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## DEEP DRAWING STEELS CONTAINING CHROMIUM

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The invention relates to deep drawing steels, to deep drawn articles made therefrom.

Deep drawing steels of the low carbon, aluminum-killed type are currently employed in large quantity by industry. However, not all low carbon fully killed steels are satisfactory for deep drawing purposes. For example, silicon-killed steels are generally less satisfactory than aluminum-killed steels, due to the hardening effect of the silicon addition. In fact, hardening agents have not been considered helpful in developing deep drawing properties.

The present invention is based upon the discovery that chromium, normally considered a hardening agent for carbon steels, may be used to deoxidize low-carbon steel, that steel so deoxidized has good deep drawing properties, and that deep drawn articles with an excellent surface finish may be made therefrom. Heretofore, a deoxidizing addition of aluminum has been regarded as a means of greatly improving the deep drawing properties of low-carbon steels. On the other hand, chromium has been regarded as not enhancing the deep drawing qualities of low carbon steels. However, in the present invention chromium is used as the deoxidizing agent in the steel and no aluminum or other deoxidizer (except for incidental manganese) is employed in its manufacture.

It is accordingly a primary object of the present invention to provide a steel having good deep drawing properties in which chromium is employed as a deoxidizing agent. Another object is to provide deep drawn articles having smooth surface characteristics. A further object is to provide a deep drawing steel deoxidized with chromium, which steel has a uniform grain size, and physical properties comparable to plain, aluminum-killed deep drawing steels.

The invention, in its broader aspect, comprises deep drawing steels or articles made therefrom containing between 0.01% and 0.20% carbon, 0.20% to 2% chromium, 0.10% to 1% manganese, remainder iron and incidental impurities, such as normally occur in the manufacture of low carbon steel of good quality. In a preferred embodiment of the invention, the upper limit of carbon is below 0.10%, the upper limit of manganese below 0.60%, and the upper limit of chromium below 1.50%.

In accordance with the present invention, deep drawn articles may be made by preparing a low carbon steel melt containing carbon in an amount less than 0.20%, preferably less than 0.10%, treating the melt with chromium in any desired form, such for example as ferrochromium, in an amount sufficient to deoxidize the melt but insufficient to leave a residual chromium content greater than 2%, preferably no greater than 1.5%, casting the steel melt, rolling the solidified steel to sheet and subjecting the sheet to a pressing operation to form a deep drawn article.

Due to the existence of many external factors which enter into deep drawing operations, there is no single standard test which can be directly interpreted in terms of commercial deep drawing properties. Among the variables encountered in the deep drawing of steel are the type of lubricant employed, the die construction, the rate of draw, and the surface finish required on the final deep drawn article. There are, however, certain physical properties, determinable by simple testing, which are accepted as indicia of the relative deep drawing characteristics of steels. In general, these properties are low yield point, moderately low tensile strength and hardness, good elongation as measured by percentage elongation in tensile test, depth of cup in cupping test, and substantial freedom from aging effects.

The excellent properties obtained by utilizing chromium as the deoxidizing agent for low carbon steels is shown in Tables A and B in which Table A sets forth the compositions of the steels and Table B the physical properties. The steels of the series were all deoxidized in the furnace, cross-rolled to form sheets 0.05 inch in thickness, sand-blasted and pack annealed. After annealing, the sheets were pickled and cold-rolled to 0.04 inch in thickness. The cold-rolled sheets were then annealed at the temperatures indicated in Table B, pickled, and finally given a cold roll pinch pass equivalent to two per cent reduction. One set of specimens was tested after the foregoing treatment. A corresponding set of annealed specimens was tested after the foregoing treatment plus an accelerated aging treatment that comprised heating the specimens at 200° C. for 24 hours in an air atmosphere. A visible oxide formed on the specimens due to the aging treatment, which oxide was not removed prior to testing the specimens.

In Table B, "Y. P." means yield point in pounds per square inch; "T. S." means tensile strength in pounds per square inch; "% El" means percentage elongation in a gauge length of two inches; "Hardness R B" means the hardness value on the Rockwell "B" scale; "Erichsen" means the greatest depth of indentation, measured in millimeters, made in the Erichsen cupping test before incipient cracking of the sheet.

TABLE A

*Composition of steels by chemical analysis (remainder substantially iron)*

| Steel No. | Percent C | Percent Cr | Percent Mn | Percent Si | Percent Al* |
|---|---|---|---|---|---|
| 1 | 0.03 | | 0.38 | 0.04 | 0.20 |
| 2 | 0.03 | 0.20 | 0.31 | 0.01 | |
| 3 | 0.03 | 0.45 | 0.33 | 0.01 | |
| 4 | 0.04 | 0.89 | 0.32 | 0.01 | |
| 5 | 0.05 | 2.05 | | | |

* Amount added.

TABLE B

*Physical properties*

| Steel No. | Heat treatment after cold rolling | Y. P. | T. S. | % El | Hardness R B | Erichsen |
|---|---|---|---|---|---|---|
| 1 | Annealed (1) | 27,150 | 42,200 | 35 | 44 | 11.5 |
| 1 | Annealed (1) and aged | 33,150 | 44,700 | 31.5 | 48 | 9.7 |
| 2 | Annealed (2) | 29,050 | 50,100 | 31 | 53 | 11.6 |
| 2 | Annealed (2) and aged | 35,000 | 50,000 | 32 | 57 | 9.3 |
| 3 | Annealed (2) | 23,000 | 46,500 | 31.5 | 36 | 11.7 |
| 3 | Annealed (2) and aged | 31,000 | 46,000 | 36.5 | 52 | 9.7 |
| 4 | Annealed (2) | 26,250 | 45,450 | 37 | 33 | 12.3 |
| 4 | Annealed (2) and aged | 32,100 | 47,100 | 36.5 | 49 | 11.4 |
| 5 | Annealed (2) | 35,800 | 51,750 | 28 | 37 | 10.7 |
| 5 | Annealed (2) and aged | 39,000 | 52,800 | 24 | 54 | 10.2 |

Annealed (1)=710° C.—furnace cool.
Annealed (2)=925° C.—furnace cool.
Aged=200° C.—24 hours—air cool.

In the tables, steel No. 1 is a low carbon aluminum-killed steel of typical physical properties, such as is currently employed in industry for deep drawing purposes. Steels Nos. 2, 3, 4 and 5 are low carbon steels, containing no aluminum and very low silicon, which have been deoxidized with various amounts of chromium. As indicated by these data, chromium when added alone for purposes of deoxidation permits the production of steels of excellent deep drawing characteristics. The steels are further characterized by a uniform small grain size. When the chromium-deoxidized steels of the present invention are rolled into sheet and pressed into final deep drawn shape the surface so produced is smooth and typical of material of fairly small and uniform grain size. There is a defintie increase in surface smoothness in the drawn areas as the chromium content is increased.

While specific examples have been given in the foregoing specification, these examples are given merely to illustrate the principles of the invention and the invention is not limited to or by such examples.

We are aware that it has previously been proposed to use chromium to kill high-phosphorus steel containing over 0.07% phosphorus; but, as indicated hereinabove, this invention does not contemplate steels containing impurities in amounts more than normal in low carbon steel of good quality.

We claim:

1. Deep drawing chromium-killed steel other than a steel containing over 0.07% of phosphorus, containing between 0.01% and 0.20% carbon, between 0.10% and 1% manganese, between 0.20% and 2% chromium, remainder iron and incidental impurities; said steel being free from deoxidizing elements, and deoxidation products thereof, other than said chromium and manganese.

2. Deep drawing chromuim-killed steel other than a steel containing over 0.07% phosphorus, containing between 0.01% and 0.10% carbon, between 0.10% and 0.60% manganese, between 0.25% and 1.50% chromium, remainder iron and incidental impurities, said chromium addition serving to deoxidize the steel and to enhance the surface smoothness in drawn areas; said steel being free from deoxidizing elements, and deoxidation products thereof, other than said chromium and manganese.

3. An article, deep drawn to requisite shape, and composed of a chromium-killed steel other than a steel containing over 0.07% phosphorus, containing between 0.01% and 0.20% carbon, between 0.10% and 1% manganese, between 0.20% and 2% chromium, remainder iron and incidental impurities, said article being characterized by the smoothness of surface in the drawn areas and the uniform small grain size of the steel of which it is composed; said steel being free from deoxidizing elements, and deoxidation products thereof, other than said chromium and manganese.

4. An article, deep drawn to requisite shape, and composed of a chromium-killed steel other than a steel containing over 0.07% phosphorus, containing between 0.01% and 0.10% carbon, between 0.10% and 0.60% manganese, between 0.25% and 1.50% chromium, remainder iron and incidental impurities, said article being characterized by the smoothness of surface in the drawn areas and the uniform small grain size of the steel of which it is composed; said steel being free from deoxidizing elements, and deoxidation products thereof, other than said chromium and manganese.

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