in any one of the preceding claims wherein the steel strip is subjected to an annealing cycle substantially as shown for cycle A in Figure 2.

10. A method for the production of soft thin steel sheet according to claim 1 substantially as herein described.

11. A method for the production of soft thin steel sheet according to claim 1 substantially as herein described in any one of the Examples.

12. Soft thin steel sheet whenever prepared by a process as claimed in any one of claims 1 to 11.

13. Thin steel sheet of temper T—3 (according to JIS G3303—1969) whenever produced by a method as claimed in any one of claims 1 to 11.

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FIG.1

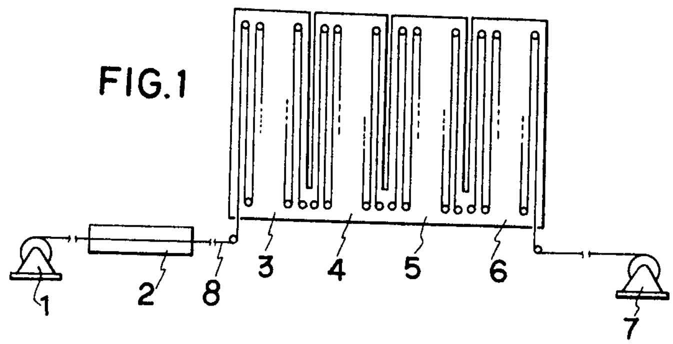

1
2
8
3
4
5
6
7

FIG.2

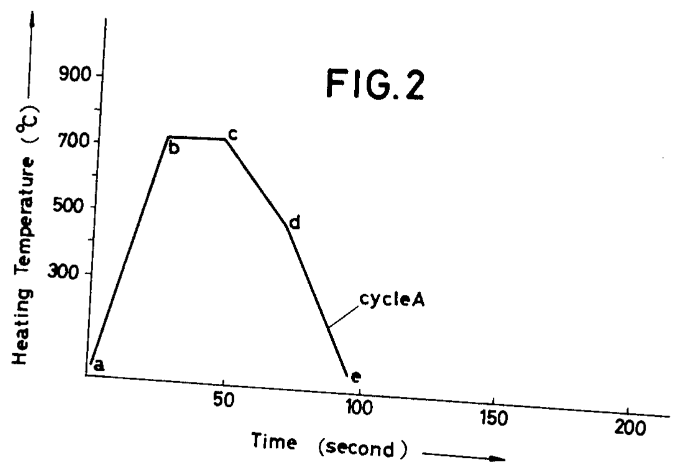

Heating Temperature (°C)
900
700
500
300
a
b
c
d
e
cycleA
50
100
150
200
Time (second)

FIG. 3

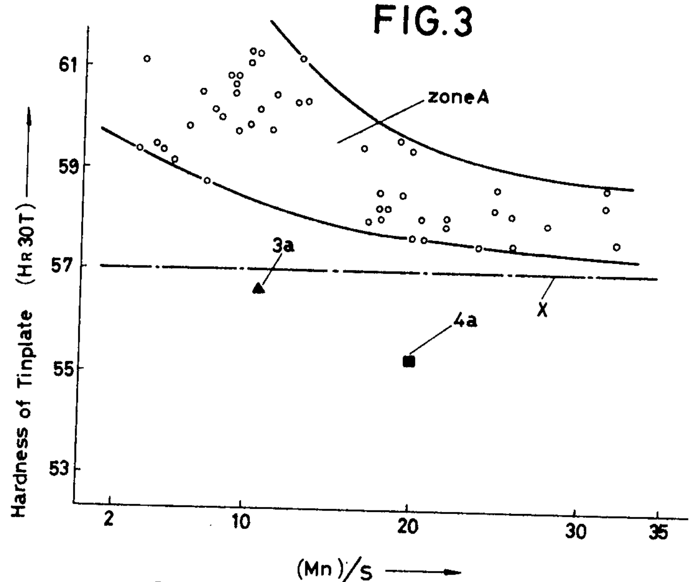
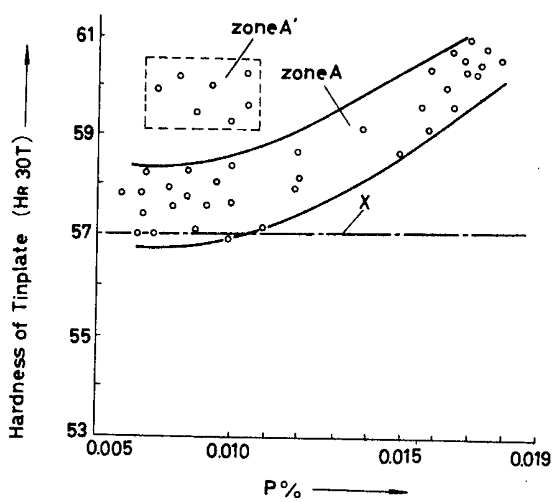

61
59
57
55
53
Hardness of Tinplate (HR 30T)
zoneA
3a
4a
X
2
10
20
30
35
(Mn)/S

FIG. 4


61
59
57
55
53
Hardness of Tinplate (HR 30T)
zoneA'
zoneA
X
0.005
0.010
0.015
0.019
P%