PROCESS FOR MANUFACTURING A COLD-ROLLED HIGH STRENGTH STEEL SHEET

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ABSTRACT

A process for manufacturing a cold-rolled high strength steel sheet particularly suitable for fabrication of car body comprising the steps of making a steel comprising 0.03 - 0.2% C, 1.6 - 3.0% Mn, 0.03 - 0.6% Si, 0.01 - 0.25% Nb, 0.01 - 0.2% Ti, and the remainder being iron excepting inherent impurities and residual deoxidizing elements, hot rolling the steel to a hot-rolled strip, cold rolling the strip to a steel sheet having a thickness of 3 mm or less, and annealing the steel sheet at a temperature of 620°C to A₃ transformation point.
PROCESS FOR MANUFACTURING A COLD-ROLLED HIGH STRENGTH STEEL SHEET

The present invention relates to a process for manufacturing a high strength steel sheet having an attractive surface and high accuracy in thickness. More particularly, the present invention relates to a process for manufacturing a high strength cold-rolled steel sheet particularly suitable for fabrication of car body.

The steel sheet used for fabrication of passenger car body has generally a thickness of 3.0mm, particularly, 2.3mm or less.

The social constantly increasing requirement for improving the security of cars obliges the manufacturer to enhance strength of car body. For this purpose, a thicker steel sheet may be used or more members may be used. But any such measures will result in the increase of weight of the car body, which is adverse to the desirable reduction of weight of the car body.

In order to improve the security by using a steel sheet having a thickness less than the limited range indicated above, a steel sheet having a sufficient strength to be proof against accident should be used, and the supply of such a steel is strongly demanded.

Although it is known that a high strength steel sheet can be manufactured by hot rolling, a thinner sheet provides more problems in the capacity of rolling mill and in the shape of steel sheet to be rolled, and particularly, manufacture of stronger steel sheets involves increased difficulties in the hot rolling. Therefore, the high strength steel sheet which is able to industrially produce by hot rolling at present has a lower limit in thickness depending on the desired tensile strength, for example, 1.6mm for 50kg/mm², 2.3mm for 60kg/mm², and 3.2mm for 80kg/mm².

An object of the present invention is to manufacture a high strength steel sheet having a high tensile strength which cannot be obtained by the conventional process, at the limited thickness described above.

Another object of the present invention is to provide a high strength steel sheet having a tensile strength of 50 to 100kg/mm² at a thickness of 3mm, particularly, 2.3mm or less.

Another object of the present invention is to provide a process for manufacturing a high strength steel sheet having a tensile strength of 50 to 100kg/mm² and an attractive surface and a uniform thickness.

A further object of the present invention is to provide a cold-rolling process for manufacturing a steel sheet having the above-mentioned properties.

The above and other objects are accomplished by the process of the present invention, wherein a steel comprising 0.03 – 0.20% C, 1.6 – 3.0% Mn, 0.03 – 0.6% Si, and remainder of Fe excepting inevitable impurities, if desired additionally containing 0.01 – 0.25% Nb or 0.01 – 0.2% Ti or Nb and Ti in total amount of 0.01 – 0.3% is hot rolled to produce a hot rolled steel strip, which is then cold rolled to a steel sheet having a desired thickness, and the steel sheet thus produced, when containing neither Nb and Ti, is heated to a temperature of 710°C to A₃ transformation point, and when containing at least one of Nb and Ti, is heated to a temperature of 620°C to A₃ transformation point to anneal, thereby to produce a steel sheet having a tensile strength of 50 to 100kg/mm² and a thickness of 3.2mm or less.

The reasons for defining the above compositions of the steel are as follows:

A carbon content less than 0.03 percent does not provide a tensile strength of 50 kg/mm² or more, and a carbon content exceeding 0.20 percent decreases the toughness and deteriorates the weldability of the steel.

A manganese content less than 1.6 percent does not provide a tensile strength of 50 kg/mm² or more, whereas a manganese content exceeding 3.0 percent renders the steel making significantly difficult. Silicon, which is used as a deoxidizer, is difficult to reduce its content to less than 0.03 percent, whereas its content exceeding 0.6 percent increases the brittleness and also deteriorates the weldability of the steel.

Niobium and titanium serve to improve the tensile strength of the steel when it is annealed at a temperature of 620°C to A₃ transformation point. A niobium content less than 0.01 percent does not produce such effect, and its content exceeding 0.25 percent does not effect further improvement. Also, a titanium content less than 0.01 percent does not produce the effect, whereas its content exceeding 0.2 percent renders the ingot making difficult.

Further, Nb and Ti can be added in combination, whereupon it is necessary to limit the combined content to a range of 0.01 to 0.3 percent.

Also, this steel may generally contain P of not more than 0.03 percent and S of not more than 0.03 percent as allowable impurities, and further may contain Cu of not more than 0.3 percent, Ni of not more than 0.3 percent, Cr of not more than 0.5 percent, Mo of not more than 0.5 percent and B of not more than 0.01 percent. These elements in amount described above do not adversely affect the tensile strength.

In the practice of the present invention, a molten steel having the above composition is prepared, and cast into ingot in a conventional manner, whereupon Al killing is desirable. The ingot is then subjected to blooming and hot rolling in a conventional manner to produce a hot rolled strip. This hot rolling is desirably performed at a finishing temperature not lower than 800°C. The hot rolled strip is then subjected to pickling, and thereafter is cold rolled in a conventional manner to a steel sheet having a desired thickness, whereupon a reduction ratio of not less than 30 percent is desirable.

According to the present invention the steel sheet thus produced is annealed at a constant temperature. This annealing temperature is necessary to be varied depending on whether Nb and Ti are contained or not.

That is, the steel containing only C, Mn and Si should be annealed at a temperature of 710°C to A₃ transformation point, and the steel additionally containing Nb and Ti at a temperature of 620°C to A₃ transformation temperature.

An annealing temperature lower than 710°C in the former case will cause the steel to recrystallize and soften during annealing, and also cause carbides to be finely dispersed, thereby rendering it difficult to obtain the desired strength.

However, the latter steel sheet (containing Nb or Ti) can be annealed at a temperature of 620°C to 710°C without causing severe softening due to the function of Nb or Ti, thereby allowing the attainment of the desired strength.
When each of the steels is annealed at a temperature of 710°C to A_{A} transformation point, an austenitic phase is formed at a portion of the grain boundary, which transforms to not only pearlite but also to martensite and bainite during cooling of the steel sheet, thereby the strength of the steel sheet can be remarkably increased and thus a cold-rolled steel sheet having a high strength of 50 kg/mm² or more is obtained.

Such martensite and bainite can be produced by such a very slow cooling rate as in the batch annealing of the cold-rolled steel sheet.

It is known that a steel having such a composition described above can be heat treated into a structure including martensite and bainite phases by means of normalizing. However, the present invention is characterized in that said martensite and bainite phases can be produced by annealing, not normalizing, of the cold-rolled steel sheet.

Also, according to the present invention, the finished steel sheet has an attractive surface, and a high accuracy in thickness as well as a remarkably improved strength.

The present invention will now be more particularly described with reference to examples thereof.

Example 1

Steel having chemical compositions indicated in Table 1 were prepared, wherein steels A, B and C are according to the present invention, and steels D and E are for comparison.

Table 1

<table>
<thead>
<tr>
<th>Steel</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.09</td>
<td>0.03</td>
<td>2.05</td>
<td>0.003</td>
<td>0.006</td>
</tr>
<tr>
<td>B</td>
<td>0.08</td>
<td>0.03</td>
<td>2.51</td>
<td>0.003</td>
<td>0.006</td>
</tr>
<tr>
<td>C</td>
<td>0.12</td>
<td>0.10</td>
<td>2.49</td>
<td>0.003</td>
<td>0.006</td>
</tr>
<tr>
<td>D</td>
<td>0.14</td>
<td>0.39</td>
<td>1.40</td>
<td>0.005</td>
<td>0.006</td>
</tr>
<tr>
<td>E</td>
<td>0.17</td>
<td>0.45</td>
<td>1.50</td>
<td>0.005</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Each of the steels was killed by Al and then cast into an ingot, and then hot rolled to a strip of a thickness of 2 mm, the hot rolling being finished at 850°C. Each steel strip was pickled and then cold rolled to a steel sheet of 0.8 mm thick.

As clearly seen in Table 1, each of the steels A, B and C according to the present invention has an improved tensile strength exceeding 50 kg/mm² as annealed at a temperature of 710°C to A_{A} transformation point. That is, the steel A indicates a tensile strength exceeding 50 kg/mm² as annealed at 730°C and higher, and the steels B and C indicate a tensile strength exceeding 50 kg/mm² as annealed at 710°C and higher, and particularly the tensile strength of the steel C reaches nearly as high as 100 kg/mm².

It has been also found that the above carbon steel containing C of 0.03 to 0.20 percent can further contain one or more of Cu, Ni, Cr, Mo and B in amounts of Cu <0.3%, Ni <0.3%, Cr <0.5%, Mo <0.5% and B <0.01% with the similarly improved tensile strength due to the annealing.

Example 2

Steels having compositions indicated in Table 3 were prepared by using a high frequency induction furnace, wherein steels F through I are according to the present invention and steels K through N are for comparison.

Table 3

<table>
<thead>
<tr>
<th>Steel</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Nb</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invented Steels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>0.09</td>
<td>0.10</td>
<td>2.83</td>
<td>0.003</td>
<td>0.008</td>
<td>0.008</td>
<td>0.09</td>
</tr>
<tr>
<td>J</td>
<td>0.07</td>
<td>0.08</td>
<td>2.77</td>
<td>0.006</td>
<td>0.008</td>
<td>0.009</td>
<td>0.09</td>
</tr>
<tr>
<td>I</td>
<td>0.07</td>
<td>0.08</td>
<td>2.14</td>
<td>0.005</td>
<td>0.008</td>
<td>0.005</td>
<td>0.04</td>
</tr>
<tr>
<td>Comparative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>0.17</td>
<td>0.45</td>
<td>1.50</td>
<td>0.005</td>
<td>0.013</td>
<td>0.013</td>
<td>0.03</td>
</tr>
<tr>
<td>M</td>
<td>0.17</td>
<td>0.10</td>
<td>1.45</td>
<td>0.013</td>
<td>0.013</td>
<td>0.013</td>
<td>0.03</td>
</tr>
</tbody>
</table>

This steel sheet was heated at a temperature of 670°C to 750°C for 6 hours followed by a slow cooling at a cooling rate of 25°C/hr.

The steel sheet thus obtained was cut into specimens for tension test, the results of the test are indicated in Table 2. FIG. 1 is the graph showing these results.

Each molten steel was killed by Al and then cast into an ingot, which was hot rolled to a strip of 2 mm thickness, wherein the hot rolling being finished at 850°C. Each strip was pickled and then cold rolled to a sheet of 0.8 mm thick.

Each sheet thus produced was heated to respective annealing temperatures indicated in Table 4, and after
holding it at the temperatures for 2 hours, it was cooled in the furnace at a cooling rate of 75°C/hr.

Each sheet was cut into test pieces specified by JIS No. 5 to perform tension test in the direction of rolling. The results are as indicated in Table 4.

<table>
<thead>
<tr>
<th>Steel</th>
<th>Anneal. Temp. °C</th>
<th>T.S. kg/mm²</th>
<th>Y.P. kg/mm²</th>
<th>Elong. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>650</td>
<td>61.5</td>
<td>43.5</td>
<td>22.0</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>64.0</td>
<td>36.6</td>
<td>22.0</td>
</tr>
<tr>
<td>F</td>
<td>650</td>
<td>76.5</td>
<td>64.2</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>68.5</td>
<td>41.6</td>
<td>17.5</td>
</tr>
<tr>
<td>G</td>
<td>650</td>
<td>72.7</td>
<td>53.4</td>
<td>18.0</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>70.4</td>
<td>42.3</td>
<td>21.5</td>
</tr>
<tr>
<td>H</td>
<td>650</td>
<td>90.0</td>
<td>76.7</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>81.8</td>
<td>55.0</td>
<td>14.0</td>
</tr>
<tr>
<td>I</td>
<td>650</td>
<td>51.3</td>
<td>24.3</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>52.6</td>
<td>22.2</td>
<td>29.0</td>
</tr>
<tr>
<td>J</td>
<td>600</td>
<td>39.2</td>
<td>26.2</td>
<td>37.5</td>
</tr>
<tr>
<td>K</td>
<td>700</td>
<td>49.1</td>
<td>39.2</td>
<td>27.5</td>
</tr>
<tr>
<td>L</td>
<td>710</td>
<td>49.2</td>
<td>41.0</td>
<td>29.0</td>
</tr>
<tr>
<td>M</td>
<td>650</td>
<td>42.8</td>
<td>38.0</td>
<td>36.0</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>49.6</td>
<td>21.2</td>
<td>32.5</td>
</tr>
</tbody>
</table>

From the results it is clear that the steels for comparison do not provide a tensile strength exceeding 50 kg/mm² by annealing at a temperature lower than 710°C, and their tensile strength significantly vary depending on the annealing temperature, whereas the steels according to the annealing temperature, constantly provide a tensile strength exceeding 50 kg/mm² by annealing at a temperature ranging from a relatively low temperature to A₃ transformation point, and its value is not fluctuant.

We claim:

1. A process for manufacturing a cold-rolled high strength steel sheet having a tensile strength of 50 to 100 kg/mm², characterized by making a steel comprising 0.03 – 0.2% C, 1.6 – 3.0% Mn, 0.03 – 0.6% Si, 0.01 – 0.25% Nb, 0.01 – 0.2% Ti, and the remainder being iron excepting inherent impurities and residual deoxidizing elements, hot rolling the steel to a hot-rolled strip, cold rolling the strip to a steel sheet having a thickness of 3 mm or less, and annealing the steel sheet at a temperature of 620°C to A₃ transformation point.

2. A process for manufacturing a cold-rolled high strength steel sheet having a tensile strength of 50 to 100 kg/mm², characterized by making a steel comprising 0.03 – 0.2% C, 1.6 – 3.0% Mn, 0.03 – 0.6% Si, and the remainder being iron, excepting inherent impurities and residual deoxidizing elements, hot rolling the steel to a hot-rolled strip, cold rolling the strip to a steel sheet having a thickness of 3 mm or less, heating the steel sheet at a temperature of 710°C to A₃ transformation point for at least 2 hours, and slow cooling it for annealing.

3. A process for manufacturing a cold-rolled high strength steel sheet having a tensile strength of 50 to 100 kg/mm², characterized by making a steel comprising 0.03 – 0.2% C, 1.6 – 3.0% Mn, 0.03 – 0.6% Si, at least one elements of 0.01 – 0.25% Nb and 0.01 – 0.2% Ti, and the remainder being iron excepting inherent impurities and residual deoxidizing elements, hot rolling the steel to a hot-rolled strip, cold rolling the strip to a steel sheet having a thickness of 3 mm or less, heating the steel sheet at a temperature of 620°C to A₃ transformation point for at least 2 hours, and slow cooling it for annealing.

4. A process for manufacturing a cold-rolled high strength steel sheet having a tensile strength of 50 to 100 kg/mm², characterized by making a steel consisting of 0.03 – 0.2% C, 1.6 – 3.0% Mn, 0.03 – 0.6% Si, and the remainder being iron excepting inherent impurities and residual deoxidizing elements, hot rolling the steel to a hot-rolled strip, cold rolling the strip to a steel sheet having a thickness of 3 mm or less, heating the steel sheet at a temperature of 710°C to A₃ transformation point, and cooling it at a rate slower than 100°C/hr.

5. A process for manufacturing a cold-rolled high strength steel sheet having a tensile strength of 50 to 100 kg/mm², characterized by making a steel consisting of 0.03 – 0.2% C, 1.6 – 3.0% Mn, 0.03 – 0.6% Si, 0.01 – 0.25% Nb or 0.01 – 0.2% Ti or 0.01 – 0.3% Nb plus Ti, and the remainder being iron excepting inherent impurities and residual deoxidizing elements, hot rolling the steel to a hot-rolled strip, cold rolling the strip to a steel sheet having a thickness of 3 mm or less, heating the steel sheet at a temperature of 620°C to A₃ transformation point, and cooling it at a rate slower than 100°C/hr.
UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,830,669
DATED : August 20, 1974
INVENTOR(S) : Takashi Matsuoka et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 47, for "N" read -- M --
Column 5, line 11, for "E" read -- F --
   line 13, for "F" read -- G --
   line 14, for "950" read -- 750 --
   line 15, for "G" read -- H --
   line 17, for "H" read -- J --
   line 20, for "J" read -- K --
   line 21, for "K" read -- L --
   line 24, insert -- M -- in the blank space

Signed and Sealed this thirtieth Day of March 1976

[SEAL]

Attest:

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Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks