This invention relates to the manufacture of steel. More particularly, it relates to an improvement in the surface quality and internal cleanliness of steel effected by control of the non-metallic inclusions therein.

In the production of high quality steel, the amount and type of non-metallic inclusions is of importance with respect to the aging and other properties of the steel. For many purposes, it is necessary that the silicon content of the steel be as low as possible and that the steel be substantially free of silicate inclusions. Particularly in deep drawing steels, these inclusions appear in and near the surface of the finished products. This detracts from the surface appearance and smoothness of the finished product and is highly undesirable.

In the basic open-hearth furnace operation, for example, one of the main sources of silicate inclusions is from the refractories used in the furnace spout, ladle, and pouring nozzle. Various methods have been practiced for producing a clean steel, based mainly on the reduction of the oxygen content of the steel by maintaining a reducing or deoxidizing slag. Also, the use of purer raw materials has been contemplated. Moreover, final deoxidizers, such as aluminum, silicon, etc., have been used to remove the oxygen from the iron oxide dissolved in the steel.

Most of these methods merely substitute one type of inclusion for another for the purpose of producing a less objectionable type of inclusion, that is one which has a more favorable effect on the aging properties of the steel. For certain types of steel, such as deep-drawing steels or steels which are heavily deformed in the course of fabrication, is particularly desirable that the steel be substantially free of silicate inclusions, regardless of whether such inclusions result from the original charge, the flux, the deoxidizers, or from the refractories with which the steel comes in contact.

With regard to any unavoidable inclusions, it is desirable that these not be present in or near the surface. Therefore, in ingot formation, while it is most desirable to have the inclusions rise to the top of the molten ingot, any inclusions which do not so rise are located desirably near the center of the ingot. This location of any unavoidable inclusions favors fewer inclusions at or near the surface upon deep drawing of the resultant solid ingot.

It has now been found that the amount of silicate inclusion in steels can be decreased most effectively and the location of such inclusions be improved so as to produce a substantially clean steel by the use of a deoxidizing alloy consisting essentially of 50-75% by weight of manganese and 50-25% by weight of aluminum. This deoxidizing alloy advantageously is added to the steel in the ladle. The amount of such alloy to be added for this purpose is advantageously in the range of 10-20 pounds, preferably 12-18 pounds of alloy per ton of the total charge. Advantageously, the silicon content of the charge materials and the deoxidizers are kept as low as possible and contact with silicate refractories is kept to a practical minimum. Silicon content advantageously is kept below 0.01% by weight.

In cases where the silicon or silicate contamination is very small, the alloy can be added immediately after the steel is poured into the mold. In such cases, less time is required for reaction of the small amount of contaminating and very often this can be effected before the steel has solidified. However, ladle addition generally is preferred.

While applicant does not wish to be restricted to any theory, it is believed that the intimate contact of manganese and aluminum in the alloy favors simultaneous and intimate reaction with the silicates to produce lower melting mixed silicates than are produced by the individual metals. The individual silicates having higher melting points precipitate nearer the outer surface of the ingot whereas the lower melting mixed silicate stays molten longer, giving it more time to rise to the top of the ingot or at least to migrate to the center part of the ingot.

The invention is illustrated best by the following examples which are intended to be merely illustrative of various methods of practicing the invention and are not to be regarded in any way as limiting the scope of the invention. Parts and percentages, here and throughout the specification, are parts and percentages by weight unless otherwise indicated.

**EXAMPLE I**

Various steel heatings are prepared in a basic open-hearth furnace, according to normal practice, having the preliminary analyses indicated in the table below. The first two of these heatings are controls, controls A and B using steels which are killed with a ferro-manganese alloy and aluminum bar. In heatings I-V, a manganese-aluminum alloy is added in the amounts indicated in the table.

In each case the metal or alloy used to kill the steel is added to the steel in the ladle, and 200 pounds of cryolite also is added to the ladle. In each case also the silicon content is less than 0.01% by weight in both analyses. The resultant ladle analyses are given in the table.

<table>
<thead>
<tr>
<th>Table</th>
<th>Preliminary Analysis of Steel</th>
<th>Control</th>
<th>Heatings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Carbon</td>
<td>.95</td>
<td>1.08</td>
<td>1.69</td>
</tr>
<tr>
<td>Mn</td>
<td>.14</td>
<td>.12</td>
<td>.08</td>
</tr>
<tr>
<td>P</td>
<td>.01</td>
<td>.07</td>
<td>.05</td>
</tr>
<tr>
<td>Si</td>
<td>.01</td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td>Total of Steel</td>
<td></td>
<td>2.07</td>
<td>2.06</td>
</tr>
<tr>
<td>Mn-Al alloy</td>
<td></td>
<td>.20</td>
<td>.20</td>
</tr>
<tr>
<td>Fe-Mn alloy</td>
<td></td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td>Al (FeAl3)</td>
<td></td>
<td>1.00</td>
<td>.00</td>
</tr>
</tbody>
</table>

*An alloy of 19.70% Mn and 39.99% Al—added to the ladle.

*Alloy of 80% Mn (medium carbon—approx. 1.5%)—added to the ladle.

*Aluminum bar—added to the ladle.

In each case the various products are processed through the blooming mill, the hot mill, the cold mill, and tested by pickling and etching. In each case the steels which are killed with the alloy show, upon microscopic examination, to be much cleaner than the two controls. These steels have excellent surface appearance and cleanliness in comparison with the controls. The deep etch test shows these alloy-killed steels to be sound and free from sub-surface inclusions, much more so than the control steels. In the blooming mill, hot and cold mill tests, these alloy-killed steels have excellent rolling and surface qualities and show uniformity of hardness, ductility, grain size, and grain shape. In the pickling test, these alloy-killed steels have improved surfaces.

While the preferred proportions of metals in the alloy are approximately 60% manganese and 40% aluminum, as used in the above example, improved results also are
obtained when the manganese content varies from 50% to 75% and the aluminum content from 50% to 25% in the alloy. While the proportion of alloy can vary from approximately 10 pounds to 20 pounds per ton of steel with improved results, preferably the amount is about 12–18 pounds of alloy per ton of steel. The alloy can be added as shot, buttons, bars, or small ingots.

Certain features of this invention have been described in detail with respect to various embodiments thereof. However, it will, of course, be apparent that other modifications can be made within the spirit and scope of this invention, and it is not intended to limit the invention to the exact details shown above except insofar as they are defined in the following claims.

The invention claimed is:

1. In a process for producing a deep-drawing steel, the step comprising the addition to said steel of a manganese-aluminum alloy subsequent to tapping of the furnace and while said steel is still in a molten state, said alloy consisting essentially of at least about 50 percent by weight of manganese and 25 percent by weight of aluminum, and no more than about 75 percent by weight of manganese and 50 percent by weight of aluminum, said steel and said alloy each containing prior to said addition less than 0.01 percent by weight of silicon, and said alloy being added in a form at least as large as shot and in an amount of at least 10 pounds and no more than about 20 pounds per ton of steel.

2. A process of claim 1 in which said alloy is added to the steel while said steel is in the ladle.

3. A process of claim 1 in which said alloy is added immediately after the steel is poured into the ladle.

4. A process of claim 1 in which said alloy consists essentially of about 60 parts by weight of manganese and 40 parts by weight of aluminum.

5. A process of claim 1 in which said alloy consists essentially of about 60 parts by weight of manganese and 40 parts by weight of aluminum, and said alloy is added in an amount of approximately 12–18 pounds per ton of steel.

References Cited in the file of this patent

UNITED STATES PATENTS

501,233 Richards et al. -------------- July 11, 1893
1,744,418 Smith --------------------- Jan. 21, 1930
2,767,084 Chandler --------------- Oct. 16, 1956

FOREIGN PATENTS

144,584 Germany ---------------- July 2, 1902

OTHER REFERENCES