United States Patent

Brickner et al.

[15] **3,655,459**

[45] **Apr. 11, 1972**

[54] METHOD FOR PRODUCING MINIMUM-RIDGING TYPE 430 MO STAINLESS STEEL SHEET AND STRIP

[72] Inventors: **Kenneth G. Brickner, O'Hara Township, Allegheny County; George A. Ratz,** Bethel Park, both of Pa.

[73] Assignee: **United States Steel Corporation**

[22] Filed: **Aug. 13, 1970**

[21] Appl. No.: **63,612**

[52] **U.S. Cl.** **148/12**

[51] **Int. Cl.** **C21d 9/48**

[58] **Field of Search** 148/12

[56] **References Cited**

UNITED STATES PATENTS

3,139,358	6/1964	Graziano	148/12
3,201,231	8/1965	Harpster	75/126

Primary Examiner—L. Dewayne Rutledge
Assistant Examiner—W. W. Stallard
Attorney—Forest C. Sexton

[57] **ABSTRACT**

A process for producing a Type 430 Mo stainless steel sheet product with substantially reduced ridging characteristics when drawn. Commencing in slab form, the Type 430 Mo steel is hot rolled at 2000°–2100°F and finished at below 1400°F, with a reduction of at least 30 percent per pass; box annealed at 1750-1850°F for at least 10 hours and then at 1450°–1500°F for at least 2 hours; cold rolled to final thickness; and continuous annealed at 1575°–1625°F.

4 Claims, No Drawings

METHOD FOR PRODUCING MINIMUM-RIDGING TYPE 430 MO STAINLESS STEEL SHEET AND STRIP

BACKGROUND OF THE INVENTION

It is well known that the 17 percent chromium ferritic stainless sheet steels (i.e., AISI Type 430 stainless steels) usually exhibit a surface defect known as "ridging" or "roping" when subjected to severe cold forming operations such as deep drawing. This defect appears as narrow raised areas similar to corrugations parallel to the cold rolling direction. Ridging is of course detrimental to the appearance of the drawn part, and expensive grinding and polishing operations are required to suitably improve the appearance.

Although many processes and procedures have been developed to overcome the ridging problems associated with the AISI Type 430 stainless steels, these processes have not been altogether satisfactory, at least from a commercial point of view. According to one process for example (U.S. Pat. No. 2,965,479), ridging can be eliminated by adding small amounts of columbium to the alloy. Although this process is used commercially to a limited extent, it greatly adds to the cost of the product, not only because of the cost of the columbium itself, but because the columbium causes processing difficulties resulting in lower yields. Most other procedures for eliminating the ridging problem have involved the careful control of processing parameters, i.e., rolling and annealing, to effect particular microstructures allegedly found to be non-ridging in nature. Of particular significance to this invention is a process disclosed in U.S. Pat. No. 2,851,384, Waxweiler, Sept. 9, 1958. According to this patent, ridging is minimized by increasing the amount of austenite to above 35 percent at the hot rolling temperatures, and then subjecting the steel to carefully controlled heat treatments to randomize the texture or orientation of the hot rolled grains. The austenite content is controlled through close control of carbon, nitrogen, silicon, nickel and manganese in a 14–18 percent chromium stainless steel. Although this process, and other prior art processes, are effective to some extent in minimizing ridging in conventional Type 430 stainless steels, none of the prior art processes have been effective in reducing ridging in the molybdenum containing Type 430 Mo stainless steels, which is particularly desirable for many drawn products because of its enhanced resistance to corrosion. On the contrary, ridging is particularly troublesome and severe in Type 430 Mo stainless steels. Therefore, despite its commercial appeal due to greater corrosion resistance, no method is known whereby ridging in Type 430 Mo stainless steel sheet can be eliminated or minimized.

SUMMARY OF THE INVENTION

An object of this invention is to provide a Type 430 Mo stainless steel sheet which can be drawn with little or no ridging in the strained portions thereof.

Another object of this invention is to provide a process for producing a Type 430 Mo stainless steel sheet having substantially reduced ridging characteristics when subjected to severe cold forming operations, and further having tensile properties equivalent to those of prior art Type 430 Mo stainless steel sheets.

These and other objects and advantages will become apparent from the following detailed description of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As noted above, the process of this invention is applicable only to the molybdenum-modified Type 430 Mo stainless steel, having a nominal composition as follows:

carbon	0.15% maximum
manganese	1.0% maximum
silicon 1.0% maximum	
chromium	16 to 18%
molybdenum	0.75 to 2%
iron	balance

Besides the above listed elements, the alloy may of course contain the usual steelmaking impurities in amounts insufficient to affect the alloy's properties.

Stated briefly, the process of this invention, whereby a Type 430 Mo stainless steel is produced with minimum ridging characteristics, involves the careful control of almost all processing parameters in producing the sheet from slab form. Of critical significance are the hot rolling temperatures and reductions, the box annealing times and temperatures following hot rolling, cold reductions, and the continuous annealing temperatures following cold reduction.

More specifically, the preferred process of this invention comprises (1) hot rolling a slab of the steel at a starting temperature between 2000° and 2100°F with a minimum reduction of 30 percent per pass; (2) finishing the hot rolling operation at a temperature below 1400°F to yield a hot band between 0.1 and 0.25 inch thick; (3) box annealing the hot band between 1750° and 1850°F for at least 10 hours, after which the temperature of the annealing furnace is lowered to about 1450°–1500°F for at least 2 hours; (4) pickling and then cold rolling the annealed hot band between 30 and 50%; and (5) continuous annealing the cold rolled sheet between 1575° and 1625°F and pickling to yield the final product. For thinner sheet materials, steps (4) and (5) can be repeated.

Although the details of the microstructural development and the cross relationships between the various parameters are not completely understood, we have found that each of the above parameters is critical if a substantially non-ridging product is to be achieved.

For reasons completely unknown to us, the slab hot rolling temperatures and reductions are critical as noted. Although ridging characteristics can be reduced to some extent by commencing hot rolling within the range 1900° to 2200°F, optimum results are achieved at preferred starting temperatures of from 2000° to 2100°F. Similarly, appreciable reductions in ridging tendencies can be achieved only if the hot reductions are of about 30 percent or more.

The box annealing procedure following hot rolling must also be critically controlled if the ridging characteristics in the final product are to be reduced. Generally speaking, increases in annealing temperature, up to 1850°F, and/or increases in annealing time, up to 12 hours, will cause some improvement in the product's resistance to ridging. Such improvements, however, are quite small and insignificant unless the annealing temperature is within the range 1750° to 1850°F, and the annealing duration at least 12 hours. As will be noted below, however, the annealing temperature can and should be lowered for the final 2 hours of the anneal. Annealing durations of less than 12 hours are insufficient to yield a product having significant and useful resistance to ridging. On the other hand, periods in excess of 12 hours, up to 72 hours, have neither favorable nor adverse effects.

The dual temperature feature of the box anneal, as described above, is primarily to prevent an undesirable "open" surface characteristic. That is to say, the pickling operation to remove surface scale following the box anneal has a tendency of producing an open or pitted surface. We believe this is caused by the pickling solution dissolving surface metal adjacent to precipitated carbides at the grain boundaries, which are formed during the high temperature box anneal. This detrimental open surface can be markedly reduced by lowering the temperature of the annealing furnace after a minimum of 10 hours at 1750°-1850°F to the range 1450°-1500°F, and holding within this latter temperature range for at least 2 hours. This low temperature treatment reduces the susceptibility of the grain boundaries to attack by the pickling solution. If preferred, the metal can be completely cooled to ambient temperatures between the 1750°-1850°F anneal and the 1450°-1500°F anneal without adverse effect.

The cold rolling procedure following the box anneal should reduce the annealed hot band from about 30 to about 50 percent. Here again the reasons for these limits are not completely understood. Nevertheless, cold reductions of 30 to 50 per-

cent have statistically been shown to produce a greater degree of resistance to ridging.

As stated above, the final continuous anneal should be at a temperature within the range 1575° to 1625°F. Temperatures below 1575°F down to about 1400°F will not necessarily be seriously detrimental, but will not of course provide the best possible product. On the other hand, temperatures modestly in excess of 1625°F or 1700°F may produce undesirable low elongations and/or coarse grain sizes. Hence, the upper limit of 1625°F for the continuous anneal is somewhat more critical than the lower limit of 1575°F.

In order to establish the above parameters, four different heats of steel were prepared having compositions as shown in the table below.

TABLE I.—COMPOSITIONS OF TYPE 430 Mo STAINLESS STEELS INVESTIGATED, PERCENT

	C	Mn	P	S	Si	Cr	Mo	N
Steel:								
1	0.076	0.36	0.020	0.008	0.30	17.0	1.00	0.050
2	0.06	0.57	0.021	0.009	0.33	17.5	1.05	0.042
3	0.06	0.38	0.021	0.007	0.34	16.2	0.94	0.043
4	0.08	0.41	0.026	0.008	0.33	16.4	1.10	0.023

From these four heats, over 100 test specimens were processed at differing parameters to ascertain the varying effects of the differing parameters. The variables studied in detail were (1) slab rolling temperatures; (2) the amount of reduction during hot rolling; (3) box annealing temperatures; (4) box annealing times; (5) the amount of cold reduction; and (6) the continuous annealing temperatures following cold reduction.

For testing purposes, specimens 1½ inch wide by 14 inches long were cut from the finished product in the longitudinal direction and then polished into a "mirror" finish. All specimens were then strained 15 percent in tension at room temperature. Specimens were visually examined and rated for severity of ridging according to the following arbitrary scale: 0 - none; 1 - very slight; 2 - slight; 3 - moderate; 4 - severe; and 5 - very severe.

Although the detailed data obtained from these tests is too voluminous to be presented here, the following examples will illustrate typical results.

For one series of tests, a commercial slab product of Steel 1 (see table) 5 inches thick was hot rolled at 2200°F into 1 inch thick material. Specimens of the 1 inch slab were then hot rolled into 0.150 inch material at starting temperatures of 1900°, 2000° or 2100°F at varying amounts of reduction per pass, at 20 percent or 40%. The hot rolled strip was given simulated box annealing at either 1600°F or 1800°F for 1 or 24 hours, and then furnace cooled. The annealed strip was then cold rolled to 0.07 inch sheet in 2 passes, annealed for 15 minutes at either 1450° or 1600°F, air cooled, cold rolled to 0.025 inch sheet in two passes and again annealed for 15 minutes at the same temperature, and finally air cooled. For testing purposes, the procedure outlined above was followed. Those specimens which were processed in accordance with this invention, i.e., hot rolled at 2100°F, hot reduced by 40 percent, box annealed at 1800°F for 24 hours and given continuous anneals at 1600°F, all had ridging ratings of 0.5. Those specimens hot rolled at 20 percent reductions had ridging ratings of from 1 to 4 with an average of 2.7 for 48 specimens. Those specimens box annealed at 1600°F had an average ridging rating of 3.2, and so on.

In another series of tests, a commercial slab product of Steel 1 (see table) 5 inches thick was hot rolled at 2200°F into 1 inch material. Specimens of this 1 inch slab were then hot rolled into 0.20 or 0.09 inch strip at either 2000° or 2200°F. The hot rolled strips were given simulated box annealing at 1600° or 1800°F for 12, 24, 48 or 72 hours and furnace cooled. The 0.09 inch specimens were cold rolled to 0.04 inch sheet in 2 passes, and the 0.2 inch specimens were cold rolled to 0.09 inch sheet in 2 passes. All material was then heated for 15 minutes at 1450°F and air cooled. The 0.04 inch material was cold rolled to 0.025 inch in one pass (35 percent reduction), whereas the 0.09 inch material was cold rolled to 0.025 inch in two passes (70 percent reduction). Prior to testing, all 0.025 inch material was annealed for 15 minutes at 1450°F and air cooled. All those specimens processed in accordance with this invention, i.e., hot rolled at 2000°F, box annealed at 1800°F, and cold rolled at a 35 percent reduction exhibited ridging ratings of 1 . Those specimens processed outside the scope of this invention exhibited an average ridging rating of 2 for 24 specimens. Those specimens with two or more parameters outside the scope of this invention had ridging ratings of 2 to 3.

Similarly other tests were conducted to study the effect of hot rolling finishing temperatures of 1400°, 1500°, 1600°, 1700° and 1800°F which showed improved results as this variable temperature was reduced. Still further tests considered the variable effects of cold reductions at 30 percent, 45 percent and 60 percent. Those specimens cold rolled at 30 and 45 percent had ridging ratings of 0 to 0.5 when the other processing parameters were within the inventive ranges.

We claim:

1. A process for producing a Type 430 Mo stainless steel sheet product with substantially reduced ridging characteristics when drawn comprising forming a steel slab having the composition by weight percent:

carbon	up to 0.15%
manganese	up to 1.0%
silicon	up to 1.0%
chromium	16 to 18%
molybdenum	0.75 to 2.0%
iron	balance except for incidental impurities;

hot rolling said slab at a starting temperature within the range 2000° to 2100° F, and a finishing temperature below 1400° F, with at least a 30 percent thickness reduction per pass; box annealing the hot rolled steel at a first annealing temperature of from 1750° to 1850° F for at least 10 hours and at a second annealing temperature of from 1450° to 1500° F for at least 2 hours; cold rolling the annealed steel to final thickness; continuous annealing the cold rolled steel at from 1575° to 1625° F; and cooling the steel product.

2. The process of claim 1 in which the cold rolling effects a thickness reduction of from 30 to 50 percent.

3. The process of claim 1 in which the cold rolling is performed in two steps with an intermediate continuous anneal of from 1575° to 1625° F.

4. A Type 430 Mo stainless steel sheet product having substantially reduced ridging characteristics when drawn, consisting of the steel produced in accordance with claim 1.

* * * * *